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# Monochromator for a 200 kV Analytical Electron Microscope

M. Mukai, W. Inami, K. Omoto, T. Kaneyama, T. Tomita, K. Tsuno, M. Terauchi*, K. Tsuda*, M. Naruse, T. Honda and M. Tanaka*

JEOL Ltd., 3-1-2 Musashino, Akishima, Tokyo 196-8558, Japan
*Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan

We have been developing a 200 kV analytical electron microscope with a monochromator equipped inside the electron gun [1]. The expected performance of this microscope is to obtain a beam diameter of smaller than 2 nm on the specimen plane and an energy resolution of better than 0.2 eV. The monochromator consists of two Wien-filters and an energy selection slit inserted between the two filters. We reported the performance of the former monochromator [2], which consisted of two octopole-type Wien-filters with different lengths of 40 mm and 10 mm. An ultimate energy resolution of 0.14 eV was attained, but unfortunately no more than an oval shaped beam was obtained on the specimen plane, indicating an imperfect achromatic focus of the monochromator.

We constructed a new monochromator, which is composed of two same filters with a 30 mm in length [3]. Each filter consists of dodecapole-type Wien-filter, which is expected to have better homogeneity of electric and magnetic fields than that of the previous one. The monochromator with two equal-length filters causes a larger energy-dispersion at the energy selection slit, which is placed at the mid-plane of the two filters. The electro static lenses placed at the entrance and exit of the monochromator were newly designed. Figure 1 shows the theoretically calculated electron trajectories from the electron gun to the accelerator. The first Wien-filter produces the first focus with energy-dispersion on the slit. The second filter cancels the energy dispersion and produces the second focus at the exit of the monochromator. At the plane of the second focus, the electron beam is expected to be achromatic and stigmatic. The electro static lens at the first stage of the accelerating tube produces the third focus above the first condenser lens. This enables us to obtain an achromatic beam or an almost round shaped beam on the specimen plane (Fig. 2). A comparison of the test results of the new monochromator with the former one is shown in Table 1. An almost round shaped probe of 1.5 x 1.6 nm with an energy spread of 0.14 eV and a current of 12 pA was obtained. The energy resolution is currently limited by the low-frequency noise of the power supplies of the new monochromator, which is under the improvement.

Figure 3 shows a 1s electron excitation spectrum of α-Boron obtained with an energy resolution of 0.2 eV. The spectrum clearly shows the presence of fine structures, which is consistent with a theoretical calculation. We emphasize that the spectrum was obtained with a probe of about 2 nm in diameter and a greatly reduced acquisition time of 16 seconds, which can be compared with a similar spectrum firstly revealed by a high energy-resolution TEM, HREA80 [4]. The present result implies that the same energy resolution as that of HREA80 with the probe size of a few nanometer diameter is obtained in a conventional analytical TEM when the monochromator is installed, which promotes innovative material researches.

References

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| | Energy dispersion @ slit [μm/eV] | Slit width [μm] | Energy resolution [eV] | Probe size [nm] | Probe current [pA] |
|---|---|---|---|---|---|
| New type | 19.5 | 1 | 0.14 | 1.5 X 1.6 | 12 |
| Former type | 10 | 1 | 0.14 | 1.7 X 5.9 | 1.8 |

Table 1. Basic test results of the new monochromator and former one

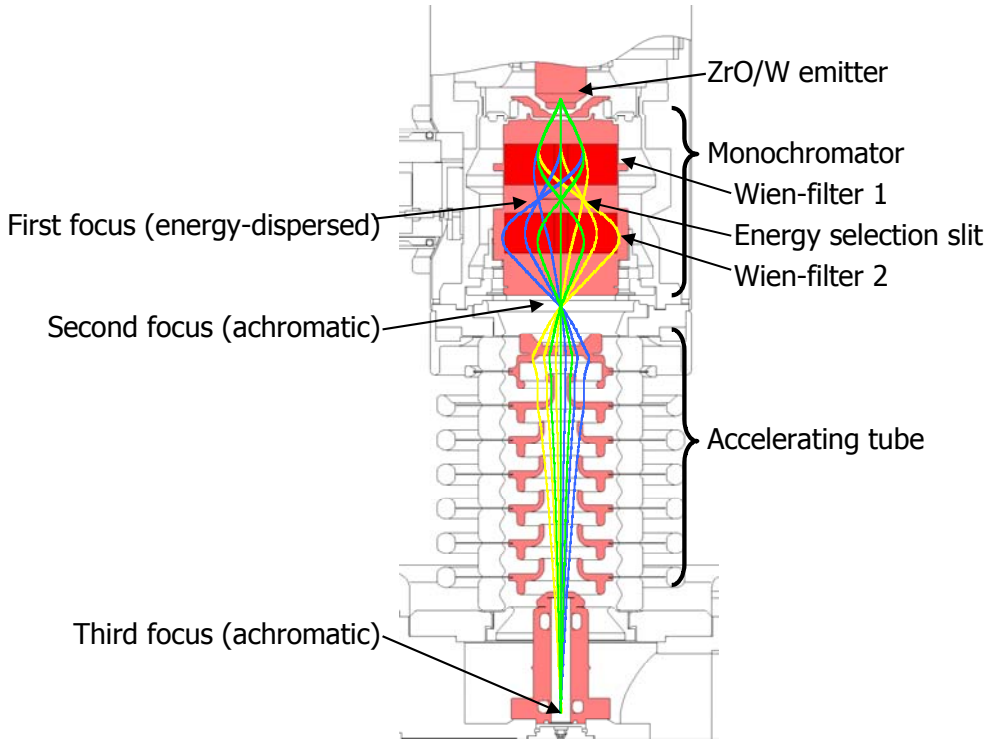


Figure1
Theoretically calculated electron trajectories from electron gun to accelerator.

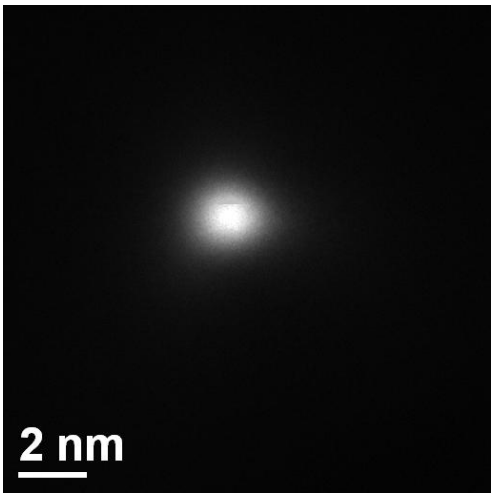


Figure.2.
Beam shape on the specimen plane with a 0.14 eV energy resolution and 12 pA probe current

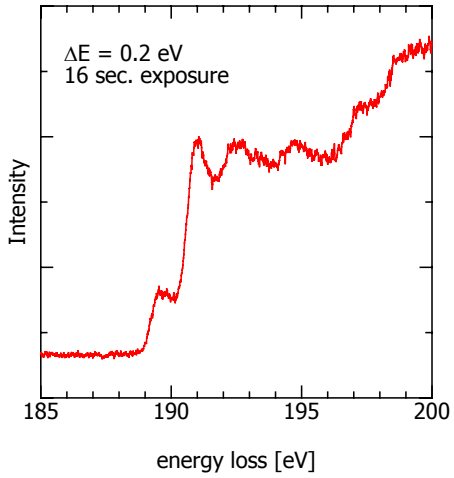


Figure.3.
1s electron excitation spectrum of α-Boron with an energy resolution of 0.2 eV

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