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No. 2011-1540

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

PEI-HERNG HOR,
Plaintiff-Appellant,

RULING MENG,
Plaintiff-Appellant,

v.

CHING-WU "PAUL" CHU,
Defendant-Appellee.

APPEAL FROM THE UNITED STATES DISTRICT COURT FOR THE SOUTHERN DISTRICT OF TEXAS IN CASE NO. 4:08-CV-3584
JUDGE KEITH ELLISON

CORRECTED BRIEF OF APPELLANT PEI-HERNG HOR

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PEI-HERNG HOR

FILED
U.S. COURT OF APPEALS FOR
THE FEDERAL CIRCUIT
APR 18 2012
JAN HORBALY
CLERK

April 12, 2012

ORAL ARGUMENT REQUESTED

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CERTIFICATE OF INTEREST

Counsel for Appellant, Pei-Herng Hor, certifies the following:

1. The full name of every party or amicus represented by me is:

   Pei-Herng Hor.

2. The name of the real party in interest (if the party named in the caption is not the real party in interest) represented by me is:

   None.

3. All parent corporations and any publicly held companies that own 10 percent or more of the stock of the party or amicus curiae represented by me are:

   None.

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or agency or are expected to appear in this court are:

   William P. Jensen
   Crain Caton & James, P.C.

   Joe W. Beverly
   Amy Hawk
   Dow Golub Remels & Beverly, LLP

Respectfully submitted,

Date: April 12, 2012

By: William Jensen by permission

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STATEMENT OF RELATED CASES

There are no related cases.

STATEMENT OF JURISDICTION

The judgment of the district court is final and was entered on February 18, 2011. A43-44. Appellant, Pei-Herng Hor, timely moved for a new trial on March 18, 2011. A57. The district court denied the motion for new trial on July 13, 2011. A57. Hor timely filed his notice of appeal on August 9, 2011. A607-609.

The district court had exclusive jurisdiction to hear this case pursuant to 28 U.S.C. § 1338(a) because this case is an action to correct inventorship of a patent under 35 U.S.C. § 256.

This Court has jurisdiction over this appeal pursuant to 28 U.S.C § 1295(a)(1).

STATEMENT OF THE ISSUES

Issue No. 1

The district court erred in holding that Hor's claim to correct inventorship under 35 U.S.C. § 256 was barred by laches because there is no express requirement of diligence in §256, and Hor did not have a claim to correct inventorship of the patents-in-suit under §256 until after the patent was issued, and he filed suit within three years after the patent issued.

Issue No. 2

Assuming that the doctrine of laches applied, the district court erred in finding that Hor unreasonably delayed filing this suit and in finding evidentiary prejudice to Chu.

Issue No. 3

The district court erred in holding that Hor's claim was barred by the doctrine of equitable estoppel because Chu never raised that issue and the elements for equitable estoppel were not met.

STATEMENT OF THE CASE

Appellant, Pei-Herng Hor, sued Appellee, Ching-Wu Chu, pursuant to 35 U.S.C. § 256 to correct inventorship of two patents: (1) No. 7,056,866 issued on June 6, 2006 ; and (2) No. 7,709,418 issued on May 4, 2010. Addendum 4 and 5.

Chu moved for summary judgment against Hor. Chu argued that Hor's claims of inventorship were barred by the doctrine of laches and also failed for lack of corroboration. A133-193.

The district court granted Chu's motion for summary judgment based on laches. Consequently, the court did not decide Chu's motion for summary judgment based on lack of corroboration. The court sua sponte further ruled that Hor's claims were barred by the doctrine of equitable estoppel. See *Hor v. Chu,* 765 F. Supp. 2d 903 (S.D. Tex. 2011); A10-44.

STATEMENT REGARDING ORAL ARGUMENT

Appellant believes that oral argument would aid the Court in deciding this appeal because: (1) the district court applied the doctrine of laches in a manner that has not previously been approved of by this Court; (2) the underlying facts of the case are somewhat complicated; and (3) the issue is of importance to the general public.

STATEMENT REGARDING CONFIDENTIALITY

Pursuant to order of the district court, the deposition of Appellee Chu and certain documents produced during discovery have been designated as confidential. A1-9. However, none of Appellants' responses to Chu's motions for summary judgment were filed under seal or designated as confidential. A455-482; 483-522; 529-560. Appellee, Chu has agreed that because the facts presented in Appellants' briefs do not include any statements that were previously filed in a confidential form with the district court, that Appellants and Appellee should not be required to file confidential briefs in this Court and that it would be a waste of time and resources for the parties and the Court to file confidential briefs. The parties have agreed that the items designated as confidential in the Confidential Joint Appendix to be filed with this Court should remain confidential, and that Appellants will also file a non-confidential Joint Appendix at the appropriate time.

TO THE HONORABLE COURT OF APPEALS FOR THE FEDERAL CIRCUIT:

Appellant, Pei-Herng Hor ("Hor") files his Appellant's Brief as follows:

STATEMENT OF THE FACTS

Introduction

This case concerns the correction of inventorship of two patents for a superconductor known as YBCO-123 and other related magnetic rare earth superconductors. Hor conceived of the primary innovations leading to the creation of YBCO-123 and the related superconductors. Dr. Chu erroneously obtained patents for these superconductors listing himself as the sole inventor. After the first of the patents issued, Hor filed suit to correct inventorship of these patents pursuant to 35 U.S.C. § 256. A58-71. After the second patent issued, Hor amended his complaint to include that patent. A118-132.

Hor is an associate professor in the Physics Department at the University of Houston ("UH") who has been engaged in superconductivity research since 1982. He has authored over 200 published papers.[1] A561.

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[1] Superconductivity is a phenomenon occurring in certain materials, characterized by zero electrical resistance and the exclusion of the interior magnetic field (known as the Meissner Effect). Electrical resistance is a measure of the degree to which a material opposes an electric current passing through it, and is measured in ohms. The electrical resistance of a superconductor drops abruptly to zero ohms when the material is cooled below its superconducting transition temperature ("T_c"). An electric current flowing in a loop of superconducting wire can persist indefinitely

In 1986, Hor was a graduate student in the UH Physics Department and a Research Assistant in Chu's research group. The group focused on researching materials that would become superconducting at high temperatures. A561. Hor planned to begin work at Bell Labs as a post-doctoral fellow in the spring of 1987. However, Chu requested that he remain at UH as the alternate Principal Investigator of the research group because Chu was beginning a one year term as a Program Director at the National Science Foundation ("NSF") in Washington D.C. in the Fall of 1986. A561-562. This full-time position required Chu to be away from UH for much of the time for a year beginning in September of 1986. A561-562. Hor agreed to stay at UH. A561; 1045-1049. During Chu's one year assignment at NSF, Hor had full authorization to lead the research group, and was responsible for the work of the group. A562; 2120.

Bednorz and Müller Discover the La-Ba-Cu-O Superconductor

In November 1986, Ruling Meng ("Meng"), a member of the research group, obtained a paper published by J. Georg Bednorz and K. Alexander Müller describing

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with no power source. Superconductors with a T_c higher than the boiling point of liquid nitrogen, approximately 77° Kelvin ("77K"), are commercially important because liquid nitrogen can be produced cheaply and is not prone to problems exhibited by other cooling agents. The liquid nitrogen could then be used to cool the superconductor to its T_c. Superconductors with a T_c above 77K are commonly referred to as High Temperature Superconductors. A561.

a La-Ba-Cu-O system (Lanthanum, Barium, Copper and Oxygen) displaying a high superconducting T_c. A2243; 1906-1910; 2111. Chu and Hor reviewed the paper and began work on the La-Ba-Cu-O system. A562; 2243. Bednorz and Müller did not identify the specific composition of the La-Ba-Cu-O system, but rather indicated that it was prepared according to a nominal 555 formula – that is a ratio of Barium to Lanthanum to Copper of 5:5:5. A1251-1256; 2255.

Meng's background was in material science and she was primarily responsible for synthesizing samples. She began synthesizing samples of La-Ba-Cu-O based on the nominal 555 formula. A562; 2111; 2165-2167; 2255-2257; 2260. Early experiments showed a large increase in T_c occurring in La-Ba-Cu-O samples that were subjected to high pressure – resulting in a Physical Review Letters paper in which Hor was listed as the second author after Chu. A562; 1050-1053.

The successful high pressure results prompted the research group to mimic physical pressure by changing the chemical composition of the La-Ba-Cu-O system through replacement of the larger Barium (Ba++) ions with smaller Strontium (Sr++) and Calcium (Ca++) ions. Using "chemical pressure" to mimic physical pressure is well-known in the field of high pressure material research. A562. A Strontium substitution increased T_c to about 42K, but a Calcium substitution actually decreased T_c. A562; 1050-1053; 2120-2121; 2250.

Hor Conceives of Yttrium Substitution

In early January 1987, Hor had a discussion in his office with M. K. Wu,[2] Meng, and Li Gao (a UH graduate student) regarding where their research should go after Calcium substitution proved to be a dead end. Hor took out a periodic table of the elements in an attempt to identify new substitutions to La-Ba-Cu-O to enhance T_c. At that point, he conceived of the idea of replacing the element Lanthanum (La+++) with the iso-valent element Yttrium (Y+++) ion. This idea resulted in the creation of a YBCO (Yttrium-Barium-Copper-Oxygen) compound (made initially by Wu) that exhibited superconductivity above 77°K. A241-242; 562-563; 2122, 2124, 2156-2157.

After this discussion, Meng ordered Yttrium for the research group to begin Yttrium substitution experiments, but because it was during UH's winter break, the order was not placed until January 12, 1987.[3] A1270; 2123-2124. Hor asked Wu to also begin work on Yttrium substitution. A562-563. Meng also suggested that Wu

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[2] Wu was a former graduate student of Chu who, at the time, was a faculty member at the University of Alabama at Huntsville. Chu asked Wu to assist the group primarily in substituting Strontium for Barium in the La-Ba-Cu-O system. A2247; 2249; 2266.

[3] Chu claims that the Yttrium oxide order was placed at his request after he allegedly instructed Meng to order Yttrium and Lutetium oxides in mid-December 1986. A2263; 2274. Meng disputed this testifying that if Chu had asked her to place this order then, she would have done so immediately. A2123-2124.

should work on Yttrium substitution; asking that when he went back to Alabama to get Yttrium oxide from "NASA in Alabama so we can start the work soon." She did this because it would take her two weeks to get yttrium oxide. A2156-2158. Hor also asked Meng to record formulas for conducting the Yttrium substitution experiments, which she did on about January 14, 1987. A563. Chu was not at the meeting in Hor's office. A1538; 2275. However, he has repeatedly confirmed that this meeting took place and attempted to use it as evidence of his conception of YBCO to defeat Wu's claim of inventorship in a patent interference proceeding filed by Wu.[4] A988-1013; 1404; 1439-1440; 2275.

January 29, 1987 – The First YBCO Superconductor

On January 29, 1987, Wu called Chu to report he had observed a reproducible superconducting T_c above 77K. Chu described the events of that day as follows:

> I received an exciting call from Maw-Kuen [Wu] from UAH at about 5 p.m., on January 29, 1987. He informed me that he and his students, Jim Ashburn and C.J. Torng, had just observed a reversible sharp R-drop [resistivity] starting at 90°K, and finishing at about 77°K in two of their samples. All of us were ecstatic, since stable and reversible superconductivity might finally have been achieved, provide a Meissner effect could be detected. Right before he called me, Maw-Kuen had also phoned Peiherng [Dr.Hor] about their exciting observation. Without divulging information about the elements of their samples, Maw-Kuen

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[4] The interference proceeding was styled *Maw-Kuen Wu and James R. Ashburn v. Ching Wu Chu*; Patent Interference No. 102,247; Before the Board of Patent Appeals and Interferences. A930-956.

> told Peiherng, "We just did what we discussed previously (in Houston in early January)." Peiherng, Ruling and I reviewed all our previous data and decided to make a few new samples containing the newly arrived Y and Yb oxides.

A1950;2253-2254.

After his conversation with Wu, Chu asked Hor to write down the elements that he and Wu had discussed in Houston. A2275. Hor wrote down formulas which included the Yttrium and Scandium substitution for Lanthanum in La-Ba-Cu-O and were based on a nominal 214 composition. A563. Hor's formulas were then recorded by Meng in her laboratory notebook dated January 29, 1987. A563; 1271-1281; 2122; 2126; 2161; 2174-2175.

Wu came to Houston on January 30, 1987 with a sample prepared to a nominal 214 formula and with the composition of $Y_{1.2}Ba_{0.8}CuO_4$. Measurement of the sample showed reproducible T_c above 77K. Hor measured the Meissner effect which indicated the resistivity transition observed by Wu was a genuine superconducting transition, and that a superconductor with a T_c above liquid nitrogen temperature existed in $Y_{1.2}Ba_{0.8}CuO_4$. A563-564; 1988-1989.

In the Physical Review Letter paper published as a result of the discovery of YBCO, Wu was the first author of the Alabama group and Hor was the first author of the Houston group. A664-667; 2252-2253. "Typically, the first author in an article like this is the person who has most directly contributed to the actual technical information that is contained in the paper." A2199.[5]

The Chemical Composition and Structure of YBCO

At the time of the discovery, the chemical composition and structure of the YBCO superconductor were not known. The precise chemical formula and crystal structure (or stoichiometry) of the YBCO superconductor was identified by a group working with Robert Hazen and David Mao at the National Geophysical Laboratory in Washington, D.C. A2184-2185; 2187-2192; 2266, 2269. To assist Hazen's group, Chu, Meng and Hor worked together and successfully separated high purity YBCO samples exhibiting T_c of 90K. A564; 2268-2269. The stoichiometry was determined to be $Y_1Ba_2Cu_3O_7$ which is commonly referred to as the 123 phase. A2193-2194, 2208. The crystal structure was determined through a complicated process of x-ray single-crystal diffraction analysis and was determined to be a square-planar structure. A610-627; 2209-2210; 2269. On March 5, 1987, Hazen informed Chu of the preliminary results of his team's analysis of the crystal structure of YBCO. A2090; 2196-2197. On March 8, 1987, Hazen first wrote up the details of the structure and phase of YBCO-123. A2091-2104; 2198-2199.

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[5] On at least five other patents obtained by Chu, the first author on the related paper is always named as a co-inventor. A564.

Hor Discovers a Series of Magnetic Rare-Earth Superconductors

After the YBCO 123-phase had been identified, Hor continued to perform experiments in an attempt to discover why YBCO-123 was a superconductor with such a high T_c. A564. At that time, it was well known among superconductor researchers that substitution of magnetic elements in a superconductor would lower the T_c, a phenomenon known as the "pair-breaking effect." Physicists working in the field of superconductors would not have substituted magnetic elements into a superconductor expecting to increase T_c. A2267-2268.

On or about March 11 or 12, 1987, Hor asked Meng to completely replace Yttrium in YBCO-123 with the magnetic rare earth element Gadolinium in order to study the pair-breaking effect due to the presence of magnetic ions. A564; 1674-1675; 2125. Gadolinium is the most magnetic of the rare-earth elements and therefore, it is the element used to begin "pair breaking" or "magnetic doping" experiments. A2264, 2274. When the Gadolinium compound was tested for superconductivity on March 15, 1987; it was found to be an HTS with a T_c around 85-90K, and thus, no "pair breaking" had occurred. A564; 1117. Hor was surprised by the result because he had expected that if the Gadolinium-123 could form, the T_c would have been reduced or even completely suppressed by inclusion of the magnetic element Gadolinium. Instead, the transition temperature was similar to that of YBCO-123. A564-565.

As a result of the Gadolinium experiment, Hor conceived the idea that substitution of the other magnetic rare-earth elements for Yttrium in the 123-phase would also produce new high temperature superconductors. A564. Hor asked Meng to perform complete substitution of Yttrium with the magnetic rare-earth elements in the periodic table, and several new superconductors were discovered. A564. The lab records clearly show that once the result of the Gadolinium experiment was obtained, an entire series of new magnetic rare-earth superconductors was created and tested.[6]

The History of the Patents-in-Suit

The two patents at issue in this case are U.S. Patent No.7,056,866 ("866 Patent") and No.7,709,418 ("418 Patent"). Addendum 4 and 5. Chu initially filed a patent application on January 12, 1987 followed by continuations-in-part on January 26, 1987 and February 6, 1987. A634-663. These applications were based, in part, on Hor's conception of Yttrium substitution for Lanthanum as a means to produce high temperature superconductors. In these applications, Chu erroneously listed himself as the sole inventor. A563; 1054-1078. Hor had no actual knowledge that

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[6] See Docket No. 82 at n. 11 for a complete listing of the magnetic rare-earth superconductors discovered by Hor. A544-545.

Chu had filed patent applications at that time. A563. After the previous applications were abandoned, the actual application for the '866 Patent was filed on March 26, 1987 and was assigned to UH. A610-627. The application for the '418 Patent was filed on January 23, 1989, and was also assigned to UH. A628-633.

It is undisputed that Hor had no actual knowledge of the filing of an application for the '418 patent until May 2, 2007, when Chu mentioned it in response to Hor's internal grievance against Chu at the UH. A566; 1911-1935.

Chu Was Responsible for Communicating Facts to the Patent Attorneys

Charles Cox was the primary patent attorney for UH (the assignee of the patents-in-suit) in prosecuting the patent applications and in later defending Chu in an interference proceeding filed by M.K. Wu and the University of Alabama - Huntsville. A930-956; 2249; 2283. Chu executed a Declaration and Power of Attorney for the '866 Patent Application and the '418 Patent Application, which appointed Cox as one of the attorneys to represent Chu during the prosecution of each application. A566; 1247-1251. Chu was primarily responsible for communicating the facts and technical information regarding the '866 Patent to Cox. A2251. Chu claims that Cox made the decision who would be named as an inventor based on the data provided him. According to Chu, this data was provided by himself and Meng. Hor did not provide any data to Cox. A2261. In his writings and publications, Chu credited Hor for much of work in discovering the patented compounds, but never communicated similar information to Cox. A2039-2041; 2265, 2267.

Chu Assures Hor

In 1987 or early 1988, Hor, Chu and Meng met with Cox to discuss their respective contributions to the superconductors that are the subject of the patents-in-suit. A566.[7] Hor did not know at the time of this meeting that Chu had already filed a patent application. Rather, Hor thought the purpose of the meeting was to assist in filing a patent application for YBCO-123. A566. In this meeting, Cox asked who was the first person to propose a substitution of Yttrium. Chu pointed to Meng and asked her if she remembered that he had called her and told her to do Yttrium substitution. Meng, not wanting to embarrass Chu, replied that she did not remember. Hor, also not wanting to embarrass Chu, stated that he did not remember either. Cox stated that it seemed from the discussion that no one seemed to remember who was the first to come up with the idea. At that point, Chu stated that Hor and Meng should be included as inventors. Cox replied that not everyone can be an

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[7] Although his memory regarding almost all other events at issue in this suit is reasonably clear, Chu claimed to have a limited recollection of this meeting, testifying that the "origin of Yttrium" was discussed and that he asked Meng if she remembered he had called her in mid-December of 1986 about Yttrium. Chu also remembers that Hor left the meeting possibly because he was upset with Chu claiming conception of Yttrium substitution and that Chu followed him and told him that he was going to talk to the lawyer. A2278.

inventor and that a "pair of hands" cannot be considered as an inventor. A221; 2170-2171.

Hor left the meeting because he was disturbed by Cox's comment. Chu followed him outside, apologized saying, "I am sorry. This lawyer does not know anything about our group. I will go back to tell him and straighten things out. A221. Hor took Chu at his word. A566-567. After the meeting with Cox, Chu never discussed either patent application with Hor, and never told Hor that he was not listed as a co-inventor on the patents. A567.[8]

The Wu Interference

In 1990, M. K. Wu and the University of Alabama at Huntsville initiated an interference proceeding that was defended by Cox. A930-956. In essence, Wu claimed that he had independently created YBCO-123. During the Wu Interference, Chu signed a declaration that he conceived of the substitution of Yttrium for Lanthanum in the La-Ba-Cu-O superconductor in mid-December of 1986. In an earlier draft of this declaration, it is obvious that practically all references to Hor were

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[8] From this evidence, the district court concluded that Hor must have known that Cox considered him to be a "pair of hands" and not an inventor. *Hor,* 965 F.Supp2d at 916. However, there is no indication as to who Cox was referring to as a "pair of hands" or that Hor even really understood what that term meant at the time. Hor was completely unfamiliar with the patent process at that time. But Hor considered a "pair of hands" to be a very insulting term. A566-567.

eliminated. A2271-2273. Chu never told Hor that he had signed this declaration, or that he was now claiming sole inventorship of the '866 Patent, or that his declaration had been edited to almost completely erase Hor from the picture. A567.

Hor's only involvement in the Wu Interference was a meeting with Cox and John Warren, UH Vice-President for Intellectual Property, in which Hor was asked to describe what had happened in the meeting with Meng and Wu in late 1986 or early 1987 where Hor had conceived of the idea of substituting Yttrium for Lanthanum in La-Ba-Cu-O. Hor signed a declaration stating that at this meeting he and Meng "discussed the concept that substitution of Y for La in a composition of La-Ba-Cu-O[.]" A567. To Hor, this statement was consistent with his understanding that he was at least a co-inventor of YBCO-123. Chu and Cox never told Hor that they were using his declaration to support Chu's claim that he was the sole inventor of the '866 Patent. If that information had been communicated to Hor, he would not have signed the declaration in that form. After this, Hor had no further involvement with the Wu Interference or Cox. A567.

Meng Comes to Hor in January of 2006

After 1993, Hor had little involvement with Chu. At that time, Hor formed his own Novel Materials research group focused on the study of materials with unusual physical properties. Hor and Chu rarely, if ever, spoke to each other and Chu was absent from UH for long periods of time while serving at foreign universities. A567.

On January 19, 2006, Meng came to Hor's office to apologize to him for not speaking the truth about the discovery of YBCO. Meng told Hor that her conscience had been bothering her for many years and that she wanted to speak out. A222. She also told him that neither of them were listed as inventors on the '866 Patent application. On January 27, 2006, Hor and Meng went to John Warren, UH Vice Chancellor for Intellectual Property, who confirmed that they were not listed as inventors on the '866 Patent. This was the first time that Hor had actual knowledge that he was not named as a co-inventor. A567.

On February 1, 2006, Hor and Meng met with UH's outside counsel, Lester Hewitt and other members of UH administration to discuss Hor's and Meng's inventorship claims concerning the '866 Patent Application. A567.

UH Claims It Will Investigate the Issue of Inventorship

On February 21, 2006, an Information Disclosure Statement ("IDS") was filed during prosecution of the '866 Patent Application. The IDS included communications from Hewitt to Meng and Hor concerning their inventorship claims discussed during the meeting on February 1, 2006. Hewitt represented that UH would "make a fair and complete investigation" of Hor's and Meng's inventorship claims.[9] A567, 1187-1197.

On February 22, 2006, a Petition to Suspend the Rules Under 37 C.F.R. 1.183 (the "Petition") was filed during prosecution of the '866 Patent Application to hold the '866 Patent Application in suspension for a period of six months from the grant of the Petition while UH investigated the inventorship claims. A567-568; 1181-1186. In the Petition, UH represented that "if there is a need to correct inventorship and, if a need to correct inventorship is determined, assignee cannot estimate the likelihood that all parties will agree." A1185.

On March 14, 2006, Hor and Meng each presented an affidavit to UH during another meeting concerning their inventorship claims in which they described their respective contributions to creation of YBCO-123 and the related superconductors and their meetings with Cox. A238-245; 568; 1203-1246.

In her affidavit, Meng recalled the meeting with Cox, Hor and Chu. Meng also described another meeting with Cox a couple of months later to discuss inventorship where Cox suggested that if she did not confirm that Chu told her to substitute

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[9] The district court erroneously concluded that when Hor and Meng approached UH officials in January of 2006 they inquired about inventorship of both patents and were advised that they were not inventors on both patents. The evidence is undisputed that Hor did not learn of the '418 patent until 2007, and the patent did not issue until May 10, 2010. A566.

Lanthanum with Yttrium, then UH "would lose the patent to University of Alabama." A243.

On March 15, 2006, another IDS was filed during prosecution of the '866 Patent Application, which included the Meng Affidavit and the Hor Affidavit. A568, 1203-1246. On March 15, 2006, an IDS was filed during prosecution of the '418 Patent Application, which included information submitted during prosecution of the '866 Patent Application in the February 21, 2006 IDS and the March 15, 2006 IDS. A568.

The Patents Issue

On June 6, 2006, the '866 Patent issued. A610-627. On May 4, 2010, the '418 Patent issued. Chu was the only named inventor for both patents. The range of superconducting compositions covered by the '866 and '418 Patents include compositions conceived of by Hor. A610-627.

Hor Attempts to Resolve the Matter Internally at UH

After the '866 Patent issued, Hor attempted to resolve his claims of inventorship for that patent by filing a grievance pursuant to UH's internal policies and grievance procedures. A568; 1259-1265. At the time of he submitted his grievance, Hor was unaware of any facts concerning the '418 Patent. A566.

Hor was rebuffed in his attempt to resolve this matter internally within UH. On April 17, 2006, the University Grievance committee held one informal hearing. After that, the committee recommended that UH form a special grievance committee with particular expertise to hear Hor's grievance. Despite repeated requests from Hor, UH administration refused to form another grievance committee, and as a result, refused to allow the grievance process to go forward and no decision on Hor's grievance was reached. A568; 1156-1180. After failing to resolve his claims through UH's internal grievance procedures, Hor filed his original complaint on December 5, 2008 seeking to correct inventorship under 35 U.S.C.§ 256. A58-71.

SUMMARY OF THE ARGUMENT

Hor sued to correct inventorship under 35 U.S.C. §256. A claim under §256 does not arise and federal courts have no jurisdiction to hear such claims until after a patent has issued. Section 256 does not expressly limit the time during which inventorship can be corrected, and there is no requirement of diligence as a matter of law for claims brought under §256 or the implementing regulations. As such, the period of delay for purposes of laches cannot begin before a plaintiff's right to sue accrues, and the existence of other possible methods to correct inventorship cannot act to bar a clear statutory right to correct inventorship that accrues only after a patent has issued.

The district court erred in broadly defining the term "claim" for purposes of laches, to encompass any possible claim that Hor might have had to correct inventorship at any time. In reaching this holding, the district court relied on non-precedential lower-court decisions that failed to adequately analyze this Court's precedents and which in turn relied on outdated law.

This Court has held that there is no *per se* requirement that an omitted inventor diligently bring a lawsuit under §256, but that diligence must be determined on the facts of the case. Hor acted diligently, because he first attempted to resolve the issue of inventorship through the internal grievance procedures of UH, his employer and the licensee of the patent. When UH refused to hear his grievance, he timely sued within less than three years after issuance of the patent.

Assuming that laches attached such that Hor was required to act diligently to correct inventorship before his right to sue for correction of inventorship accrued under §256, the district court erred in finding unreasonable delay and evidentiary prejudice as a matter of law.

The evidence established that Hor acted diligently and that any delay in filing suit under §256 was not unreasonable. Hor acted reasonably in trusting Chu to "straighten things out" with UH's patent attorney regarding invention of YBCO-123, because Hor was a long-time collaborator of Chu, and was the alternate Principle

Investigator for the research group at the relevant time. Hor could have reasonably believed he was named as an inventor because he was paid $137,000 by UH for his contributions to the invention, he was named as the first author on all of the relevant scientific publications, and Chu consistently credited him in writing for the discovery of YBCO-123 and the related magnetic rare earth superconductors.

The evidence also established that there was no evidentiary prejudice. The discovery of YBCO-123 was well-documented in contemporaneous lab records and scientific papers. Chu himself wrote several accounts of the history of the discovery over the course of ten years. One of Chu's collaborators, Hazen, wrote a book about the discovery which all parties used in discovery. Hazen's papers were preserved and available for all parties to examine. The deposition testimony of the primary witnesses, Chu, Hor, Meng and Hazen all demonstrate a reasonable ability to remember the critical facts of the case. Only one possible witness has since died and he was a graduate student who had no direct involvement in the discovery of the inventions.

The district court erred in finding that Hor's claims were barred by equitable estoppel. There is no evidence of any intent by Hor to mislead Chu or UH sufficient to invoke estoppel, and again Chu failed to establish evidentiary prejudice.

At a minimum, there were clearly genuine issues of material fact which precluded granting summary judgment based on laches and equitable estoppel.

ARGUMENT

The Standard of Review for Summary Judgment

This court reviews a district court's grant of a motion for summary judgment without deference, applying the summary judgment standard anew. See *Atmel Corp. v. Info. Storage Devices, Inc.*, 198 F.3d 1374, 1378 (Fed.Cir.1999). A motion for summary judgment lies only when there is no genuine issue of material fact. See *Southern Distributing Co. v. Southdown, Inc.*, 574 F2d 824 (5th Cir. 1974). The court cannot weigh disputed evidence, decide questions of credibility or draw inferences about knowledge and intent of parties from conflicting evidence adversely to the nonmovant because these are the exclusive functions of trier of fact to be discharged after consideration of testimony and evidence presented in an adversarial trial environment. See *Hanover Ins. Co. v. American Engineering Co.*, 33 F.3d 727, 730 (6th Cir. 1994). Courts should not credit evidence offered by the movant that comes from interested witnesses - such as Chu. See *Reeves v. Sanderson Plumbing Products, Inc.*, 530 U.S. 133, 150-51 (2000). And cases that turn on witness credibility should not be resolved on summary judgment. See *Bazan v. Hidalgo County,* 246 F.3d 481, 492 (5th Cir. 2001). Finally, a court may only reach factual conclusions on summary judgment if they are the "the only reasonable interpretation" of the record. *Blow v. City of San Antonio*, 236 F.3d 293, 297 (5th Cir. 2001).

The Patent Statute at Issue

Hor sought to be named as an inventor of the patents-in-suit under 35 U.S.C. §256, which provides:

> Whenever through error a person is named in an issued patent as the inventor, or through error an inventor is not named in an issued patent and such error arose without any deceptive intention on his part, the Director may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate correcting such error.
>
> The error of omitting inventors or naming persons who are not inventors shall not invalidate the patent in which such error occurred if it can be corrected as provided in this section. The court before which such matter is called in question may order correction of the patent on notice and hearing of all parties concerned and the Director shall issue a certificate accordingly.

This provision, enacted in 1952, is remedial in nature. Prior to its enactment, if an inventor was erroneously named or excluded in an issued patent, the only mechanism to correct the error was to invalidate the patent. See, e.g., *Pannu v. Iolab Corp.*, 155 F.3d 1344, 1350 (Fed.Cir.1998). Section 256 has been characterized by this Court as a "savings provision"; it allows the correction of the patent instead of automatic invalidation. *Id.*

Issue No. 1 Restated

> The district court erred in holding that Hor's claim to correct inventorship under 35 U.S.C. § 256 was barred by laches because there is no express requirement of diligence in §256, and Hor did not have a claim to correct inventorship of the patents-in-suit under §256 until after the patent was issued, and he filed suit within three years after the patent issued.

The District Court Erred in Ruling That Laches Barred Hor's Claims Under 35 U.S.C. §256

The district court held that the "laches period of delay may begin when a plaintiff knew or should have known that the defendant filed a patent application covering his alleged inventive contributions and failed to name him as an inventor." *Hor,* 765 F.Supp.2d at 916. The district court's holding was derived primarily from two unpublished opinions which the district court admitted were not precedential. See, *Moore v. Broadcom Corp.*, 2008 WL 425932 (N.D. Cal. Feb. 14, 2008) and *Frugoli v. Fougnies*, 74 U.S.P.Q.2d (D. Ariz. Aug. 25, 2004).

The district court relied on *Moore* and *Frugoli* to support an expansive definition of the term "claim." Despite never having pled for any relief beyond correction of inventorship under §256, the court interpreted the definition of Hor's claim for purposes of laches to encompass any possible action that he might have filed to claim inventorship. Rather than confine the term claim to the actual claim asserted by Hor under §256, the district court held that for determining the relevant period of delay, Hor's claim was a general claim of inventorship. *Hor,* 965 F.Supp.2d at 916. The district court thus held that the laches period for purposes of Hor's claim under §256 began when he knew or should have know that a patent application had been filed. *Id.* Without this overly broad interpretation of the term claim, the district court admitted that the laches period could not begin any earlier than the date of issuance of the patent. *Id.* at 915.

The district court committed error in this holding because: (1) 35 U.S.C. §256 does not expressly limit the time during which inventorship can be corrected, and claims under that statute are not ripe until a patent issues; (2) this Court has explicitly disclaimed the imposition of a *per se* diligence standard for actions brought under §256; (3) the summary judgment evidence clearly raised issues of material fact as to whether Hor acted diligently; and (4) the district court relied on a diligence requirement formerly found in 37 C.F.R. §1.48, the implementing regulation for actions brought under 35 U.S.C. §116, which was removed in a 1997 amendment. In short, the district court erred in barring Hor's claim because laches generally could not bar his claim under §256 until at least six years after the patent issued and he sued well within that time.

Laches is Measured from the Issuance of the Patent at the Earliest

Section 256 does not expressly limit the time during which inventorship can be corrected, which serves the public policy of preserving property rights from avoidable forfeiture. See *Stark v. Advanced Magnetics, Inc.*, 29 F.3d 1570, 1571-1573 (Fed. Cir. 1994). The district court recognized that in a suit to correct inventorship under 35 U.S.C. §256, the plaintiff's claim applies only to an "issued patent"and provides a means for correction only after the patent has issued. In fact, a district court lacks jurisdiction to adjudicate inventorship issues prior to the issuance of a patent. *Sagoma Plastics, Inc. v. Gelardi*, 366 F.Supp.2d 185 (D. Me. 2005). Clearly, a plaintiff can neither know of or even assert a claim under §256 until a patent has actually issued. Logically, for an action under §256, laches cannot attach until the issuance of a patent at the earliest.

This Court's decisions do not support the conclusions reached by the district court. In *Advanced Cardiovascular Systems, Inc. v. SciMed Life Systems, Inc.*, 988 F.2d 1157, 1161 (Fed. Cir. 1993) this Court held that an inventor's claim under 35 U.S.C. §256 claim cannot arise until the patent issues. This Court held that under §256 inventorship may be corrected at any time and, in that case, the time for measuring laches runs from the date the alleged inventor knew or should have known that the patent issued. *Id.*; see also *Studio & Partners v. KI*, 2007 WL 3342597 at *5

(E.D. Wis. 2007) (following *Advanced Cardiovascular* and finding that a correction of inventorship claim accrued only when patents were issued. "In other words, the correction of inventorship claim arises only when there is something in an existing patent to 'correct'.").

In *Advanced Cardiovascular*, there was no indication that the omitted inventor knew of the existence of patent applications prior to issuance of the patent. However, the Court expressly drew an analogy to suits for patent infringement, noting that in those actions the period of delay is measured from when the patent owner knew or should have known of the infringement. *Id.* at 1161, citing *A.C. Aukerman v. R.L. Chaides Construction Co.*, 960 F.2d 1020, 1032 (Fed. Cir. 1992). This Court in *Aukerman*, however, held that the "period of delay . . . does not begin prior to issuance of the patent." *Id.* citing, *Bott v. Four Star Corp.*, 807 F.2d 1567, 1575 (Fed.Cir.1986) and *Studiengesellschaft Kohle mbH v. Eastman Kodak Co.*, 616 F.2d 1315, 1326 (5th Cir.), cert. denied, 449 U.S. 1014 (1980); see also *Watkins v. Northwestern Ohio Tractor Pullers Ass'n, Inc.*, 630 F.2d 1155, 1161 (6th Cir. 1980) ("If the patentee has no right to sue until he has the patent, then waiting until the patent issues, even with full knowledge of an alleged infringer's activities, cannot be an unreasonable delay. . . .[T]he six-year period cannot start running before the issue date of the patent."). The same rationale should apply to actions to correct inventorship §256 because there is no right for the omitted inventor to sue to correct inventorship and nothing to correct under that statute until the patent issues. Logically, the period of delay for purposes of laches cannot begin before a person had the right to sue under the applicable statute. A clear statutory right to sue to correct a patent after it has issued should not be eviscerated by the existence of other possible rights to sue prior to issuance of a patent.

The District Court Erred in Relying on *Moore* and *Frugoli* to Define the Term Claim and Find that Laches Barred Hor's Claims

The primary cases cited by the district court, *Moore v. Broadcom Corporation*, 2008 WL 425932 (N.D.Cal. 2008), and *Frugoli v. Fougnies*, 74 USPQ2d 1716, 1719-1722 (D. Ariz. 2004), fail to take into account the critical holding from this Court's decision in *Aukerman*. In *Frugoli*, the court cites *Aukerman*, but only for the proposition that the time period begins when one reasonably should know of his or her purported rights. 74 USPQ2d at 1722. In *Moore*, the court at least acknowledged that *Aukerman* holds that the period of delay for a patent infringement action cannot begin before the patent issues, but then goes on to misread the decision in *Advanced Cardiovascular* as supporting a holding that the period of delay can be measured from a time before the patent issued. 2008 WL 425932 at *3. *Advanced Cardiovascular* actually holds that the date of the issuance of the patent does not start the period of delay if the omitted inventor does not have actual knowledge that the patent has been issued. 988 F.2d at 1161. Thus, the primary decisions relied on by the district court are clearly deficient in their analysis of this Court's precedents.

The district court's reliance on the holdings in *Moore*, 2008 WL 425932 and *Frugoli*, 74 U.S.P.Q. 2d 1716, was further misplaced because those cases are based on a misunderstanding of the underlying statute and regulations.

In *Moore*, the district court relied primarily on its interpretation of this Court's decision in *Advanced Cardiovascular*, 988 F.2d 1157 and diligence requirements found in 35 U.S.C §116 which provides a method to correct inventorship prior to issuance of a patent.

> While not discussed in *Advanced Cardiovascular Systems*, pursuant to 35 U.S.C. § 116, correction of inventorship may be accomplished prior to the issuance of a patent by application to the commissioner. See 35 U.S.C. § 116; 37 C.F.R. § 1.48. In addition, an action to correct inventorship while the patent application is still pending, under 35 U.S.C. § 116, includes the requirement that such amendment must be diligently made. See 37 C.F.R. § 1.48; *Stark v. Advanced Magnetic, Inc.*, 29 F.3d 1570, 1574 (Fed.Cir.1994). The requirement of diligence supports a finding that delay is discouraged, and laches may apply, even at these early stages. Thus, the rationale of *Advanced Cardiovascular Systems*, that laches may apply at any time that inventorship may be remedied but should not apply before the omitted inventor has learned of the claim, applies in equal force to the time during which a patent application is pending, but before it is issued.

Moore, at *4.

In broadly defining the term "claim" to encompass more than Hor's claim brought under §256, the district court relied on the statement in *Moore* that an action for correction of inventorship could be pursued under 35 U.S.C. §116 while the patent application was pending and that such actions required diligence under 37 C.F.R. §1.48. *Hor,* 965 F.Supp.2d at 915. The district court in effect held that Hor's claim under §256 was also a "claim" under §116, and that, because a lack of diligence could bar a §116 claim, the mere issuance of a patent could not revive that same claim under §256. *Hor,* 965 F.Supp.2d at 916.

However, the diligence requirement on which the district court and *Moore* relied has not existed since 1997. "As of December 1, 1997, however, the requirement that an amendment of the inventorship under section 1.48 be made 'diligently' has been removed." *Schulze v. Green*, 136 F.3d 786, 789, n.3 (Fed. Cir. 1998). This change in law eviscerates the primary rational cited for laches in *Moore* and, thus, the district court's reliance on *Moore* is questionable at best.

A different regulation governs the correction of inventorship of issued patents and it does not contain a diligence requirement:

> Whenever a patent is issued and it appears that the correct inventor or inventors were not named through error without deceptive intention on the part of the actual inventor or inventors, the Commissioner may, on petition of all the parties and the assignees and satisfactory proof of the facts and payment of the fee set forth in § 1.20(b), or on order of a court

> before which such matter is called in question, issue a certificate naming only the actual inventor or inventors. A request to correct inventorship of a patent involved in an interference shall comply with the requirements of this section and shall be accompanied by a motion under § 1.634.

37 C.F.R. § 1.324.

The comments to the 1997 rule change make clear that the purpose of amending §1.48 was to harmonize it with the long-standing provisions of §1.324. See 62 Fed. Reg. 53,132 (October 10, 1997). The Rule publication first provided that: "Section 1.48 is amended in its title to clarify that the section concerns patent applications, other than reissue applications, and not patents." *Id.* at 53,137. Additionally, the Final Rule expressly states that "[t]he requirement that any amendment of the inventorship under §1.48(a) be 'diligently' made has been removed." *Id.* at 53138. Thus, §1.48 and §1.324 are independent regulations governing correction of inventorship in separate contexts. The Final Rules expressly considered and rejected imposing a "diligence" requirement on § 256 (§1.324):

> Section 1.324 is amended by creating paragraphs (a) and (b). The requirement for factual showings to establish a lack of deceptive intent is deleted, with a statement to that effect being sufficient, paragraph (a).
>
> Office practice is to require the same type and character of proof of facts as in petitions under §1.48(a). . . . Unlike former §1.48, former §1.324 contained no diligence requirement. See *Stark v. Advanced Magnetics*, Inc., 29 F.3d 1570, 1574 (Fed. Cir. 1994). Section 1.324 (and § 1.48) as

> adopted contain no diligence requirement, for the reasons set forth in the discussion of §1.48.

Id. at 53171.

As this Court noted in *Stark v. Advanced Magnetics, Inc.,* 119 F.3d 1551, 1553-54 (Fed. Cir. 1997), to the extent that the language of §116 and §256 lead to different and, arguably, inconsistent results, only Congress has the power to resolve the conflicts. The district court clearly erred to the extent that it used the rationale put forth in *Moore* as a basis to bar Hor's inventorship claims under §256 for any perceived action or inaction while the patent applications were pending.

In *Frugoli,* 74 U.S.D.Q. 2d 1716, the court was clearly influenced by the posture of the case in finding that laches barred Frugoli's claim. The patent in that case involved software to facilitate sales and service of prepaid wireless cellular phone airtime to credit-challenged customers. *Id.* at 1178. The facts established that Frugoli only brought a claim to correct inventorship under §256 after he was approached by Verizon Wireless, a direct competitor for the phone services facilitated by the patented software. Verizon paid Frugoli $200,000 up-front in exchange for any rights Frugoli might have in the patent and Frugoli agreed to bring the lawsuit for correction of inventorship. The lawsuit was financed and controlled by Verizon which agreed to pay Frugoli additional money if the suit was successful. *Id.* at 1720.

None of those factors were present here. In fact, if Hor were named as an inventor he would be required to assign his rights to UH and any payments he received would be according to UH policy. A568.

In short, *Moore* and *Frugoli* are not precedential, do not adequately analyze this Court's decisions in *Advanced Cardiovascular* and *Aukerman*, and mistakenly rely on outdated law. The district court erred in relying on those decisions to find that laches barred Hor's claims under §256.

This Court Has Expressly Disclaimed a *Per Se* Diligence Requirement for §256 Claims

This Court has found that neither "35 U.S.C. § 256 nor 37 C.F.R. § 1.324 [a regulation relating to § 256] expressly require that an omitted inventor of an issued patent must diligently bring a lawsuit to correct inventorship or be forever barred from doing so." *Stark v. Advanced Magnetics, Inc.*, 29 F.3d 1570, 1574 (Fed. Cir. 1994). This Court noted that "lack of diligence may be an appropriate basis for barring legal action when there is an affirmative obligation on the claimant to act promptly and without significant pause in establishing a legal right." *Id.* There was no evidence of an affirmation obligation on Hor to act prior to issuance of the patent.

This Court in *Stark* correctly analyzed where other courts had gone wrong in finding diligence requirements under §256. The defendant in *Stark* relied on two district court opinions that had imposed a diligence requirement. *Id.* at 1574, referencing, *Crainich v. Feinstein*, 1991 WL 259448 (N.D.Ill. 1991) and *Rival Manufacturing Co. v. Dazey Products Co.*, 358 F.Supp. 91 (W.D. Mo. 1973).[10] This court noted that although "these district court cases are not of precedential value, we point out that their statements that §256 requires diligence, as a matter of law, go beyond the statute and implementing regulation." *Id.* at 1575.

In *Crainich* the omitted inventor knew that he was omitted from a pending patent application, communicated with the patentee without raising inventorship rights, and did not object until five years later when he sued to correct inventorship under 35 U.S.C. § 256. The court found estoppel, in view of detrimental reliance by and prejudice to the other party. "Citing *Rival v. Dazey*, the district court stated that there was a diligence requirement in § 256, thus continuing the unwarranted reading of the statute." *Stark,*29 F.3d at 1575.

Thus, this Court has recognized that there is no *per se* diligence requirement inherent in §256, and each case must be judged on its own facts.

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[10] This Court found *Rival* to be of no guidance because the statute at that time did not allow for correction of inventorship under the facts of the case.

> Absent any statutory or regulatory requirement of diligence in bringing legal action to correct inventorship of an issued patent, it was error to hold that [an] action to correct inventorship was barred for lack of diligence as a matter of law. Whether diligent action is required in a particular case must be determined on the facts of that case.

Id. at 1575. The facts surrounding Hor's case clearly established that, at a minimum, there was a genuine issue of fact regarding whether he acted diligently to pursue a claim under §256.

The Summary Judgment Evidence Raised Genuine Issues of Material Fact Regarding Any Diligence Requirement

This court's decision in *Stark* clearly establishes that the district court erred because there were genuine issues regarding whether Hor acted diligently. In *Stark*, the plaintiff filed suit in 1992 seeking correction of inventorship on six issued patents. *Id.* at 1572. The district court granted summary judgment against Stark because he should have known of the existence of one of the patents at issue in early 1989 but failed to exercise diligence in bringing the suit about three and one-half years later. *Id.* The district court measured Stark's diligence from the time he received an Advanced Magnetics, Inc. ("AMI") annual report disclosing a patent application. Stark claimed that he made inquiries of AMI soon after he received the Report, and that he was told that the patent did not concern his work. AMI did not contradict Stark's claims. This Court found that under the summary judgment standard of review, Stark's statements "must be accepted as true" and any controverting evidence by AMI could only serve to place the fact in dispute. *Id.* at 1575-1576.

> The record describes a scientific collaboration and consulting relationship between Dr. Stark and the AMI scientists, of several years' duration. Whether Dr. Stark was deliberately misled by persons he had reason to trust, and whether he behaved reasonably in failing to seek prompt verification and diligent correction, are questions of fact. On the averments before the district court these facts had been placed in issue, and are material to the result. Since these facts could not be found or inferred adversely to Dr. Stark on AMI's motion, summary judgment in favor of AMI was improperly granted.

Id. at 1576.

Similarly, the issue of whether Hor acted diligently was placed in issue in this case by the summary judgment evidence. As set forth in detail in Issue No. 2, Hor relied on Chu's assurances that misled him into believing he was to be named as an inventor. And Hor could have reasonably believed that he was named as an inventor because he was the alternate Principal Investigator for the group at the critical time, he was a long-time collaborator of Chu, he was paid $137,000 for his contributions to YBCO-123, he was named as the first author on all of the published scientific papers resulting from the discovery of YBCO-123 and the related magnetic rare earth superconductors, Chu consistently credited him with having been instrumental in the discovery of YBCO-123, and no one ever told him that he was not an inventor.

Finally, it is undisputed that Hor did not know anything about the '418 patent until 2007 at the earliest. A566. The district court discounted all of this evidence and construed the evidence and inference to be drawn therefrom in favor of Chu.

Issue No. 2 Restated

> Assuming that the doctrine of laches applied, the district court erred in finding that Hor unreasonably delayed filing this suit and in finding evidentiary prejudice to Chu.

There Was No Unreasonable Delay or Lack of Diligence by Hor

Under the appropriate standard of review, the district court erred in concluding that Hor unreasonably delayed filing suit. In this regard, the district court construed the evidence in the light most favorable to Chu and drew all inferences in his favor. The primary evidence relied on by the court was Hor's attendance at the meeting with Chu and Cox in 1987 or 1988. *Hor*, 965 F.Supp.2d at 916. At that meeting, Chu suggested to Cox that Hor and Meng should be named as inventors. When Cox replied that not everyone can be inventor and that a "pair of hands" cannot be considered an inventor, Hor was admittedly upset and left. When Chu followed him and told him that the lawyer "did not know anything about our group" and that he would "go back to tell him and straighten things out", Hor took him at his word. A566-567. Chu's basic position was that Hor was wrong to trust him and should have done something more.

But as a long-time collaborator of Chu, Hor did trust Chu and it appeared that his trust was well-placed. A561-562. When Chu had to leave for his one-year term at the NSF, he made Hor the alternate Principle Investigator even though he was a graduate student at the time. A561-562. In 1988, after the discovery of YCO-123, Chu made sure that Hor was paid the sum of $137,000 for his contributions to the discovery of YBCO-123 out of the funds paid by DuPont. A2246. This payment could easily have lead a reasonable person to believe that Chu was living up to his word and Hor could have reasonably relied on the fact that he was paid a sum more than 3 times his annual salary to believe that he was included in any resulting patent applications.

In addition, over the years, Chu himself consistently credited Hor as being instrumental in the discovery of YBCO-123 and especially the related magnetic rare earth superconductors. For example, Chu wrote the Chairman of the UH Physics Department on October 6, 1992, to support Dr. Hor's bid for promotion and tenure:

> Over the last five years, Pei's contributions to our research on high temperature superconducting (HTS) and related materials have been significant and numerous. I would like to give only a few examples of advances that he has single-handedly made possible. He and colleagues working under his direction discovered the whole series of the so-called 123 compounds $REBa_2Cu_3O_7$ [RE stands for rare-earth] – the most important HTS compound system to date for both scientific study and large-current applications above 77K. The results appeared in the May

> 1987 issue of [Physical Review Letters] which became the most cited physics paper in 1987 . . . and 1988.

A2039-2041.

Chu again credited Hor with discovery of the magnetic rare-earth superconductors in a paper published in 1987:

> In an attempt to identify the active elements giving rise to the 90K superconductivity, Hor, et al. at Houston decided to employ the standard technique of probing the superconductivity by magnetic rare-earth ions. To our great surprise, the 90 K superconductivity in YBCO was hardly affected at all even when Y was completely replaced by strongly magnetic rare-earth elements such as Gd, Sm, Eu, etc.

A2035.

Finally, Hor was listed as the first author from the Houston group on all of the relevant scientific publications regarding the creation of YBCO and the magnetic rare-earth superconductors. A664-667; 2042-2045. This position connotes that person made the most important technical and scientific contribution to the work. A566; 2199. And the evidence established that on at least five other patents obtained by Chu, the first author on the related paper was named as a co-inventor. A564.

Clearly, given Hor's position in the research group at the time of the discovery of YBCO-123, Chu's representations to Hor, his payment of money to Hor, and his consistent crediting of Hor for the inventions that are the subject of the patents-in-suit, there was sufficient evidence to raise a genuine issue of fact as to whether Hor "behaved reasonably in failing to seek prompt verification and diligent correction" of inventorship of the patents-in-suit. *Stark*, 29 F.3d at 1576.

Moreover, Hor's actions in pursuing this action showed reasonable diligence. Almost immediately upon learning that he was not named as a co-inventor, Hor took action by notifying UH of his claim. A567. When UH and Chu failed to take any action to correct inventorship, Hor attempted to resolve this matter within UH's internal grievance process. A1259-1265. This was met with a strong and detailed denial from Chu. A1911-1935. And then despite repeated attempts by Hor to have his grievance heard, UH administration prevented Hor's grievance from going forward. A1158-1180.

Finally, if Hor had attempted to act before the patents-in-suit issued to correct inventorship, both Chu and UH would have had to effectively consent to Hor's claim of inventorship under 37 C.F.R. §§ 1.48 and 1.63. Given their actions in opposing Hor both before and after the patents issued, the only reasonable inference that can be drawn from the evidence is that neither UH nor Chu would have cooperated with Hor in attempting to resolve this matter through the USPTO. UH has consistently sided with Chu, has paid his attorney's fees in this suit and in Hor's internal grievance at UH, and has supported Chu's belief that Hor is not a co-inventor. A2276-2277; 1911-1935. Essentially, the district court believed that Hor should have engaged in a futile course of action and that his failure to do so precludes him from presenting his case under § 256. However, an unreasonable delay cannot stem from the failure to take actions that would have been futile and met with opposition from Chu and UH. There was no unreasonable delay.

Hor Sufficiently Rebutted Any Presumption of Evidentiary Prejudice

The district court further erred in finding that there was evidentiary prejudice to Chu.[11] The court's decision ignored most of the rebuttal evidence offered by Hor and the fact the discovery of YBCO-123 was one of the best documented scientific discoveries of the last 25 years. For example, Chu not only prepared scientific papers documenting the discoveries, but also wrote several accounts concerning the history of the discovery of YBCO ranging from articles written in 1987 (shortly after the discovery) until 1997 (approximately ten years after the events in question). The work of the research group and the scientific and technical aspects of the discoveries are well documented in these articles written by Chu. A1936-1976; 1977-1979; 2017-2033; 2034-2038; 2042-2045; 2046-2047; 2048-2062; 2063-2089. A1672-1712, 1733-1737, 1747-1761 and 1779-1778. Chu was also able to capably respond to Hor's grievance with a great amount of detail. A1911-1935. To the extent that

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[11] The court correctly did not find any evidence of economic prejudice as it did not address that issue.

certain dates were in questions, Chu produced a copy of his calendar from the relevant time period. A1266-1269. In addition, all of the laboratory notebooks from the relevant time period have been preserved. A1456-1905. These notebooks provide a wealth of detail about the experiments that led to the discovery of YBCO and the magnetic rare earth superconductors.

The deposition testimony also demonstrated that Hor, Meng and Hazen were also able to remember many details from the relevant time period. A2107-2181;2182-2212; 2213-2235. In addition, Hazen (whose group was responsible for identifying the chemical composition and stoichiometry of YBCO-123) wrote a book in 1987 about many of the events in question entitled Superconductivity: The Breakthrough which was used by all parties during discovery. A2184-2185.[12] Much of Hazen's book is based on his interviews with Chu which were shortly after the events in question as he wrote the book in the summer of 1987. A2184-2186; 2201-2203; 2207; 2211-2212. Finally, Chu's or UH's attorneys have had possession of thousands

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[12] An example of how the district court construed the evidence in favor of Chu is the reference in its opinion to one email from Hazen stating that his memory of details from 1987 was "completely lost." *Hor*, 765 F.Supp.2d at 919. First, Hazen had no first hand knowledge of the events leading to the discovery of YBCO-123 and the related superconductors. Second, a review of Hazen's deposition testimony indicates his memory of events possibly relevant to the issues in this lawsuit was reasonably clear. A2182-2212. While Chu complained Hazen had no memory of the events in question, his counsel noticed Hazen's deposition and traveled to Washington, D.C. to take that deposition. A2182.

of pages Dr. Hazen's notes and other documents utilized in the preparation of his book since at least 1989 and those documents were made available in this lawsuit. A2200.

In short, to the extent witnesses' memories have faded (if they have) there were abundant documents from which recollections were refreshed during discovery in this case. Lawsuits frequently revolve around events that occurred many years ago; and there was no evidence that the passage of time in this case was so detrimental as to constitute the evidentiary prejudice found by the district court.

The critical events relevant to Hor's claim of inventorship are concentrated over an approximately four month time frame from November of 1986 through March of 1987. Although the witnesses' memories regarding some of the events are not perfectly clear, their memories regarding the essential events are remarkable. In that vein, the district court accepted at face value Chu's attempt to paint a picture of lost recollections. A717-751 (cataloguing answers to deposition questions). However, looking at that testimony in context, it is clear that whatever facts the witnesses do not remember do not bear significantly on the essential issues and do not vary considerably from what might be expected in a case where events occurred more recently. For example, despite claiming that Ms. Meng suffers from memory lapses, Chu's counsel found her memory of events sufficient enough to require more than seven hours of detailed cross-examination at her deposition. A569.

Other than a brief mention of the lab notebooks, the district failed to consider any of the considerable amount of documentary evidence that is still available to all of the parties and witnesses in this lawsuit. The court failed to address the fact that Chu himself wrote numerous published accounts of the history of the YBCO-123 discovery, that Chu was able to respond to Hor's internal UH grievance in considerable detail, that Chu has his calendar from the relevant time period, that Hazen wrote an entire book about the discovery based on interviews with Chu and others, that all of Hazen's notes have been preserved, and that all parties were able to recall most events in considerable detail in their deposition and affidavit testimony. Moreover, the court's conclusion that the lab notebook is "of little help in identifying the source of the inventive conceptions" is a mere conclusion and the district court clearly would have benefitted from testimony on the contents of those notebooks in a full trial on the merits. The court merely assumed that the notebooks were immaterial to the issues here.

Finally, the court cites the death of Peter Huang. *Hor*, 965 F.Supp.2d at 919. Huang was a graduate student at the time of the discoveries whose primary job was to test samples for superconductivity. Although he was a good student, he was not directly involved in the critical events at issue and the results of his superconductivity tests have been preserved. A569. Chu and the district court never provided any cogent explanation as to why Huang's testimony would have been important. It is mere surmise to conclude that Huang's testimony could have had any impact on this case.

Any possibility of evidentiary prejudice was clearly rebutted by the summary judgment evidence. At a minimum, there was clearly sufficient rebuttal evidence to place the issue of evidentiary prejudice genuinely in issue. See *Serdarevic v. Advanced Medical Optics, Inc.*, 532 F.3d 1352, 1359-1360 (Fed. Cir. 2008).

Issue No. 3 Restated

> The district court erred in holding that Hor's claim was barred by the doctrine of equitable estoppel because Chu never raised that issue and the elements for equitable estoppel were not met.

Standard of Review for Equitable Estoppel

Equitable estoppel to assert a claim is a defense addressed to the sound discretion of the trial court. *Olympia Werke Aktiengesellschaft v. General Elec. Co.*, 712 F.2d 74, 77 (4th Cir.1983). When a defendant asserts equitable estoppel, the evidence must be viewed in the light most favorable to the plaintiff, and all inferences must drawn in favor of the plaintiff. *Aukerman,* 960 F.2d at 1043.

The elements of the defense of equitable estoppel are: (1) an actor, who usually must have knowledge of the true facts, communicates something in a misleading way, either by words, conduct or silence; (2) the other relies upon that communication; (3) the other would be materially prejudiced if the actor is later permitted to assert any claim inconsistent with his earlier conduct. *Aukerman*, 960 F.2d at 1041 (declining to hold equitable estoppel barred the plaintiff's inventorship claims). Unlike laches, no presumption adheres to an equitable estoppel defense. A defendant must prove all of the factual elements of estoppel. *Id.* at 1043. Moreover, even if the three elements of estoppel are established, the court must take into consideration any other evidence and equities of the parties in deciding whether to allow the defense to bar the suit. *Id.*

The Evidence did not Support a Finding of Equitable Estoppel

Chu never pleaded equitable estoppel or asserted it as a ground for granting summary judgment. Nonetheless, the district court found that equitable estoppel precluded Hor's claims for correction of inventorship under §256 actions. *Hor,* 765 F.Supp.2d at 922.

With respect to applying equitable estoppel to bar Hor's claims, only one act of Hor is cited by the court. When Hor was asked by Cox in the meeting with Hor, Chu and Meng in 1987 or 1988, which one of them came up with the idea of Yttrium substitution, Chu asked Meng if she remembered that he had suggested that in a telephone call to her. Hor testified that he was "shocked" at Chu's statement, but did want to embarrass Chu. After Meng had responded that she did not remember, Hor stated that he too did not remember. A566-567. However, what Hor was stating that he did not remember was an alleged phone call from Chu to Meng. There was nothing inherently misleading in stating that he did not remember an alleged phone call to which he was not a party.

The district court turned Hor's attempt to spare Chu some embarrassment into admission of "misleading Chu and UH into believing [his] participation in the discoveries did not rise to the level of inventorship." and act of untruthfulness sufficient to call the doctrine of equitable estoppel into play. *Hor*, 965 F.Supp.2d at 922-923. First, there is no evidence that at the time Hor understood what it meant to be an inventor for purposes of the patent process. Moreover, the district court completely ignored what happened immediately after Hor's one statement. When Cox protested that not everyone can be an inventor and stated that a "pair of hands" cannot be an inventor, Hor abruptly left the room. Chu followed Hor and told him that Cox did not understand how their group worked and promised to "straighten him out." A566-567. The district court cited nothing more than this one instance, and it is hardly sufficient to meet the first element of the test for equitable estoppel.

"The second element, reliance, is . . . essential to equitable estoppel." *Heckler v. Community Health Svcs.*, 467 U.S. 51, 59 (1984). Chu had the burden to establish that he substantially relied on the misleading conduct of Hor in connection with taking some action. See *Aukerman*, 960 F.2d at 1042. The reliance element has been described as requiring a defendant to show that the plaintiff's conduct lulled them into a sense of security in going ahead with their own actions. See *Stewart & Stevenson Services, Inc. v. Serv-Tech, Inc.*, 794 F.Supp. 202, 206 (S.D. Tex. 1992).

The district court cites no evidence to support a finding of reliance or any actions that Chu or UH undertook in reliance on Hor's action or inaction. Rather, the evidence establishes that Chu was not misled by Hor's statements and did not rely on them as evidenced by his promise to take action to correct any misconception that Cox might have. Chu clearly failed to act as promised to Hor and yet, somehow the district court painted Hor as being maximally untruthful.

There was no evidence that Cox relied on Hor's one statement and it would have been unreasonable for him to do so. Chu and Cox had a duty of candor, good faith, and honesty in their dealings with the U.S. Patent and Trademark Office. See *Molins PLC v. Textron, Inc.*, 48 F.3d 1172, 1178 (Fed.Cir.1995). Both Chu and Cox were or should have been aware of Hor's involvement. Hor was the alternate Principal Investigator of the research group during the relevant time period. A562.

Hor was listed as the first author on the relevant scientific papers relating to the discovery of YBC-123 and the magnetic rare-earth superconductors. A566; 664-667; 2042-2045. Hor also received payment of $137,000 from the UH based on his work on YBCO-123 and the related superconductors. A2246. Despite all of this, Cox apparently never made further inquiries of Hor. Hor's conduct in the only incident cited by the court, when taken as a whole and when considered in light of Chu's own conduct and the other evidence cannot support any finding of equitable estoppel.

Nonetheless, the district court claimed that "Chu and UH's counsel relied on Hor's alleged lack of recollection and Meng's repeated representations that Chu conceived of the Yttrium substitution." Hor, 965 F.Supp.2d at 922-923. But the court did not identify any positive acts that either Chu or UH took in reliance on Hor's conduct in the meeting with Cox. There is no evidence of any other action by Cox in the record. Thus, only Chu could establish reliance. But rather than analyze evidence, the court engaged in mere supposition of what might have transpired; *i.e.* that UH might have investigated Hor's claims had they been made known. *Id.* There is no evidence to even support an inference of this regard in the summary judgment record. Because Chu did not raise equitable estoppel as a bar to Hor's claims, he made no effort to establish that he or UH relied on anything that Hor did or did not do. The district court supposed that UH (a non-party) could have investigated Hor's claims, but there is no evidence that they did not in fact undertake some investigation. And UH, as licensee and its counsel, were obligated by the duty of candor and good faith to make sure that the proper inventors were named in the patent regardless of any action by Hor. Even if UH had investigated Hor's role in the discovery of YBCO-123 and the magnetic rare earth superconductors and determined that he should be named as an inventor, it would not have materially altered UH's subsequent conduct in defending the patents. As a UH employee, Hor was obligated to assign his patent rights to UH and UH would have had no less incentive to defend the patents simply because another UH employee was correctly named as an inventor.

Finally, Chu must establish material economic or evidentiary prejudice or harm to establish a defense of equitable estoppel *Aukerman,* 960 F.3d at 1043. Chu made no effort to do so. The court summarily concludes that by "changing [Hor's story] and bringing claims to inventorship more than twenty years later, Chu has been greatly prejudiced in defending his position as the sole inventor." *Hor*, 965 F.Supp.3d at 923. As detailed above, the evidence presented in summary judgment is clearly insufficient to establish evidentiary prejudice to Chu, and in fact demonstrates that the documentary evidence needed to try the case is available and that the witnesses are reasonably capable of recalling the facts surrounding what was obviously one of the most important events of their lives.

The district court's sua sponte holding that equitable estoppel bars Hor's correction of inventorship claims was unsupported by the evidence and should be reversed.

CONCLUSION

The district court erred in granting summary judgment for Chu based on the doctrines of laches and equitable estoppel. At a minimum, the summary judgement evidence raised genuine issues of material fact as to whether those doctrines apply to the facts of this case.

For the reasons stated herein, Appellant Pei-Herng Hor respectfully requests that the Court reverse the judgment of the district court, and remand this case for further proceedings.

Respectfully submitted,

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ADDENDUM

1. Final Judgment (Docket No. 107)
2. Memorandum and Order (Docket No. 105)
3. Order Denying Motion for New Trial (Docket No. 110)
4. U.S. Patent No. 7,056,866
5. U.S. Patent No. 7,709,418
6. 35 U.S.C. § 116
7. 35 U.S.C. § 256
8. 37 C.F.R. §1.324
9. 37 C.F.R. §1.48

IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

PEI-HRENG HOR, Plaintiff, v. CHING-WU "PAUL" CHU, Defendant.	§ § § § § § § § § § §	CASE NO. 4:08-cv-03584

FINAL JUDGMENT

On January 21, 2011, the Court issued its Memorandum and Order, GRANTING Defendant Ching-Wu "Paul" Chu's Motion for Summary Judgment on the Inventorship Claims of Pei-Herng Hor and Ruling Meng Based on Laches (Dkt. #45) and Defendant Chu's Motion to Dismiss or in the Alternative for Summary Judgment Upon Intervenor Meng and Plaintiff Hor's Unclean Hands Defenses Under Rule 12(b)(6) or Rules 12(c)/56(b) (Dkt. ##66 & 68). After consideration of any opposition, the Court hereby grants Defendant Chu's Motion for Entry of Final Judgment.

THE COURT HEREBY ORDERS that this Judgment be entered in accordance with the Court's Memorandum and Order entered on January 21, 2011 (Dkt. #105).

THE COURT HEREBY ORDERS that Plaintiff Hor's claim of inventorship under 35 U.S.C. § 256 is barred by the doctrines of laches and/or equitable estoppel.

THE COURT HEREBY ORDERS that Intervenor Meng's claim of inventorship under 35 U.S.C. § 256 is barred by the doctrines of laches and/or equitable estoppel.

THE COURT HEREBY ORDERS that Plaintiff Hor's defense of unclean hands is dismissed.

THE COURT HEREBY ORDERS that Intervenor Meng's defense of unclean hands is dismissed.

THE COURT HEREBY ORDERS that each party shall bear its own costs and attorneys fees.

IT IS SO ORDERED.

This is a **FINAL JUDGMENT**.

Signed at Houston, Texas, on this 18th day of February 2011.

KEITH P. ELLISON
UNITED STATES DISTRICT JUDGE

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

PEI-HRENG HOR,	§	
	§	
Plaintiff,	§	
	§	
v.	§	**CIVIL ACTION NO. 4:08-cv-3584**
	§	
CHING-WU "PAUL" CHU,	§	
	§	
Defendant.	§	

MEMORANDUM AND ORDER

Pending before the Court is Defendant Ching-Wu "Paul" Chu's Motion for Summary Judgment on the Inventorship Claims of Pei-Hreng Hor and Ruling Meng Based on Laches (Doc. No 45), Defendant's Motion for Partial Summary Judgment on Pei-Hreng Hor's and Ruling Meng's Claims of Inventorship Based on Lack of Corroboration (Doc. No. 46), Defendant's Motion to Dismiss or in the Alternative Motion for Summary Judgment Upon Intervenor Meng's Unclean Hands Defense (Doc. No. 66), and Defendant's Motion to Dismiss or in the Alternative Motion for Summary Judgment Upon Plaintiff Hor's Unclean Hands Defense (Doc. No. 68).

Having considered the parties' filings, all responses and replies thereto, and the applicable law, the Court finds that Defendant's Motion for Summary Judgment Based on Laches should be **GRANTED** and Defendant's Motions to Dismiss or in the Alternative for Summary Judgment Upon Intervenor Meng's and Plaintiff Hor's Unclean Hand Defenses should be **GRANTED**. The Court declines to reach Defendant's remaining motion, as laches is a complete defense to claims of inventorship under 35 U.S.C. § 256.

I. BACKGROUND

This cases arises out of a dispute over rightful inventorship of U.S. Patent Nos. 7,056,866 ("the '866 Patent") and 7,709,418 ("the '418 Patent") (collectively "patents-in-suit"). The patents-in-suit involve superconducting compositions with transition temperatures ("T_c") higher than the boiling point of liquid nitrogen (approximately 77° Kelvin).[1]

Dr. Ching-Wu "Paul" Chu ("Defendant" or "Chu") is listed as the sole inventor on both of the patents-in-suit. Dr. Pei-Herng Hor ("Plaintiff" or "Hor") filed the present suit to correct inventorship in December 2008 pursuant to 35 U.S.C. §256, alleging that he is a joint inventor of the scientific advancements that underlie the patents-in-suit. (Doc. No. 1.) In March 2010, the Court granted a Motion to Intervene by Ruling Meng ("Intervenor" or "Meng") who also claims joint inventorship of the patents-in-suit. (Doc. No. 25-1.)

A. Invention of and Applications for the Patents-in-Suit

The high temperature superconducting compositions that are the subject of the patents-in-suit were conceived of between November 1986 and March 1987. During this time, Chu, Hor, and Meng worked together in the physics research laboratory Chu directed at the University of Houston ("UH") where Chu held an appointment as a Professor of Physics. In September of 1986, Chu left UH to begin service as a Program Director at the National Science Foundation ("NSF"). (Hor. 2006 Aff. at 2; Meng 2006 Aff. at 2.) During Chu's one-year term with NSF, Chu named Hor, then a UH graduate student in the Physics Department and one of his Research

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[1] Superconductivity, first discovered in 1911, is a phenomenon occurring in certain materials, characterized by zero electrical resistance and the exclusion of the interior magnetic field (known as the Meissner Effect). Electrical resistance is a measure of the degree to which a material opposes an electric current passing through it. Electrical resistance is measured in ohms. The electrical resistance of a superconductor drops abruptly to zero ohms when the material is cooled below its superconducting T_c. An electric current flowing in a loop of superconducting wire can persist indefinitely with no power source. Superconductivity of a material occurs, however, only at very low temperatures. Superconductors with a T_c higher than the boiling point of liquid nitrogen, which is approximately 77° Kelvin, are commercially valuable because liquid nitrogen can be produced cheaply and is not prone to some of the problems exhibited by the cooling agents required to achieve lower temperatures. Superconductors with a T_c above 77°K are commonly referred to as High Temperature Superconductors. (Hor 2010 Decl. at ¶ 3, Doc. No. 77; U.S. Patent 7,709, 418 at 2.).

Assistants, as the alternate Principal Investigator for his UH research group. (Hor. 2006 Aff. at 2; Hor 2010 Decl. ¶5.) In Chu's absence, Meng continued to serve Chu's research group in her capacity as an independent materials scientist, synthesizing and characterizing various compounds for the group's research. (Meng Compl. ¶ 9; Meng 2006 Aff. at 1.) During his year away, Chu returned regularly to his laboratory at UH on the weekends and stayed in close contact with the members of his research group, including Hor and Meng, calling the laboratory as often as every four hours. (Hor 2006 Aff. at 2; Meng 1993 Dep. 47:2-8.)

1. Initial Discoveries

In November 1986, Chu, Hor, and Meng reviewed an article written by J. Georg Bednorz and K. Alexander Müller, which related the discovery of relatively high temperature superconductivity using a Barium-Lanthanum-Copper-Oxygen (Ba-La-Cu-O) chemical composition. (Meng 2006 Aff. at 2; Hor 2006 Aff. at 2.) The article prompted Chu's research group to attempt to achieve a superconducting composition with an even higher T_c than that reported by Bednorz and Müller. (*Id.*) The Bednorz and Müller article indicated that their superconducting sample was prepared according to a nominal 5:5:5 ratio of Barium to Lanthanum to Copper. (Hor 2010 Decl. ¶ 8.) Using a solid state reaction protocol, the group at UH synthesized samples and performed experiments which resulted in observed superconductivity greater than 40°K T_c. (Hor 2006 Aff. at 3.) Meng alleges that she advised Chu that the solid state reaction method, rather that the wet chemistry method, should be used to repeat Bednorz and Müller's results. (Meng 2010 Dep. 42:21-43:14; Meng 2006 Aff. at 2.) Chu, however, denies that it was Meng's idea to use the solid state reaction method. He claims that Meng was convinced by the conclusion of the Bednorz and Müller article that the solid state reaction method would not work, but that Chu felt the group had nothing to lose by trying the technique, and so instructed Meng to proceed with it first. (Chu Dep. 399:13-400:23.)

Chu reported the results of the group's successful experiments at an early December 1986 meeting of the Materials Research Society. At the meeting, Chu discussed his group's work with Dr. M.K. Wu ("Wu"), his former graduate student and then Assistant Professor at the University of Alabama, Huntsville. (Hor 2006 Aff. at 3.) According to Hor and Meng, during these conversations, Chu asked Wu to begin experimenting with a Strontium (Sr) substitution for Barium in Bednorz and Müller's Ba-La-Cu-O system. (Hor 2006 Aff. at 3; Meng 2006 Aff. at 2.) Chu's UH research group also continued to manipulate the chemical composition of their samples in an effort to create so-called "chemical pressure" to mimic physical pressure, thereby raising the T_c. (Hor 2010 Decl. ¶ 10.) Through Wu's experiments, Chu's research group soon discovered that a Strontium substitution for Barium did indeed increase the system's T_c to about 42°K.

Aside from the dispute over the initial decision to use the solid state reaction method, the parties more or less agree about the events surrounding these foundational experiments. The conception of the chemical compositions that ultimately achieved superconductivity at a T_c higher than 77°K, however, is at the heart of the dispute in this case. Indeed, several subsequent advancements involving elemental substitutions and the identification of the compounds' chemical structure are hotly contested. The Court will attempt to summarize the parties' conflicting claims regarding these discoveries.

2. Invention of the Patents-in-Suit

In late December 1986 or early January 1987, Wu brought a La-Sr-Cu-O compound sample to UH for magnetic testing. (Meng 2006 Aff. at 2.) During Wu's visit, Hor, Meng, and

Li Gao, a UH graduate student, had a discussion with Wu and one of his graduate students in Hor's UH office. (Meng 2006 Aff. at 2; Hor 2006 Aff. at 3; Hor Dep. 50:2-53:5.) According to Hor, the scientists discussed the direction the UH group's research should go after an attempted substitution of Calcium for Strontium actually decreased the compound's T_c. (*Id.*; Hor 2010 Decl. ¶ 11.) Hor claims that, during the meeting, he took out a periodic table in an attempt to identify new substitutions that could be made to the Ba-La-Cu-O system in order to increase its T_c. (*Id.*) At that point, Hor alleges, he conceived of the idea to replace the element Lanthanum with the element Yttrium (Y). (*Id.*) Meng claims that, during this same meeting, she conceived of and suggested replacing Lanthanum with Lutetium (Lu). (Meng 2010 Dep. 103:15-104:5; Meng 2006 Aff. at 3.)

Hor's claim to conception of the Yttrium substitution is significant because the group's subsequent substitution of Yttrium for Lanthanum resulted in the creation of the Yttrium-Barium-Copper-Oxygen ("Y-Ba-Cu-O" or "Y-B-C-O") compound that first exhibited superconductivity above 77°K. (Hor 2010 Decl. ¶ 12; Meng Dep. 101-102; 116; 385-389.) Hor claims that, immediately after the discussion at UH about the Yttrium substitution, Meng ordered the element for the research group to begin conducting the substitution experiments. (Hor 2006 Aff. at 3.) Meng recalls that, because UH was not in session due to its winter break, she did not place the order until January 12, 1987. (Meng 2010 Dep. 111-114, 385-386.) Hor claims that he asked Wu also to begin working on the Yttrium substitution. (Hor 2010 Decl. ¶ 12.) Additionally, Meng allegedly suggested to Wu that he obtain Yttrium from NASA in Huntsville, Alabama, and begin working on the substitution immediately because Meng would be unable to get the element to UH for two weeks. (Meng 2010 Dep. 387:13-388:15; Meng 2006 Aff. at 3.)

After the meeting, Hor alleges that he asked Meng to record formulas for conducting the Yttrium substitution experiments, which she did on about January 13, 1987. (Hor 2010 Decl. ¶ 13.)

Chu does not dispute that a conversation took place at UH in late December or early January between members of his research group and Wu, or that the Yttrium substitution concept was discussed at that meeting. Chu has long maintained, however, that his colleagues merely communicated *Chu's* Yttrium substitution concept to Wu. Chu allegedly conceived of the idea in mid-December, and by the 26th of that month, he concluded that Yttrium and Lutetium would indeed create high temperature superconductors. (Chu Dep. 150:6-18.) Chu alleges that, prior to Hor and Meng's meeting with Wu at UH, Chu had a phone conversation with Meng in which he described to her his idea for the Yttrium substitution. Chu has also testified that it was he who instructed Meng to order the Yttrium for the UH laboratory. (Chu Dep. 150:19-151:5.)

On January 12, 1987, Chu filed the first patent application related to the Y-B-C-O superconductor (U.S. Patent Application No. 07/002,089, now abandoned). In addition to the Y-B-C-O concept, the application also described the substitution of Lanthanum and Lutetium for Yttrium. On January 26, 1987, Chu filed a continuation-in-part application (U.S. Patent Application No. 07/006,991, now abandoned), which, according to Hor, did not include significant changes to the basic inventions described in the January 12, 1987 application.

On January 29, 1987, Wu called Chu claiming that he had observed superconductivity above 77°K in a compound in which he had substituted Yttrium for Lanthanum. (Hor. 2010 Decl. ¶ 17; Meng 2006 Aff. at 3.) Chu asked Wu to bring the sample to UH for magnetic measurements to confirm the results. (Meng 2006 Aff. at 3.) Following the phone call, Hor claims that Chu asked him to write down the formulas that Hor discussed with Wu during the

December 1986 meeting at UH. (Hor 2010 Decl. ¶ 17.) These formulas included, Hor alleges, a Y-B-C-O compound using a nominal 2-1-4 formula ("2-1-4 Y-B-C-O"). (*Id.*)[2]

On about January 29 or 30, 1987, Wu brought a 2-1-4 Y-B-C-O sample to UH in which he had earlier observed superconductivity above 77°K. (Hor 2010 Decl ¶ 18.) The testing at UH confirmed that the sample was genuinely superconducting with a reproducible 77°K T_c. The discovery of superconductivity above 77°K in the 2-1-4 Y-B-C-O sample prompted Chu's research group to focus on studying the compound's structure and properties. Specifically, the group wanted to determine which stage of the multi-phase 2-1-4 Y-B-C-O sample actually contributed to the system's superconducting properties. (Meng 2006 Aff. at 3.)

Hor claims that Chu, Meng, and Hor worked together to successfully separate out high purity Y-B-C-O samples exhibiting superconductivity at a T_c of 90°K. (Hor 2010 Decl. ¶ 21.) Meng, on the other hand, alleges that she independently performed the analysis to separate the black and green crystals from the mixed green phase by studying a group of Y-B-C-O samples of varying compositions. (Meng Resp. to Chu Interrogs. at 7.) Meng claims that, through her experiments, she concluded that the black phase was the superconducting portion. (*Id.*) As a result, she argues that her experiments contributed to the conception of the high temperature Y-B-C-O formula and structure identified in the '866 patent, which had a Yttrium-Barium-Copper ratio of 1:2:3. The parties often refer to this as the "123-phase." Chu, however, argues that it was actually Drs. Hazen and Mao of Washington's Geophysical Laboratory who first identified the superconducting black phase and the insulating green phase, as well as the critical 1-2-3

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[2] In addition to the Yttrium substitution formulas Hor recorded, he alleges that he also recorded formula for a compound in which Scandium (Sc) was included. Chu subsequently filed a continuation-in-part application on February 6, 1987 in which added the elemental substitution of Scandium. Chu alleges that, although included in the February 6, 1987 application, the Scandium substitution is not claimed in either the '866 or the '418 Patent.

formula when they were conducting tests on samples at Chu's request. (Def.'s Mot. for Summ. J. at 17.)

Hor contends that he continued to experiment in order to determine why the Y-B-C-O compound exhibited superconductivity at such a high T_c. He claims that he wanted to study the pair-breaking effect, a phenomenon in which the T_c of a compound degrades in the presence of magnetic elements. (Hor 2010 Decl. ¶ 23.) As part of these experiments, on March 11 or 12, 1987, Hor alleges that he asked Meng to completely replace Yttrium in the Y-B-C-O 123-phase with the magnetic rare earth element Gadolinium (Gd). (*Id.*) To Hor's alleged surprise, he did not observe degradation of the T_c. (Hor. 2006 Aff. at 4.) The negative result of the magnetic pair-breaking effect, Hor contends, prompted him to conceive of the idea to substitute other magnetic ions into the 123-phase to produce new high temperature superconductors. (Hor 2010 Decl. 23.) Hor allegedly asked Meng to perform a complete substitution of Yttrium with different series of magnetic rare earth elements, and several new superconductors were discovered. (Hor 2010 Decl. ¶ 24.) Indeed, Hor claims that he conceived of all of the substitutions of the rare earth elements Neodymium, Samarium, Europium, Gadolinium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium and Lutetium, which are claimed in the patents-in-suit. (Hor Compl. ¶ 62.)

Meng, on the other hand, alleges that she suggested experimenting with all of the claimed rare earth elements except Gadolinium, which she agrees Hor proposed. (Meng 2010 Dep. 390:4-9.) Additionally, Meng claims that she independently developed the optimal processing conditions for the individual rare earth compounds and successfully synthesized the whole series of rare earth compounds using those parameters. (Meng Compl. ¶ 12.) She allegedly used differential thermal analysis for each of the different rare earth compounds to determine decomposition temperature, reaction temperature, and melting temperature by observing the material's weight change as a function of temperature. These experiments allegedly resulted in her observation that the rare earth compounds formed at a wide variety of temperatures (800-1000°C). (Meng Resp. to Chu Interrogs. at 8.)

Chu, for his part, claims that it was he who asked Meng to order rare earth oxides in January, long before Hor allegedly conceived of the idea to perform rare earth element substitutions. Chu also contends that he had already been conducting partial rare earth element substitution experiments beginning in late February before Hor allegedly asked Meg to undertake the experiments.

The rare earth element substitutions used to produce high temperature superconductors appeared in the continuation-in-part application Chu filed on March 26, 1987 (U.S. Patent Application No. 07/032,041). In this application, Chu also revised the composition ranges included in the previous Y-B-C-O applications to reflect the 123-phase discovery. This was the final application related to what ultimately issued as the '866 Patent. Another closely related patent application was filed on January 23, 1989, which resulted in the issuance of the '418 Patent.[3]

B. Post-Invention Events

In 1987, Chu submitted two papers that were published the same year based on aspects of the superconductor discoveries underlying the patents-in-suit. Both Hor and Meng admit to, at the time, reviewing every paper prepared by Chu. (Hor Dep. 92:4-93:11; Meng Dep. 205:17-206:20.) The two papers published in 1987 reference the filing of Chu's patent application

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[3] Meng alleges in her Complaint that the Wu Interference, discussed *infra*, resulted in the creation of this later-filed application.

describing the Y-B-C-O superconductor as "C.W. Chu, U.S. Patent Application (12 January 1987)." (Doc. No. 48-8.)

At some time in 1987 or 1988, Hor, Meng, and Chu met with one of UH's patent attorneys, Charles Cox, to discuss the scientists' respective contributions to the superconductor discoveries, apparently in relation to the filing of patent applications. (Hor 2006 Aff. at 6.) At the meeting, Hor claims that Cox asked the group, "Who was the first person to propose the Y-substitution?"[4] (*Id.*) Chu allegedly responded, pointing to Meng, "Ruling, do you remember that I called you and told you to do the Y-Substitution?" (*Id.*) Hor claims that both he and Meng replied that they could not remember who first proposed the Y-Substitution. (*Id.*) Chu then allegedly suggested that Hor and Meng should also be included as inventors on the patent applications. (*Id.*) In response, Cox stated, "Not everyone can be an inventor. A pair of hands cannot be considered an inventor." (*Id.*) According to Hor, he was disturbed by Cox's comment and so he stood up and walked out of the room. (*Id.*) Hor claims that Chu then followed him outside, apologized, and said, "I am sorry. This lawyer does not know anything about our group. I will go back to tell him and straighten things out." (*Id.*) Following the meeting, neither Hor nor Meng followed up with Chu or any UH official regarding their respective inventorship statuses on either of the patents-in-suit. (Hor Dep. 114:15-115:5; Meng Dep. 298:21-24; Meng 2006 Aff at 5.) Both Hor and Meng have testified that no one ever told them they would be included as inventors on either of the patents-in-suit. (Hor Dep. 114:15-115:5; Meng Dep. 582:8-18.)

Both of the applications for the patents-in-suit assigned any resulting patents to UH. In December of 1988, DuPont paid UH a sum of money for the future licensing rights to the inventions underlying the '866 Patent. (Chu Dep. 25:9-26:6.) Pursuant to an agreement between

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[4] "Y-substitution" refers to the Yttrium substitution.

Chu and UH, as inventor, Chu was to receive 50% of the net income derived from the technology, which amounted to approximately $680,000 in the case of the DuPont license. (Doc. No. 78-9.) In a letter dated December 22, 1988, UH's General Counsel informed UH's President that Chu intended to "pay some of his colleagues a percentage share of his share of the initial Du Pont proceeds." (*Id.*) An appendix attached to the letter indicates that Chu kept approximately $240,000 for himself and distributed the remainder of his share among twelve different colleagues, including Hor, Meng, and Wu, who all received $137,000. (*Id.*)

Although Cox was retained by UH, Chu executed a Declaration and Power of Attorney authorizing Cox to represent him during the prosecution of the patents-in-suit. (Doc. Nos. 84-5 & 84-6.) In approximately 1990, the University of Alabama initiated an interference proceeding on behalf of Chu's former student, Wu, ("Wu Interference") to contest priority of invention and inventorship of the patents-in-suit. In essence, Wu and one of his graduate students claimed that they had first independently discovered the 123 Y-B-C-O superconductor.

During the Wu Interference in 1990, at Cox's request, Meng executed a declaration describing certain events related to the development of the high temperature superconductors. Meng's declaration affirmed that Chu was the person who conceived of the critical Yttrium substitution. Specifically, Meng stated that "[d]uring a phone call in about mid-December 1986, C.W. Chu described to me his belief that the substitution of Y for La in a composition La-Ba-Cu-O would produce a composition of Y-Ba-Cu-O which superconducts at a T_c greater than that of a La-Ba-Cu-O." (Meng 1990 Decl. ¶ 2.) Meng's declaration also stated that Chu's concept was described to Wu at the late December 1986 meeting at UH. (*Id.* at ¶ 3.) In a 1993 declaration, also prepared for the Wu Interference, Meng stated that she attempted to replicate Bednorz and Müller's results using the solid state reaction technique "as directed by Dr. Chu." (Meng 1993

Decl. ¶ 4.) Additionally, Meng repeated her 1990 affirmation that Chu conveyed his conception for the Yttrium and Lutetium substitutions to her via telephone in mid-December 1986. (*Id.* at ¶ 9.)

Meng also gave deposition testimony in 1993 during the Wu Inference in which she testified that Chu conceived of the Yttrium substitution as well as the substitutions of Lutetium, Erbium, and other rare earth elements with a smaller atomic ratio than Lanthanum. (Meng 1993 Dep. 25:21-26:9.) In response to whether she had knowledge of whether anyone at UH ever prepared a patent application covering the discoveries she described in her declaration, Meng also stated, "I remember I had saw (sic) one patent application, but I'm not sure was end the 86 (sic), but I couldn't remember exactly." (Meng 1993 Dep. 88:13-89:15.) Meng also submitted a declaration in the 1989 *Qadri v. Chu* Interference in which she stated, "I have reviewed and am familiar with the contents of United States Application Serial No. 32,041 filed March 26, 1987 by C.W. Chu (hereafter the "Chu application)." (Meng 1989 Decl. ¶ 5.) The declaration also refers to her replication of Examples XIII and XIV listed in the body of the same patent application. The cover page and the first page of the March 26, 1987 patent application identify Chu as the sole inventor.

In connection with Meng's participation in the interference proceedings, on November 11, 1991, Cox sent Meng a five-page fax containing the abstracts of two patent applications that ultimately led to the patents-in-suit. (Doc. No. 71-1.) The fax also contained the abstracts of two other patent applications, one of which listed Hor and Meng as co-inventors along with Chu. The abstracts of the applications that led to the patents-in-suit, however, listed Chu as the sole inventor. (*Id.*)

In 1990, Hor submitted a declaration as part of the Wu Interference in which he recounted the conception of the Yttrium substitution in a manner consistent with Chu's version of the events. (Hor 1990 Decl., Doc. No. 49-2.) Specifically, Hor stated that, in a meeting at UH in late December 1987 in which Wu was in attendance, he "discussed the concept that the substitution of Y for La in a composition of La-Ba-Cu-O would produce a composition which superconducts at a T_c temperature greater than that of a La-Ba-Cu-O composition. Ru-Ling and I initiated the discussion of this concept with M.K. Wu." (*Id.* at ¶ 2.) Hor's declaration does not state that Hor was the source of the idea, only that he and Meng discussed it with Wu. (*Id.*) In his 2009 deposition, Hor admitted that he understood as of December 1990 that the Wu Interference resulted from the University of Alabama's challenge to the patent application UH filed. (Hor Dep. 58:10-59:11.) In addition to the aforementioned 1987 or 1988 meeting with Cox, Hor also met with Cox and John Warren, Vice Chancellor for Intellectual Property at UH, during the Wu Interference. Hor knew from these meetings that UH had filed patent applications on the high temperature superconductors on which he worked. (Hor. 2006 Aff. at 6-7.)

In 1999, Chu ultimately prevailed in the Wu Interference before the USPTO Board of Patent Appeals and Interferences, which awarded him priority of the patent application. The University of Alabama appealed that decision to federal district court. The suit was dismissed in 2000.

In January of 2006, nearly twenty years after the filing of the first patent application, Hor and Meng approached UH officials to inquire about inventorship of the patents-in-suit. Meng allegedly came to Hor's office with a heavy conscience, disclosing to Hor that she had lied about the conception of the Yttrium substitution during the Wu Interference. During that meeting, Meng claims that Hor asked her, "[D]o you know we are also inventors (sic)?" (Meng 2006 Aff.

at 5.) Meng allegedly responded, "I think we should but I do not know, I never asked." (*Id.*) Hor supposedly suggested that they find out. (*Id.*)

Plaintiff and Meng allege that, during a meeting in January 2006 with John Warren, they learned for the first time that they were not included as inventors on the applications for the patents-in-suit. On February 1, 2006, while both patents-in-suit were still pending before the PTO, Plaintiff and Meng met with UH outside counsel and other UH officials to discuss their claims to inventorship.

As a result, on February 21, 2006, counsel for UH and Chu filed an Information Disclosure Statement ("IDS") with the PTO, which included copies of letters from UH's outside counsel to Hor and Meng concerning their inventorship claims. The PTO subsequently granted Defendant's Petition to Suspend the Rules, which postponed the issuance of the '866 patent for a period of one month while UH investigated Plaintiff and Meng's claims.

On March 14, 2006, during another meeting regarding their inventorship claims, Plaintiff and Meng presented affidavits to UH officials. The affidavits described each scientist's alleged contributions to the development of the inventions underlying the patents-in-suit. Meng's 2006 affidavit disavowed her Wu Interference testimony that Chu told her of the Yttrium substitution idea, but swore that the remainder of her deposition testimony was true. (Meng 2006 Aff. at 5.) In Meng's 2010 deposition, however, she also recanted her Wu Interference testimony that she worked under Chu's direction in performing her experiments, thereby contradicting her 2006 affidavit statement that the remainder of her Wu Interference testimony was true. (Meng 2010 Dep. 227:1-229:6.)

II. LEGAL STANDARD FOR SUMMARY JUDGMENT

A motion for summary judgment under Federal Rule of Civil Procedure 56 requires the Court to determine whether the moving party is entitled to judgment as a matter of law based on the evidence thus far presented. *See* FED. R. CIV. P. 56(c). Summary judgment is proper "if the pleadings, depositions, answers to interrogatories, and admissions on file, together with the affidavits, if any, show that there is no genuine issue as to any material fact and that the moving party is entitled to judgment as a matter of law." *Kee v. City of Rowlett*, 247 F.3d 206, 210 (5th Cir. 2001) (quotations omitted).

A genuine issue of material fact exists if a reasonable jury could enter a verdict for the non-moving party. *Crawford v. Formosa Plastics Corp.*, 234 F.3d 899, 902 (5th Cir. 2000). This Court must view all evidence in the light most favorable to the non-moving party and draw all reasonable inferences in that party's favor. *Id.* Hearsay, conclusory allegations, unsubstantiated assertions, and unsupported speculation are not competent summary judgment evidence. FED. R. CIV. P. 56(e)(1); *see also Little v. Liquid Air Corp.*, 37 F.3d 1069, 1075 (5th Cir. 1994) (noting that a non-movant's burden is "not satisfied with 'some metaphysical doubt as to the material facts'" (citing *Matsushita Elec. Indus. Co. v. Zenith Radio Corp.*, 475 U.S. 574, 586 (1986))). Indeed, to survive a motion for summary judgment that is properly made and supported, the opposing party's response cannot rely merely on allegations or denials in the pleadings, but must point to specific facts showing a genuine issue for trial. *See* FED. R. CIV. P. 56(e)(2).

III. LEGAL STANDARD FOR LACHES

Chu moves for summary judgment on Hor and Meng's claims of joint inventorship, arguing that they are precluded by the doctrine of laches. Indeed, "[l]aches is an equitable defense that may bar an inventorship claim." *Serdarevic v. Advanced Med Optics, Inc.*, 532 F.3d

1352, 1358 (Fed. Cir. 2008). Its application "is committed to the sound discretion of the district court." *Id.* A court must look at all of the particular facts and circumstances of each case and weigh the equities of the parties. *A.C. Aukerman Co. v. R.L. Chaides Const. Co.*, 960 F.2d 1020, 1032 (Fed. Cir. 1992) (*en banc*). In general, to properly invoke a laches defense, a defendant bears the burden of proving two factors: 1) the plaintiff delayed in filing suit for an unreasonable and inexcusable length of time from the time the plaintiff knew or reasonably should have know of its claim against the defendant, and 2) the delay operated to the prejudice or injury of the defendant. *Id.* "Both of these factual premises must be met, predicate to the weighing of the facts of delay and prejudice to determine whether justice requires that the claim be barred." *Advanced Cardiovascular Sys., Inc. v. SciMed Life Sys. Inc.*, 988 F.2d 1157, 1161 (Fed. Cir. 1993). As the defendant, Chu must establish the laches defense by a preponderance of the evidence. *Aukerman*, 960 F.2d at 1045.

When applying laches in order to bar a claim, "the period of delay is measured from when the claimant had actual notice of the claim or would have reasonably been expected to inquire about the subject matter." *Advanced Cardiovascular Sys.*, 988 F.2d at 1161. Indeed, "the plaintiff is chargeable with such knowledge as he might have obtained upon inquiry, provided the facts already known by him were such as to put upon a man of ordinary intelligence the duty of inquiry." *Id.* at 1162.

A delay of more than six years after the omitted inventor knew or should have known of the claim will produce a rebuttable presumption of laches. *Id.* at 1163. Once the presumption of laches attaches, a party can remain "utterly mute" on the issue of prejudice and nonetheless prevail. *Serdarevic*, 532 F.3d at 1358. Certainly, "[w]here the presumption applies, the two facts of unreasonable delay and material prejudice '*must* be inferred, absent rebuttal evidence.'"

Moore v. Broadcom Corp., No. C06-05647 MJJ, 2008 WL 425932, at *3 (N.D. Cal. Feb. 14, 2008) (quoting *Aukerman*, 960 F.2d at 1037*)*. The plaintiff may "rebut the presumption of laches by offering evidence to show an excuse for the delay or that the delay was reasonable, or by offering evidence sufficient to place the matters of evidentiary prejudice genuinely at issue." *Serdarevic*, 532 F.3d at 1359-60 (quoting *Aukerman*, 960 F.2d at 1038) (quotations omitted).

With regard to the law of laches, the parties disagree about the time from which the period of delay may properly be measured. Chu argues that the period begins once the plaintiff knew or should have known of the claim to inventorship, regardless of whether the patent had already issued. On the other hand, Hor and Meng, analogizing from the patent infringement context, argue that the period of delay cannot begin prior to the issuance of the patent.

Hor and Meng are correct that, in infringement actions, "the period does not begin prior to the issuance of the patent." *Aukerman*, 960 F.2d at 1032. The Federal Circuit, however, has never had an occasion to pass on the question in the inventorship context and therefore "has not . . . explicitly ruled on whether the period of delay may begin prior to the issuance of a patent." *Moore*, 2008 WL 425932, at *4.

Indeed, the Federal Circuit cases involving laches in the inventorship context have not concerned plaintiffs who allegedly knew or should have known of their omission as inventors prior to the issuance of the patent. *See, e.g.*, *Advanced Cardiovascular Sys.*, 988 F.2d 1157; *Serdaveric*, 532 F.3d 1352. Although no precedent binds this Court, there is persuasive authority addressing the question presented. At least two district courts have found that the period of delay may begin prior to issuance of the patent. In so holding, a Northern District of California court explained:

> [T]he [Federal] Circuit, in *Advanced Cardiovascular Systems*, clearly held that unlike infringement cases, the claimant's knowledge, rather than the date of the

> issuance of the patent, controls for establishing the period of delay. In that case, however, the period of delay at issue occurred after the issuance of the patent.

Moore, 2008 WL 425932, at *4. In *Moore*, the alleged joint inventor filed a complaint alleging joint inventorship and seeking correction pursuant to 35 U.S.C. § 256 in 2006. The relevant patent application was filed in 1997 and the patent issued in 2001. Although Moore filed his suit fewer than six years after the patent's issuance, the court found that Moore knew the provisional patent application was filed in 1997 and that he was not listed as an inventor. *Id.* at *5. Accordingly, the court applied the six-year laches presumption despite the fact that the relevant period of delay began four years *before* the patent issued. After applying the presumption, which the putative inventor could not rebut, the court granted summary judgment for the defendant.

Similarly, in *Frugoli v. Fougnies*, a District of Arizona court held that the period of delay began prior to the issuance of the relevant patents. 74 U.S.P.Q.2d 1716 (D. Ariz. Aug. 25, 2004). Frugoli, the alleged joint inventor of the patents, filed suit to correct inventorship in 2002, only two years after the PTO granted the later-issued patent. Notwithstanding this short delay between the patent issuance and Frugoli's lawsuit, the court found that, although Frugoli did not have actual knowledge of the patents until 2002, he should have known of his rights as early as 1995. *Id.* at 1722. Thus, applying the known or should have known standard articulated in *Advanced Cardiovascular Systems*, the court found that the laches period of delay began in 1995 when Frugoli "reasonably should have known, that Defendants had filed an application for a patent . . . and failed to name him." *Id.* at 1720-1722.

Hor attempts to counter this strong support for Chu's position by citing to *Studio & Partners v. KI*, a case from the Eastern District of Wisconsin. No. 06-C-628, 2007 WL 3342597 (E.D. Wis. Nov. 7, 2007). In *Studio & Partners*, the court held in a footnote that "[t]he Federal Circuit views the accrual of the inventorship claim . . . at the time the putative inventor . . . learns that a patent has been issued." *Id.* at *5 n.7. Accordingly, the court found that, because the patent did not issue until 2003, there was no basis for a laches defense.[5] There are several issues with the court's conclusion that render it of limited persuasive value. First, there are very few facts and little analysis related to the laches question. Indeed, it is not even possible to ascertain the date on which the alleged joint inventor knew or should have known about the relevant patents and his omission from them, in order to determine whether the facts in that case presented the same issue now before the Court. Second, the court cites *Advanced Cardiovascular Systems* to support its characterization of the Federal Circuit's view of an inventorship claim. The section it cites, however, holds only that, "in the absence of proof that [the alleged inventor] knew or should have known that the patent had issued and that he was omitted as a joint inventor" the district court erred in measuring the period of delay from the date of the issuance of the patent. 988 F.2d at 1162. Indeed, the court addressed the date of the issuance of the patent in order to reject the defendant's argument that the alleged joint inventor should be charged with *constructive notice* of the patent and his lack of inventorship status as of that date. The Federal Circuit believed it more prudent to measure the period of delay from the time the alleged inventor actually knew or should have known of the patent and the fact that he was omitted as a joint inventor. The court explained that this rule ensured that an alleged inventor would not be barred from remedy before he reasonably could have known of his claim. *Id.* at 1162. In short, the court in *Advanced Cardiovascular Systems* emphasized, without qualification, the known or should have known standard for measuring the period of delay

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[5] Although the year the plaintiff filed the suit to correct inventorship is not specified, the court's Decision and Order is dated November 7, 2007, and, therefore, only four years had elapsed between the patent issuance and the resolution of the dispositive motions in the case. Thus, the plaintiff must have filed the lawsuit within six years of the patent's 2003 issuance.

without stating an opinion as to whether an inventorship claim may accrue before the issuance of the patent.

Certainly, the central question is the proper interpretation of the word "claim" in the context of the Federal Circuit's laches case law. The laches period of delay begins when the alleged inventor "had actual notice of the *claim* or would have reasonably been expected to inquire about the subject matter." (emphasis added). The existing precedent leaves open the question of whether "claim" should be limited to a cause of action in federal court under 35 U.S.C. § 256. Indeed, the judicial power to resolve an inventorship contest under 35 U.S.C. § 256 is limited to *issued* patents. *See Eli Lilly & Co. v. Aradigm Corp.*, 376 F.3d 1352, 1356 n.1 (Fed. Cir. 2004) ("[S]ection 256 creates a cause of action in the district courts only to modify inventorship on issued patents.") Thus, if "claim" were defined to encompass only a lawsuit under 35 U.S.C. § 256, the laches period arguably could not begin until the patent issued. There are, however, means available to remedy an alleged joint inventor's omission from a *pending* patent. Indeed, the *Moore* court noted:

> While not discussed in *Advanced Cardiovascular Systems,* pursuant to 35 U.S.C. § 116, correction of inventorship may be accomplished prior to the issuance of a patent by application to the commissioner. *See* 35 U.S.C. § 116; 37 C.F.R. § 1.48. In addition, an action to correct inventorship while the patent application is still pending, under 35 U.S.C. § 116, includes the requirement that such amendment must be diligently made. *See* 37 C.F.R. § 1.48; *Stark v. Advanced Magnetic, Inc.*, 29 F.3d 1570, 1574 (Fed. Cir. 1994). The requirement of diligence supports a finding that delay is discouraged, and laches may apply, even at these early stages. Thus, the rationale of *Advanced Cardiovascular Systems*, that laches may apply at any time that inventorship may be remedied but should not apply before the omitted inventor has learned of the claim, applies in equal force to the time during which a patent application is pending, but before it is issued.

2008 WL 425932 at *4.

The Court also observes that, in addition to petitioning to correct inventorship pursuant to 35 U.S.C. §116, an alleged joint inventor may also file a competing patent application and seek to secure inventorship through an interference proceeding. *Display Research Laboratories, Inc. v. Telegen Corp.*, 133 F.Supp.2d 1170, 1175 (N.D. Cal. 2001). In fact, "[t]he normal procedure for resolving inventorship contests is through an interference proceeding in the Patent and Trademark Office ('PTO')." *Fordham v. Onesoft Corp.*, No. CIV. A. 00-1078-A, 2001 WL 641759, *3 (E.D. Va. Jan. 24, 2001); *see also Chou v. University of Chicago*, 254 F.3d 1347, 1358 n.2 (Fed. Cir. 2001) (recognizing that, while an alleged inventor has standing to sue to correct inventorship under 35 U.S.C. § 256, "[o]ne other means for a putative inventor to assert her inventorship right is for her to file her own patent application and seek to have the PTO declare an interference in order to establish inventorship.") These multiple mechanisms allow omitted inventors to secure their rights prior to the patent's issuance and without resort to federal court litigation. The Court believes it would be inequitable to permit a plaintiff to sit on his rights to those remedies, yet defeat a laches defense by waiting so long to pursue an inventorship claim that the only remaining remedy is one that does not mature until the patent issues.

Indeed, in light of the availability of remedies during the pendency of the patent application, the Court does not believe the word "claim" should be read so narrowly as to encompass only a suit pursuant to 35 U.S.C. § 256. Rather, "claim," as it is used for purposes of determining the relevant period of delay, is more properly viewed as a "claim" of *inventorship.* Thus, the laches period of delay may begin when a plaintiff knew or should have known that the defendant filed a patent application covering his alleged inventive contributions and failed to name him as an inventor, regardless of whether such notice occurred prior to the patent's issuance.

A. Period of Delay

"[T]he period of delay is measured from when the claimant had actual notice of the claim or would have reasonably been expected to inquire about the subject matter." Thus, the Court must analyze when Hor and Meng knew or should have known of the existence of the patents-in-suit and the fact of their omission as inventors.

Hor and Meng both assert that they learned for the first time that they were not included as inventors on the patents-in-suit in 2006. Chu argues that, although Hor and Meng may contend they lacked actual notice until their 2006 meeting with UH officials, they possessed sufficient facts long before that meeting which triggered a duty of inquiry.

The evidence shows that both Hor and Meng knew by 1990, at the latest, that patent applications were filed covering inventions which they now claim to have conceived. Thus, the critical question is when Meng and Hor had actual notice of their omission as inventors or would have reasonably been expected to inquire about the inventorship of those patent applications.

The evidence suggests that Hor and Meng knew in roughly 1987 or 1988 that patent applications were being filed that included claims to which they now allege they made inventive contributions. In the 1987 or 1988 meeting with Cox, he informed Meng and Hor that he believed they were not inventors, but merely a "pair of hands." During that same time period, both Hor and Meng admit to reading Chu's 1987 publications, which reference Chu as the sole inventor of the first of the patent applications that ultimately resulted in the patents-in-suit.

In addition, Meng was involved in at least two of the interference proceedings that took place in the late 1980s and early 1990s. She executed declarations in the proceedings and had her deposition taken at least once. As recited in Part I, *supra*, during the Wu Inference Meng testified, "I remember I had saw (sic) one patent application, but I'm not sure was end the 86 (sic), but I couldn't remember exactly." Meng also submitted a declaration in the 1989 *Qadri v.*

Chu Interference in which she stated, "I have reviewed and am familiar with the contents of United States Application Serial No. 32,041 filed March 26, 1987 by C.W. Chu (hereafter the "Chu application)." The cover page and first page of the patent applications list Chu as the sole inventor. In one of Meng's declarations, she also describes experiments she conducted to replicate two of the patent's Examples contained in the body of the patent application. Additionally, Cox sent Meng a five-page fax in 1991 containing the abstracts of applications for the patents-in-suit, which clearly listed Chu as the sole inventor.

Although Meng denies actual knowledge of the information contained in the patent applications, she never explains how she could have seen them and/or the abstracts Cox sent her without noticing the absence of her name. Knowledge of Meng's omission from the patent applications can be imputed to her, notwithstanding her denial. In *Expert Microsystems, Inc. v. University of Chicago*, the alleged inventor uncovered the relevant patents during a prior art search and purchased and printed copies of them. Although he claimed to only have seen the front page and did not review the patents' content, the court held:

> Plaintiff was sufficiently put on notice of his potential inventorship claims by reading the first page of the patents. 'The Supreme Court has consistently imputed to parties who failed to examine readily available information the knowledge contained in it and the results of inquiries that the knowledge would have motivated a reasonable man to conduct.'

No. CIV. 2:09-586 WBS JFM, 2010 WL 1407981, at *4 (E.D. Cal. Apr. 2, 2010). Like the alleged inventor in *Expert Microsystems*, Meng, at the very least, reviewed the first page of the patents. In this case, even the first page of the application was sufficient to put Meng on notice that she was not an inventor. Thus, notwithstanding her denial of actual knowledge of her omission as inventor, Meng should have known of her claim by at least the early 1990s when she admitted reviewing the relevant patent applications and/or abstracts in which her name was omitted as an inventor.

Even if Meng had not actually seen the patent applications, she had a duty to inquire about her status given the other information available to her. Indeed, she received a clear indication that Cox did not consider her an inventor, and she participated in at least two intervention proceedings in which she understood the inventorship of the patents-in-suit was at issue, yet Meng never once asked Cox or Chu, or any other UH official whether she was an inventor. A reasonable person in Meng's position, especially one who participated in defending others' claims to inventorship of the patents, should have inquired about her own status. Of course, Meng "is chargeable with such knowledge as [s]he might have obtained upon inquiry, provided the facts already known by [her] were such as to put upon a [person] of ordinary intelligence the duty of inquiry." *Advanced Cardiovascular Sys.*, 988 F.2d at 1162. The facts known to Meng surely put upon her a duty to inquire about the subject of inventorship.

Hor was also present at the 1987 meeting where Cox expressed his opinion that Hor and Meng were not inventors of the patents-in-suit. Cox's judgment was so upsetting to Hor that he allegedly left the room in anger. Hor claims Chu assured Hor that he would attempt to "straighten things out" with Cox, yet Hor never followed up with Chu or Cox, or any other UH official, to discover whether his name was included. Hor had a subsequent meeting with UH's counsel during the Wu Interference, at a time in which Hor understood that other parties were contesting inventorship of the patents-in-suit. Despite signing a declaration, which was submitted in support of UH's claim, Hor never asked whether *he* was a named inventor on the patent. Although there is less evidence indicating Hor may had *actual* knowledge of his omission as inventor on the applications for the patents-in-suit, like Meng, the "facts already known by him were such as to put upon a man of ordinary intelligence the duty of inquiry." There is no question that given the information Hor possessed, any reasonable person would have taken the simple step of confirming his inventor status with Cox or Chu.

B. Rebuttal of Laches Presumption

Having found that Meng and Hor should have known of their lack of inventorship status by the early 1990s at the latest, the six-year presumption applies. Indeed, Hor and Meng waited nearly twenty years before asking UH officials about the inventorship of the patents-in-suit. Hor waited two more years before filing this lawsuit, and Meng did not intervene until four years after she purportedly acquired actual notice of her omission as inventor. Because the presumption applies, the two facts of unreasonable delay and material are inferred, absent rebuttal evidence. Hor and Meng, however, can rebut the presumption of laches "by offering evidence to show an excuse for the delay or that the delay was reasonable" or by offering evidence "sufficient to place the matters of [evidentiary] prejudice and economic prejudice genuinely in issue." *Serdarevic*, 532 F.3d at 1359-1360 (quoting *Aukerman*, F.2d at 1038) (internal quotations omitted).

1. Reasonable or Excusable Delay

To excuse her delay, Meng suggests that it was caused, in part, because she was from China, and as a result, was ignorant of American law and the patent system. She also makes much of the fact that, at times, Chu referred to the patents-in-suit as "our" patents. Additionally, she asserts that she reasonably believed she was an inventor because she received a sum of money from UH shortly after the patent applications were filed. Meng admits, however, that no one ever told her she was receiving the funds because she was an inventor of the patents-in-suit. Indeed, at no time did anyone ever tell Meng that she was an inventor. Meng also makes no attempt to rebut the evidence indicating that she actually saw the patent applications in which she was clearly not listed as an inventor.

Although Meng may not have understood the patent law system, she had direct access to UH in-house and outside counsel, and could have, as she did in 2006, quickly confirmed that she was not named an inventor. Given the strong indications she received that she was not an inventor, the fact that, in casual conversation, Chu referred to the patents as "ours," and that she received a sum of money from UH, is insufficient to rebut the presumption that her approximately twenty year delay was reasonable. Her "failure to investigate [her] potential claim after [she] saw information that warranted further inquiry . . . is unreasonable and therefore insufficient to absolve [her] of knowledge . . . for the purposes of laches." *Expert Microsystems*, 2010 WL 1407981, at *4.

Hor argues that his delay was not unreasonable because Chu told him that he would speak to Cox about his "pair of hands" comment. It was simply not reasonable, however, for Hor to have relied for twenty years on Chu's assurances that he would try to "straighten things out" with Cox. Indeed, even if Hor believed that Chu would, as promised, attempt to convince Cox that Hor deserved to be an inventor, there was absolutely no guarantee Chu would be successful. There is no doubt that any reasonable person would have followed up on a conversation of such consequence.

Additionally, Hor argues that it would have been futile to bring his claim to Chu's or UH's attention earlier, given their negative responses when he raised it in 2006. He claims that both Chu and UH would have had to effectively consent to his claim of inventorship in order to secure correction and that, given their resistance to his grievance in 2006, they would not have agreed. Although consent may be necessary under the provisions Hor cites, as discussed *supra*, there were alternatives available to Hor had he asserted a claim to inventorship when he first should have known he was omitted. Thus, UH's and Chu's resistance to Hor's claim in 2006 does not excuse Hor's significant delay taking action to correct inventorship.

2. Prejudice

"Material prejudice . . . may be either economic or evidentiary. Evidentiary, or 'defense' prejudice, may arise by reason of a defendant's inability to present a full and fair defense on the merits due to the loss of records, the death of a witness, or the unreliability of memories of long past events, thereby undermining the court's ability to judge the facts. . . . Economic prejudice may arise where a defendant and possibly others will suffer the loss of monetary investments or incur damages which likely would have been prevented by an earlier suit." *Serdarevic*, 532 F.3d at 1360 (quoting *Aukerman*, 960 F.2d at 1033) (internal quotations omitted).

In this case, twenty-three years have passed since the events surrounding the relevant inventions. Since that time, Peter Huang, one of the graduate students who worked in Chu's laboratory with Chu, Hor, and Meng, has died. Dr. Hazen of the Geophysical Laboratory who carried out the analysis of the UH research group's Y-B-C-O samples responded to a request for deposition stating, "any details of what happened during February of 1987—especially the exact days and times of our work—is completely lost from my memory." (Hazen email to Hewitt, Jun. 11, 2010.) Moreover, the parties themselves suffer from dimming memories. Chu, Hor, and Meng have all experienced difficulty in recalling the timing and content of important events surrounding the inventions, which is unsurprising given the significant passage of time.

In *Frugoli*, the court found that a delay from 1994 to the date the suit was filed in 2002 caused evidentiary prejudice, noting that "[r]ecalling events from the 1994-1995 time-frame would be difficult for any percipient witness." 74 U.S.P.Q.2d at 1721. Similarly, the *Serdarevic* court found that the alleged inventor failed to meet her burden to rebut the presumption of evidentiary prejudice, in part, because there was "cumulative and inherent prejudice from the dimming memories of all the participants, including Serdarevic herself." 532 F.3d at 1360. In that case, roughly nineteen years had passed between the issuance of the first relevant patent and the time the plaintiff brought her lawsuit. *Id.* at 1356.

Meng argues that, because the parties have given almost 1,300 pages of deposition testimony and Meng's laboratory notebook remains available as evidence, there has been no evidentiary prejudice. Meng's focus on the quantity of deposition testimony, however, is misplaced. As Chu points out, there are several key issues with regard to which the parties' memories have faded. Moreover, although Meng's lab notebook provides some assistance in determining the timing of certain events and the identity of the scientists who performed certain experiments, it is of little help in identifying the *source* of the inventive conceptions, the ultimate inquiry in this case. Not only have Hor and Meng failed to rebut the presumption of prejudice, but the Court is convinced that its ability judge the facts has been significantly undermined by the passage of more than twenty years.

C. Unclean Hands Claims

Both Meng and Hor have raised the doctrine of unclean hands, which if proven, could defeat Chu's laches defense. Under the unclean hands doctrine, "[e]ven if unable to overcome the presumption, a [plaintiff] may be able to preclude application of the laches defense with proof that the [defendant] was itself guilty of misdeeds towards the [plaintiff]." *Aukerman,* 960 F.2d at 1038. To succeed in an unclean hands claim, a plaintiff is required to show that the defendant has "engaged in particularly egregious conduct which would change the equities significantly in plaintiff's favor." *Id.* at 1033 (citing *Bott v. Four Star Corp.*, 807 F.2d 1567, 1576 (Fed. Cir. 1986)). In the inventorship context, "a plaintiff relying on the unclean hands doctrine to defeat a defense of laches must show not only that the defendant engaged in misconduct, but moreover that the defendant's misconduct was responsible for the plaintiff's delay in bringing suit." *Sedarevic*, 532 F.3d at 1361.

Chu has moved to dismiss Hor and Meng's unclean hands claims under Federal Rule of Civil Procedure 12(b)(6), or in the alternative, for summary judgment. Chu first argues that Rule 9(b) requires that unclean hands allegations sounding in fraud to be plead with particularity. A charge of fraud should be stricken from a pleading where "it is clear that, under no circumstances, could proof, conforming to the strict requirements provided in the fraud charges, be introduced under the pleadings, which would probably convince the trier of the facts that fraud had in fact been perpetrated." *Massey-Ferguson, Inc. v. Bent Equip. Co.*, 283 F.2d 12, 15 (5th Cir. 1960). Obviously, the threshold question is whether Hor and Meng's unclean hands claims, in fact, allege fraudulent conduct on part of the defendant. Chu's motion and reply, however, fail to adequately explain the basis for his contention that Meng's unclean hands claim sounds in fraud. Indeed, as discussed below, Meng essentially argues that Chu's counsel engaged in misconduct by failing to advise her properly during the Wu Interference, but it is unclear whether Meng alleges that this misconduct amounted to fraud. Thus, the Court declines to analyze whether Hor and Meng have met Rule 9(b) pleading standards.

Alternatively, Chu argues that Hor and Meng have failed to raise a genuine issue of material fact as to the required elements for unclean hands. Meng argues that Chu is guilty of unclean hands because Chu's counsel, Cox, "set up Meng-particularly through her declarations-for the argument that she was acting as a 'pair of hands' because that argument benefitted Chu and UH in the interference, possibly at her expense." (Meng Resp. at 33.) Thus, Meng does not allege that *Chu* engaged in misconduct. Rather she claims that UH's counsel, Cox, engaged in egregious conduct by failing to inform her that she was not an inventor on the patent application and that Wu argued the patent was invalid for failure to name Wu and, possibly, Meng, as inventors. Hor, for his part, did not respond to Chu's motion. Thus, the Court is unaware of the egregious conduct in which Hor alleges Chu engaged.

Although Meng may have raised a genuine issue of material fact as to whether Cox failed to tell her she was not named as an inventor or that Wu alleged she should have been included, she has not explained why she believes Cox's omissions can be attributed to Chu. She also fails to demonstrate that Cox's actions amounted to egregious conduct or that his actions are responsible for her long delay in bringing suit.

Indeed, Meng fails to cite authority indicating that the conduct of someone other than the defendant may suffice for purposes of making out a successful unclean hands claim. In arguing that *Cox* engaged in misconduct, Meng alleges that he violated Texas Disciplinary Rules of Professional Conduct 1.06(b)(2), 1.12(e), and 4.03 by not advising Meng that her interests were potentially at issue in the proceeding. The three sections Meng cites, however, do not actually stand for the proposition that Cox had a duty to inform Meng, an unrepresented witness, of Wu's allegations. Indeed, the most applicable of the three rules, 4.03, states:

> In dealing on behalf of a client with a person who is not represented by counsel, a lawyer shall not state or imply that the lawyer is disinterested. When the lawyer knows or reasonably should know that the unrepresented person misunderstands the lawyer's role in the matter, the lawyer shall make reasonable efforts to correct the misunderstanding.

Meng has not alleged that Cox stated or implied that he was disinterested in the matter. In fact, she admits that she understood at all relevant times that Cox was UH's lawyer, not her own. As long as Cox advised Meng that he represented UH's interests in the proceeding, it does not appear Cox violated the rules she cites. Further, prior to the start of the Wu Interference, Cox made it clear that, based on the information Meng provided, in his judgment, she was simply a pair of hands and not an inventor. By the time the Wu Interference began, Meng had provided Cox with no information inconsistent with his belief. She then attested to facts that confirmed to Cox that she was indeed not a source of inventive contributions. Under these circumstances, the Court believes there is no question that Cox's failure to affirmatively advise Meng of Wu's interference claims does not amount to egregious conduct.

Even if Cox had engaged in misconduct, the Court is not persuaded that his failure to inform Meng of Wu's allegations led to her delay in correcting inventorship. Of course, the Court has already determined that Meng should have known that she was not an inventor based on the information available to her at the time. Thus, Meng's own lack of diligence is responsible for her delay in filing suit, not Cox's failure to confirm that which she should have known already. Moreover, it is unclear what Meng claims she would have done differently had Cox advised her of Wu's allegations. Indeed, the Court is troubled by the implication that she would not have sworn to what she now claims were lies, had she known they harmed her own claims to inventorship. In conclusion, Meng's allegations against Cox do not rise to the level of egregious conduct that would change the equities significantly in her favor.

D. Equitable Estoppel

Relatedly, although not raised by Chu, the Court is convinced that, in addition to laches, the doctrine of equitable estoppel applies to bar Hor's and Meng's claims of inventorship. "Equitable estoppel to assert a claim is another defense addressed to the sound discretion of the trial court." *Aukerman*, 960 F.2d 1041. Where equitable estoppel is established, all relief on a claim may be barred." *Id.* The defense generally has three important elements: 1) the actor, who usually must have knowledge of the true facts, communicates something in a misleading way, either by words, conduct or silence, 2) the other relies upon that communication, and 3) the other would be harmed materially if the actor is later permitted to assert any claim inconsistent with his earlier conduct. *Id.*

The first element of equitable estoppel concerns the statements or conduct of the alleged co-inventor, which must "'communicate something in a misleading way.'" *Id.* at 1042. In this case, Meng and Hor both claim they were untruthful during the 1987 or 1988 meeting with Cox in which they asserted that they did not remember who first conceived of the Yttrium substitution. In addition, Meng claims that she was again dishonest during the Wu Interference when she testified that it was Chu who communicated the Yttrium substitution idea to her. She also now recants her 1990 and 1993 statements in which she stated that she was working pursuant to Chu's direction when she made the rare earth superconductor discoveries that now, in part, form the basis of her inventorship claim.

In naming Chu as the sole inventor, Chu and UH's legal counsel relied on Hor's alleged lack of recollection and Meng's repeated representations that Chu conceived of the Yttrium substitution. They also relied on Meng's statements that she worked pursuant to Chu's direction in conducting the rare earth element substitution experiments. Had Chu and UH's counsel known at the time that Meng and Hor believed that they actually conceived of multiple inventions covered by the patents-in-suit, they could have investigated the scientists' claims over twenty years ago when the parties' memories were fresh. If UH determined their claims had merit, it could have included them as inventors on the initial applications or petitioned to correct inventorship while the patents were still pending. Even if UH had deemed them non-inventors, Hor and Meng could have elected to pursue one of the previously discussed pre-issuance remedies. Hor and Meng, however, admit to misleading Chu and UH into believing their participation in the discoveries did not rise to the level of inventorship. As explained *supra*, by changing their stories and bringing claims to inventorship more than twenty years later, Chu is greatly prejudiced in defending his position as the sole inventor. As such, the Court also finds Hor's and Meng's claims to inventorship are alternatively barred by the doctrine of equitable estoppel.

IV. CONCLUSION

Hor and Meng unreasonably delayed in taking action to correct the inventorship of the patents-in-suit from the time they knew or should have known of their claims. The significant passage of time has caused Chu prejudice in defending his position as the sole inventor. The actions of UH's counsel during the Wu Interference do not sufficiently change the equities in Hor and Meng's favor. As such, Chu's Motion for Summary Judgment on the Inventorship Claims of Pei-Hreng Hor and Ruling Meng Based on Laches is **GRANTED**. Additionally, Defendant's Motions to Dismiss or in the Alternative for Summary Judgment Upon Intervenor Meng's and Plaintiff Hor's Unclean Hand Defenses are **GRANTED**.

IT IS SO ORDERED.

SIGNED at Houston, Texas, on this the 20th day of January, 2011.

Keith P. Ellison

KEITH P. ELLISON
UNITED STATES DISTRICT JUDGE

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

PEI-HRENG HOR, §
§
Plaintiff, §
§
v. § **CIVIL ACTION NO. 4:08-cv-3584**
§
CHING-WU "PAUL" CHU, §
§
Defendant. §

MEMORANDUM & ORDER

Plaintiff Pei-Hreng Hor and Intervenor Ruling Meng seek a new trial. (Doc. No. 108.) For the following reasons, their Joint Motion must be denied.

Contrary to the arguments in the Joint Motion, the Court did not intend to, and did not, add to 35 U.S.C. § 256 a diligence requirement. Rather, the Court applied the equitable doctrine of laches which has long predated § 256. No authority that has been cited purports to strip trial courts of this long-established, necessary, and directly applicable doctrine.

As to the Court's *sua sponte* invocation of equitable estoppel as an alternative grounds for barring Hor and Meng's inventorship claims, Hor and Meng do not controvert the evidence that they remained silent from 1987-88 to 2006 regarding their claims. Nor do they offer any reason to doubt that Hor's silence and Meng's support for Defendant Chu was relied on by Chu. Finally, Hor and Meng's silence and misleading actions have undoubtedly caused material evidentiary prejudice.

The Joint Motion is **DENIED.**

IT IS SO ORDERED.

SIGNED at Houston, Texas, on this the 12th day of July, 2011.

KEITH P. ELLISON
UNITED STATES DISTRICT JUDGE

US007056866B1

(12) United States Patent

Chu

(10) **Patent No.:** **US 7,056,866 B1**

(45) **Date of Patent:** **Jun. 6, 2006**

(54) **SUPERCONDUCTIVITY IN SQUARE-PLANAR COMPOUND SYSTEMS**

(75) Inventor: **Ching-Wu Chu**, Houston, TX (US)

(73) Assignee: **University of Houston-University Park**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 785 days.

(21) Appl. No.: **07/032,041**

(22) Filed: **Mar. 26, 1987**

Related U.S. Application Data

(63) Continuation-in-part of application No. 07/012.205, filed on Feb. 6. 1987, now abandoned, which is a continuation-in-part of application No. 07/006.991, filed on Jan. 26, 1987, now abandoned, which is a continuation-in-part of application No. 07/002.089, filed on Jan. 12. 1987, now abandoned.

(51) **Int. Cl.**

C04B 101/00	(2006.01)
H01L 39/12	(2006.01)
H01B 12/00	(2006.01)

(52) **U.S. Cl.** 505/125: 505/126: 505/490: 505/500: 505/780

(58) **Field of Classification Search** 252/520, 252/521. 518; 423/263. 593; 501/104, 108, 501/123. 126. 135, 152; 29/599; 420/901, 428/930; 505/100. 125. 126. 779, 780, 490, 505/500

See application file for complete search history.

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* cited by examiner

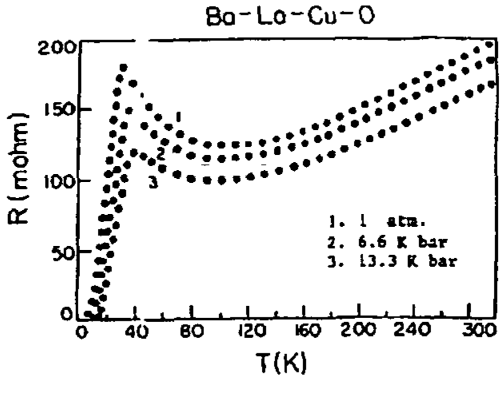
Primary Examiner Mark Kopec

(74) *Attorney, Agent, or Firm*—Akin Gump Strauss Hauer & Feld LLP; Charles M. Cox

(57) **ABSTRACT**

Described is a superconducting composition comprising an oxide complex of the formula $[L_{1-x}M_x]_aA_bO_y$ wherein L is lanthanum, lutetium, yttrium, or scandium; A is copper, bismuth, titanium, tungsten, zirconium, tantalum, niobium, or vanadium; M is barium, strontium, calcium, magnesium or mercury; and "a" is 1 to 2; "b" is 1; and "x" is a number in the range of 0.01 to 1.0; and "y" is about 2 to about 4. The oxide complexes of the invention are prepared by a solid-state reaction procedure which produces an oxide complex having an enhanced superconducting transition temperature compared to an oxide complex of like empirical composition prepared by a coprecipitation high temperature decomposition procedure. With an oxide complex prepared by the solid-state reaction of the invention a transition temperature as high as 100°K has been observed even under atmospheric pressure

15 Claims, 5 Drawing Sheets



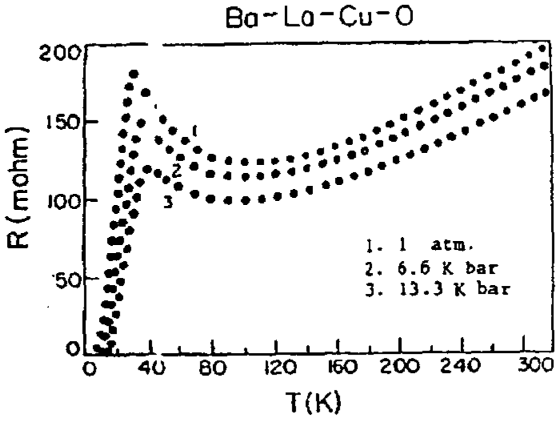
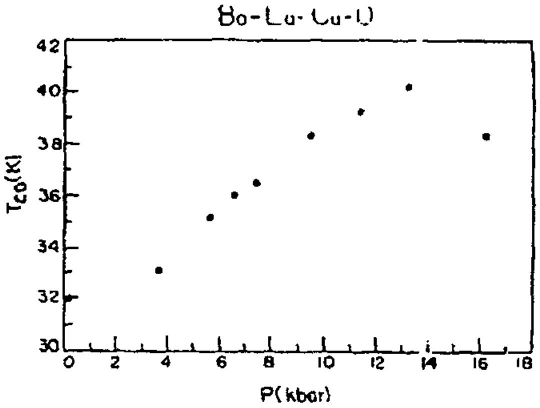


FIG. 1

FIG. 2



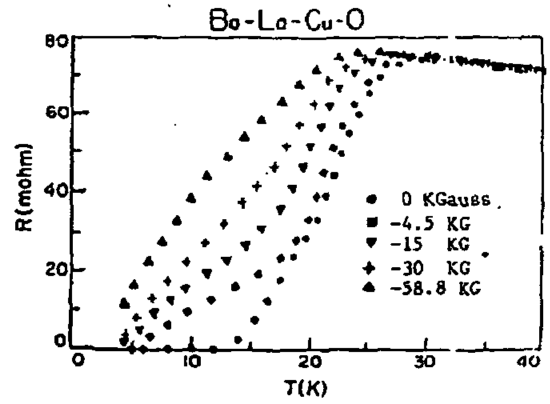


FIG. 3

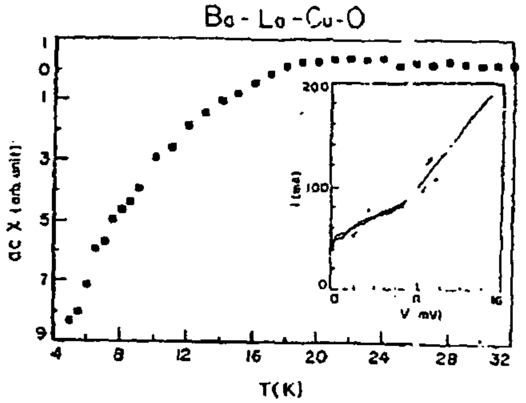
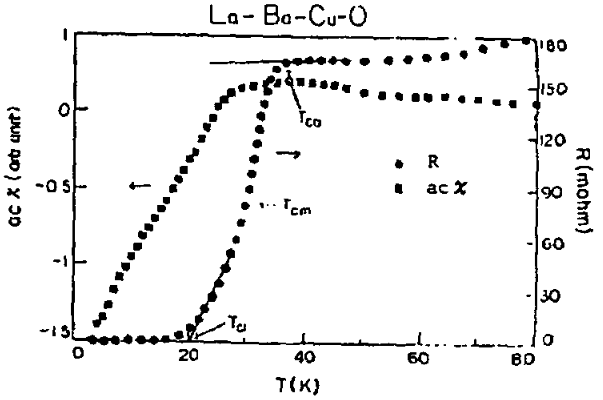


FIG. 4

FIG. 5



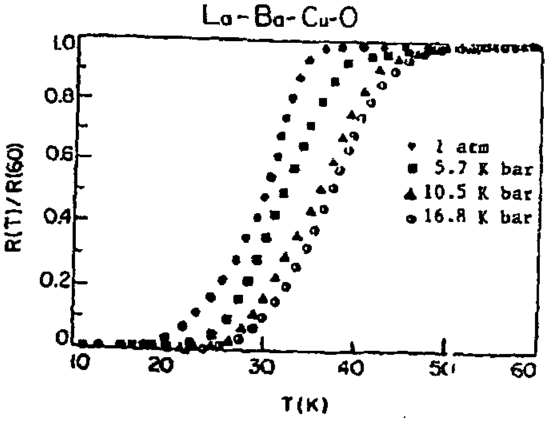


FIG. 6

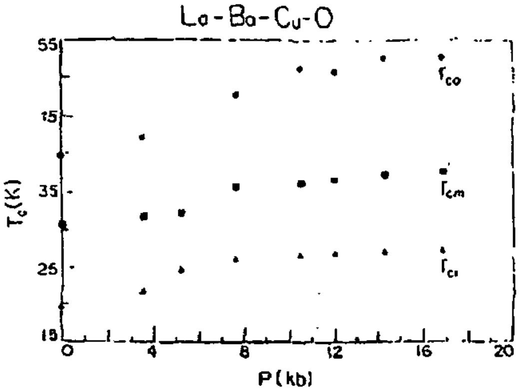
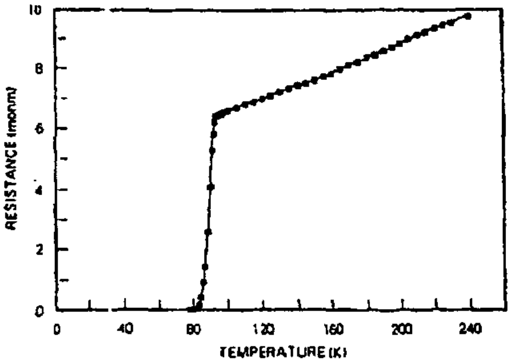


FIG. 7

FIG. 8



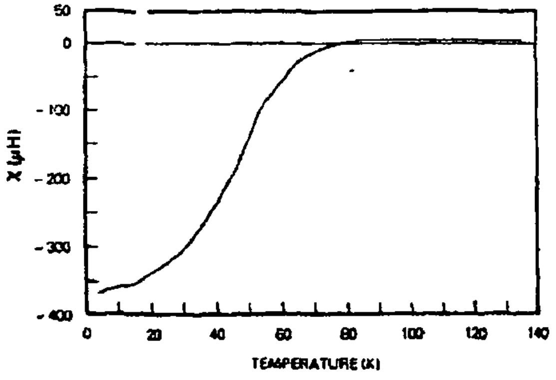


FIG. 9

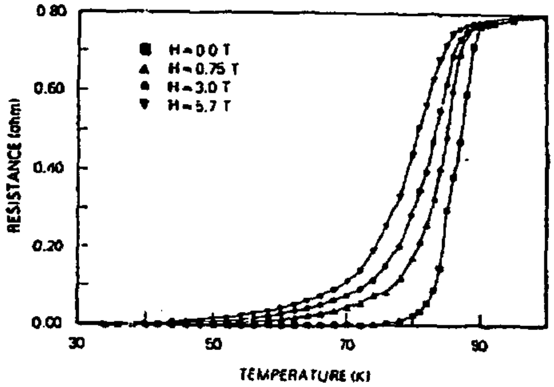
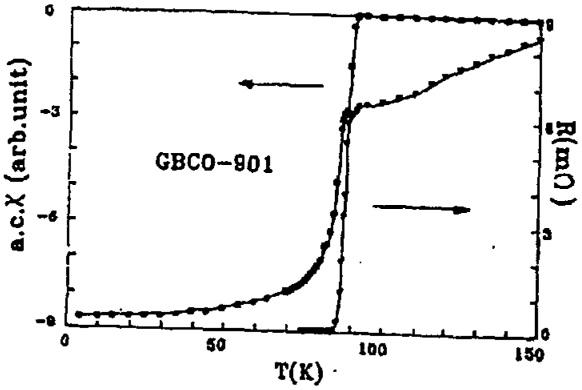


FIG. 10

FIG. 11



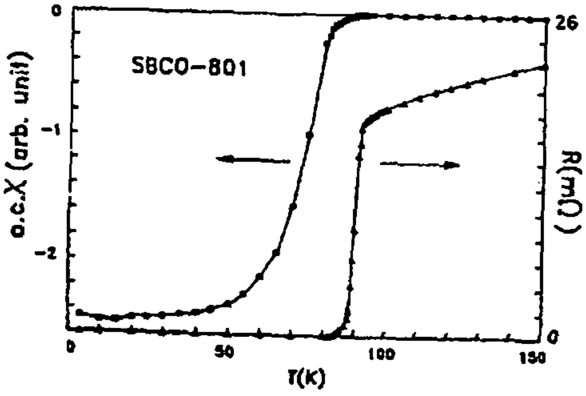


FIG. 12

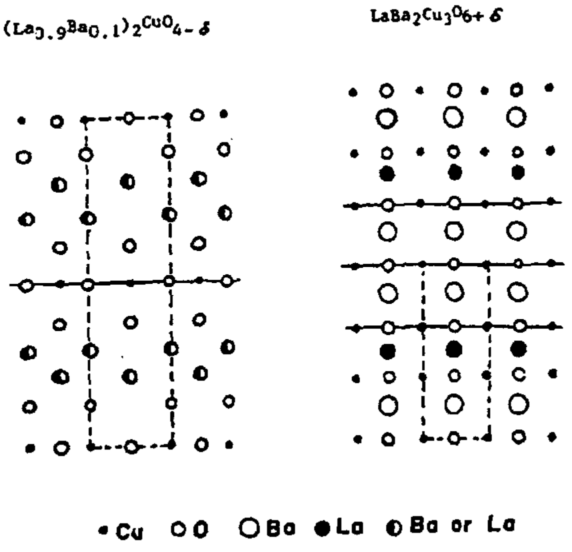

$(La_{0.9}Ba_{0.1})_2CuO_{4-\delta}$
$LaBa_2Cu_3O_{6+\delta}$
• Cu
O O
○ Ba
● La
◐ Ba or La

FIG. 13

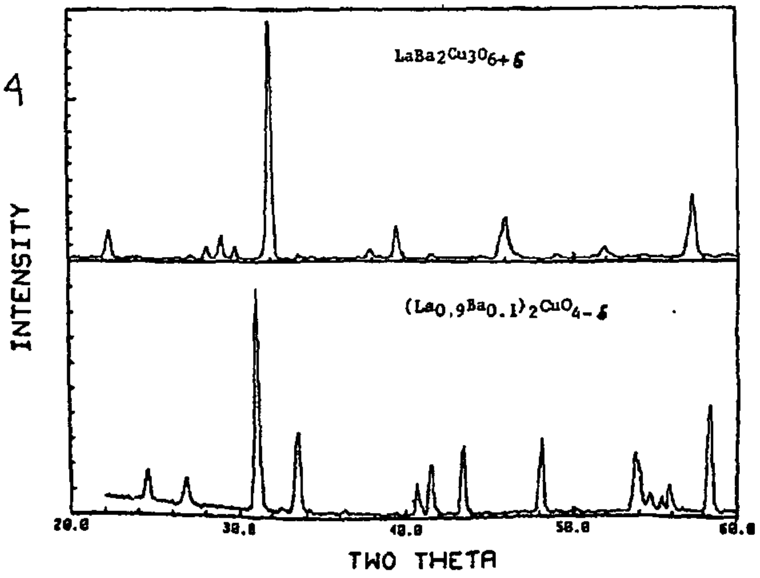

$LaBa_2Cu_3O_{6+\delta}$
$(La_{0.9}Ba_{0.1})_2CuO_{4-\delta}$
INTENSITY
20.0
30.0
40.0
50.0
60.0
TWO THETA

FIG. 14

SUPERCONDUCTIVITY IN SQUARE-PLANAR COMPOUND SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of Ser. No. 07/012,205, filed Feb. 6, 1987 entitled "High Transition Temperature Superconducting Composition", now abandoned, which in turn is a continuation-in-part of Ser. No. 07/006,991, filed Jan. 26, 1987, entitled "Superconducting Compositions And Method For Enhancing Their Transition Temperatures By Pressure", now abandoned, which in turn is a continuation-in-part of Ser. No. 07/002,089, filed Jan. 12, 1987, entitled "Superconducting Composition and Method.", now abandoned.

STATEMENTS REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with United States Government support under Grant No. DMR-8204173 awarded by the National Science Foundation and Grant No. NAGW-997 awarded by the National Aeronautics and Space Administration, and the United States Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

This invention relates to superconducting compositions, i.e., compositions offering no electrical resistance at a temperature below a critical temperature; to processes for their production and to methods for their use; and to methods for increasing the superconducting transition temperature of superconducting compositions.

Superconductivity was discovered in 1911. Historically, the first observed and most distinctive property of a superconductive material is the near total loss of electrical resistance by the material when at or below a critical temperature that is a characteristic of the material. This critical temperature is referred to as the superconducting transition temperature of the material, T_c. The criteria by which a selection of the critical temperature value is determined from a transition in the change in resistance observed is often not obvious from the literature. Many past authors have chosen the mid-point of such curve as the probable critical temperature of their idealized material, while many others have chosen to report as the critical temperature the highest temperature at which a deviation from the normal state resistivity property is observed. Hence, the literature may report differing temperatures within a narrow range as the critical or superconducting transition temperature for the same material, depending on the particular author's method for selecting T_c from the observed data.

The history of research into the superconductivity of specific materials began with the discovery in 1911 that mercury superconducts at a transition temperature of about 4°K. In the late 1920's, NbC was found to superconduct at a higher temperature, namely up to about 10.5°K. Thereafter other compounds and alloys of Nb were examined and various Nb compositions were discovered with progressively, but only slightly higher, superconducting transition temperatures. In the early 1940's NbN was observed with a transition temperature of about 14°K; Nb_3Sn was reported in the early 1950's; Nb_3 (Al—Ge) was reported in the late 1960's; and Nb_3Ge was reported in the early 1970's to have a transition temperature of about 17°K. Careful optimization of Nb_3Ge thin films led to an increase of the critical temperature for such material up to 23.3°K. While this work led to progress the maximum temperature at which superconductivity could occur was raised to only 23.3°K since research started three-quarters of a century ago. The existing theories explained the superconductivity of these materials, but did not predict superconductivity of higher than 40°K. Significant progress in finding materials which superconduct at higher transition temperatures than that of Nb_3Ge thin films was not made until 1986.

In 1986, specially prepared coprecipitated and heat treated mixtures of lanthanum, barium, copper and oxygen, that have an abrupt decrease in resistivity "reminiscent of the onset of percolative superconductivity" were reported by J. G. Bednorz and R. A. Muller, "Possible High T_c Superconductivity In The Ba La Cu O System," Z. Phys. B. Condensed Matter, 64, pp. 189-193 (1986). Under atmospheric pressure conditions, the abrupt change in resistivity for these compositions—i.e., that temperature at which a portion of the material begins to show properties reminiscent of percolative superconductivity—were reported to approach the 30°K range. The authors refer to this phenomenon as a "possible" case of superconductivity. The compositions reported by Bednorz et al to have such properties at a temperature as high as 30° K comprise $La_{5-x}Ba_xCu_5O_{5(3-y)}$, where X 0.75 to 1 and Y>0. The Bednorz et al compositions are prepared by coprecipitation of Ba-, La- and Cu-nitrate solutions by addition to an oxalic acid solution followed by decomposition and solid-state reaction of the coprecipitate at 900° C. for 5 hours. Thereafter, the composition is pressed to pellets at 4 kilobars and the pellets are sintered at a temperature below 950° C. in a reduced oxygen atmosphere of 0.2×10^{-4} bar. Bednorz et al reported that this method of sample preparation is of crucial importance to obtaining the observed phenomena.

Superconductivity is a potentially very useful phenomenon. It reduces heat losses to zero in electrical power transmission, magnets, levitated monorail trains and many other modern devices. However, superconductivity of a material occurs only at very low temperatures. Originally, and until the inventions outlined herein, liquid helium was the required coolant to provide the conditions necessary for superconductivity to occur.

It would be desirable to produce a superconducting composition that has a transition temperature which exceeds those of superconducting compositions previously described. It would be particularly desirable to develop a superconducting composition that has the potential of having a T_c of 77°K or higher. Such a composition would enable the use of liquid nitrogen instead of liquid helium to cool the superconducting equipment and would dramatically decrease the cost of operating and insulating superconducting equipment and material.

BRIEF SUMMARY OF THE INVENTION

Described is a superconducting composition comprising an oxide complex of the formula $[L_{1-x}M_x]_aA_bO_y$, wherein "L" is scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, or lutetium, and preferably "L" is yttrium, lanthanum neodymium, samarium, europium, gadolinium, erbium or lutetium; "A" is copper, bismuth, titanium, tungsten, zirconium, tantalum, niobium, or vanadium and "A" perferably is copper; "M" is barium, strontium, calcium, magnesium or mercury and "M" is preferably barium or strontium; and "a" is 1 to 2; "b" is 1; and "y" is about 2 to about 4 and "x" is from about 0.01 to 1.0 maximum, and when "a" is 1 "x" is preferably from about 0.60 to about 0.90 and most preferably from about 0.65 to about 0.80 and when "a" is 2 "x" is preferably from about 0.01 to about 0.5 and most preferably from about 0.07 to about 0.5. The oxide complexes of the invention are prepared by a solid-state reaction procedure which produces an oxide complex having an enhanced superconducting transition temperature compared to an oxide complex of like empirical composition prepared by a coprecipitation-high temperature decomposition procedure.

When "L" is lanthanum and "M" is barium, the transition temperatures of onset and complete superconductivity, T_{co} and T_{c1} (as seen in FIG. 5), respectively, may be increased by subjecting the barium species of a lanthanum containing oxide complex to pressure up to 18 kilobars. Likewise the non-barium species of the oxide complexes of the invention exhibit an enhancement to higher limits of their superconducting transition temperatures when subjected to high pressures.

The application and maintenance of high pressure on such oxide complexes is believed to enhance the transition temperature to higher limits by reducing the interatomic spacings between elements L, A, M and O compared to their respective spacings when the oxide complex is under atmospheric pressure only.

Alternatively, an alkaline earth metal having an atomic radius smaller than barium may be used in whole or in part to fulfill the alkaline earth metal constituent requirement to provide an oxide complex having reduced interatomic spacings between elements. L, A, M and O even when the oxide complex is under only atmospheric pressure, compared to a pure barium species, thus increasing T_{co} and T_{c1}. Application of pressure up to 18 kilobars will even further enhance the T_{co} and T_{c1} of such substituted or non-barium oxide complex species.

It has also been found that oxide complexes having superconductivity in the 90°K range are produced wherein "L" is yttrium, lanthanum, neodymium, samarium, europium, gadolinium, erbium or lutetium and "a" is 1 and "x" is from about 0.65 to about 0.80, preferably about 0.667. Such oxides may be produced to have unique square planar "A"-atoms each surrounded by four oxygen atoms. The 90°K range for superconductivity of such oxides wherein "A" is copper and "M" is barium is believed to be attributable to the quasi-two-dimensional assembly of CuO_2—Ba—CuO_2-layers sandwiched between two "L" layers.

With an oxide complex prepared by the solid-state reaction of the invention a transition temperature as high as *100°K has been observed even under atmospheric pressure.*

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the reduction in electrical 5 resistance as temperature is decreased of a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 2 illustrates the enhancement towards higher temperatures of the onset transition temperature (T_{co}) as applied pressure is increased upon a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 3 illustrates the magnetic field effect on resistivity of a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 4 illustrates the magnetic susceptibility as a 15 function of temperature of a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 5 illustrates the resistivity and diamagnetic shift as a function of temperature of a La—Ba—Cu—O composition prepared according to Example III.

FIG. 6 illustrates the resistivity as a function of temperature under different applied pressures of 5.7 kilobars, 10.5 kilobars and 16.8 kilobars of a La—Ba—Cu—O composition as prepared according to Example III.

FIG. 7 illustrates the effect of applied pressure on onset temperatures (T_{co}), midpoint temperature (T_{cm}) and temperature for complete superconductivity (T_{c1}) of a La—Ba—Cu—O composition prepared according to Example III.

FIG. 8 illustrates the reduction in electrical resistance as temperature is decreased of a Y—Ba—Cu—O composition as prepared according to Example XI.

FIG. 9 illustrates the temperature dependence of magnetic susceptibility of a Y—Ba—Cu—O composition as prepared according to Example XI.

FIG. 10 illustrates the magnetic field effect on the resistance of a Y—Ba—Cu—O composition as prepared according to Example XI.

FIG. 11 illustrates the temperature dependence of resistance and magnetic suspectibility of a $GdBa_2Cu_3O_{6+\delta}$ oxide complex as prepared according to Example XIV.

FIG. 12 illustrates the temperature dependence of resistance and magnetic suspectibility of a $SmBa_2Cu_3O_{6+\delta}$ oxide complex as prepared according to Example XIV.

FIG. 13 is a schematic representation of the structures of a $(La_{1-x}Ba_{x-1})CuO_{4-\delta}$ oxide complex structure as prepared according to Example VIII and of a $LaBa_2Cu_3O_{6+\delta}$ oxide complex structure as prepared according to Example XIII.

FIG. 14 is the X-ray diffraction patterns for a $(La_{1-x}Ba_{x+1})CuO_{4-\delta}$ oxide complex as prepared according to Example VIII and for an $LaBa_2Cu_3O_{6+\delta}$ oxide complex as prepared according to Example XIII.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMEMTS

Superconducting compositions of this invention comprise an oxide complex defined by the following formula:

$$[L_{1-x}M_x]_aA_bO_y$$

wherein "L" is an element selected from the group consisting of scandium, yttrium, lanthanum, cerium, prasesdymium, neodymium, samarium, europium, gadolinium, terbium, dyprosium, holmium, erbium, thulium, ytterbium, lutetium or a mixture of one or more of these elements, and preferably "L" is yttrium, lanthanum neodynium, samarium, europium, gadolinium, erbium or lutetium; wherein "A" is an element selected from the group consisting of copper, bismuth, titanium, tungsten, zirconium, tantalum, niobium, vanadium or a mixture of one or more of these elements and "A" is preferably copper; wherein "M" is an element selected from the group consisting of barium, strontium, calcium, magnesium and mercury or a mixture of one or more of these elements and "M" is preferably barium or strontium; and wherein "a" is 1 to 2, "b" is 1, and "y" is about 2 to about 4, "x" is from about 0.01 to 1.0 maximum. Preferably when "a" is 1, "x" is from about 0.60 to about 0.90 and most preferably about 0.65 to about 0.80, whereas when "a" is 2 "x" is preferably from about 0.01 to about 0.5 and most preferably from about 0.075 to about 0.5. The amount of oxygen present in the compositions of the present invention depends upon the valence requirements of the other elements and the defects resulting from the particular heat treatment used to make the composition. The molar oxygen content "y" is about 2 to 4 times "b," as used in the preceding equation.

It has been observed that the transition temperature of such an oxide complex is increased by the application of pressure to the composition. It is believed that subjecting the oxide complex to high pressures decreases the interatomic distances or lattice spacing in such complexes and that this may, at least in part, account for the enhancement of transition temperatures that has been observed. Another way to obtain a decrease of the interatomic distances or lattice spacings is during the preparation of the oxide complex. Thus, for example, an alkaline earth metal having an atomic radius smaller than barium may be used in whole or in part to fulfill the alkaline earth metal requirement to produce an oxide complex having reduced interatomic distances or lattice spacing compared to an oxide complex with barium alone, with a consequent increase in the transition temperature of the non-barium oxide complex resulting compared to one produced with barium alone. The transition temperature is increased in such an oxide complex even as measured under atmospheric pressure.

The present invention also provides a solid-state reaction method for making such superconducting oxide complexes, one embodiment of which is described as follows and for convenience is referred to as the powder reaction method. Selected amounts of solid powdered compounds containing L, M, A, and O, preferably appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO are thoroughly mixed. Preferably mixing of the solid powder compounds is performed by an intensive mixer such as a jar mill or more preferably a ball mill. The powdered mixture is then heated in an oxygen-containing atmosphere, at an appropriate pressure, and at a temperature of between about 640° C. and 800° C. for a time sufficient to react the mixture in the solid state. The temperature of the mixture is conveniently increased to the 640–800° C. target temperature at a rate of 10° C. per minute. The mixture is kept at this target temperature for a time sufficient to allow the solid-state mixture to react. Preferably, the mixture is allowed to react for about an hour. The resulting mixture is then heated at a temperature between about 900° C. and 1100° C., preferably for at least twelve hours. The temperature is raised to about 900 to about 1100° C., conveniently at a rate of about 30° C. per minute. The samples are kept at the 900 to 1100° C. temperature for a time sufficient to complete the solid state reaction of the materials, the completed solid state reacted product being that product having the components completely diffused through the composition. The samples are then cooled to room temperature. The reaction mixture is then homogenized. The sample is homogenized preferably by pulverizing the reacted mixture in a jar mill and more preferably in a ball mill for at least 1 hour. The pulverized mixture is then heated rapidly to between 900–1100° C. The mixture is maintained at this temperature preferably for at least 6 hours. After this step, the mixture is compressed under a pressure of at least one kilobar. This compresses the powdered mixture into pellets or other coherent compacted form. The pellets are then sintered into solid cylinders. This sintering process is preferably performed at a pressure between zero to two kilobars at a temperature of between about 900–1100° C. and for about four hours. Finally, the samples are quenched rapidly from this temperature of between 900–1100° C. to room temperature, in air or an inert gas atmosphere such as Ar. This final step, along with thorough mixing of this mixture, decreases the range of the superconducting transition of the composition. This superconducting transition range is the range of temperatures between the point when a portion of the material shows superconductive properties (onset transition temperature) and the temperature at which the composition shows complete superconductive properties.

Compositions made in this process may be compressed to pressures that exceed atmospheric pressure, preferably in the range of 1 to 20 kilobars. This increase in pressure typically increases the T_c of the composition.

An alternative method for making such oxide complex superconductive compositions includes the following steps, and for convenience is referred to as the compressed powder reaction method. Selected amounts of solid powdered compounds containing L, M, A, and O are thoroughly mixed, preferably by selecting appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO. The thoroughly mixed powder mixture is compressed into pellets which are thereafter reacted at a temperature between about 800° C. and about 1100° C., preferably about 900° C. to about 1100° C., for a time sufficient to complete the solid state reaction.

Thereafter the reacted pellets are rapidly quenched to room temperature. Again, mixing is preferably accomplished by an intensive mixer such as a jar mill or more preferably a ball mill. Pelletization of the oxide mixture is carried out at an applied pressure of from about 100 to about 30,000 psi and preferably at an applied pressure of from about 100 to about 500 psi, most preferably at about 500 psi. Reaction of the pelletized mixture may be conducted in air for about 5 minutes to about 24 hours, and most preferably in a reduced oxygen atmosphere of about 2000μ for about 5 to about 30 minutes preferably for about 5 to about 15 minutes. Following the completion of the reaction step the reacted pellet composition is rapidly quenched to room temperature in air, such as by being placed on an aluminum plate as a heat sink. Wherein the oxide complex is prepared by reaction under a reduced oxygen atmosphere the reacted pellet may be rapidly quenched by passing a flow of ambient temperature oxygen through the oven over the sample.

Another method for preparing oxide complexes which exhibit significantly enhanced transition temperatures includes the following steps: thoroughly mixing selected amounts of solid powdered compounds containing L, M, A and O, preferably by selecting appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO; depositing the oxide mixture on a copper substrate which has been cleaned of its copper oxide surface film, preferably by acid cleaning in dilute hydrochloric acid solution; compressing the oxide mixture against the copper substrate at an applied pressure of from about 100 to about 1000 psi, preferably at about 100 to 200 psi, to form the oxide mixture into a film or layer on the copper substrate; heating the copper substrate and oxide mixture layered thereon to a temperature of from about 900 to about 1100° C. in air for from about 5 minutes to about 24 hours, and preferably for about 5 to about 15 minutes; and quenching the copper substrate and oxide mixture layered thereon to room temperature in air. Inspection of the oxide mixture layer which results from this method of preparation discloses that it comprises three phases, the first of which adjacent the copper substrate comprises a glassy insulating layer phase; the second phase is the superconducting layer phase; and the third phase which borders with the second superconducting phase is a powdery compound which is also an insulator layer phase.

Still another alternative method includes within any of the immediately foregoing solid-state reaction methods the step of reducing interatomic distances, either by the application of pressure to the oxide complex or by the use of atomic elements which provides smaller lattice spacings. A preferred oxide complex which exhibits a significantly enhanced superconducting transition temperature is prepared by utilizing yttrium as the "L" component.

Oxide complexes of the formula $[L_{1-x}M_x]_aA_bO_y$ prepared by a solid-state reaction procedure as described exhibit superconducting properties at transition temperatures higher than heretofore reported. The barium species of the oxide complex, that is wherein "M" is only barium, as prepared by the described solid-state reaction procedures exhibits superconducting properties beginning at a higher onset temperature (T_{co}) than the temperature reported by Bednorz et al as that wherein, for an oxide complex of similar empirical composition but prepared by a coprecipitation method, a phenomenon "reminiscent of the onset of percolative superconductivity" was observed. Further, it has been surprisingly found that the superconductivity transition temperature of oxide complexes of the formula $[L_{1-x}M_x]_aA_bO_y$ prepared by the solid-state reaction procedure is further enhanced towards higher limits by the application to and maintenance of pressure on the oxide complex up to about 18 kilobars.

Based upon present belief, it is thought that the application of and maintenance of high pressure on such oxide complexes enhances their superconducting transition temperature by producing a reduction of the interatomic distance or lattice spacing between the metal atoms forming the complex. The application and maintenance of high pressure on such oxide complexes may also enhance the transition temperature by suppressing instabilities detrimental to a high temperature superconductivity and thus permitting the existence of superconducting phase species to occur within the body of the oxide complex at a higher temperature than that at which such phase could form at atmospheric pressure. Pressure has been found to enhance the T_c of La—Ba—Cu—O and La—Sr—Cu—O oxide complexes at a rate of greater than 10^{-3}°K-bar^{-1} and to raise the onset T_{co} to 57°K, reaching a zero-resistance state T_{c1} at 40°K. It is believed that pressure reduces the lattice parameter and enhances the Cu^{+3}/Cu^{+2} ratio in the compounds. The unusually large pressure effect on T_c suggests that the high temperature superconductivity in La—Ba—Cu—O and La—Sr—Cu—O complexes may be associated with interfacial effects arising from mixed phases; interfaces between the metal and insulator layers, or concentration fluctuations within the K_2NiF_4 phase; strong superconducting interactions due to the mixed valence states; or a yet unidentified phase. Although the unexpected enhancement of transition temperature that the application of pressure to such oxide complexes produces has been repeatedly observed, a mechanism which adequately explains the pressure effect has not yet been fully determined.

The transition temperature of such oxide complexes is enhanced by the application of pressure, and that this effect is at least in part due to a resulting reduction in interatomic spacing in the oxide complex is evidenced by an enhancement of transition temperature that may be produced without the application of extrinsic pressure by employing in the formation of the oxide complex an alkaline earth metal having smaller atomic radius than that of barium. A similar enhancement of transition temperature has been observed when yttrium is used as the "L" component rather than lanthanum.

Hence, when preparing an oxide complex of the invention, it is preferred to completely or partially substitute for the barium atoms, atomic radius of 2.22 angstroms, smaller alkaline earth metal atoms, i.e., strontium, atomic radius of 2.15 angstroms, calcium, atomic radius of 1.97 angstroms, or magnesium, atomic radius of 1.6 angstroms. Similarly, complete or partial substitution of the lanthanum atoms, atomic radius of 1.87 angstroms, with the smaller lutetium atoms, atomic radius of 1.75 angstroms, or yttrium, atomic radius 1.78 angstroms, will provide this same effect. The application of pressure to such oxide complexes that are prepared to have decreased interatomic spacings will further enhance the transition temperature of such compositions to higher limits.

Alternatively, the deposition of a lanthanum, barium, copper, oxide film on a substrate with smaller lattice parameters, such as a lanthanum, calcium, copper oxide substrate, will reduce the interatomic spacing of the superconducting composition, and thus will increase the T_c of the oxide complex composition. Further, cladding of a lanthanum, barium, copper oxide composition with metals having larger thermal expansion coefficients, such as copper, will apply and maintain the pressure required to reduce the interatomic distances between the elements in the oxide complex composition and hence will increase the T of the composition.

When yttrium was utilized as the "L" component in substitution of lanthanum to provide an oxide complex of the nominal composition $Y_{1.2}Ba_{0.8}CuO_y$, the oxide complex exhibited superconductivity starting at 98°K and a zero-resistance state at 94°K. In strong contrast to the La—Ba—Cu—O and La—Sr—Cu—O oxide systems with a K_2NiF_4 like phase structure, the Y—Ba—Cu—O oxide system was observed to have only a slight enhancement of its transition temperature by the application of pressure up to 19 Kbar. Examination of the Y—Ba—Cu—O oxide revealed that it was comprised of mixed phases. The phases were separated and identified as tetragonal $YBa_2Cu_3O_{6+\delta}$ (black) and orthorhombic Y_2BaCuO_5 (green). The black and green phases comprised at lease 95% by volume of the initial Y—Ba—Cu—O oxide complex. Magnetic measurements on the oxide complex showed that the black phase was responsible for the high temperature superconductivity detected. Single phase $YBa_2Cu_3O_{6+\delta}$ samples (hereafter referred to as "YBCO") were prepared and exhibited a 100% ac diamagnetic shift. The molar oxygen content of the black phase is greater than twice that of the molar content of copper by an exact amount as yet undetermined, as indicated by the δ symbol in the phase formula.

The high temperature superconducting black phase, on a single phase basis, corresponds to the formula $[L_{1-x}M_x]_aA_bO_y$ wherein "L" is yttrium, "M" is barium, "A" is copper, "a" is 1, "b" is 1, "y" is 2 to 4 and "x" is 0.667. Further tetragonal oxide species were prepared according to the formula as above stated, but where "L" is lanthanum, neodymium, samarium, europium, gadolinium, erbium or lutetium. For convenience the oxide complexes so prepared are hereafter referred to as LaBCO, NeBCO, SaBCO, GaBCO, ErBCO, and LuBCO, respectively. All such oxide species were found to be superconducting with an onset temperature T_{co} between 90 and 95°K and a zero-resistance state T_{c1} between 70 and 94°K. This shows that different trivalent "L"-atoms do not dramatically affect the superconductivity property which is an intrinsic property in this class of compounds. The high temperature superconductivity observed in this class of compounds is believed to be associated with the CuO_2—Ba—CuO_2—Ba—CuO_2 plane assembly sandwiched between the "L"-layers. The significance of the inter-plane coupling within the layer-assembly is especially evident from the enhanced superconducting transition from ~30°K in the K_2NiF_4 like structure of a La—Ba—Cu—O or La—Sr—Cu—O type oxide (of Examples I–VIII) to ~90°K in the $LBa_2Cu_3O_{6+\delta}$ structure as so prepared. Bigger layer-assembly is predicted to yield even higher T_c superconducting oxides.

All samples of the LaBCO, NeBCO, SaBCO, EBCO, GaBCO, ErBCO and LuBCO with an $LBa_2Cu_3O_{6+\delta}$ structure were synthesized by the solid state reaction of appropriate amounts of sesqui oxides of La, Nd, Sm, Eu, Gd, Er and Lu, with appropriate amounts of $BaCO_3$ and CuO in a fashion as described in Examples XII to XIV Structural analyses were carried out with a Rigaku D-MAX X-ray power diffractometer. Samples of dimensions 1 mm×0.5 mm×4 mm were cut from the sintered cylinders. A standard four-lead technique was employed for the resistance R measurements, and a Linear Research ac inductance bridge was used for the magnetic susceptibility χ determinations The temperature was measured using an Au+0.07% Fe-Chromel or chromel-alumel thermocouple above 30°K and a Ge-thermometer below.

The powder X-ray diffraction patterns showed that all samples except LuBCO possess the single tetragonal $YBa_2Cu_3O_{6+\delta}$ structure, although for a couple of cases orthohombic symmetry was also detected. The lattice parameters are given in Table 1. In addition to the tetragonal $LBa_2Cu_3O_{6+\delta}$ structure, LuBCO exhibits other phases, which, it is believed, can be eliminated by proper heat-treatments.

All samples studied show rather sharp R-drops with an onset temperature T_{co} between 91–95°K, a zero-R state temperature T_{c1} between 70–94°K, and a deviation from linear temperature dependence of R at temperature T_{d} between 93 and 160°K. Whether T_{d} represents the beginning of superconductivity is yet to be determined. All relevant data are given in Table 1 and the typical temperature-dependence of R is displayed in FIGS. 11 and 12 for GaBCO and SaBCO, respectively. It is, therefore, evident that the sample starts to superconduct at ~90 K consistent with the R-measurements, and the whole sample becomes superconducting at lower temperatures.

The observation of superconductivity with an almost 30 constant T_{co} in the $LBa_2Cu_3O_{6+\delta}$ class for "L"=Y, La, Nd, Eu, Sm, Gd, Er and Lu clearly demonstrates that superconductivity in this class of compounds is not sensitive to "L". This is particularly true in view of the wide range of the magnetic properties of the "L"-atoms in the compounds. The present results, therefore, strongly suggest that superconductivity in $LBa_2Cu_3O_{6+\delta}$ class must be associated with the CuO_2—Ba—CuO_2 Ba CuO_2 plane assembly sandwiched by two layers of L-atoms, as represented in FIG. 13 for "L"=La. These Ba-coupled triple CuO_2-layers of ~7.7 Å thick may be disrupted by the L-layers only along the c-axis and thus may retain their quasi-two-dimensional characteristics. In the K_2NiF_4 structure of a $(La_{0.9}Ba_{0.1})_2CuO_{4-\delta}$ type oxide as shown also in FIG. 13, only individual square-lines of Cu-atoms with 6-coordination exist with a different stacking sequence. They are disrupted along the c-axis by the disordered La—Ba layers. The X-ray diffraction patterns for the two structural LaBCO compounds are also shown in FIG. 14 for comparison. The difference between the two structures is believed to be responsible for the 3-fold difference in T_c It is expected that higher T_c may be obtainable by structures with more than three CuO_2-layers coupled by more than two Ba-layers.

Although the $LM_2A_3O_{6+\delta}$ class of high temperature superconducting oxide complexes may be prepared by either the powder or compressed powder embodiment of the solid-state reaction method as previously described, it is preferred to use the compressed powder reaction method. Sample preparation parameters can affect the electronic and magnetic properties of the $LM_2A_3O_{6+\delta}$ class of oxide compounds drastically. It has been observed that the formation conditions for $LBa_2Cu_{6+\delta}$ for different "L's" are different. The reaction-time, the reaction temperature, the quenching rate, the reaction atmosphere and the compositions are all inter-related. For instance, oxide complexes within this class can be made insulating, partially superconducting or completely superconducting by varying the reaction atmosphere and the quenching rate while keeping the compositions unchanged. In spite of this wide range of variation of electrical properties, samples showed only very slight differences in their X-ray diffraction patterns, strongly suggesting that oxygen-content plays an important role in superconductivity of oxides.

Generally wherein the reaction atmosphere is a reduced oxygen atmosphere of about 2000μ the reaction may be conducted at a lower temperature than where the reaction is carried out under atmospheric conditions. Under a reduced oxygen atmosphere of about 2000μ the reaction temperature required to produce an oxide complex having superconducting properties is from about 800 to about 1000° C. and preferably from about 820 to about 950° C. For a reaction under atmospheric conditions the temperature required to produce superconducting properties is from about 900 to about 1100° C., preferably from about 950 to about 1000° C. For either type of reaction atmosphere higher temperatures, up to the melting point of the lowest melting component of the starting materials, could be employed; however it is generally preferred not to use such higher reaction temperatures since they may tend to degrade the superconducting properties of the resulting oxide complex compared to the optimum attainable by use of lower reaction temperatures. The optimum reaction temperature is dependent upon the elemental composition of the oxide complex being prepared and the optimum reaction temperature for a particular oxide complex may be established without undue experimentation. Reactions carried out at temperatures significantly lower than as discussed above generally result in an oxide complex that has only insulating or semiconducting electrical properties rather than superconducting properties.

The reaction atmosphere employed also influences the time of reaction to completion. Generally, reaction under a reduced oxygen atmosphere of about 2000μ requires a significantly shorter reaction, on the order of about 15 to 45 minutes for gram size reactions, compared to an atmospheric reaction which generally requires from about 45 minutes to 8 hours for gram size reactions. A similar trend would be expected for larger scale reactions, although the optimum reaction time for such larger scale reaction would have to be determined by observation. One method for determination of the completion of reaction is to monitor samples by X-ray diffraction for depletion of diffraction peaks that correspond to the starting material and growth to maximum intensity of diffraction peaks which correspond to the desired tetragonal $LM_2A_3O_{6+\delta}$ phase The optimum reaction time is dependant upon the elemental composition of the oxide complex being prepared and may be established by observation without undue experimentation. Optimum superconducting properties are obtained by timing the reaction to that point wherein the maximum amount of starting materials have been converted to the desired tetragonal $LM_2A_3O_{6+\delta}$.

When the reaction has proceeded to the point of maximum attainable $LM_2A_3O_{6+\delta}$ phase content, it is desirable to then rapidly quench the reaction material to room temperature. This generally produces a narrower temperature transition range between T_{co} and T_{c1} for the oxide complex so produced and also terminates any side reaction that may occur which would otherwise convert the $L M_2 A_1 O_{6-y}$ phase content to a nonsuperconducting phase structure. For material produced under atmospheric conditions rapid quenching is conveniently obtained by immediately transferring the reacted material from the heated reaction vessel to a heat sink. For gram quantities of material an aluminum plate adequately functions as a suitable heat sink for rapid quenching. Wherein the reacted material has been prepared in a reduced oxygen atmosphere, upon completion of the reaction the sample may be rapidly quenched by passing oxygen at ambient temperature over the reacted sample.

The superconducting compositions of the present invention have the potential for being used in a wide variety of applications. For example, when used in a wire or conductor form, they may be used in electrical power transmission, energy storage, controlled fusion reaction, electricity generation, mass transportation and magnets.

In a thin film form, they may be used in ultra-sensitive detectors and in ultra-fast computers. In addition, they may be used in a superconducting-magnetic-superconducting multi-layer form for use in ultra-sensitive ultra-fast electromagnetic micro devices.

The following examples are representative of the oxide complexes and methods of producing the oxide complexes of the invention. The examples for certain of the compositions also illustrate the enhancement of transition temperature that is produced by the application and maintenance of high pressure on the oxide complexes. Generally, the standard 4-probe technique was used to measure resistivity, and an inductance bridge was employed for ac magnetic susceptibility χ-determination. The temperature was measured using the Au+0.07% Fe-chromel, and chromel-alumel thermocouples in the absence of a magnetic field, and a carbon-glass thermometer in the presence of a field. The latter was calibrated against the former without a field. Magnetic fields up to 6T were generated by a superconducting magnet.

EXAMPLE I

6.0 grams of La_2O_3, 0.61 grams of $SrCO_3$ and 1.63 grams of CuO were mixed in ajar mill for about 12 hours. The mixture was then heated at a rate of about 10° C. per minute in air at 1 atmosphere pressure, until it reached a temperature of about 720° C. The mixture was then allowed to react for about an hour at about 720° C. After this reaction step, the temperature was raised to a temperature of about 1000° C. at a rate of about 30° C. per minute. Once at a 1000° C. temperature, the samples were maintained at this temperature for about twenty-one hours. This allowed the completion of a solid state reaction. After cooling to room temperature, the reacted mixture was pulverized in a jar mill for about 6 hours until the sample was homogenized. The pulverized mixture was then heated rapidly to a temperature of about 1000° C., and kept at that temperature for about seven hours. After this period, the mixture was cooled to room temperature and then compressed under a pressure of six kilobars. This compression converted the mixed powder into pellets. The pellets were then sintered into solid cylinders by heating them at a temperature of about 1000° C. for a period of about four hours at a pressure of almost zero kilobars. Finally, the sample was rapidly quenched from this temperature to room temperature in air.

The resulting lanthanum-strontium-copper-oxide composition had an empirical formula of $La_{1.8}Sr_{0.2}Cu_1O_y$. This corresponds to an oxide complex of the general formula $[La_{1-x}Sr_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is 2 to 4. The oxide complex composition had an onset superconductivity transition temperature (T_{co}) of 45°K, with a narrow transition width to complete superconductivity of about 10°K at ambient pressure.

EXAMPLE II

6.0 grams of La_2O_3, 0.61 grams of $SrCO_3$ and 1.63 grams of CuO were mixed mechanically in a jar mill for approximately 24 hours. The resulting mixture was then compressed into pellets by applying a pressure of about 2 kilobars. The pellets were heated to about 1000° C., and allowed to react for about twenty-four hours in air. The reacted pellets were then quenched rapidly to room temperature.

The La—Sr—Cu—O composition produced from this process had a formula of $La_{1.8}Sr_{0.2}Cu_1O_y$. This corresponds to an oxide complex of the general formula $[La_{1-x}Sr_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is 2 to 4. This composition showed superconductive properties at a temperature of about 42°K, with a narrow transition width of about 6°K at ambient pressure.

EXAMPLE III

6.0 grams of La_2O_3, 0.81 grams of $BaCO_3$ and 1.63 grams of CuO were mixed in a mortar-pestle apparatus for about 3 hours. The mixture was then heated at a rate of about 10° C. per minute in oxygen at a pressure of about 2000 microns Hg, until it reached a temperature of 720° C. The mixture was then allowed to react for about an hour at about 720° C. After this reaction, the temperature was raised to a temperature of about 950° C., this raise in temperature was made at a rate of about 30° C. per minute. Once at this temperature, the sample was maintained at this temperature for about twenty-one hours. After this period, the sample was cooled to room temperature and then the reacted mixture was pulverized until the sample was homogenized. The pulverized mixture was then heated rapidly to a temperature of about 950° C., and kept at that temperature for about seven hours. After this period, the sample was again cooled to room temperature and the mixture was compressed under a pressure of six kilobars. This compression converted the mixed powder into pellets. The pellets were then sintered into solid cylinders by heating them at a temperature of about 950° C. for a period of about four hours at ambient atmospheric pressure. Finally, the sample was rapidly quenched from this temperature to room temperature in air. The resulting lanthanum-barium-copper-oxide composition had the formula $La_{1.8}Sr_{0.2}Cu_1O_y$. The oxide complex so formed was of the formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is 2 to 4. This composition was found to be superconducting at 39°K at ambient pressure. This composition was then placed inside a pressure cell and the composition was compressed to a pressure of 14 kilobars at room temperature. After this compression step, the temperature was gradually reduced until the composition showed superconducting properties. This composition showed superconductivity properties at a temperature of 52.5°K at the applied pressure of 10 kilobars.

A sample prepared as described above exhibits only X-ray powder diffraction patterns characteristic of the single K_2NiF_4 phase with a resolution ~5%. The resistivity of this sample at ambient pressure decreases monotonically with decreasing temperature but at a reduced rate below 60°K. A large drop in resistivity sets in at ~39°K, indicative of the onset of a superconducting transition, and resistivity becomes zero at T_{c1} ~20°K as shown in FIG. 5. Preliminary ac χ-measurement showed diamagnetic shift starting at

~32°K and reaching a maximum of 10% of the signal of a superconducting Pb sample of a similar size. Under applied pressure, the superconducting transition is broadened but with an overall shift toward higher temperatures as shown in FIG. 6. T_{c0} has been enhanced from 39° to 52.5°K and the T_{c1} from 20° to 25°K by application of a pressure of 12 kilobars as displayed in FIG. 7. The enhancement rate of T_{c0} and T_{c1} is significantly reduced above 12 kilobars. The pressure effect on the midpoint temperature T_{cm} where it has dropped by 50% of that at T_{c0} is also given in FIG. 7. T_{cm} increases from 31° to 36°K under pressure. The decrease in the rate of T_c enhancement at 12 kilobars is accompanied by an overall resistivity increase at about T_{c0}, indicating the possible commencement of physical or chemical instabilities. Serious deterioration of samples is also detected upon removal of pressure, as evidenced by the dramatic increase in resistivity and a semiconducting behavior at low temperatures preceded by a drop in resistivity starting at T_{c0}. The exact causes and remedy for the pressure induced sample deterioration above ~12 kilobars are currently under study.

One method of preparing the composition of this example in a wire form, while simultaneously reducing the interatomic distances between the atoms in the material, may include performing these reaction steps while La_2O_3 or $La(OH)_3$, $BaCO_3$ and CuO have been placed in a copper sleeve, or placing the reaction product of this mixture directly in the sleeve followed by drawing or extrusion. Because of the relative thermal expansion coefficients of the copper compared to the superconducting composition, the resulting lanthanum-barium-copper-oxide would be compressed by the walls of the copper sleeve. This compression will cause the T_c of the material within the copper sleeve (the copper sleeve itself is not part of the superconductive material) to increase.

EXAMPLE IV

2.0 grams of La_2O_3, 0.2 grams of $BaCO_3$ and 0.53 grams of CuO were mixed mechanically in a mortar-pestle apparatus for approximately 3 hours. The resulting mixture was then compressed into pellets by applying a pressure of about 2 kilobars. The pellets were heated to about 1000° C., and allowed to react for about twenty-four hours in air. The reacted pellets were then quenched rapidly to room temperature.

The La—Ba—Cu—O composition produced from this process corresponds to the formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.075, Ha "is 2, "b" is 1 and "y" is 2 to 4. The oxide complex of this example showed superconductive properties at a temperature of 36°K at atmospheric pressure.

EXAMPLE V

4.9 grams of La_2O_3, 1.1 grams of $BaCO_3$ and 2.8 grams of CuO were mixed in a mortar-pestle for 3 hours. The mixture was then heated in oxygen at a pressure of 15 microns Hg, until it reached a temperature of about 720° C. The temperature was increased at a rate of about 10° C. per minute. The mixture was then allowed to react for about an hour at about 720° C. After this reaction, the temperature was raised to a temperature of about 925° C., this raise in temperature was made at a rate of about 30° C. per minute. Once at this temperature, the samples were maintained at this temperature for about twenty-one hours. After this period, the mixture was cooled to room temperature and then the reacted mixture was pulverized until the sample was homogenized. The pulverized mixture was then heated rapidly to a temperature of about 925° C., and kept at that temperature for about seven hours. After this period, the mixture was compressed with a pressure of six kilobars. This compression converted the mixed powder into pellets. The pellets were then sintered into solid cylinders by heating them at a temperature of about 925° C. for a period of about four hours at ambient pressure. Finally, the sample was rapidly quenched from this temperature to room temperature in air. The oxide complex so formed corresponds to the general formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.15, "a" is 1, "b" is 1 a and "y" is 2 to 4

The resulting lanthanum-barium-copper-oxide composition, superconducting at 32°K at ambient pressure, was then placed under a pressure of 9 kilobars using a Be—Cu high pressure clamp using a fluid pressure medium. Pressure was measured using a superconducting Pb-manometer situated next to the sample at room temperature. As this compressed composition was cooled, it began showing superconductivity properties at a temperature of 40.2°K.

Powder X-ray diffraction patterns at room temperature showed that the sample was multiphased, consisting predominantly of K_2NiF_4 (~90%) and unidentified phases (<10%). Under applied pressures, resistivity at 300°K is suppressed and the drop in resistivity is broadened slightly, but with an overall shift toward higher temperature as shown in FIG. 1. T_{c0} increases rapidly with pressures as shown in FIG. 2. At 13 kilobars, T_{c0} is ~40.2°K. Under pressure, T_{c0} increases from 32° to 40.2°K at 13 kilobars at a rate ~0.9×10^{-3}°K bar^{-1}. Above 13 kilobars, the sample was damaged due to a shear strain introduced accidentally by applying pressure below −20° C., as evidenced by the appearance of a rapid resistivity increase following the resistivity drop at T_{c0} on cooling and the irreversibility of resistivity after the pressure was reduced.

FIG. 3 displays the magnetic field effect on 5 resistivity as a function of temperature. It is clear that the rapid resistivity drop is suppressed and the zero resistivity state at 4°K can be destroyed by magnetic fields. Below 18°K, a diamagnetic shift is clearly evident and reaches a maximum of 2% of the signal of a superconducting Pb sample of the same size as shown in FIG. 4. The insert of FIG. 4 shows the current-voltage characteristics for the sample at 4.2°K. The zero resistivity state is removed as current exceeds a critical value which increases with decreasing temperature. All these strongly demonstrate that the resistivity drop is associated with a superconducting transition.

EXAMPLE VI

6.0 grams of La_2O_3, 0.61 grams of $SrCO_3$ and 1.63 grams CuO were mixed mechanically in a mortar-pestle for approximately 3 hours. The resulting mixture was then compressed into pellets by applying a pressure of about 3 kilobars. The pellets were heated to about 1000° C., and allowed to react for about twenty-four hours in air. The reacted pellets were then quenched rapidly to room temperature.

The La—Sr—Cu—O composition produced from this process corresponds to the general formula $[La_{1-x}Sr_x]_aCu_bO_y$ where "x" is 0.1, "a" is 2, "b" is 1, and "y" is 2 to 4. The oxide complex was placed under a pressure of 16 kilobars, at room temperature. Upon cooling this oxide complex composition showed superconducting properties at a temperature of 42° K at atmospheric pressure. The oxide complex composition under a pressure of 16 kilobars showed superconducting properties at 54° K.

EXAMPLE VII

The magnetic layer in a superconducting-magnetic-superconducting multi-layer device could consist of a lanthanum-barium-copper-oxide base composition. Such a composition may be prepared as follows. 3.0 grams La_2O_3, 3.6 grams $BaCO_3$ and 2.9 grams CuO were mixed and heated in a vacuum about 10 microns Hg at a temperature of about 1000° C. for about twenty-four hours.

The resulting product formed a magnetic compound with a 10 magnetic ordering temperature below 40°K.

The superconducting-magnetic-superconducting multi-layer structures may therefore be formed by subjecting the overlayer of La—Ba—Cu—O, which is separated from the superconducting underlayer by an ultra-thin protective covering of, for example SiO_2, to a vacuum of 10 microns Hg at a temperature of between about 900° C. and 1100° C. Thin film samples of the composition of the present invention may be synthesized by alternative current or radio frequency sputtering of a sintered La—Ba—Cu—O target in an argon atmosphere having about 10% oxygen and a pressure of between 10^{-2} and 2 microns Hg. Heat treatment of such film samples at 15-2000 microns Hg pressure in an oxygen atmosphere should make the superconducting properties of the film samples similar to those for the sintered samples.

EXAMPLE VIII

A La—Ba—Cu—O composition was prepared in accordance with the procedure described in Example II except that La_2O_3, $BaCO_3$ and CuO were used in the amounts appropriate to provide an oxide complex of the formula $[La_{1-x}B_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is between 3 and 4, and an intensive mixer ball mill was used rather than a jar mill The oxide complex 50 produced showed superconductive properties at a temperature of 60°K at an applied pressure of 12 kilobars.

EXAMPLE IX

A La-A(trace)—Cu—O composition was prepared in accordance with the procedure described in Example II except that La_2O_3, ACO_3 and CuO were used in the amounts appropriate to provide an oxide complex of the formula $[La_{1-x}B_a]Cu_bO_y$ wherein "x" is about 0.01, "a" is 2, "b" is 1 and "y" is between 3 and 4, and an intensive mixer ball mill was used for mixing rather than a jar mill. "A" was either barium or strontium. The oxide complex so produced showed superconductive properties at an onset temperature of 100°K at 1 atmosphere.

EXAMPLE X

A La—Ba—Cu—O composition was prepared in accordance with the procedure of Example II except that La_2O_3, $BaCO_3$ and CuO were used in the amounts appropriate to provide an oxide complex of the formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is about 0.4, "a" is 1, "b" is 1 and "y" is between 2 and 3, and the heat treatment was done at 10^{-4} microns Hg in air, rather than at atmospheric pressure. The oxide complex so produced showed superconductive properties at an onset temperature of 100°K.

EXAMPLE XI

A yttrium oxide complex was prepared with a nominal composition represented by $[Y_{1-x}B_x]_aCu_bO_y$ wherein "x" is 0.4, "a" is 2, "b" is 1 and "y" is less than or equal to 4. The yttrium oxide complex was prepared by intensively mixing appropriate amounts of Y_2O_3, $BaCO_3$ and CuO. The oxide mixture was then compressed to pellets at an applied pressure of 100 to 500 psi, the resulting pellets were then heated in air at a temperature between 900 to 1100° C. for about 15 minutes then rapidly quenched to room temperature in air.

Bar samples of dimensions 1 mm×0.5 mm×4 mm were cut from the sintered cylinders. A four-lead technique was employed for the resistance (R) measurements and an ac inductance bridge for the magnetic susceptibility (χ) determinations.

The temperature dependence of resistance for this Y—Ba—Cu—O oxide complex was determined in a simple liquid nitrogen dewar with results as shown in FIG. 8. Resistance (R) initially dropped linearly with temperature (T). A deviation of resistance from the linear temperature dependence was evidenced at 93° K. A zero resistivity state was achieved at 80°K. (However, when the pellets were quenched on an aluminum plate as a heat sink to room temperature in air, the zero resistance state was achieved at 90°K.) The variation of magnetic susceptibility (χ) with temperature was measured with the results as shown in FIG. 9. A diamagnetic shift was observed to start at 91°K and the size of the shift increased rapidly with further cooling. At 4.2°K, the diamagnetic signal corresponded to 24% of the superconducting signal of a lead sample with similar dimensions. In a magnetic field, the drop in resistivity shifted toward lower temperature as shown in FIG. 10. At the maximum field applied, the zero reisitivity state remained at temperature as high as 40°K. Preliminary X-ray powder diffraction patterns showed the existence of multiple phases apparently uncharacteristic of the K_2NiF_4 structure in the samples.

The above results demonstrate unambiguously that superconductivity occurs in the Y—Ba—Cu—O oxide complex with a transition between 80 and 93°K (and 90-93°K when quenched on the aluminum plate). The upper critical field $H_{c2}(T)$ was determined resistively. If the positive curvature at very low fields is neglected, a value of dH_{c2}/dt near T is observed to be the 3T/K or 1.3T/K, depending on if $H_{c2}(T_c)$ is taken at the 10% drop of the normal state resistivity, or the 50% drop. In the 35 weak-coupling limit, $H_{c2}(O)$ was estimated as between 80 and 180T in the Y—Ba—Cu—O oxide complex. The paramagnetic limiting field to 0°K for a sample with a T_c~90K is 165T.

EXAMPLE XII

100 mg of Y_2O_3, 349.57 mg of $BaCO_3$ and 211.39 mg of CuO were thoroughly mixed by mortar-pestle. Mixing continued until microscopic examination revealed that the white Y_2O_3 and $BaCO_3$ powders had thoroughly mixed with the dark CuO powder to produce a mixture of uniform color without any regions or streaks of white or lighter color. The powder mixture was then pressed to pellets of about 3/16 inch diameter and 1/16 inch thickness in a pellet die by application of about 250 psi pelletization pressure. The pellets were then reacted under atmospheric conditions at a temperature of 1000° C. for about 20 to about 30 minutes and thereafter removed from the oven and placed upon an aluminum heat sink plate to rapidly quench the reacted pellets to ambient temperature. The T_{c1}, T_{cv}, T_{c1} and X-ray diffraction lattice parameters measured for this YBCO complex are reported in Table 1.

EXAMPLE XIII

100 mg of La_2O_3, 242.271 mg of $BaCO_3$ and 146.478 mg of CuO were thoroughly mixed by mortar-pestle until a mixture of uniform color was obtained as determined by microscopic examination. The powder mixture was then pressed to pellets of about 3/16 inch diameter and 1/8 inch thickness in a pellet die by application of about 250 psi pelletization pressure. The pellets were then reacted in air for about 8 hours following which the pellets were reacted for about 20–30 minutes under a reduced-oxygen atmosphere (~2000μ) at 850° C., then quenched by passing ambient temperature oxygen through the reaction zone containing the pellets. The T_{c1}, T_{co}, T_c, and X-ray diffration lattice parameters determined for this LaBCO complex are reported in Table I.

EXAMPLE XIV

$LBa_2Cu_3O_{6+\delta}$ oxide complexes wherein "L" is Nd, Sm, Eu, Gd, Er and Lu were prepared with the quantities of materials and at the reaction temperatures as given below:

L_2O_3	$BaCO_3$	CuO	Reaction Temp. ° C.
Nd_2O_3 100 mg	234.588 mg	141.834 mg	900° C.
Sm_2O_3 100 mg	226.25 mg	136.79 mg	950° C.
Eu_2O_3 100 mg	224.27 mg	135.6 mg	950° C.
Gd_2O_3 100 mg	217.73 mg	133.18 mg	900° C.
Er_2O_3 100 mg	206.358 mg	124.763 mg	820° C.
Lu_2O_3 100 mg	198.359 mg	119.927 mg	830° C.

In each instance the powder components were thoroughly mixed by mortar-pestle until microscopic examination revealed a powder mixture of uniform color. In each instance the resulting powder mixture was pressed into pellets of about 3/16 inch diameter and 1/16 thickness in a pellet die by application of about 250 psi pelletization pressure. In each instance the resulting pellets were then reacted for about 20 minutes under a reduced oxygen atmosphere (~2000μ) at the reaction temperatures as above indicated, following which each was quenched to ambient temperature by passing ambient temperature oxygen over the reacted pellets. The T_{c1}, T_{co}, T_{c1} and X-ray diffraction lattice parameters measured for each of the resulting NeBCO, SaBCO, EBCO, GaBCO, ErBCO and LuBCO samples are reported in Table I.

TABLE I

OXIDE COMPLEX	Resistance-Temperatures Properties T_{co} (° K)	T_{c1} (° K)	T_{a1} (° K)	X-Ray Lattice Parameters a(A)	b(A)	c(A)
$YBa_2Cu_3O_{6+\delta}$	98	94	100	3.86 ± 0.02	3.86 ± 0.02	11.71 ± 0.02
$LaBa_2Cu_3O_{6+\delta}$	91	75	99	3.95 ± 0.02	3.95 ± 0.02	11.79 ± 0.02
$NdBa_2Cu_3O_{6+\delta}$	91	70	95	3.89 ± 0.02	3.89 ± 0.02	11.73 ± 0.02
$SmBa_2Cu_3O_{6+\delta}$	94	82	135	3.88 ± 0.02	3.88 ± 0.02	11.73 ± 0.02
$EuBa_2Cu_3O_{6+\delta}$	94	88	160	3.86 ± 0.02	3.86 ± 0.02	11.74 ± 0.04

TABLE I-continued

OXIDE COMPLEX	Resistance-Temperatures Properties T_{co} (° K)	T_{c1} (° K)	T_{a1} (° K)	X-Ray Lattice Parameters a(A)	b(A)	c(A)
$GdBa_2Cu_3O_{6+\delta}$	95	92	135	3.89 ± 0.02	3.89 ± 0.02	11.73 ± 0.02
$ErBa_2Cu_3O_{6+\delta}$	94	87	120	3.83 ± 0.02	3.85 ± 0.02	11.65 ± 0.02
$LuBa_2Cu_3O_{6+\delta}$	91	85	120	3.83 ± 0.02	3.37 ± 0.02	11.73 ± 0.02

As is readily apparent from the above description, additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific examples shown and described. Accordingly, departures may be made from the details shown in the examples without departing from the spirit or scope of the disclosed general inventive concept.

What is claimed is:

1. A composition which is superconductive at a temperature of 70°K and higher, comprising:

a metal oxide the formula

$$[L_{1-x}M_x]_aA_bO_y$$

wherein:

"L" is yttrium, lanthanum, neodymium, samarium, europium, gadolinium, dyprosium, holmium, erbium, thulium, ytterbium, lutetium, or mixtures thereof; "M" is barium, strontium, or mixtures thereof; "A" is copper; "x" is from about 0.65 to 0.80; "a" is 1; "b" is 1; and "y" is a value from about 2 to about 4 that provides the metal oxide with zero electrical resistance at a temperature of 70°K or above.

2. The superconducting composition of claim 1, wherein "M" is barium.

3. The superconducting composition of claim 2, wherein "x" is about 0.667.

4. The superconducting composition of claim 3, wherein "L" is yttrium, lanthanum neodymium, samarium, europium, gadolinium, erbium or lutetium.

5. The superconducting composition of claim 1, wherein the metal oxide has the formula

$$LM_2A_3O_{6+\delta}$$

and δ is a number value from about 0.1 to about 1.0 that provides the oxide complex with zero electrical resistance at a temperature of 70°K or above.

6. The superconducting composition of claim 5, wherein "M" is barium.

7. The superconducting composition of claim 6, wherein "L" is yttrium, lanthanum neodymium, samarium, europium, gadolinium, erbium or lutetium.

8. A material containing a sufficient quantity of a superconductive crystalline phase to cause the material to exhibit substantially zero electrical resistance at a temperature of 77°K or above; said crystalline phase composition having the formula $LM_2Cu_3O_{6+\delta}$, wherein "L" is Y, La, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, Yb, Lu, or mixtures thereof; "M" is Ba, Sr or mixtures thereof; and δ is a value from about 0.1 to

about 1.0 that provides the composition with zero electrical resistance at a temperature of 77°K or above.

9. The material of claim 8 wherein L is Y and M is Ba.

10. The material of claim 8 wherein L is. Sm. Eu. Gd. Er. or Lu and M is Ba.

11. A method for making a superconducting metal oxide. comprising the steps of:

mixing solid compounds containing L. M. A and O in amounts appropriate to yield the formula $[L_{1-x}M_x]_a A_b O_y$ wherein "L" is yttrium. lanthanum. neodymium. samarium. europium. gadolinium. dysprosium. holmium. erbium. thulium. ytterbium, lutetium, or a combination thereof; "M" is barium. strontium. or a combination thereof: "A" is copper, "a" is 1 to 2: "b" is 1: "x" is about 0.01 to about 1.0: and "y" is a value from about 2 to about 4 that provides the metal oxide with zero electrical resistance at a temperature of 40°K or above;

compacting the mixture into a solid mass by application of pressure from about 100 to about 30,000 psi:

heating the solid mass in air to a temperature of from about 800 to about 1000° C. for a time sufficient to react the compacted mixture in the solid state; and quenching the solid mass to ambient temperature in air.

12. The method of claim 11. wherein "M" is barium.

13. The method of claim 12. wherein "x" is about 0.65 to about 0.80 and "a" is 1.

14. The method of claim 13, wherein the mixture is compacted to a solid mass by application of pressure of from about 100 to about 500 psi.

15. The method of claim 14. wherein the solid mass is heated under a reduced oxygen atmosphere of about 2000μ at a temperature of from about 820° C. to about 950° C.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,056,866 B1 Page 1 of 1
APPLICATION NO. : 07/032041
DATED : June 6, 2006
INVENTOR(S) : Chu

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page,
[*] delete "Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 785 days."

Signed and Sealed this

Fifth Day of June, 2007

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

US007709418B1

(12) **United States Patent**
Chu

(10) **Patent No.: US 7,709,418 B1**
(45) **Date of Patent: *May 4, 2010**

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(54) HIGH TRANSITION TEMPERATURE SUPERCONDUCTING COMPOSITIONS

(75) Inventor: **Ching-Wu Chu**, Houston, TX (US)

(73) Assignee: **University of Houston**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **07/300,063**

(22) Filed: **Jan. 23, 1989**

Related U.S. Application Data

(63) Continuation of application No. 07/102,205, filed on Feb. 6, 1987, now abandoned, which is a continuation-in-part of application No. 07/006,991, filed on Jan. 26, 1987, now abandoned, which is a continuation-in-part of application No. 07/002,089, filed on Jan. 12, 1987, now abandoned.

(51) **Int. Cl.**
H01L 39/12 (2006.01)
C04B 35/45 (2006.01)

(52) **U.S. Cl.** 505/126; 505/780

(58) **Field of Classification Search** 29/599; 252/518, 520, 521; 420/901; 423/263, 593; 428/930; 501/104, 108, 123, 126, 135, 152; 505/125, 126, 490, 500, 780
See application file for complete search history.

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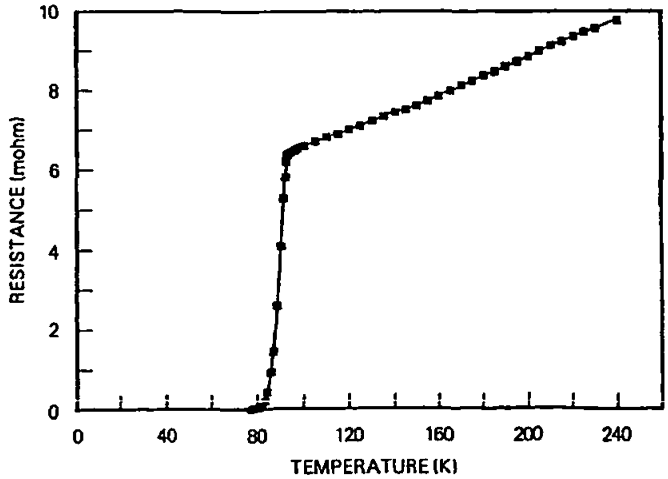
(57) ABSTRACT

Described is a superconducting composition comprising an oxide complex of the formula $[L_{1-x}M_x]_aA_bO_y$ wherein L is lanthanum, lutetium, yttrium or scandium; A is copper, bismuth, titanium, tungsten, zirconium, tantalum, niobium, or vanadium; M is barium, strontium, calcium, magnesium or mercury; and "a" is 1 to 2; "b" is 1; "x" is a number in the range of 0.01 to 0.5 and preferably 0.075 to 0.5; and "y" is about 2 to about 4. The oxide complexes of the invention are prepared by solid-state reaction procedure which produce oxide complexes having enhanced superconducting transition temperatures compared to an oxide complex of like empirical composition prepared by a coprecipitation—high temperature decomposition procedure. With a solid-state reaction prepared oxide complex of the invention a transition temperature as high as 100° K has been observed even under atmospheric pressure.

8 Claims, 10 Drawing Sheets



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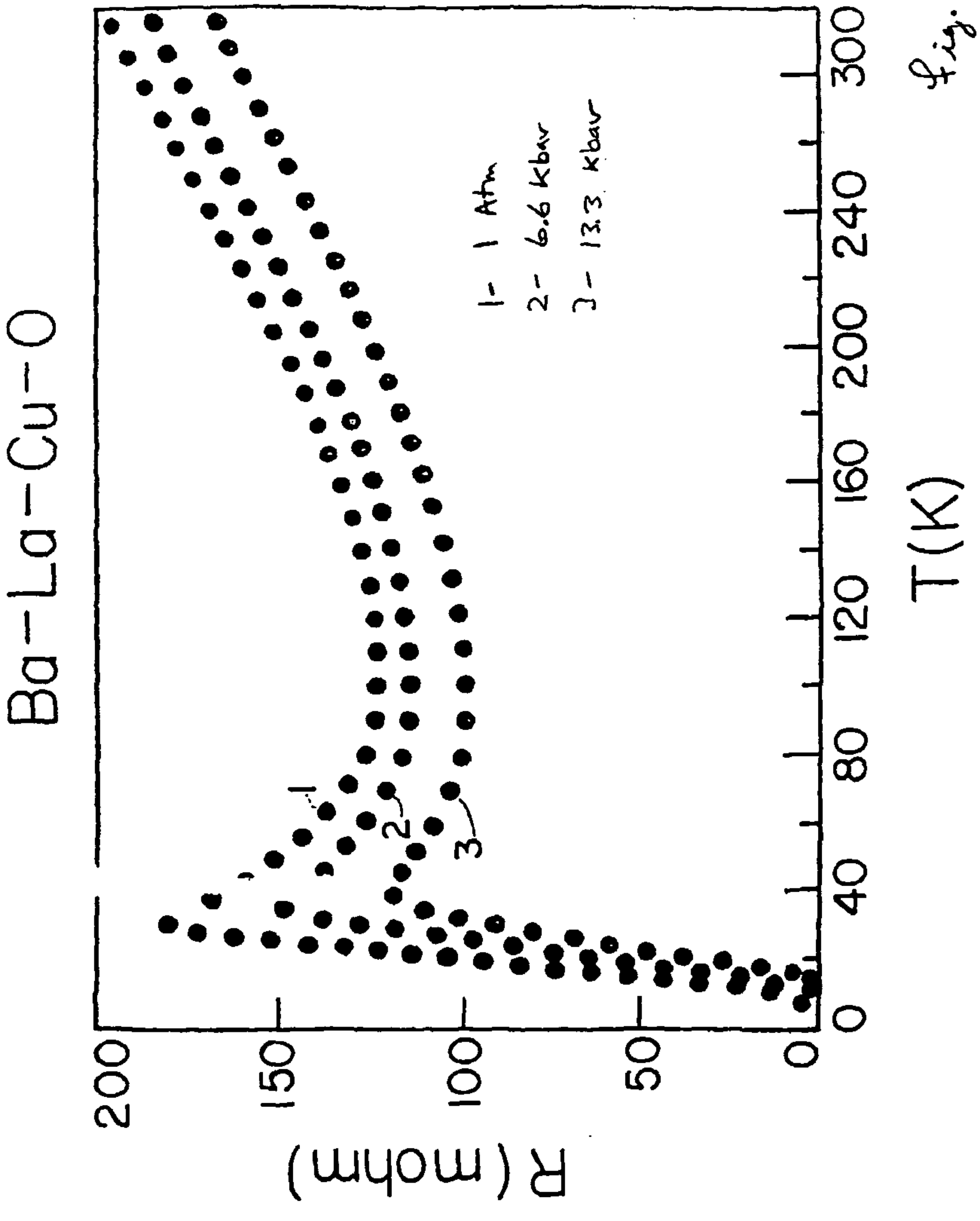
Ba-La-Cu-O
R (mohm)
200
150
100
50
0
T(K)
0
40
80
120
160
200
240
300
1- 1 Atm
2- 6.6 Kbar
3- 13.3 Kbar
1
2
3

fig. 1

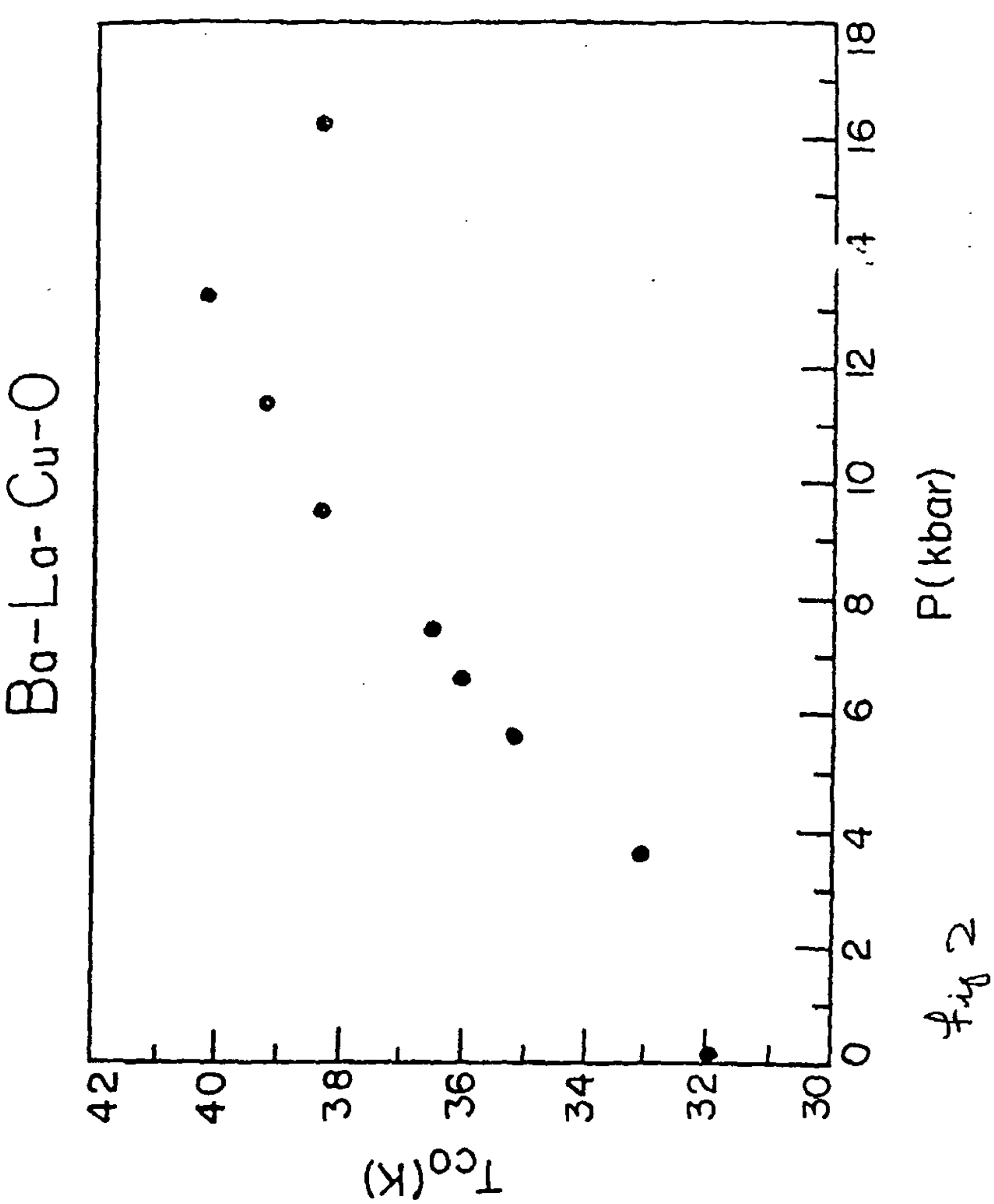

fig 2

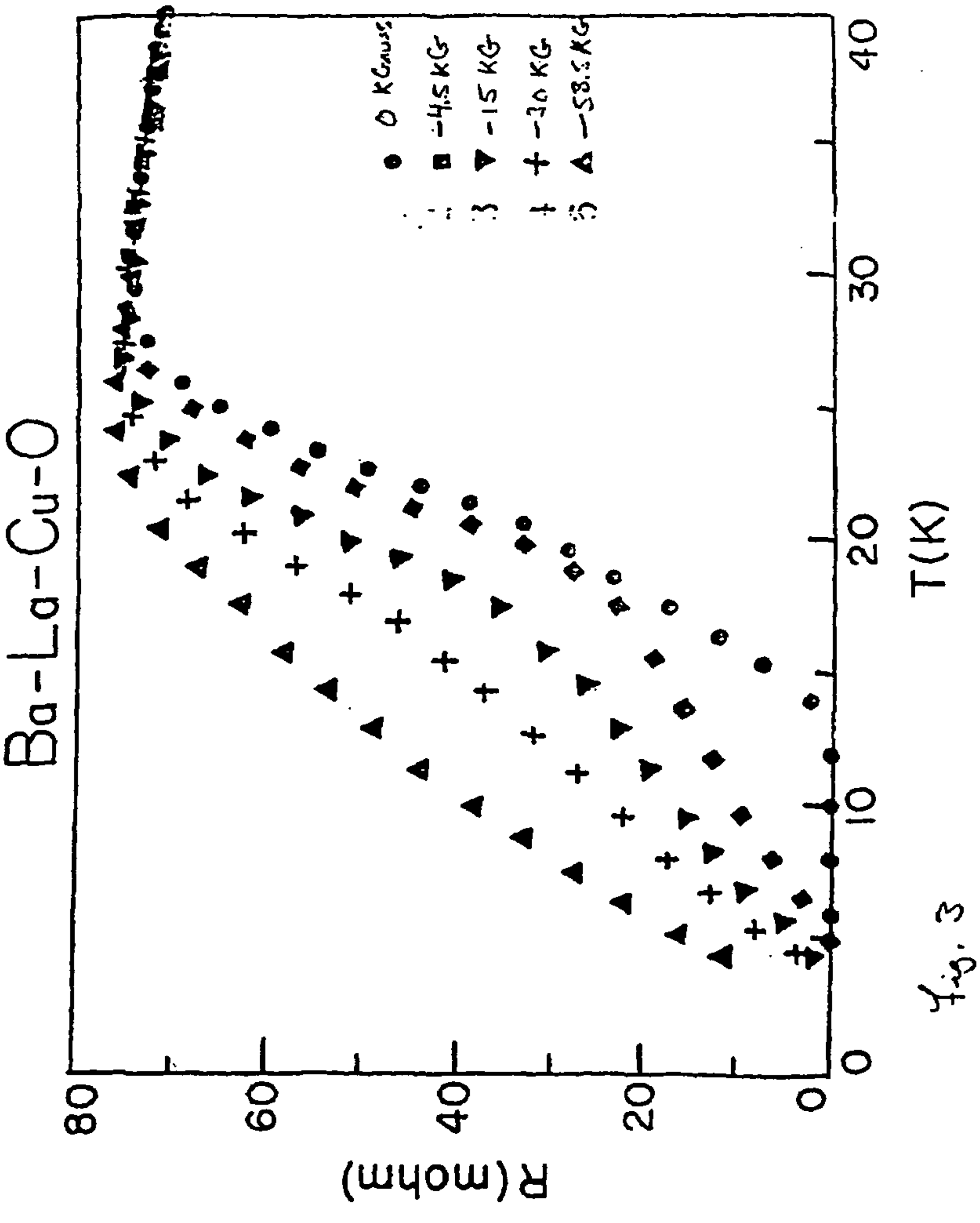
Ba-La-Cu-O
R (mohm)
80
60
40
20
0
T(K)
0
10
20
30
40
● 0 KGauss
3 ▼ -15 KG
■ -4.5 KG
4 + -30 KG
5 ▲ -58.5 KG

Fig. 3

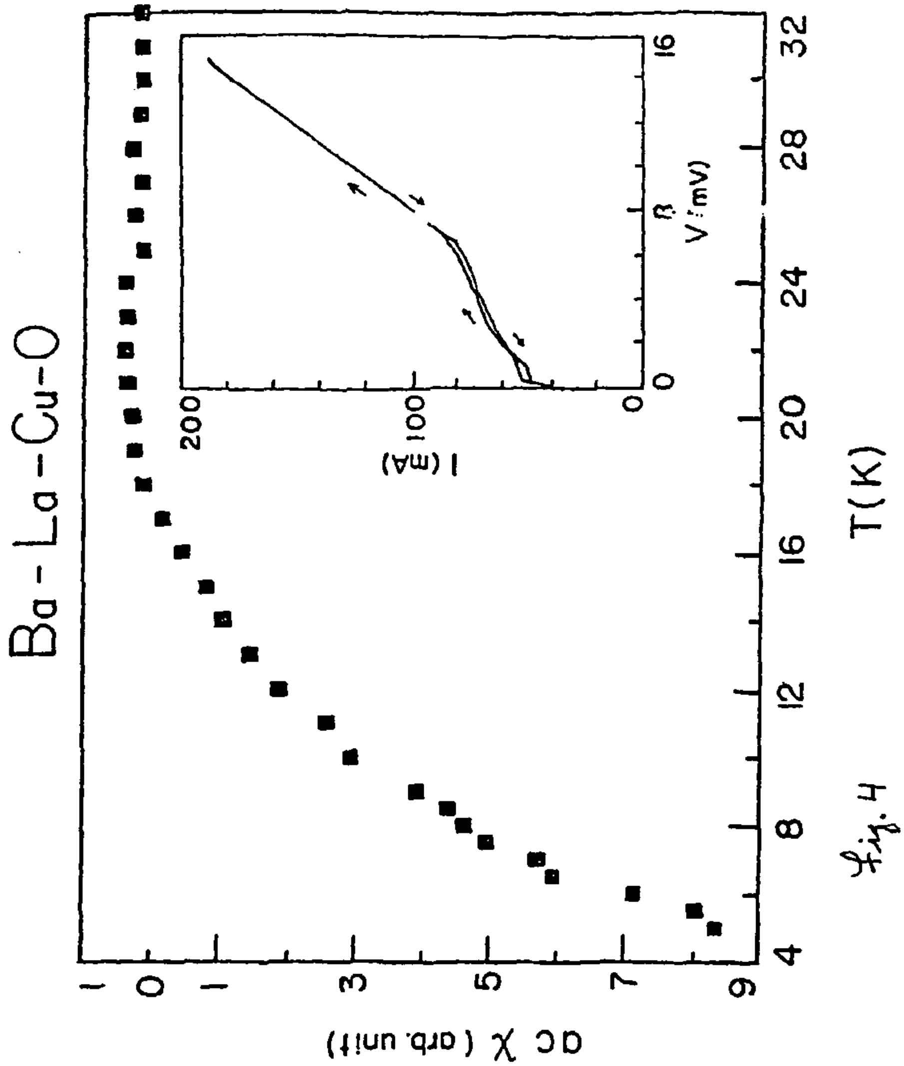
Ba - La - Cu - O
ac χ (arb. unit)
-1
0
1
3
5
7
9
T(K)
4
8
12
16
20
24
28
32
I (mA)
0
100
200
V (mV)
0
8
16

Fig. 4

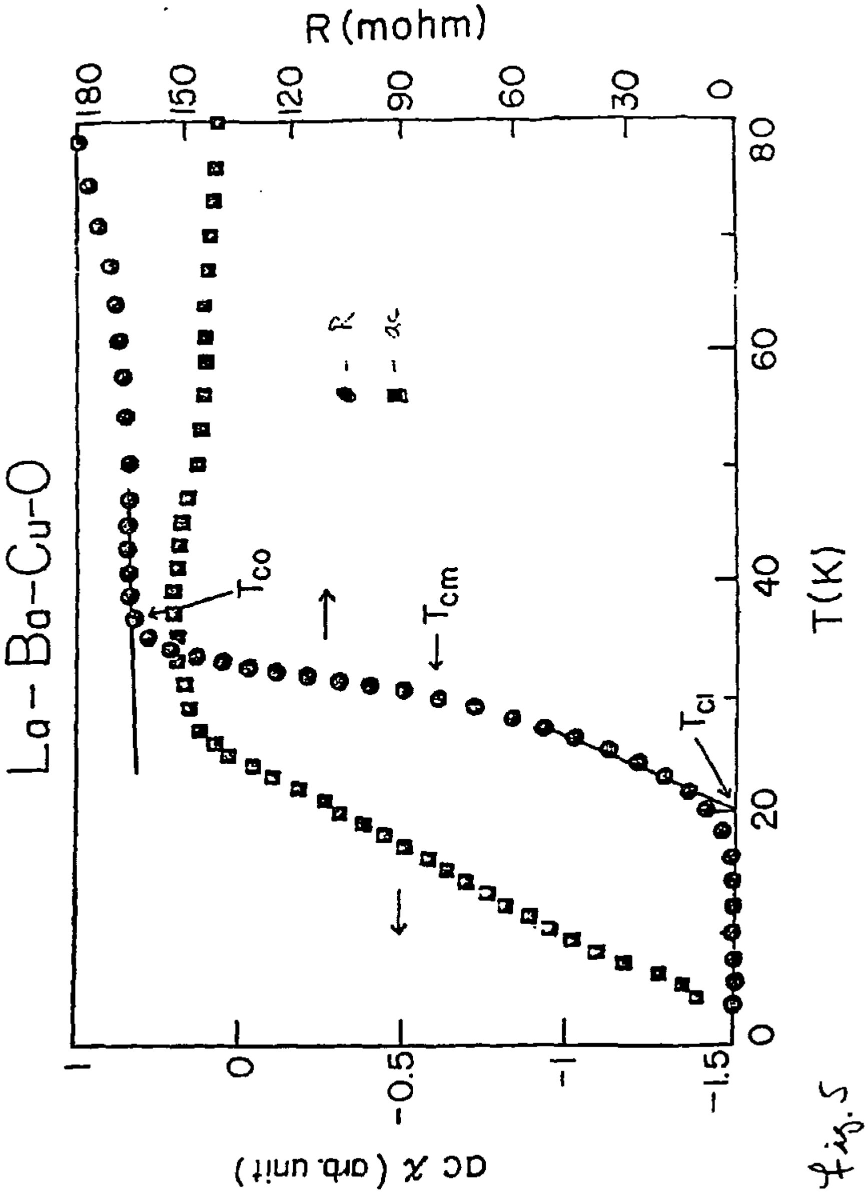
La-Ba-Cu-O
R (mohm)
180
150
120
90
60
30
0
T(K)
0
20
40
60
80
ac χ (arb. unit)
1
0
-0.5
-1
-1.5
T_{co}
T_{cm}
T_{ci}
● - R
■ - ac

fig. 5

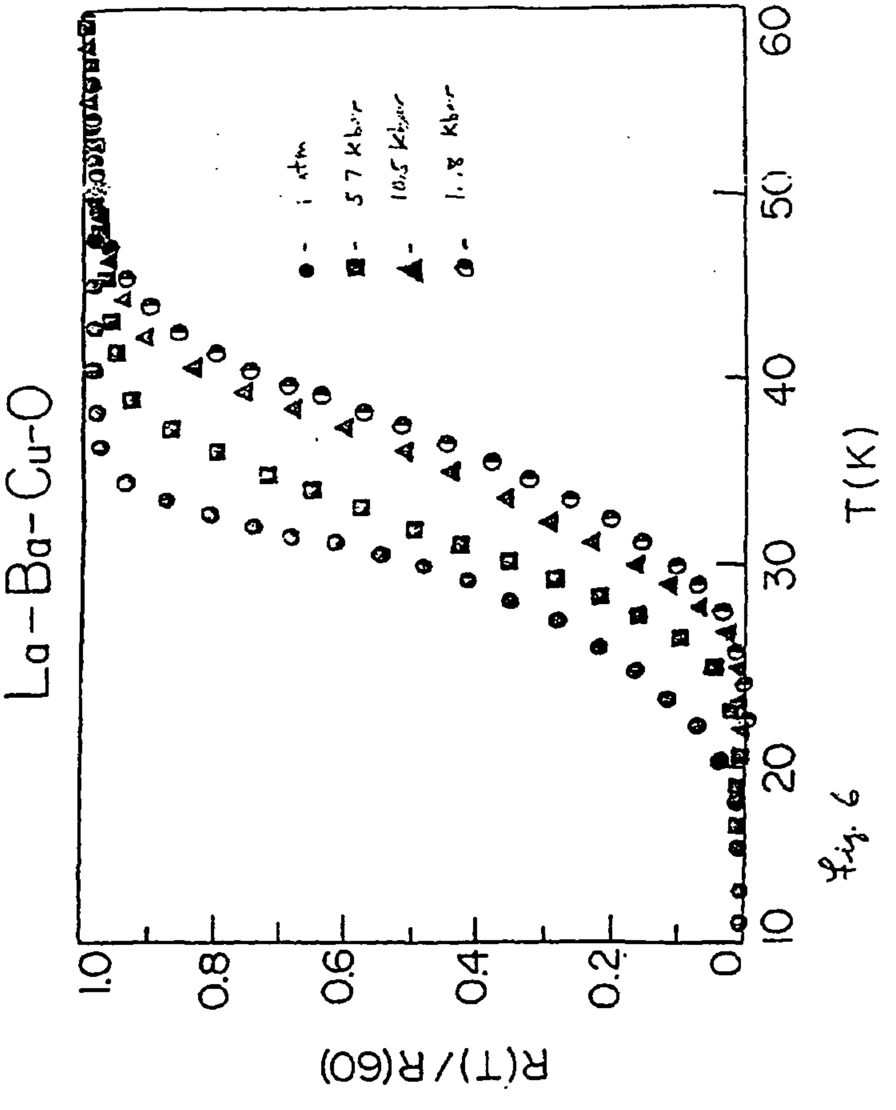
La-Ba-Cu-O
R(T)/R(60)
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
T(K)
● - 1 atm
■ - 5.7 kbar
▲ - 10.5 kbar
ϴ - 1.8 kbar

Fig. 6

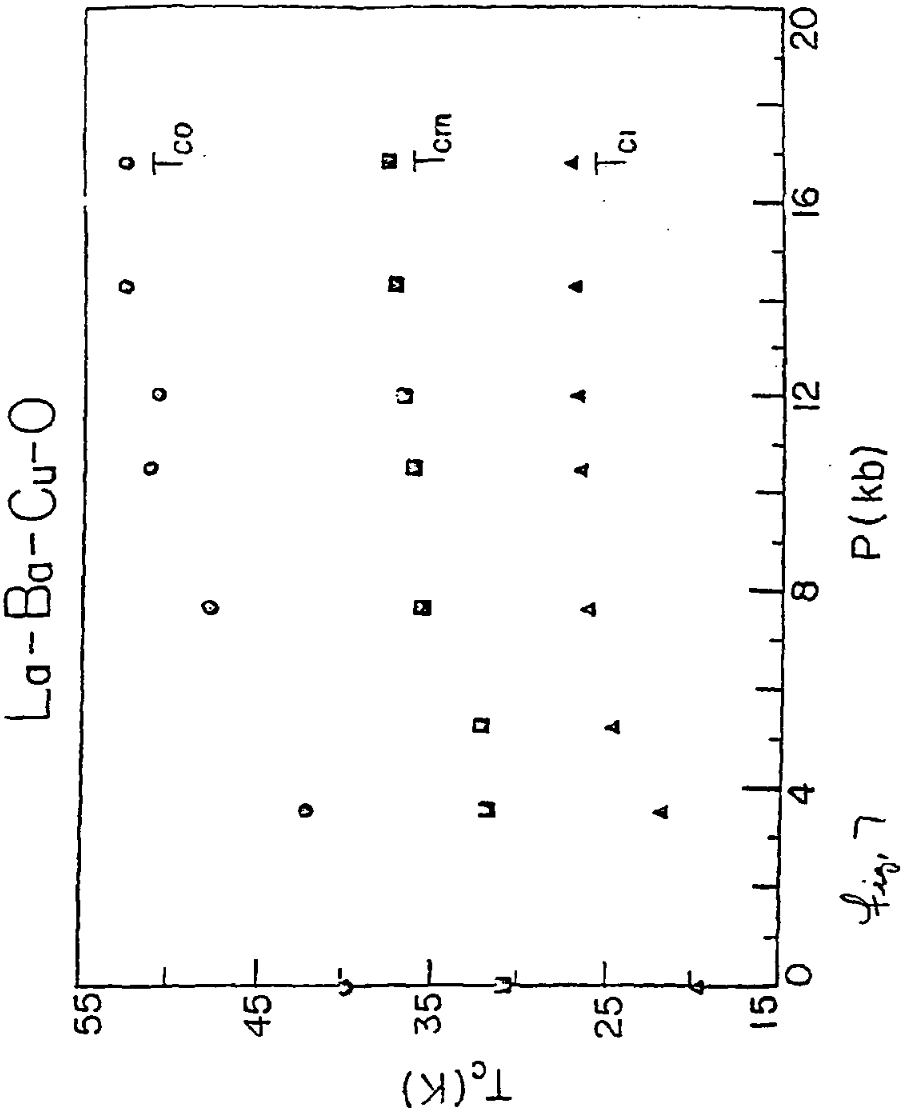

Fig. 7

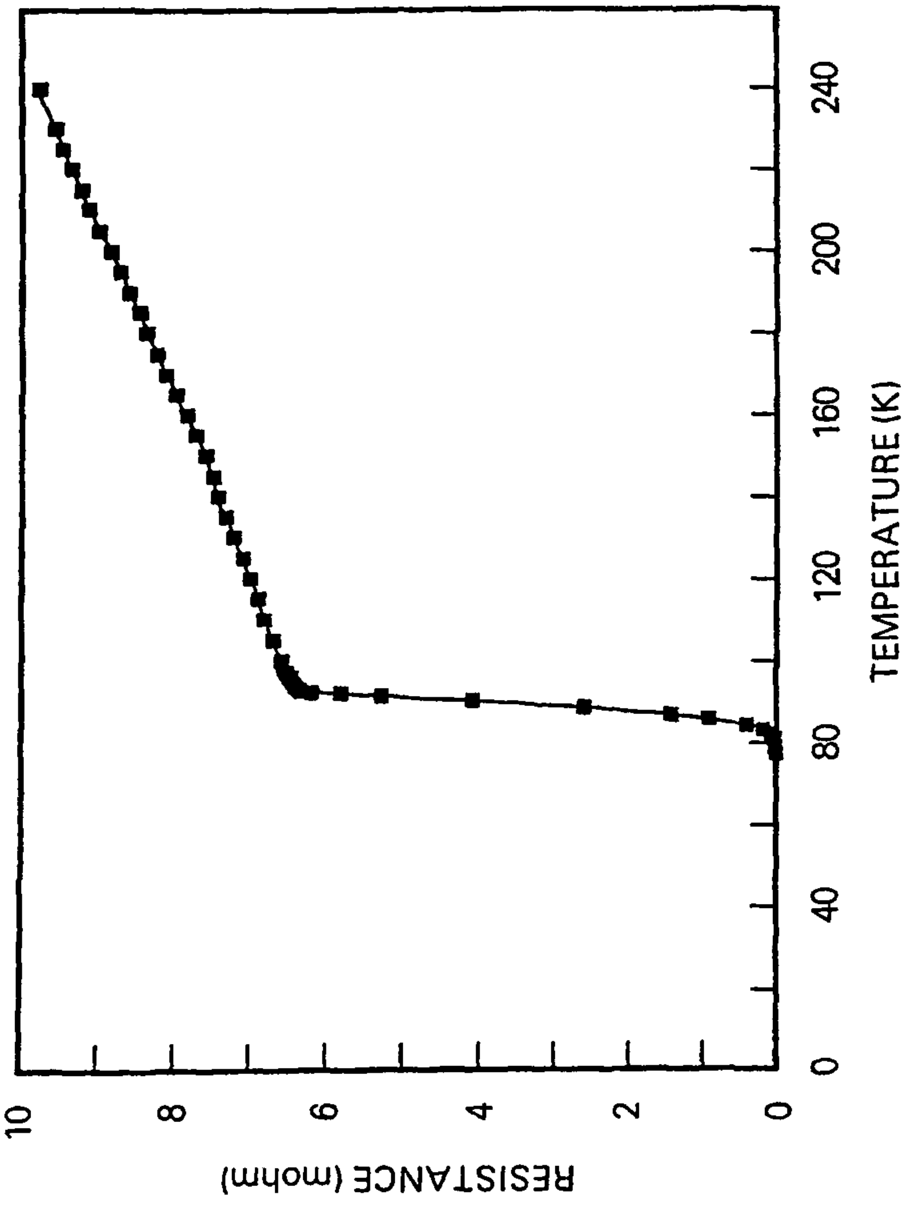
RESISTANCE (mohm)
10
8
6
4
2
0
TEMPERATURE (K)
0
40
80
120
160
200
240

FIG. 8

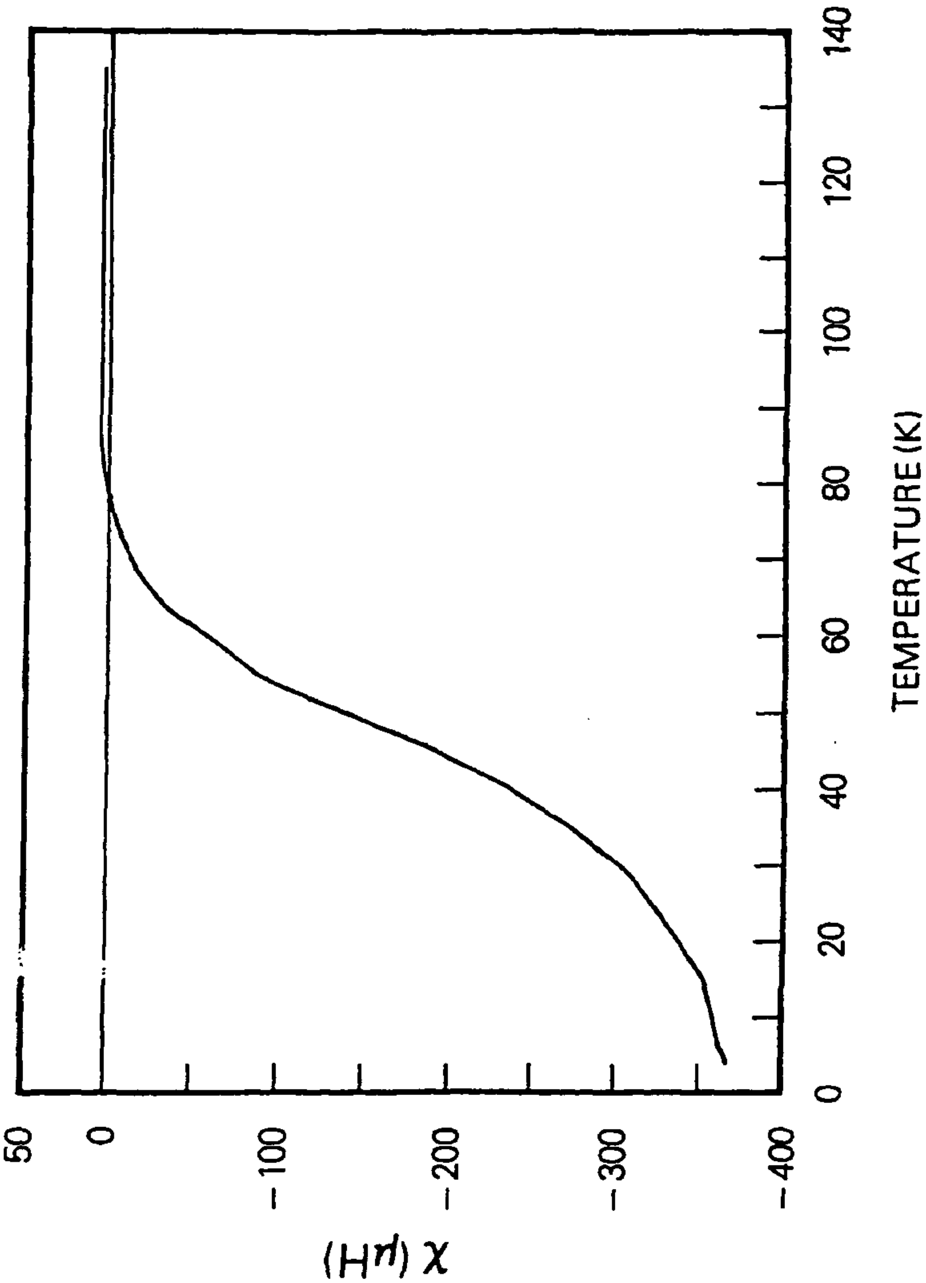

Fig. 9

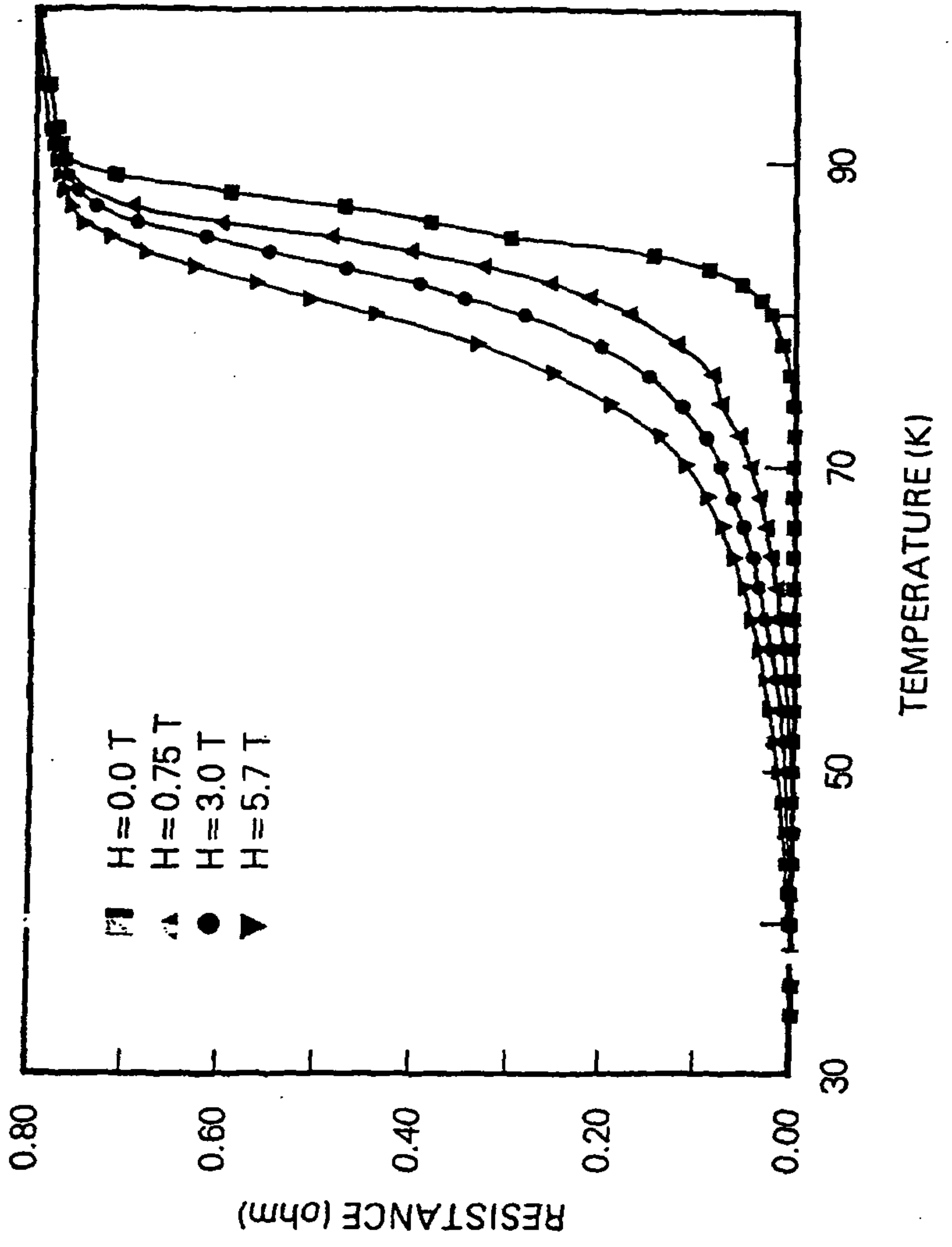
■ H = 0.0 T
▲ H = 0.75 T
● H = 3.0 T
▼ H = 5.7 T
0.80
0.60
0.40
0.20
0.00
RESISTANCE (ohm)
30
50
70
90
TEMPERATURE (K)

Fig. 10

HIGH TRANSITION TEMPERATURE SUPERCONDUCTING COMPOSITIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a file-wrapper continuation of Ser. No. 07/102,205 filed Feb. 6, 1987 now abandoned, which is a continuation-in-part of Ser. No. 07/006,991, filed Jan. 26, 1987, entitled "Superconducting Compositions and Method for Enhancing Their Transition Temperatures By Pressure," now abandoned, which in turn is a continuation-in-part of Ser. No. 07/002,089, filed Jan. 12, 1987, entitled "Superconducting Composition and Method," now abandoned.

STATEMENTS REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with Government support under Grant No. DMR-8204173 awarded by the National Science Foundation and Grant No. NAGW-977 awarded by the National Aeronautics and Space Administration, and the Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

This invention relates to superconducting compositions, i.e., compositions offering no electrical resistance at a temperature below a critical temperature; to processes for their production and to methods for their use; and to methods for increasing the superconducting transition temperature of superconducting compositions.

Superconductivity was discovered in 1911. Historically, the first observed and most distinctive property of a superconductive material is the near total loss of electrical resistance by the material when at or below a critical temperature that is a characteristic of the material. This critical temperature is referred to as the superconducting transition temperature of the material, T_C. The criteria by which a selection of the critical temperature value is determined from a transition in the change in resistance observed is often not obvious from the literature. Many past authors have chosen the mid-point of such curve as the probable critical temperature of their idealized material, while many others have chosen to report as the critical temperature the highest temperature at which a deviation from the normal state resistivity property is observed. Hence, the literature may report differing temperatures within a narrow range as the critical or superconducting transition temperature for the same material, depending on the particular author's method for selecting T_C from the observed data.

The history of research into the superconductivity of specific materials began with the discovery in 1911 that mercury superconducts at a transition temperature of about 4° K. In the late 1920's, NbC was found to superconduct at a higher temperature, namely up to about 10.5° K. Thereafter other compounds and alloys of Nb were examined and various Nb compositions were discovered with progressively, but only slightly higher, superconducting transition temperatures. In the early 1940's NbN was observed with a transition temperature of about 14° K; Nb_3Sn was reported in the early 1950's; Nb_3 (Al—Ge) was reported in the late 1960's; and Nb_3Ge was reported in the early 1970's to have a transition temperature of about 17° K. Careful optimization of Nb_3Ge thin films led to an increase of the critical temperature for such material up to 23.3° K. While this work led to progress the maximum temperature at which superconductivity could occur was raised to only 23.3° K since research started three-quarters of a century ago. The existing theories explained the superconductivity of these materials, but did not predict superconductivity of higher than 40° K. Significant progress in finding materials which superconduct at higher transition temperatures than that of Nb_3Ge thin films was not made until 1986.

In 1986, specially prepared coprecipitated and heat treated mixtures of lanthanum, barium, copper and oxygen, that have an abrupt decrease in resistivity at an onset temperature as high as 30° K which exhibited a phenomena "reminiscent of the onset of percolative superconductivity" were reported by J. G. Bednorz and R. A. Muller, "Possible High T_C Superconductivity in The Ba—La—Cu—O System," *Z. Phys. B.—Condensed Matter*, 64, pp. 189-193 (1986). Under atmospheric pressure conditions, the abrupt change in resistivity for these compositions—i.e., that temperature at which a portion of the material begins to show properties reminiscent of percolative superconductivity—were reported to approach the 30° K range. The authors refer to this phenomenon as a "possible" case of superconductivity. The compositions reported by Bednorz et al to have such properties at a temperature as high as 30° K comprise $La_{5-x}Ba_xCu_5O_{3-y}$ where x=0.75 to 1 and Y>0. The Bednorz et al compositions are prepared by coprecipitation of Ba—, La— and Cu— nitrate solutions by addition to an oxalic acid solution followed by decomposition and solid-state reaction of the coprecipitate at 900° C. for 5 hours. Thereafter, the composition is pressed to pellets at 4 kilobars and the pellets are sintered at a temperature below 950° C. in a reduced oxygen atmosphere of 0.2×10^{-4} bar. Bednorz et al reported that this method of sample preparation is of crucial importance to obtaining the observed phenomena.

Superconductivity is a potentially very useful phenomenon. It reduces heat losses to zero in electrical power transmission, magnets, levitated monorail trains and many other modern devices. However, superconductivity of a material occurs only at very low temperatures. Originally, and until the inventions outlined herein, liquid helium was the required coolant to provide the conditions necessary for superconductivity to occur.

It would be desirable to produce a superconducting composition that has a transition temperature which exceeds those of superconducting compositions previously described. It would be particularly desirable to develop a superconducting composition that has the potential of having a T_C of 77° K or higher. Such a composition would enable the use of liquid nitrogen instead of liquid helium to cool the superconducting equipment and would dramatically decrease the cost of operating and insulating superconducting equipment and material.

SUMMARY OF THE INVENTION

Described is a superconducting composition comprising an oxide complex of the formula $[L_{1-x}M_x]_aA_bO_y$ wherein, L is lanthanum, lutetium, yttrium or scandium; A is copper, bismuth, titanium, tungsten, zirconium, tantalum, niobium, or vanadium; M is barium, strontium, calcium magnesium or mercury; and "a" is 1 to 2; "b" is 1; "x" is about 0.01 to about 0.5 and preferably 0.075 to 0.5; and "y" is about 2 to about 4. The oxide complexes of the invention are prepared by a solid-state reaction procedure which produce oxide complexes having enhanced superconducting transition temperatures compared to an oxide complex of like empirical composition prepared by a coprecipitation—high temperature decomposition procedure.

When M is barium, the transition temperatures of onset and complete superconductivity, T_{C0} and T_{C1} (as seen in FIG. 5), respectively, may be increased by subjecting the barium species of the oxide complex to pressure up to 18 kilobars. Likewise the non-barium species of the oxide complexes of the invention exhibit an enhancement to higher limits of their superconducting transition temperatures when subjected to high pressures.

The application and maintenance of high pressure on such oxide complexes is believed to enhance the transition temperature to higher limits by reducing the interatomic spacings between elements L, A, M and O compared to their respective spacings when the oxide complex is under atmospheric pressure only.

Alternatively, an alkaline earth metal having atomic radius smaller than barium may be used in whole or in part to fulfill the alkaline earth metal constituent requirement to provide an oxide complex having reduced interatomic spacings between elements, L, A, M, and O even when the oxide complex is under only atomospheric pressure, compared to a pure barium species, thus increasing T_{C0} and T_{C1} of such substituted or non-barium oxide complex species.

With a solid-state reaction prepared oxide complex of the invention a transition temperature as high as 100° K has been observed even under atmospheric pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the reduction in electrical resistance as temperature is decreased of a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 2 illustrates the enhancement towards higher temperatures of the onset transition temperature (T_{C0}) as applied pressure is increased upon a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 3 illustrates the magnetic field effect on resistivity of a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 4 illustrates the magnetic susceptibility as a function of temperature of a La—Ba—Cu—O composition as prepared according to Example V.

FIG. 5 illustrates the resistivity and diamagnetic shift as a function of temperature of a La—Ba—Cu—O composition prepared according to Example III.

FIG. 6 illustrates the resistivity as a function of temperature under different applied pressures of 5.7 kilobars, 10.5 kilobars and 16.8 kilobars of a La—Ba—Cu—O composition as prepared according to Example III.

FIG. 7 illustrates the effect of applied pressure on onset temperatures (T_{C0}), midpoint temperature (T_{cm}) and temperature for complete superconductivty (T_{C1}) of a La—Ba—Cu—O composition prepared according to Example III.

FIG. 8 illustrates the reduction in electrical resistance as temperature is decreased of a Y—Ba—Cu—O composition as prepared according to Example XI.

FIG. 9 illustrates the temperature dependence of magnetic susceptibility of a Y—Ba—Cu—O composition as prepared according to Example XI.

FIG. 10 illustrates the magnetic field effect on the resistance of a Y—Ba—Cu—O composition as prepared according to Example XI.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Superconducting compositions of this invention comprise an oxide complex defined by the following formula:

$$[L_{1-x}M_x]_a A_b O_y$$

wherein "L" is an element selected from the group consisting of lanthanum, lutetium, yttrium and scandium, or a mixture of one or more of these elements; wherein "A" is an element selected from the group consisting of copper, bismuth, titanium, tungsten, zirconium, tantalum, niobium, vanadium or a mixture of one or more of these elements; wherein "M" is an element selected from the group consisting of barium, strontium, calcium, magnesium and mercury or a mixture of one or more of these elements; and wherein "x" is from about 0.01 to about 0.5, and preferably 0.075 to 0.5; "a" is 1 to 2, "b" is 1, and "y" is about 2 to about 4. The amount of oxygen present in the compositions of the present invention depends upon the valence requirements of the other elements and the defects resulting from the particular heat treatment used to make the composition. The molar oxygen content "y" is about 2 to 4 times "b," as used in the preceding equation. Lanthanum is the preferred "L" component, barium and strontium are the preferred "M" components, and copper is the preferred "A" component.

It has been observed that the transition temperature of such an oxide complex is increased by the application of pressure to the composition. It is believed that subjecting the oxide complex to high pressures decreases the interatomic distances or lattice spacing in such complexes and that this may, at least in part, account for the enhancement of transition temperatures that has been observed. Another way to obtain a decrease of the intertomic distances or lattice spacings is during the preparation of the oxide complex. Thus, for example, an alkaline earth metal having an atomic radius smaller than barium may be used in whole or in part to fulfill the alkaline earth metal requirement to produce an oxide complex having reduced interatomic distances or lattice spacing compared to an oxide complex with barium alone, with a consequent increase in the transition temperature of the non-barium oxide complex resulting compared to one produced with barium alone. The transition temperature is increased in such an oxide complex even as measured under atmospheric pressure.

The present invention also provides a solid-state reaction method for making such superconducting oxide complexes which comprises; thoroughly mixing selected amounts of solid powdered compounds containing L, M, A, and O, preferably by selecting appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO; heating the powdered mixture in an oxygen containing atmosphere, at an appropriate pressure, and at a temperature of between about 640° C. and 800° C. for a time sufficient to react the mixture in the solid state; heating the resulting mixture at a temperature between about 900° C. and 1100° C., preferably for at least twelve hours; homogenizing said reaction mixture; heating the homogenized reaction mixture at a temperature between about 900° C. and about 1100° C., preferably for at least six hours; compressing said composition with a pressure of at least one kilobar to produce pellets; sintering said pellets; and quenching said sintered pellets rapidly from the sintering temperature to room temperature in air or in an inert gas atmosphere such as Ar. Preferably mixing of the solid powder compounds is performed by an intensive mixer such as a ball mill.

An alternative method for making such oxide complex superconductive compositions includes the following steps: thoroughly mixing selected amounts of solid powdered compounds containing L, M, A, and O, preferably by selecting appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO; compressing said mixture into pellets; reacting said mixture at a temperature between about 900° C. and about 1100° C. for a time sufficient to complete the solid state reaction; and rapidly quenching said pellets to room temperature. Again, mixing is preferably accomplished by an intensive mixer such as a ball mill. Pelletization of the oxide mixture is carried out at an applied pressure of from about 100 to about 30,000 psi and preferably at an applied pressure of from about 100 to about 500 psi, most preferably at about 500 psi. Reaction of the pelletized mixture is preferably conducted in air for about 5 minutes to about 24 hours, and most preferably for about 5 to about 15 minutes. Following the completion of the reaction step the reacted pellet composition is preferably quenched to room temperature in air, most preferably on an aluminum plate as a heat sink.

Another method for preparing oxide complexes which exhibit significantly enhanced transition temperatures includes the following steps: thoroughly mixing selected amounts of solid powdered compounds containing L, M, A and O, preferably by selecting appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO; depositing the oxide mixture on a copper substrate which has been cleaned of its copper oxide surface film, preferably by acid cleaning in dilute hydrochloric acid solution; compressing the oxide mixture against the copper substrate at an applied pressure of from about 100 to about 1000 psi, preferably at about 100 to 200 psi, to form the oxide mixture into a film or layer on the copper substrate; heating the copper substrate and oxide mixture layered thereon to a temperature of from about 900 to about 1100° C. in air for from about 5 minutes to about 24 hours, and preferably for about 5 to about 15 minutes; and quenching the copper substrate and oxide mixture layered thereon to room temperature in air. Inspection of the oxide mixture layer which results from this method of preparation discloses that it comprises three phases, the first of which adjacent the copper substrate comprises a glassy insulating layer phase; the second phase is the superconducting layer phase; and the third phase which borders with the second superconducting phase is a powdery compound which is also an insulator layer phase.

Still another alternative method includes the immediately foregoing steps and the step of reducing interatomic distances, either by the application of pressure to the oxide complex or by the use of atomic elements which provides smaller lattice spacings. A preferred oxide complex which exhibits a significantly enhanced superconducting transition temperature is prepared by utilizing yttrium as the "L" component.

Oxide complexes of the formula $[L_{1-x}M_x]_aA_bO_y$ prepared by a solid-state reaction procedure as described exhibit superconducting properties at transition temperatures higher than heretofore reported. The barium species of the oxide complex, that is wherein "M" is only barium, as prepared by the described solid-state reaction procedure exhibits superconducting properties beginning at a higher onset temperature (T_{co}) than the temperature reported by Bednorz et al as that wherein, for an oxide complex of similar empirical composition but prepared by a coprecipitation method, a phenomenon "reminiscent of the onset of percolative superconductivity" was observed. Further, it has been surprisingly found that the superconductivity transition temperature of oxide complexes of the formula $[L_{1-x}M_x]_aA_bO_y$ prepared by the solid-state reaction procedure is further enhanced towards higher limits by the application to and maintenance of pressure on the oxide complex up to about 18 kilobars.

Based upon present belief, it is thought that the application of and maintenance of high pressure on such oxide complexes enhances their superconducting transition temperature by producing a reduction of the interatomic distance or lattice spacing between the metal atoms forming the complex. The application and maintenance of high pressure on such oxide complexes may also enhance the transition temperature by suppressing instabilities detrimental to a high temperature superconductivity and thus permitting the existence of superconducting phase species to occur within the body of the oxide complex at a higher temperature than that at which such phase could form at atmospheric pressure. Pressure has been found to enhance the T_C of La—Ba—Cu—O and La—Sr—Cu—O oxide complexes at a rate of greater than $10^{-3\circ}$ K-bar^{-1} and to raise the onset T_C to 57° K, reaching a zero-resistance state at 40° K. It is believed that pressure reduces the lattice parameter and enhances the Cu^{+3}/Cu^{+2} ratio in the compounds. The unusually large pressure effect on T_c suggest that the high temperature superconductivity in La—Ba—Cu—O and La—Sr—Cu—O complexes may be associated with interfacial effects arising from mixed phases; interfaces between the metal and insulator layers, or concentration fluctuations within the K_2NiF_4 phase; strong superconducting interactions due to the mixed valence states; or a yet unidentified phase. Although the unexpected enhancement of transition temperature that the application of pressure to such oxide complexes produces has been repeatedly observed, a mechanism which adequately explains the pressure effect has not yet been fully determined.

The transition temperature of such oxide complexes is enhanced by the application of pressure, and that this effect is at least in part due to a resulting reduction in interatomic spacing in the oxide complex is evidenced by an enhancement of transition temperature that may be produced without the application of extrinsic pressure by employing in the formation of the oxide complex an alkaline earth metal having smaller atomic radius than that of barium. A similar enhancement of transition temperature has been observed when yttrium is used as the "L" component rather than lanthanum.

Hence, when preparing an oxide complex of the invention, it is preferred to completely or partially substitute for the barium atoms, atomic radius of 2.22 angstroms, smaller alkaline earth metal atoms, i.e., strontium, atomic radius of 2.15 angstroms, calcium, atomic radius of 1.97 angstroms, or magnesium, atomic radius of 1.6 angstroms. Similarly, complete or partial substitution of the lanthanum atoms, atomic radius of 1.87 angstroms, with the smaller lutetium atoms, atomic radius of 1.75 angstroms, or yttrium, atomic radius 1.78 angstroms, will provide this same effect. The application of pressure to such oxide complexes that are prepared to have decreased interatomic spacings will further enhance the transition temperature of such compositions to higher limits.

Alternatively, the deposition of a lanthanum, barium, copper, oxide film on a substrate with smaller lattice parameters, such as a lanthanum, calcium, copper oxide substrate, will reduce the interatomic spacing of the superconducting composition, and thus will increase the T_c of the oxide complex composition. Further, cladding of a lanthanum, barium, copper oxide composition with metals having larger thermal expansion coefficients, such as copper, will apply and maintain the pressure required to reduce the interatomic distances between the elements in the oxide complex composition and hence will increase the T_c of the composition.

The oxide complexes of the present invention may be made, for example, following either of the following processes.

1. Appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3 and AO are thoroughly mixed. This mixing is preferably done mechanically, as in a jar mill or more preferably in an intensive mixer such as a ball mill, for at least 12 hours. The mixing produces finely ground particles. The mixture is then heated in an oxygen containing atmosphere, at an appropriate pressure, and at a temperature between about 640-800° C. The temperature of the mixture is conveniently increased to the

640-800° C. target temperature at a rate of 10° C. per minute. The mixture is kept at this target temperature for a time sufficient to allow the solid-state mixture to react. Preferably, the mixture is allowed to react for about an hour. After this reaction step, the temperature is raised to about 900 to about 1100° C., conveniently at a rate of about 30° C. per minute. The samples are kept at the 900 to 1100° C. temperature for a time sufficient to complete the solid state reaction of the materials, the completed solid state reacted product being that product having the components completely diffused through the composition. The samples are then cooled to room temperature.

The next step is to homogenize the sample, preferably by pulverizing the reacted mixture in a jar mill and more preferably in a ball mill for at least 1 hour. The pulverized mixture is then heated rapidly to between 900-1100° C. The mixture is maintained at this temperature preferably for at least 6 hours. After this step, the mixture is compressed under a pressure of at least one kilobar. This compresses the powdered mixture into pellets or some other coherent compacted form as desired. The pellets are then sintered into solid cylinders. This sintering process is preferably performed at a pressure between zero to two kilobars at a temperature of between about 900-1100° C. and for about four hours. Finally, the samples are quenched rapidly from this temperature of between 900-1100° C. to room temperature, in air, or an inert gas atmosphere. This final step, along with thorough mixing of this mixture, decreases the range of the superconducting transition of the composition. This superconducting transition range is the range of temperatures between the point when a portion of the material shows superconductive properties (onset transition temperature) and the temperature at which the composition shows complete superconductive properties.

Compositions made in this process may be compressed to pressures that exceed atmospheric pressure, preferably in the range of 1 to 20 kilobars. This increase in pressure typically increases the T_c of the composition.

2. A second process for producing superconducting compositions of the present invention comprises: thoroughly mixing, preferably for at least about 12 hours, appropriate amounts of L_2O_3 or $L(OH)_3$, MCO_3, and AO, by mechanical means, such as in a jar mill or more preferably in a ball mill, compressing the mixture into pellets; and reacting the pellets at about 900-1100° C. This reaction preferably takes place in an air atmosphere; after which the reacted pellets are rapidly quenched to room temperature.

This second method sometimes results in multiphase samples in a less controllable way.

The superconducting compositions of the present invention have the potential for being used in a wide variety of applications. For example, when used in a wire or conductor form, they may be used in electrical power transmission, energy storage, controlled fusion reaction, electricity generation, mass transportation and magnets. In a thin film form, they may be used in ultra-sensitive detectors and in ultra-fast computers. In addition, they may be used in a superconducting-magnetic-superconducting multi-layer form for use in ultra-sensitive ultra-fast electromagnetic micro devices.

The following examples are representative of the oxide complexes and methods of producing the oxide complexes of the invention. The examples for certain of the compositions also illustrate the enhancement of transition temperature that is produced by the application and maintenance of high pressure on the oxide complexes. Generally, the standard 4-probe technique was used to measure resistivity, and an inductance bridge was employed for ac magnetic susceptibility x-determination. The temperature was measured using the Au+0.07% Fe-chromel, and chromel-alumel thermocouples in the absence of a magnetic field, and a carbon-glass thermometer in the presence of a field. The latter was calibrated against the former without a field. Magnetic fields up to 6T were generated by a superconducting magnet.

EXAMPLE I

6.0 grams of La_2O_3, 0.61 grams of $SrCO_3$ and 1.63 grams of CuO were mixed in a jar mill for about 12 hours. The mixture was then heated at a rate of about 10° C. per minute in air at 1 atmosphere pressure, until it reached a temperature of about 720° C. The mixture was then allowed to react for about an hour at about 720° C. After this reaction step, the temperature was raised to a temperature of about 1000° C. at a rate of about 30° C. per minute. Once at a 1000° C. temperature, the samples were maintained at this temperature for about twenty-one hours. This allowed the completion of a solid state reaction. After cooling to room temperature, the reacted mixture was pulverized in a jar mill for about 6 hours until the sample was homogenized. The pulverized mixture was then heated rapidly to a temperature of about 1000° C., and kept at that temperature for about seven hours. After this period, the mixture was cooled to room temperature and then compressed under a pressure of six kilobars. This compression converted the mixed powder into pellets. The pellets were then sintered into solid cylinders by heating them at a temperature of about 1000° C. for a period of about four hours at a pressure of almost zero kilobars. Finally, the sample was rapidly quenched from this temperature to room temperature in air.

The resulting lanthanum-strontium-copper-oxide composition had an empirical formula of $La_{1.8}Sr_{0.2}Cu_1O_y$. This corresponds to an oxide complex of the general formula $[La_{1-x}Sr_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is 2 to 4. The oxide complex composition had an onset superconductivity transition temperature (T_{co}) of 45° K, with a narrow transition width to complete superconductivity of about 10° K at ambient pressure.

EXAMPLE II

6.0 grams of La_2O_3, 0.61 grams of $SrCO_3$ and 1.63 grams of CuO were mixed mechanically in a jar mill for approximately 24 hours. The resulting mixture was then compressed into pellets by applying a pressure of about 2 kilobars. The pellets were heated to about 1000° C., and allowed to react for about twenty-four hours in air. The reacted pellets were then quenched rapidly to room temperature.

The La—Sr—Cu—O composition produced from this process had a formula of $La_{1.8}Sr_{0.2}Cu_1O_y$. This corresponds to an oxide complex of the general formula $[La_{1-x}Sr_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is 2 to 4. This composition showed superconductive properties at a temperature of about 42° K, with a narrow transition width of about 6° K at ambient pressure.

EXAMPLE III

6.0 grams of La_2O_3, 0.81 grams of $BaCO_3$ and 1.63 grams of CuO were mixed in a mortar-pestle apparatus for about 3 hours. The mixture was then heated at a rate of about 10° C. per minute in oxygen at a pressure of about 2000 microns Hg, until it reached a temperature of 720° C. The mixture was then allowed to react for about an hour at about 720° C. After this reaction, the temperature was raised to a temperature of about

950° C., this raise in temperature was made at a rate of about 30° C. per minute. Once at this temperature, the sample was maintained at this temperature for about twenty-one hours. After this period, the sample was cooled to room temperature and then the reacted mixture was pulverized until the sample was homogenized. The pulverized mixture was then heated rapidly to a temperature of about 950° C., and kept at that temperature for about seven hours. After this period, the sample was again cooled to room temperature and the mixture was compressed under a pressure of six kilobars. This compression converted the mixed powder into pellets. The pellets were then sintered into solid cylinders by heating them at a temperature of about 950° C. for a period of about four hours at ambient atmospheric pressure. Finally, the sample was rapidly quenched from this temperature to room temperature in air.

The resulting lanthanum-barium-copper-oxide composition had the formula $La_{1.8}Ba_{0.2}Cu_1O_y$. The oxide complex so formed was of the formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is 2 to 4. This composition was found to be superconducting at 39° K at ambient pressure. This composition was then placed inside a pressure cell and the composition was compressed to a pressure of 14 kilobars at room temperature. After this compression step, the temperature was gradually reduced until the composition showed superconducting properties. This composition showed superconductivity properties at a temperature of 52.5° K at the applied pressure of 10 kilobars.

A sample prepared as described above exhibits only X-ray powder diffraction patterns characteristic of the single K_2NiF_4 phase with a resolution ~5%. The resistivity of this sample at ambient pressure decreases monotonically with decreasing temperature but at a reduced rate below 60° K. A large drop in resistivity sets in at ~39° K, indicative of the onset of a superconducting transition, and resistivity becomes zero at T_{c1} ~20° K as shown in FIG. 5. Preliminary ac χ-measurement showed diamagnetic shift starting at ~32° K and *reaching a maximum of 10% of the signal of a superconducting* Pb sample of a similar size. Under applied pressure, the superconducting transition is broadened but with an overall shift toward higher temperatures as shown in FIG. 6. T_{C1} has been enhanced from 39° to 52.5° K and the T_{c1} from 20° to 25° K by application of a pressure of 12 kilobars as displayed in FIG. 7. The enhancement rate of T_{co} and T_{c1} is significantly reduced above 12 kilobars. The pressure effect on the midpoint temperature T_{cm} where it has dropped by 50% of that at T_{co} is also given in FIG. 7.

T_{cm} increases from 31° to 36° K under pressure. The decrease in the rate of T_{co}, enhancement at 12 kilobars is accompanied by an overall resistivity increase at about T_{co}, indicating the possible commencement of physical or chemical *instabilities. Serious deterioration of samples* is also detected upon removal of pressure, as evidenced by the dramatic increase in resistivity and a semiconducting behavior at low temperatures preceded by a drop in resistivity starting at T_{co}. The exact causes and remedy for the pressure induced sample deterioration above ~12 kilobars are currently under study.

One method of preparing the composition of this example in a wire form, while simultaneously reducing the interatomic distances between the atoms in the material, may include performing these reaction steps while La_2O_3 or $La(OH)_3$, $BaCO_3$ and CuO have been placed in a copper sleeve, or placing the reaction product of this mixture directly in the sleeve followed by drawing or extrusion. Because of the *relative thermal expansion coefficients of the copper compared* to the superconducting composition, the resulting lanthanum-barium-copper-oxide would be compressed by the walls of the copper sleeve. This compression will cause the T_C of the material within the copper sleeve (the copper sleeve itself is not part of the superconductive material) to increase.

EXAMPLE IV

2.0 grams of La_2O_3, 0.2 grams of $BaCO_3$ and 0.53 grams of CuO were mixed mechanically in a mortar-pestle apparatus for approximately 3 hours. The resulting mixture was then compressed into pellets by applying a pressure of about 2 kilobars. The pellets were heated to about 1000° C., and allowed to react for about twenty-four hours in air. The reacted pellets were then quenched rapidly to room temperature.

The La—Ba—Cu—O composition produced from this process corresponds to the formula $[L_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.075, "a" is 2, "b" is 1 and "y" is 2 to 4. The oxide complex of this example showed superconductive properties at a temperature of 36° K at atmospheric pressure.

EXAMPLE V

4.9 grams of La_2O_3, 1.1 grams of $BaCO_3$ and 2.8 grams of CuO were mixed in a mortar-pestle for 3 hours. The mixture was then heated in oxygen at a pressure of 15 microns Hg, until it reached a temperature of about 720° C. The temperature was increased at a rate of about 1° C. per minute. The mixture was then allowed to react for about an hour at about 720° C. After this reaction, the temperature was raised to a temperature of about 925° C., this raise in temperature was made at a rate of about 30° C. per minute. Once at this temperature, the samples were maintained at this temperature for about twenty-one hours. After this period, the mixture was cooled to room temperature and then the reacted mixture was pulverized until the sample was homogenized. The pulverized mixture was then heated rapidly to a temperature of about 925° C., and kept at that temperature for about seven hours. After this period, the mixture was compressed with a pressure of six kilobars. This compression converted the mixed powder into pellets. The pellets were then sintered into solid cylinders by heating them at a temperature of about 925° C. for a period of about four hours at ambient pressure. Finally, the sample was rapidly quenched from this temperature to room temperature in air. The oxide complex so formed corresponds to the general formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.15, "a" is 1, "b" is 1 and "y" is 2 to 4.

The resulting lanthanum-barium-copper-oxide composition, superconducting at 32° K at ambient pressure, was then placed under a pressure of 9 kilobars using a Be—Cu high pressure clamp using a fluid pressure medium. Pressure was measured using a superconducting Pb—manometer situated next to the sample at room temperature. As this compressed composition was cooled, it began showing superconductivity properties at a temperature of 40.2° K.

Powder X-ray diffraction patterns at room temperature showed that the sample was multiphased, consisting predominantly of K_2NiF_4 (~90%) and unidentified phases (<10%). Under applied pressures, resistivity at 300° K is suppressed and the drop in resistivity is broadened slightly, but with an overall shift toward higher temperature as shown in FIG. 1. T_{co} increases rapidly with pressures as shown in FIG. 2. At 13 kilobars, T_{co} is ~40.2° K. Under pressure, T_{co} increases from 32° to 40.2° K at 13 kilobars at a rate ~0.9× 10^{-3}° K bar^{-1}. Above 13 kilobars, the sample was damaged *due to a shear strain introduced accidentally* by applying pressure below ~20° C., as evidenced by the appearance of a rapid resistivity increase following the resistivity drop at T_{co} on cooling and the irreversibility of resistivity after the pressure was reduced.

FIG. 3 displays the magnetic field effect on resistivity as a function of temperature. It is clear that the rapid resistivity drop is suppressed and the zero resistivity state at 4° K can be destroyed by magnetic fields. Below 18° K, a diamagnetic shift is clearly evident and reaches a maximum of 2% of the signal of a superconducting Pb sample of the same size as shown in FIG. 4. The insert of FIG. 4 shows the current-voltage characteristics for the sample at 4.2° K. The zero resistivity state is removed as current exceeds a critical value which increases with decreasing temperature. All these strongly demonstrate that the resistivity drop is associated with a superconducting transition.

EXAMPLE VI

6.0 grams of La_2O_3, 0.61 grams of $SrCO_3$ and 1.63 grams CuO were mixed mechanically in a mortar-pestle for approximately 3 hours. The resulting mixture was then compressed into pellets by applying a pressure of about 3 kilobars. The pellets were heated to about 1000° C., and allowed to react for about twenty-four hours in air. The reacted pellets were then quenched rapidly to room temperature.

The La—Sr—Cu—O composition produced from this process corresponds to the general formula $[La_{1-x}Sr_x]_aCu_bO_y$ where "x" is 0.1, "a" is 2, "b" is 1, and "y" is 2 to 4. The oxide complex was placed under a pressure of 16 kilobars, at room temperature. Upon cooling this oxide complex composition showed superconducting properties at a temperature of 42° K at atmospheric pressure. The oxide complex composition under a pressure of 16 kilobars showed superconducting properties at 54° K.

EXAMPLE VII

The magnetic layer in a superconducting-magnetic-superconducting multi-layer device could consist of a lanthanum-barium-copper-oxide base composition. Such a composition may be prepared as follows.

3.0 grams La_2O_3, 3.6 grams $BaCO_3$ and 2.9 grams CuO were mixed and heated in a vacuum about 10^{-4} microns Hg at a temperature of about 1000° C. for about twenty-four hours. The resulting product formed a magnetic compound with a magnetic ordering temperature below 40° K.

The superconducting-magnetic-superconducting multi-layer structures may therefore be formed by subjecting the overlayer of La—Ba—Cu—O, which is separated from the superconducting underlayer by an ultra-thin protective covering of, for example SiO_2, to a vacuum of 10^{-4} microns Hg at a temperature of between about 900° C. and 1100° C.

Thin film samples of the composition of the present invention may be synthesized by alternative current or radio frequency sputtering of a sintered La—Ba—Cu—O target in an argon atmosphere having about 10% oxygen and a pressure of between 10^{-2} and 2 microns Hg. Heat treatment of such film samples at 15-2000 microns Hg pressure in an oxygen atmosphere should make the superconducting properties of the film samples similar to those for the sintered samples.

EXAMPLE VIII

A La—Ba—Cu—O composition was prepared in accordance with the procedure described in Example II except that La_2O_3, $BaCO_3$ and CuO were used in the amounts appropriate to provide an oxide complex of the formula $[La_{1-x}Ba_x]_aCu_bO_y$ wherein "x" is 0.1, "a" is 2, "b" is 1 and "y" is between 3 and 4, and an intensive mixer ball mill was used rather than a jar mill. The oxide complex so produced showed superconductive properties at a temperature of 60° K at an applied pressure of 12 kilobars.

EXAMPLE IX

A La—A(trace)-Cu—O composition was prepared in accordance with the procedure described in Example II except that La_2O_3, ACO_3 and CuO were used in the amounts appropriate to provide an oxide complex of the formula $[La_{1-x}Ba_x]Cu_bO_y$ wherein "x" is about 0.01, "a" is 2, "b" is 1 and "y" is between 3 and 4, and an intensive mixer ball mill was used for mixing rather than a jar mill. "A" was either barium or strontium. The oxide complex so produced showed superconductive properties at an onset temperature of 100° K at 1 atmosphere.

EXAMPLE X

A La—Ba—Cu—O composition was prepared in accordance with the procedure of Example II except that La_2O_3, $BaCO_3$ and CuO were used in the amounts appropriate to provide an oxide complex of the formula $[La_{1-x}Ba_x]_aCu_b,O_y$ wherein "x" is about 0.4, "a" is 1, "b" is 1 and "y" is between 2 and 3, and the heat treatment was done at 10^{-4} microns Hg in air, rather than at atmospheric pressure. The oxide complex so produced showed superconductive properties at an onset temperature of 100° K.

EXAMPLE XI

An yttrium oxide complex was prepared with a nominal composition represented by $(Y_{1-x}Ba_x)_aCu_b,O_y$ wherein "x" is 0.4, "a" is 2, "b" is 1 and Y is less than or equal to 4. The yttrium oxide complex was prepared by intensively mixing appropriate amounts of Y_2O_3, $BaCo_3$ and CuO. The oxide mixture was then compressed to pellets at an applied pressure of 100 to 500 psi, the resulting pellets were then heated in air at a temperature between 900 to 1100° C. for about 15 minutes then rapidly quenched to room temperature in air.

Bar samples of dimensions 1 mm×0.5 mm×4 mm were cut from the sintered cylinders. A four-lead technique was employed for the resistance (R) measurements and an ac inductance bridge for the magnetic susceptibility (X) determinations.

The temperature dependence of resistance for this Y—Ba—Cu—O oxide complex was determined in a simple liquid nitrogen dewar with results as shown in FIG. 8. Resistance (R) initially dropped linearly with temperature (T). A deviation of resistance from the linear temperature dependence was evidenced at 93° K. A zero resistivity state was achieved at 80° K. (However, when the pellets were quenched on an aluminum plate as a heat sink to room temperature in air, the zero resistance state was achieved at 90° K.) The variation of magnetic susceptibility (χ) with temperature was measured with the results as shown in FIG. 9. A diamagnetic shift was observed to start at 91° K and the size of the shift increased rapidly with further cooling. At 4.2° K, the diamagnetic signal corresponded to 24% of the superconducting signal of a lead sample with similar dimensions. In a magnetic field, the drop in resistivity shifted toward lower temperature as shown in FIG. 10. At the maximum field applied, the zero resistivity state remained at temperature as high as 40° K. Preliminary X-ray powder diffraction patterns showed the existence of multiple phases apparently uncharacteristic of the K_2NiF_4-structure in the samples.

The above results demonstrate unambiguously that superconductivity occurs in the Y—Ba—Cu—O oxide complex with a transition between 80 and 93° K (and 90-93° K when quenched on the aluminum plate). The upper critical field $H_{c2}(T)$ was determined resistively. If the positive curvature at very low fields is neglected, a value of dH_{c2}/dT near T_c is observed to be the 3T/K or 1.3T/K, depending on if $H_{c2}(T_c)$ is taken at the 10% drop of the normal state resistivity, or the 50% drop. In the weak-coupling limit, $H_{c2}(0)$ was estimated as between 80 and 180T in the Y—Ba—Cu—O oxide complex. The paramagnetic limiting field to 0° K for a sample with a T_c~90K is 165T.

As is readily apparent from the above description, additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific examples shown and described. Accordingly, departures may be made from the details shown in the examples without departing from the spirit or scope of the disclosed general inventive concept.

I claim:

1. A composition of matter comprising a Y—Ba—Cu—O complex of nominal formula:

$(Y_{1-x}Ba_x)_aCu_bO_y$, wherein "x" is about 0.01 to 0.5, "a" is about 1 to 2, "b" is 1, and "y" is about 2 to about 4, containing a superconductive crystalline phase consisting essentially of Y, Ba, Cu and O which has zero electrical resistance at 77° K or above, said superconductive crystalline phase having a crystal structure uncharacteristic of that of a K_2NiF_4 crystal structure, and said superconductive crystalline phase being present in said composition of matter in a quantity sufficient to provide the composition with a diamagnetic signal at 4.2° K corresponding to at least 24% of the superconducting signal of a lead sample with similar dimensions.

2. A composition of matter comprising a Y—Ba—Cu—O complex of nominal formula:

$(Y_{1-x}Ba_x)_aCu_bO_y$, wherein "x" is 0.4, "a" is 2, "b" is 1, and "y" is about 2 to about 4, containing a superconductive crystalline phase consisting essentially of Y, Ba, Cu and O which has zero electrical resistance at 77° K or above, said superconductive crystalline phase having a crystal structure uncharacteristic of that of a K_2NiF_4 crystal structure, and said superconductive crystalline phase being present in said composition of matter in a quantity sufficient to provide the composition with a diamagnetic signal at 4.2° K corresponding to about 24% of the superconducting signal of a lead sample with similar dimensions.

3. A method for conducting an electrical current without electrical resistive losses, comprising the steps of:

utilizing as a conductor a composition of matter comprising a Y—Ba—Cu—O complex of nominal formula $(Y_{1-x}Ba_x)_aCu_bO_y$, wherein "x" is about 0.01 to 0.5, "a" is about 1 to 2, "b" is 1, and "y" is about 2 to about 4, containing a superconductive crystalline phase consisting essentially of Y, Ba, Cu and O which has zero electrical resistance at 77° K or above, said superconductive crystalline phase having a crystal structure uncharacteristic of that of a K_2NiF_4 crystal structure, and said superconductive crystalline phase being present in said composition of matter in a quantity sufficient to provide the composition with a diamagnetic signal at 4.2° K corresponding to at least 24% of the superconducting signal of a lead sample with similar dimensions;

cooling said composition of matter to a temperature at or below that at which said crystalline phase becomes superconductive; and

initiating a flow of electrical current within said composition of matter while maintaining said composition of matter at or below the temperature at which said crystalline phase becomes superconductive.

4. A method for conducting an electrical current without electrical resistive losses, comprising the steps of:

utilizing as a conductor a composition of matter comprising a Y—Ba—Cu—O complex of nominal formula $(Y_{1-x}Ba_x)_3Cu_bO_y$, wherein "x" is 0.4, "a" is 2, "b" is 1, and "y" is about 2 to about 4, containing a superconductive crystalline phase consisting essentially of Y, Ba, Cu and O which has zero electrical resistance at 77° K or above, said superconductive crystalline phase having a crystal structure uncharacteristic of that of a K_2NiF_4 crystal structure, and said superconductive crystalline phase being present in said composition of matter in a quantity sufficient to provide the composition with a diamagnetic signal at 4.2° K corresponding to about 24% of the superconducting signal of a lead sample with similar dimensions;

cooling said composition of matter to a temperature at or below that at which said crystalline phase becomes superconductive; and

initiating a flow of electrical current within said composition of matter while maintaining said composition of matter at or below the temperature at which said crystalline phase becomes superconductive.

5. A superconducting composition exhibiting zero electrical resistance at a temperature of 40° K or above of having the nominal formula

$$[Y_{1-x}Ba_x]_aCu_bO_y$$

wherein x is 0.4, a is 2, b is 1, and y is 2 to 4.

6. The superconducting composition of claim 5 wherein the composition exhibits zero electrical resistance at a temperature of 77° K or above.

7. The superconducting composition of claim 5 wherein said composition has a crystal structure uncharacteristic of that of a K_2NiF_4 crystal structure.

8. A superconducting composition exhibiting zero electrical resistance at a temperature of 77° K or above having the nominal formula:

$$Y_aBa_bCu_cO_x$$

wherein "a" is about 1.2, "b" is about 0.8, "c" is about 1.0, and "x" is about 2 to 4.

* * * * *

Effective: November 2, 2002

United States Code Annotated Currentness
Title 35. Patents (Refs & Annos)
Part II. Patentability of Inventions and Grant of Patents (Refs & Annos)
Chapter 11. Application for Patent (Refs & Annos)
→ **§ 116. Inventors**

When an invention is made by two or more persons jointly, they shall apply for patent jointly and each make the required oath, except as otherwise provided in this title. Inventors may apply for a patent jointly even though (1) they did not physically work together or at the same time, (2) each did not make the same type or amount of contribution, or (3) each did not make a contribution to the subject matter of every claim of the patent.

If a joint inventor refuses to join in an application for patent or cannot be found or reached after diligent effort, the application may be made by the other inventor on behalf of himself and the omitted inventor. The Director, on proof of the pertinent facts and after such notice to the omitted inventor as he prescribes, may grant a patent to the inventor making the application, subject to the same rights which the omitted inventor would have had if he had been joined. The omitted inventor may subsequently join in the application.

Whenever through error a person is named in an application for patent as the inventor, or through error an inventor is not named in an application, and such error arose without any deceptive intention on his part, the Director may permit the application to be amended accordingly, under such terms as he prescribes.

CREDIT(S)

(July 19, 1952, c. 950, 66 Stat. 799; Aug. 27, 1982, Pub.L. 97-247, § 6(a), 96 Stat. 320; Nov. 8, 1984, Pub.L. 98-622, Title I, § 104(a), 98 Stat. 3384; Nov. 29, 1999 Pub.L. 106-113, Div. B, § 1000(a)(9) [Title IV, § 4732(a)(10)(A)], 113 Stat. 1536, 1501A-582; Nov. 2, 2002, Pub.L. 107-273, Div. C, Title III, § 13206(b)(1)(B), 116 Stat. 1906.)

HISTORICAL AND STATUTORY NOTES

Revision Notes and Legislative Reports

1952 Acts. The first paragraph is implied in the present statutes, and the part of the last paragraph relating to omission of an erroneously joined inventor is in the Patent Office rules. The remainder is new and provides for the correction of a mistake in erroneously joining a person as inventor, and for filing an application when one of several joint inventors cannot be found. This section is ancillary to § 256.

1982 Acts. House Report No. 97-542, see 1982 U.S. Code Cong. and Adm. News, p. 765.

1984 Acts. Section-by-Section Analysis, see 1984 U.S. Code Cong. and Adm. News, p. 5827.

1999 Acts. Statement by President, see 1999 U.S. Code Cong. and Adm. News, p. 290.

2002 Acts. House Conference Report No. 107-685 and Statement by President, see 2002 U.S. Code Cong. and Adm. News, p. 1120.

Amendments

2002 Amendments. Pub.L. 107-273, § 13206(b)(1)(B), amended directory language of Pub.L. 106-113 [§ 4732(a)(10)(A)], requiring no change in text. See 1999 Amendments note under this section.

1999 Amendments. Pub.L. 106-113 [§ 4732(a)(10)(A)], as amended by Pub.L. 107-273, § 13206(b)(1)(B), struck out "Commissioner" and inserted "Director" throughout the section.

1984 Amendments. Pub.L. 98-622 struck out "and each sign the application" after "patent jointly" and added the sentence beginning "Inventors may apply" in the first paragraph.

1982 Amendments. Pub.L. 97-247, § 6(a), substituted "Inventors" for "Joint Inventors" as section heading, and substituted "through error a person is named in an application for patent as the inventor, or through error an inventor is not named in an application" for "a person is joined in an application for patent as joint inventor through error, or a joint inventor is not included in an application through error".

Effective and Applicability Provisions

1999 Acts. Amendment by Pub.L. 106-113 [§ 4732(a)(10)(A)], effective 4 months after the date of enactment of this Act [Nov. 29, 1999, which is the date of enactment of Pub.L. 106-113, 113 Stat. 1501, which in Div. B, § 1000(a)(9), enacted into law this Act as an Appendix], see Pub.L. 106-113 [§ 4731], set out as a note under section 1 of this title.

1984 Acts. Amendment by Pub.L. 98-622, applicable to all United States patents granted before, on, or after Nov. 8, 1984 and to all amendments for United States patents pending on or filed after that date, except as otherwise provided, see section 106 of Pub.L. 98-622, set out as an Effective Date of 1984 Amendment note under section 103 of this title.

1982 Acts. Amendment by Pub.L. 97-247 effective six months after Aug. 27, 1982, see § 17(c) of Pub.L. 97-247, set out as an Effective Date note under § 294 of this title.

CROSS REFERENCES

Correction of inventor named in issued patent, see 35 USCA § 256.
Joint owners, see 35 USCA § 262.

CODE OF FEDERAL REGULATIONS

Joint inventors, application by, see 37 CFR § 1.45, set out in the Appendix.

LIBRARY REFERENCES

American Digest System

▷

Effective: November 02, 2002

United States Code Annotated Currentness
Title 35. Patents (Refs & Annos)
Part III. Patents and Protection of Patent Rights
Chapter 25. Amendment and Correction of Patents (Refs & Annos)

➡§ 256. Correction of named inventor

Whenever through error a person is named in an issued patent as the inventor, or through error an inventor is not named in an issued patent and such error arose without any deceptive intention on his part, the Director may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate correcting such error.

The error of omitting inventors or naming persons who are not inventors shall not invalidate the patent in which such error occurred if it can be corrected as provided in this section. The court before which such matter is called in question may order correction of the patent on notice and hearing of all parties concerned and the Director shall issue a certificate accordingly.

CREDIT(S)

(July 19, 1952, c. 950, 66 Stat. 810; Aug. 27, 1982, Pub.L. 97-247, § 6(b), 96 Stat. 320; Nov. 29, 1999, Pub.L. 106-113, Div. B, § 1000(a)(9) [Title IV, § 4732(a)(10)(A)], 113 Stat. 1536, 1501A-582; Nov. 2, 2002, Pub.L. 107-273, Div. C, Title III, § 13206(b)(1)(B), 116 Stat. 1906.)

HISTORICAL AND STATUTORY NOTES

Revision Notes and Legislative Reports

1952 Acts. This section is new and is companion to § 116.

The first two paragraphs provide for the correction of the inadvertent joining or nonjoining of a person as a joint inventor. The third paragraph provides that a patent shall not be invalid for such cause, and also provides that a court may order correction of a patent; the two sentences of this paragraph are independent.

1982 Acts. House Report No. 97-542, see 1982 U.S. Code Cong. and Adm. News, p. 765.

1999 Acts. Statement by President, see 1999 U.S. Code Cong. and Adm. News, p. 290.

2002 Acts. House Conference Report No. 107-685 and Statement by President, see 2002 U.S. Code Cong. and Adm. News, p. 1120.

Amendments

2002 Amendments. Pub.L. 107-273, § 13206(b)(1)(B), amended directory language of Pub.L. 106-113 [§ 4732(a)(10)(A)], requiring no change in text. See 1999 Amendments note under this section.

1999 Amendments. Pub.L. 106-113 [§ 4732(a)(10)(A)], as amended by Pub.L. 107-273, § 13206(b)(1)(B), struck out "Commissioner" and inserted "Director" throughout the section.

1982 Amendments. Pub.L. 97-247, § 6(b), substituted "Correction of named inventor" for "Misjoinder of inventor" as the section catchline and, in text, substituted "Whenever through error a person is named in an issued patent as the inventor, or through error an inventor is not named in an issued patent and such error arose without any deceptive intention on his part, the Commissioner may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate correcting such error" for "Whenever a patent is issued on the application of persons as joint inventors and it appears that one of such persons was not in fact a joint inventor, and that he was included as a joint inventor by error and without any deceptive intention, the Commissioner may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate deleting the name of the erroneously joined person from the patent", substituted "The error of omitting inventors or naming persons who are not inventors shall not invalidate the patent in which such error occurred it if can be corrected as provided in this section" for "Whenever a patent is issued and it appears that a person was a joint inventor, but was omitted by error and without deceptive intention on his part, the Commissioner may, on application of all the parties and assignees, with proof of the facts and such other requirements as may be imposed, issue a certificate adding his name to the patent as a joint inventor", and struck out provision that the misjoinder or nonjoinder of joint inventors not invalidate a patent, if such error can be corrected as provided in this section.

Effective and Applicability Provisions

1999 Acts. Amendment by Pub.L. 106-113 [§ 4732(a)(10)(A)], effective 4 months after the date of enactment of this Act [Nov. 29, 1999, which is the date of enactment of Pub.L. 106-113, 113 Stat. 1501, which in Div. B, § 1000(a)(9), enacted into law this Act as an Appendix], see Pub.L. 106-113 [§ 4731], set out as a note under section 1 of this title.

1982 Acts. Amendment by Pub.L. 97-247 effective six months after Aug. 27, 1982, see § 17(c) of Pub.L. 97-247, set out as an Effective Date note under § 294 of this title.

CROSS REFERENCES

Application for patent by joint inventors, see 35 USCA § 116.

CODE OF FEDERAL REGULATIONS

Correction of inventorship, see 37 CFR §§ 1.48, 1.324, set out in the Appendix.

LAW REVIEW COMMENTARIES

Ex parte patent practice and the rights of third parties. Russell E. Levine, Jay L. Alexander and William E. Devitt, 45 Am.U.L.Rev. 1987 (1996).

LIBRARY REFERENCES

American Digest System

Patents 🔑126.

Key Number System Topic No. 291.

Corpus Juris Secundum

CJS Patents § 134, Of Joint Invention.

CJS Patents § 210, Name of Patentee.

CJS Patents § 216, Correction of Named Inventor.

C

Effective:[See Text Amendments]

Code of Federal Regulations Currentness

Title 37. Patents, Trademarks, and Copyrights
Chapter I. United States Patent and Trademark Office, Department of Commerce (Refs & Annos)
Subchapter A. General
Patents
Part 1. Rules of Practice in Patent Cases (Refs & Annos)
Subpart B. National Processing Provisions
Correction of Errors in Patent

→ § 1.324 Correction of inventorship in patent, pursuant to 35 U.S.C. 256.

(a) Whenever through error a person is named in an issued patent as the inventor, or through error an inventor is not named in an issued patent and such error arose without any deceptive intention on his or her part, the Director, pursuant to 35 U.S.C. 256, may, on application of all the parties and assignees, or on order of a court before which such matter is called in question, issue a certificate naming only the actual inventor or inventors. A petition to correct inventorship of a patent involved in an interference must comply with the requirements of this section and must be accompanied by a motion under § 41.121(a)(2) or § 41.121(a)(3) of this title.

(b) Any request to correct inventorship of a patent pursuant to paragraph (a) of this section must be accompanied by:

(1) Where one or more persons are being added, a statement from each person who is being added as an inventor that the inventorship error occurred without any deceptive intention on his or her part;

(2) A statement from the current named inventors who have not submitted a statement under paragraph (b)(1) of this section either agreeing to the change of inventorship or stating that they have no disagreement in regard to the requested change;

(3) A statement from all assignees of the parties submitting a statement under paragraphs (b)(1) and (b)(2) of this section agreeing to the change of inventorship in the patent, which statement must comply with the requirements of § 3.73(b) of this chapter; and

(4) The fee set forth in § 1.20(b).

(c) For correction of inventorship in an application, see §§ 1.48 and 1.497.

(d) In a contested case before the Board of Patent Appeals and Interferences under part 41, subpart D, of this title, a request for correction of a patent must be in the form of a motion under § 41.121(a)(2) or § 41.121(a)(3) of this title.

[24 FR 10332, Dec. 22, 1959, as amended at 48 FR 2713, Jan. 20, 1983; 49 FR 48454, Dec. 12, 1984; 50 FR 23123, May 31, 1985; 62 FR

53199, Oct. 10, 1997; 65 FR 54677, Sept. 8, 2000; 69 FR 50001, Aug. 12, 2004; 69 FR 56545, Sept. 21, 2004; 70 FR 3891, Jan. 27, 2005]

SOURCE: 24 FR 10332, Dec. 22, 1959; 60 FR 14518, March 17, 1995; 65 FR 14871, March 20, 2000; 65 FR 33455, May 24, 2000; 65 FR 50103, Aug. 16, 2000; 65 FR 56793, Sept. 20, 2000; 65 FR 70490, Nov. 24, 2000, unless otherwise noted.

AUTHORITY: 35 U.S.C. 2(b)(2), unless otherwise noted.

37 C. F. R. § 1.324, 37 CFR § 1.324

Current through October 27, 2011; 76 FR 66844

END OF DOCUMENT

C

Effective:[See Text Amendments]

Code of Federal Regulations Currentness

Title 37. Patents, Trademarks, and Copyrights
Chapter I. United States Patent and Trademark Office, Department of Commerce (Refs & Annos)
Subchapter A. General
Patents
Part 1. Rules of Practice in Patent Cases (Refs & Annos)
Subpart B. National Processing Provisions
Who May Apply for a Patent

→ § 1.48 Correction of inventorship in a patent application, other than a reissue application, pursuant to 35 U.S.C. 116.

(a) Nonprovisional application after oath/declaration filed. If the inventive entity is set forth in error in an executed § 1.63 oath or declaration in a nonprovisional application, and such error arose without any deceptive intention on the part of the person named as an inventor in error or on the part of the person who through error was not named as an inventor, the inventorship of the nonprovisional application may be amended to name only the actual inventor or inventors. Amendment of the inventorship requires:

(1) A request to correct the inventorship that sets forth the desired inventorship change;

(2) A statement from each person being added as an inventor and from each person being deleted as an inventor that the error in inventorship occurred without deceptive intention on his or her part;

(3) An oath or declaration by the actual inventor or inventors as required by § 1.63 or as permitted by §§ 1.42, 1.43 or § 1.47;

(4) The processing fee set forth in § 1.17(i); and

(5) If an assignment has been executed by any of the original named inventors, the written consent of the assignee (see § 3.73(b) of this chapter).

(b) Nonprovisional application--fewer inventors due to amendment or cancellation of claims. If the correct inventors are named in a nonprovisional application, and the prosecution of the nonprovisional application results in the amendment or cancellation of claims so that fewer than all of the currently named inventors are the actual inventors of the invention being claimed in the nonprovisional application, an amendment must be filed requesting deletion of the name or names of the person or persons who are not inventors of the invention being claimed. Amendment of the inventorship requires:

(1) A request, signed by a party set forth in § 1.33(b), to correct the inventorship that identifies the named inventor or inventors being deleted and acknowledges that the inventor's invention is no longer being claimed in the nonprovisional application;

and

(2) The processing fee set forth in § 1.17(i).

(c) Nonprovisional application--inventors added for claims to previously unclaimed subject matter. If a nonprovisional application discloses unclaimed subject matter by an inventor or inventors not named in the application, the application may be amended to add claims to the subject matter and name the correct inventors for the application. Amendment of the inventorship requires:

(1) A request to correct the inventorship that sets forth the desired inventorship change;

(2) A statement from each person being added as an inventor that the addition is necessitated by amendment of the claims and that the inventorship error occurred without deceptive intention on his or her part;

(3) An oath or declaration by the actual inventors as required by § 1.63 or as permitted by §§ 1.42, 1.43, or § 1.47;

(4) The processing fee set forth in § 1.17(i); and

(5) If an assignment has been executed by any of the original named inventors, the written consent of the assignee (see § 3.73(b) of this chapter).

(d) Provisional application--adding omitted inventors. If the name or names of an inventor or inventors were omitted in a provisional application through error without any deceptive intention on the part of the omitted inventor or inventors, the provisional application may be amended to add the name or names of the omitted inventor or inventors. Amendment of the inventorship requires:

(1) A request, signed by a party set forth in § 1.33(b), to correct the inventorship that identifies the inventor or inventors being added and states that the inventorship error occurred without deceptive intention on the part of the omitted inventor or inventors; and

(2) The processing fee set forth in § 1.17(q).

(e) Provisional application--deleting the name or names of the inventor or inventors. If a person or persons were named as an inventor or inventors in a provisional application through error without any deceptive intention on the part of such person or persons, an amendment may be filed in the provisional application deleting the name or names of the person or persons who were erroneously named. Amendment of the inventorship requires:

(1) A request to correct the inventorship that sets forth the desired inventorship change;

(2) A statement by the person or persons whose name or names are being deleted that the inventorship error occurred without deceptive intention on the part of such person or persons;

(3) The processing fee set forth in § 1.17(q); and

(4) If an assignment has been executed by any of the original named inventors, the written consent of the assignee (see § 3.73(b) of this chapter).

(f)(1) Nonprovisional application--filing executed oath/declaration corrects inventorship. If the correct inventor or inventors are not named on filing a nonprovisional application under § 1.53(b) without an executed oath or declaration under § 1.63 by any of the inventors, the first submission of an executed oath or declaration under § 1.63 by any of the inventors during the pendency of the application will act to correct the earlier identification of inventorship. See §§ 1.41(a)(4) and 1.497(d) and (f) for submission of an executed oath or declaration to enter the national stage under 35 U.S.C. 371 naming an inventive entity different from the inventive entity set forth in the international stage.

(2) Provisional application--filing cover sheet corrects inventorship. If the correct inventor or inventors are not named on filing a provisional application without a cover sheet under § 1.51(c)(1), the later submission of a cover sheet under § 1.51(c)(1) during the pendency of the application will act to correct the earlier identification of inventorship.

(g) Additional information may be required. The Office may require such other information as may be deemed appropriate under the particular circumstances surrounding the correction of inventorship.

(h) Reissue applications not covered. The provisions of this section do not apply to reissue applications. See §§ 1.171 and 1.175 for correction of inventorship in a patent via a reissue application.

(i) Correction of inventorship in patent. See § 1.324 for correction of inventorship in a patent.

(j) Correction of inventorship in a contested case before the Board of Patent Appeals and Interferences. In a contested case under part 41, subpart D, of this title, a request for correction of an application must be in the form of a motion under § 41.121(a)(2) of this title and must comply with the requirements of this section.

[48 FR 2709, Jan. 20, 1983; 49 FR 48452, Dec. 12, 1984; 50 FR 9379, March 7, 1985; 57 FR 56447, Nov. 30, 1992; 60 FR 20222, April 25, 1995; 62 FR 53185, Oct. 10, 1997; 65 FR 54663, Sept. 8, 2000; 67 FR 523, Jan. 4, 2002; 69 FR 49998, Aug. 12, 2004]

SOURCE: 24 FR 10332, Dec. 22, 1959; 60 FR 14518, March 17, 1995; 65 FR 14871, March 20, 2000; 65 FR 33455, May 24, 2000; 65 FR 50103, Aug. 16, 2000; 65 FR 56793, Sept. 20, 2000; 65 FR 70490, Nov. 24, 2000, unless otherwise noted.

AUTHORITY: 35 U.S.C. 2(b)(2), unless otherwise noted.

37 C. F. R. § 1.48, 37 CFR § 1.48

Current through October 27, 2011; 76 FR 66844

END OF DOCUMENT

PROOF OF SERVICE

I hereby certify that Appellant's Brief was filed with the Court by federal express; and that two true and correct copies of Appellant's Brief was served via federal express on:

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on April 12, 2012

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CERTIFICATE OF COMPLIANCE

I certify that this brief complies with the type-volume limitations of FED. R. APP. P. 32(a)(7)(B) because:

1. Excluding the parts of the brief exempted by FED. R. APP. P. 32(a)(7)(B)(iii), the brief contains 12,339 words.

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DECLARATION OF JOE W. BEVERLY

William Jensen has authorized me to sign the brief on his behalf.

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