4.5
Electron Microscopes and Microscopy in Japan

4.5A Electron Microscope Development at Hitachi in the 1940s

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Electron microscope history began at Hitachi, Ltd., in 1939, when Hitachi took part in a development project of the Japan Society for Promotion of Science, to build electron microscopes in Japan. The first instrument was designed by K. Kasai, and was handed over to B. Tadano for experiment. They were experienced cathode-ray oscillograph engineers. This was coincident with Knoll and Ruska, who developed the first electron microscope in the 1930s. They also were cathode-ray oscillograph engineers.

The first electron microscope at Hitachi was completed in 1941 and was named HU-1. It had electromagnetic lenses and a horizontal column as shown in Fig. 1. It was built on an optical bench. There were no data or know-how to design an electron microscope. The engineers had to design and build the first instrument based on their knowledge of cathode-ray oscillographs. They ran into many technical as well as engineering difficulties before completing the microscope.

For example, the column was made of a bronze casting, so vacuum leak problems frequently occurred. The horizontal column posed a difficulty in aligning the beam and lenses, and it was quite sensitive to vibrations. One day, Tadano excitedly jumped out of a dark room, having succeeded in recording a sharp-quality image. It was already midnight and there was no one left in the entire building. It was through this experience that Tadano understood the problem of vibration, which was the primary cause of image disturbance!

Figure 2 is an enlarged part of a diatom shell recorded with the first microscope. It had a resolving power permitting a high magnification of about 20,000×.

Later, in 1941, K. Kasai and B. Tadano started designing the next electron microscope, based on the precious data and know-how obtained from the HU-1. A vertical column was employed to permit better alignment and

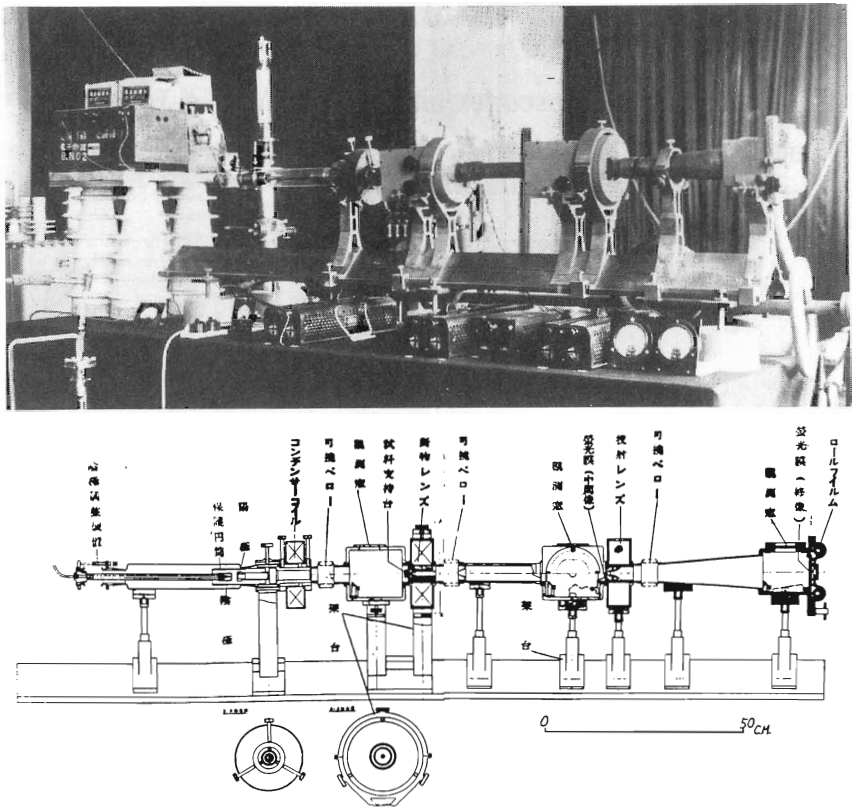

FIGURE 1. General view and cross section of the first electron microscope, HU-1, built at Hitachi (1941).

better stability against vibrations. A permalloy magnetic shield was placed along the electron beam path so that the column might be less susceptible to magnetic field disturbances. In order to achieve a better vacuum, sheet metal was used instead of cast materials.

This instrument was completed in 1942, and it was called HU-2 (Fig. 3). Two units of this model were manufactured. One was installed at the Central Research Laboratory of Hitachi, and the other at Prof. Sakaki's laboratory in the Engineering Department of Nagoya University, which was the first electron microscope installed at a customer's site in Japan.

The HU-2 had many superior points over the HU-1. High-voltage stability, mechanical stability against vibration, and electron optical lens performance were some of them. It was easy to record images at several ten thousand times. The objective lens was built with a very high mechanical accuracy and it had very low astigmatism even without any correcting

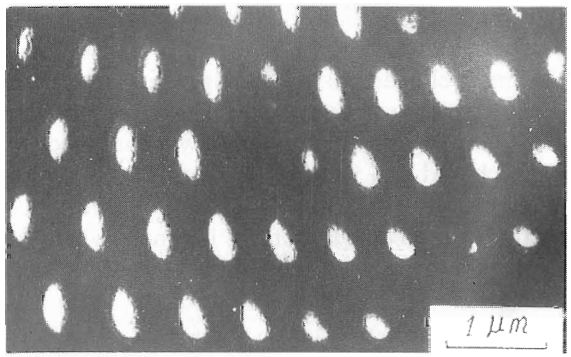

FIGURE 2. A part of a diatom shell taken with the HU-1 (1941).

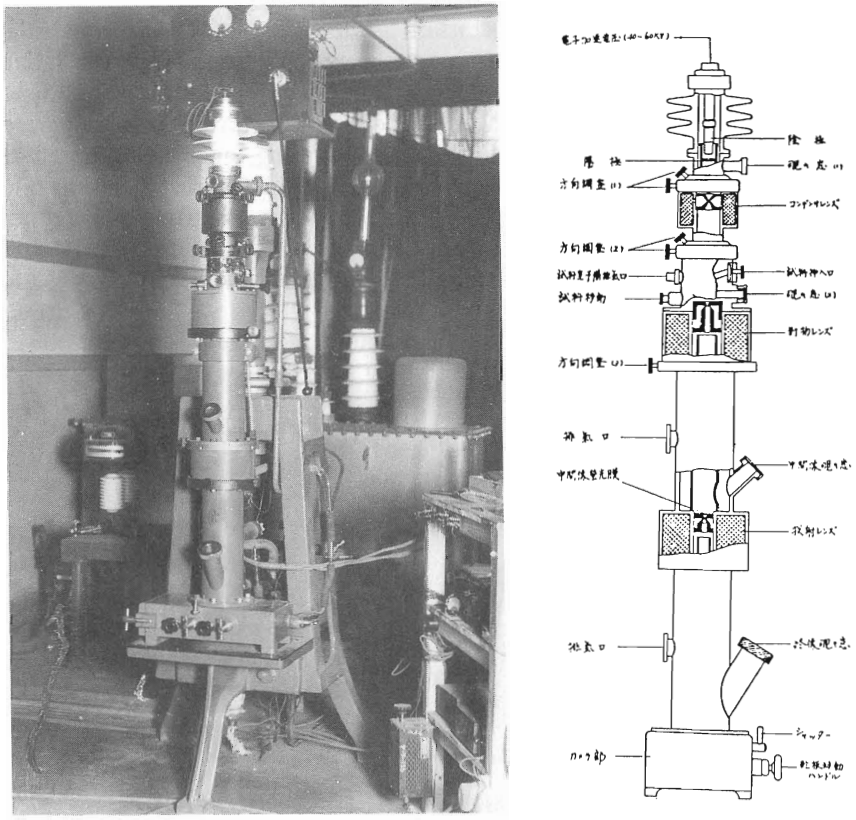

FIGURE 3. General view and cross section of HU-2 (1942).

devices. Many researchers at that time believed that spherical aberration was the most crucial factor for the microscope resolution. Tadano *et al.* already at this time believed that the astigmatism due to mechanical or machining inaccuracy was even more important. The objective lens pole-piece of the HU-2 employed an inlaid metalwork in which all components were precisely machined and finely put together as a final structure. This precise machining accuracy for the lens laid the foundation for high-resolution electron microscopy at Hitachi for many years to come.

Figures 4, 5, and 6 are typical micrographs recorded with the HU-2. Specimens are cubic crystals of magnesium oxide, carbon black, which is used as a filler for rubber, and proteus vulgaris, a kind of bacteria. All of these micrographs are good-quality images even by today's standards. Figure 6 was in particular the most memorable one, in that it showed flagelli without staining, which gave many biological and medical scientists a very good impression about electron microscopy.

From 1944 to 1945, Tokyo was heavily attacked by the U.S. Air Force almost every night, and the Central Research Laboratory of Hitachi in Kokubunji, where the HU-2 was installed, was becoming a dangerous area. The engineers were advised to move to a mountainous area near the Japan Alps. In view of the anticipated delay in microscope research, Tadano vigorously rejected the move. Many sandbags were prepared and placed around the HU-2 to protect it from the bombing, and the researchers continued their work wearing steel helmets! Their correct decision and enthusiastic effort for developing technologies for electron microscopes made a great contribution to the uninterrupted development of Hitachi's electron microscopes even during the destructive period in and after World War II.

The present electron microscope technology at Hitachi is a great flower in bloom on the foundations laid by many forerunners during the 1940s.

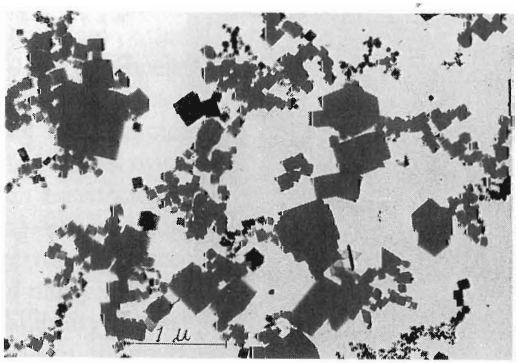

FIGURE 4. Magnesium oxide crystals taken with HU-2 (1943).

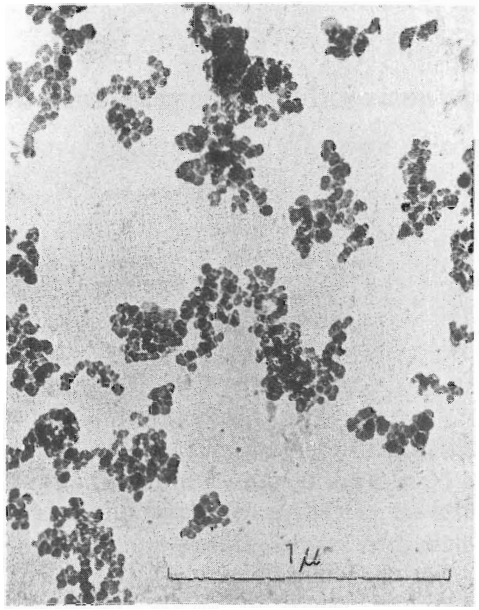

FIGURE 5. Carbon black taken with HU-2 (1943).

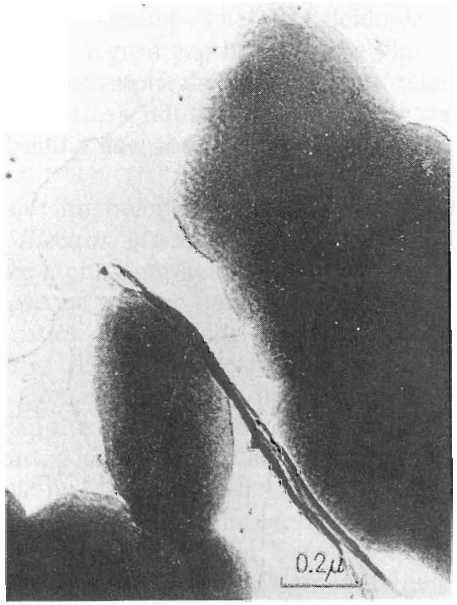

FIGURE 6. Proteus vulgaris.