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Development of a 300 kV ultrahigh resolution analytical electron microscope

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Introduction.

A 300 kV ultrahigh resolution analytical electron microscope (UHRAEM), JEM-3010, has been newly developed on the base of JEM-2010 [1]. Intended for atomic-level observation and analysis in the materials science field, this instrument is provided with a variety of results of new technologies such as a compact 300 kV electron gun, a 4-stage independent illumination lens system, a new C/O lens [2-5], a new cantilever-type goniometer, new specimen holders, motor control for the 5 axes (X, Y, X-tilt, Y-tilt), a new type direct-coupling SIP for attaining clean vacuum, and a new EDS with improved analysis sensitivity. There are two versions; the UHR version, intended for ultrahigh resolution observation with a point resolution of 0.17 nm and the multi-purpose HT version, featuring specimen high tilt angles as large as $\pm 40°$ and heating and cooling holders. The external view of the JEM-3010 is shown in figure 1.

1. Electron gun.

A high-stability electron gun is very important for high-resolution analytical electron microscope. The JEM-3010 employs an extremely stable compact 300 kV electron gun and a high-voltage generator which are insulated by SF6 gas.

2. Illumination lens system.

To obtain the compatibility between ultrahigh resolution observation and microarea analysis, a powerful illumination lens system having widely variable illumination conditions is needed. The

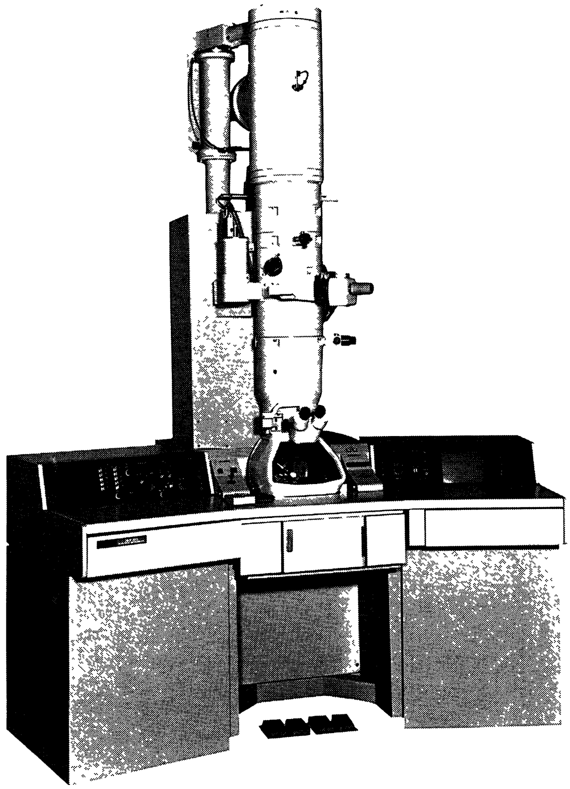

Fig. 1. — External view of JEM-3010.

JEM-3010 is provided with four independent condenser lenses, which allow instantaneous selection of the following four modes, as shown in figure 2.
1) TEM mode, which provides parallel illumination for high resolution image observation.
2) EDS mode, which provides a nanoprobe with a large beam current.
3) NBD mode, which provides a nanoprobe at a small illumination angle.
4) CBD mode, which provides a microbeam that allows wide control of the illumination angle.

Since the lens system and the deflection system are controlled by a CPU, a series of operations — high-resolution observation and X-ray analysis and micro-micro electron diffraction of the same view of field — can be carried out efficiently.

For nanometer analysis, the minimum spot sizes of the UHR version and HT version are as small as 1.0 nm and 1.5 nm, respectively. Both versions allow ultrahigh-resolution image observation and EDS analysis simultaneously. The X-ray take-off angle is 17.5° with the UHR version and 25° with the HT version, and the detection solid angle is 0.068 str. with the UHR version and 0.13 str. with the HT version, thus allowing high-sensitivity EDS analysis.

3. Objective lens.

For ultrahigh resolution at 300 kV, the JEM-3010 has a new C/O lens with a coil wound with special Cu tape, and a newly designed pole-piece. The UHR version has a spherical aberration

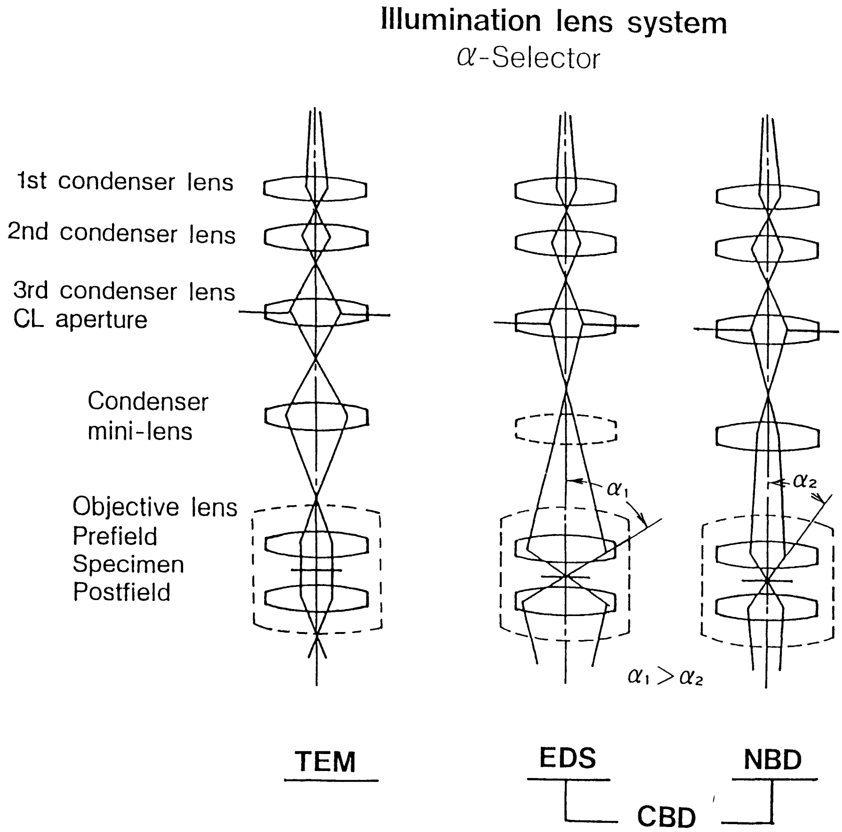

Fig. 2.

coefficient of 0.6 mm, a chromatic aberration coefficient of 1.4 mm, a point resolution of 0.17 nm, and maximum tilt angles of ±10°. The HT version has a spherical aberration coefficient of 1.4 mm, a chromatic aberration coefficient of 2.2 mm, a point resolution of 0.21 nm, and maximum tilt angles of ±40°.

4. Goniometer.

In order to realize ultrahigh resolution, the JEM-3010 employs a new cantilever type goniometer and new specimen holders shown in figure 3. They are more vibration-resistant than the conventional side-entry goniometer.

The conventional goniometer has used the suction force of atmospheric pressure, for specimen movement. Since the specimen holder is constantly subjected to compressive force, the specimen is held by the holder in an unstable state. With the cantilever type goniometer, in which the specimen holder tip is not moved by a rod in contact with it, but by a lever located closer to the atmosphere side, no stress at all is applid to the tip of specimen holder, thus greatly improving the vibration resistance of the goniometer. In addition, the space between a double O-ring is constantly held under a high vacuum, while completely eliminating small gas leaks during specimen

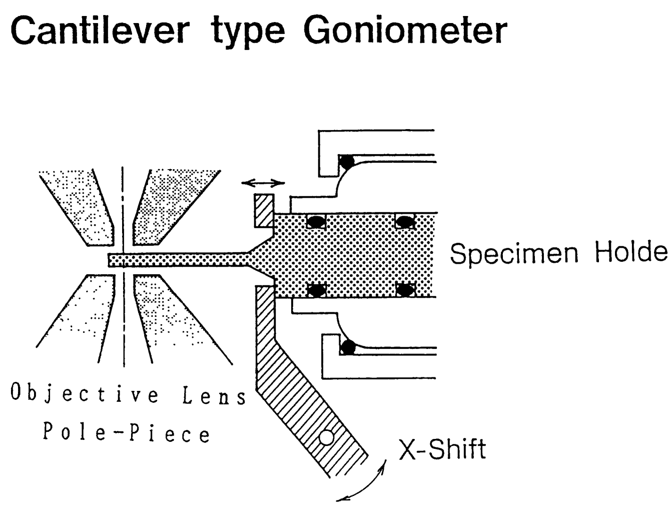

Fig. 3.

movement. Above the goniometer is a 5-axis motor drive system, which ensures smooth specimen movement and ease of operation.

5. Vacuum system.

Specimen contamination lowers the reliability of data. The column of the JEM-3010 is designed to minimize the amount of outgassing by employing such means as a bake-out function, double O-ring seals, metal gaskets, vacuum brazing and bellows. And to prevent contaminants that are brought in by the specimen itself, an anti-contamination cold trap is provided. Also, a direct coupling sputter ion pump shown in figure 4 has been developed, which provides largely improved evacuation conductance (effective evacuation speed) by means of evacuation ports provided near the portions to be evacuated. The realization of a clean specimen environment has made possible long-time observation of the same field of view.

6. Application.

High resolution images of SIC, GaAs and H-Nb_2 O^5 are shown in figures 5, 6 and 7, respectively.

7. Conclusion.

A newly developed JEM-3010 electron microscope has the highest performance as an UHRAEM. Th microscope ensures nanometer area structural and chemical analysis with a nanometer probe by EDS, EELS and CBED in high resolution electron microscopy.

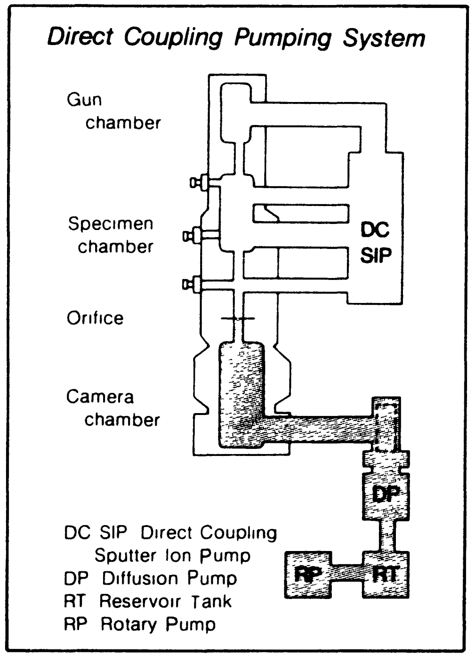

Fig. 4.

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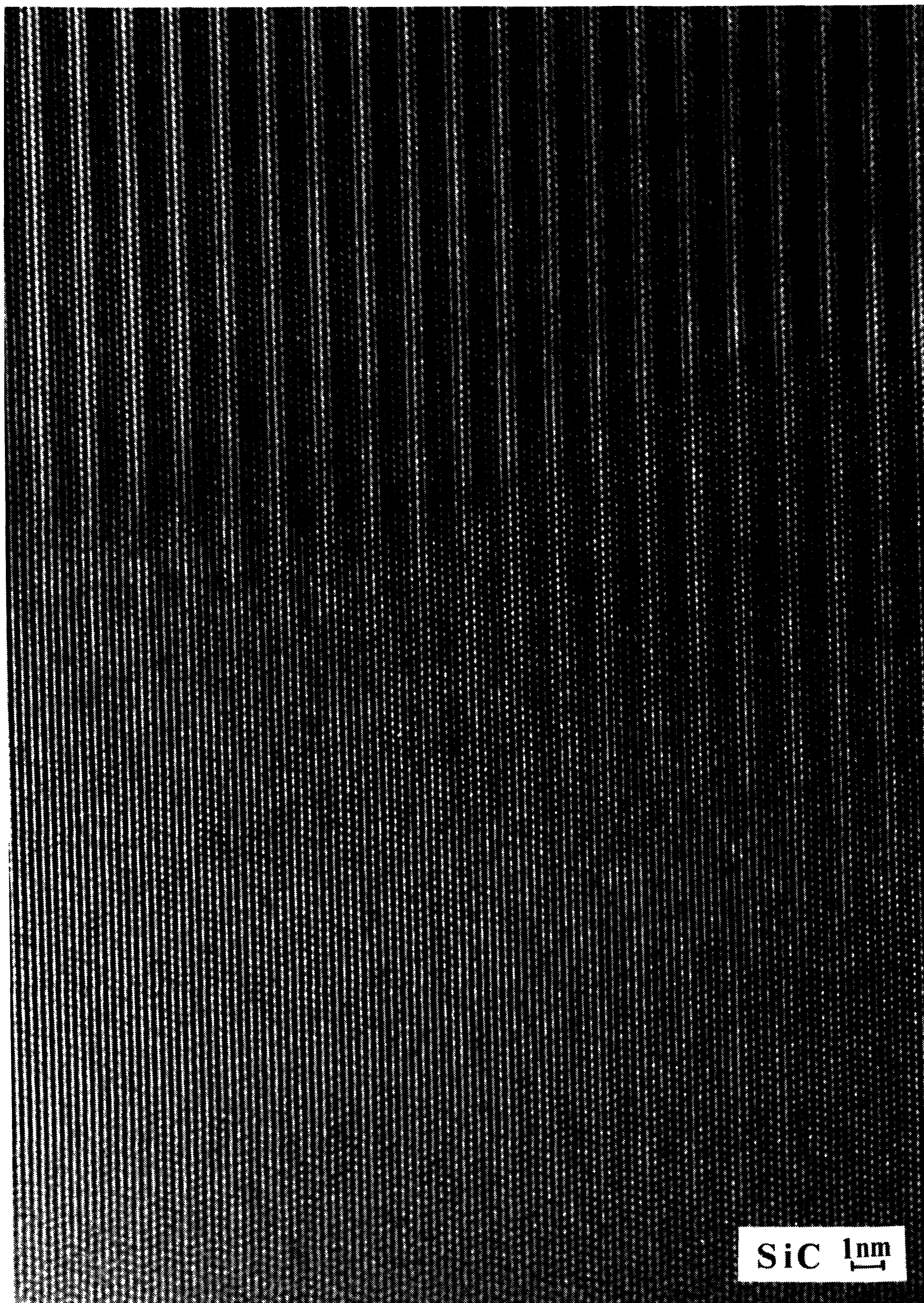

Fig. 5.

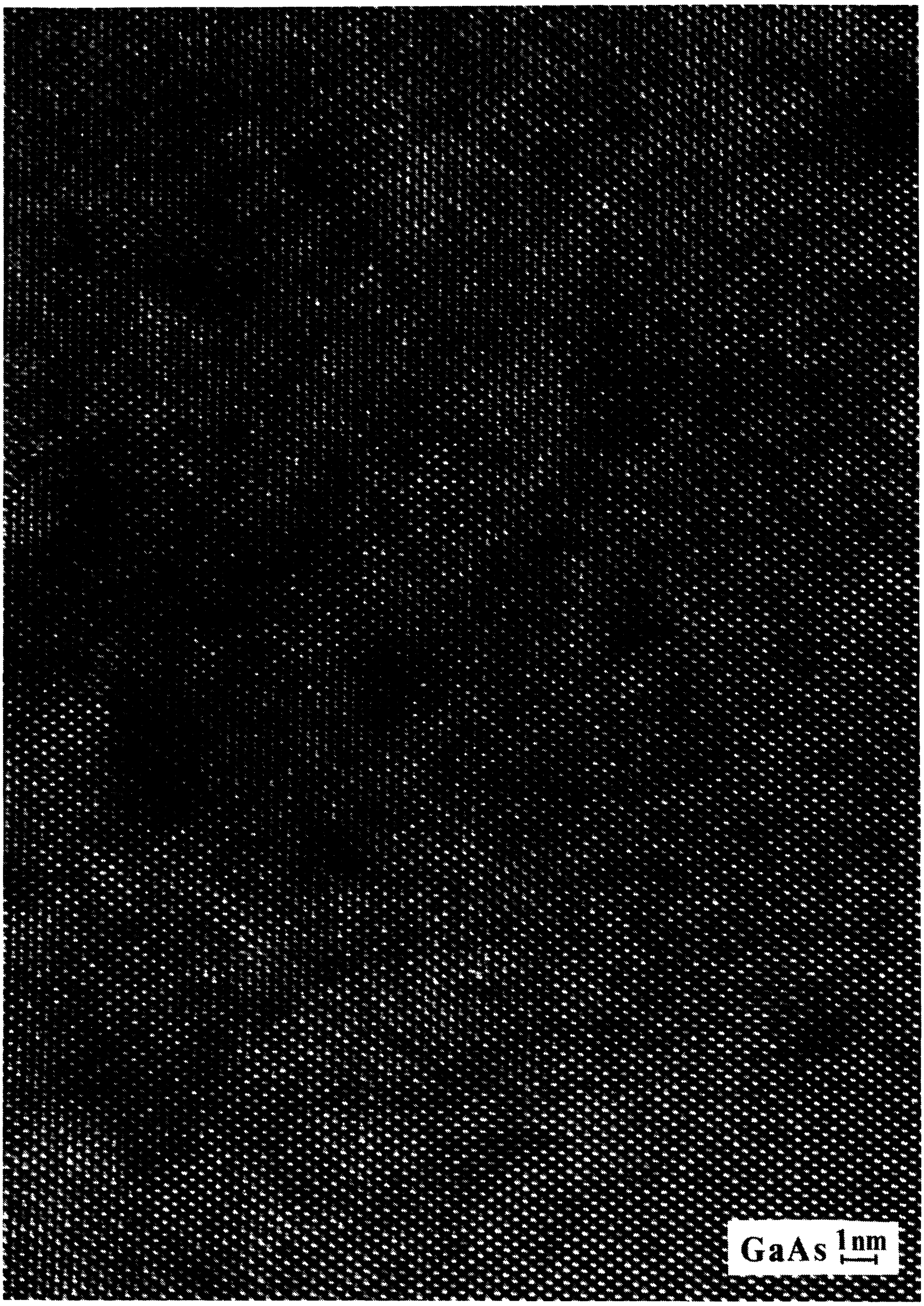

Fig. 6.

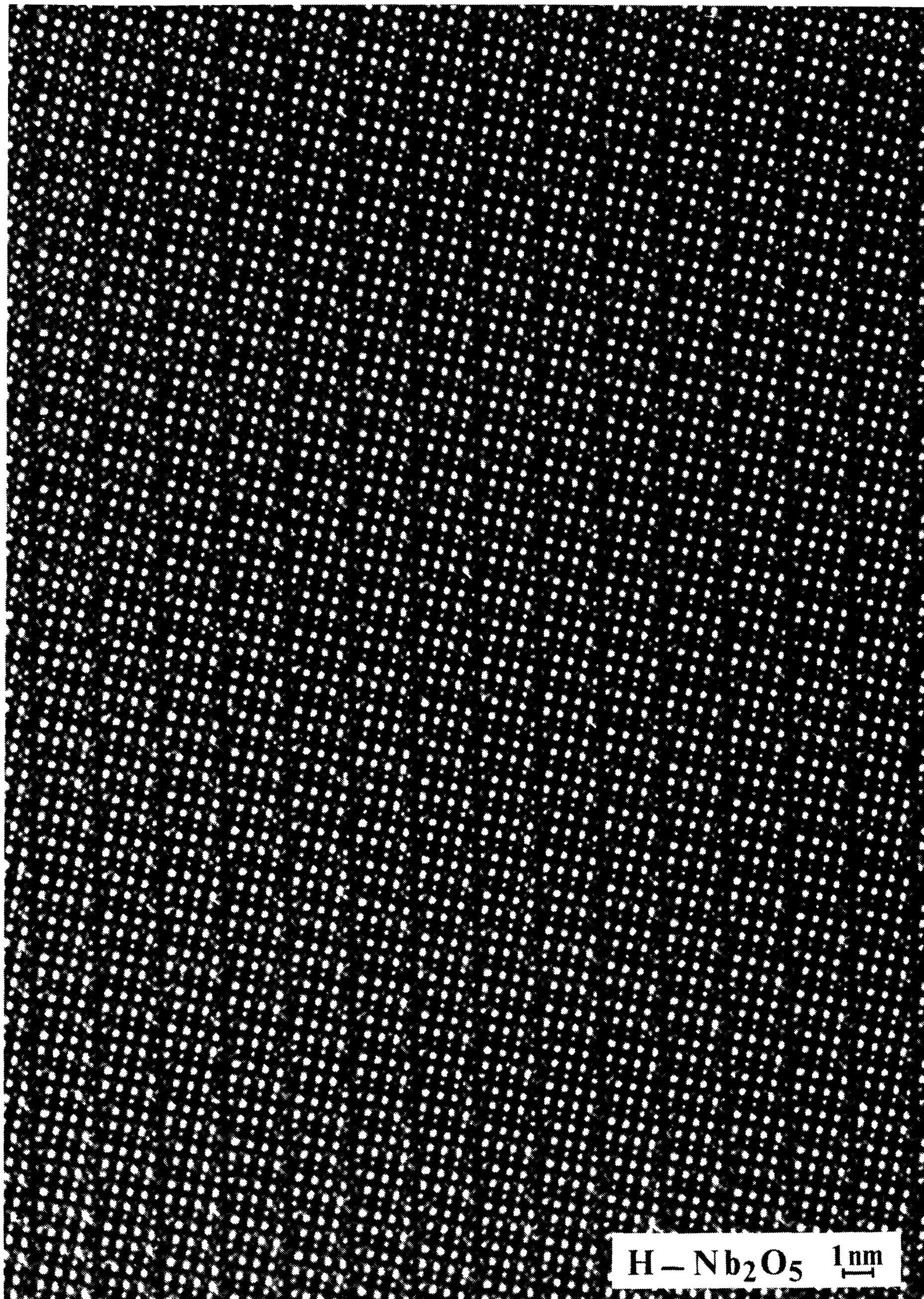

Fig. 7.

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