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# A New High Energy-resolution Soft-X-ray Spectrometer for A Transmission Electron Microscope

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We have been developing a high energy-resolution soft-X-ray spectrometer for a transmission electron microscope to obtain the information of the density of states (DOS) of the valence band (occupied states) from identified small specimen areas [1,2].
The spectrometer ($2^{nd}$ version [3]) was composed of varied-line-spacing (VLS) gratings and a CCD detector. An energy range from 60 eV to 1200 eV was accessible by using two VLS gratings, which have line densities of 1200 and 2400 lines/mm. The size of the CCD detector was 27.6x27.6mm$^2$(2kx2k), which corresponds to a collection angle of $6.5 \times 10^{-4}$ sr. By introducing X-ray reflection flat mirrors, spectral intensity was improved by 2.2 times. Thus, the effective collection angle of the spectrometer was $1.4 \times 10^{-3}$ sr. Energy resolutions of this spectrometer for Si *L*-emission (~100eV), B *K*-emission (~180eV) and Cu *L*-emission (~930 eV) were evaluated to be 0.1, 0.4 and 1.4 eV, respectively. This $2^{nd}$ spectrometer successfully obtained the DOS of the valence band from specified small specimen areas of *h,c,w*-BN, $\alpha,\beta$-boron, Si, carbon allotropes and quasicrystals. However, the collection angle and the energy resolution of higher energy region were not enough.
We have designed and produced new X-ray reflection mirrors and a new VLS grating. The new X-ray reflection curved mirrors were designed to improve the solid angle of the spectrometer by about two times bigger than that of the $2^{nd}$ spectrometer. The mirrors were produce by a sputtering of tungsten on substrates. The tungsten layer is about 100 nm in thickness. The new grating was designed to have a focal distance of about 50 cm, which is about two times larger than that of the previous grating. Thus, the dispersion of the new one is about two times larger than before. Figure 1 shows energy dispersions (energy / CCD channel) of the previous gratings of 1200 l/mm, 2400 l/mm and the newly designed grating of 2400 l/mm. Aberration is smaller than one CCD pixel size. Thus, an energy resolution of about 0.7 eV is expected for X-ray energy of about 1000 eV. Figure 2 shows a photo of the spectrometer ($3^{rd}$ version) attached to a transmission electron microscope of JEM2000FX. The design and the performance of the spectrometer will be presented.

[1] M. Terauchi, H. Yamamoto and M. Tanaka: J. Electron Microscopy, 50 (2001) 101.
[2] M. Terauchi, H. Yamamoto and M. Tanaka: Microsc. Microanal., 7 suppl.2 (2001) 228.

[3] M. Terauchi and M. Kawana: Microsc. Microanal., 8 suppl.2 (2002) 644.

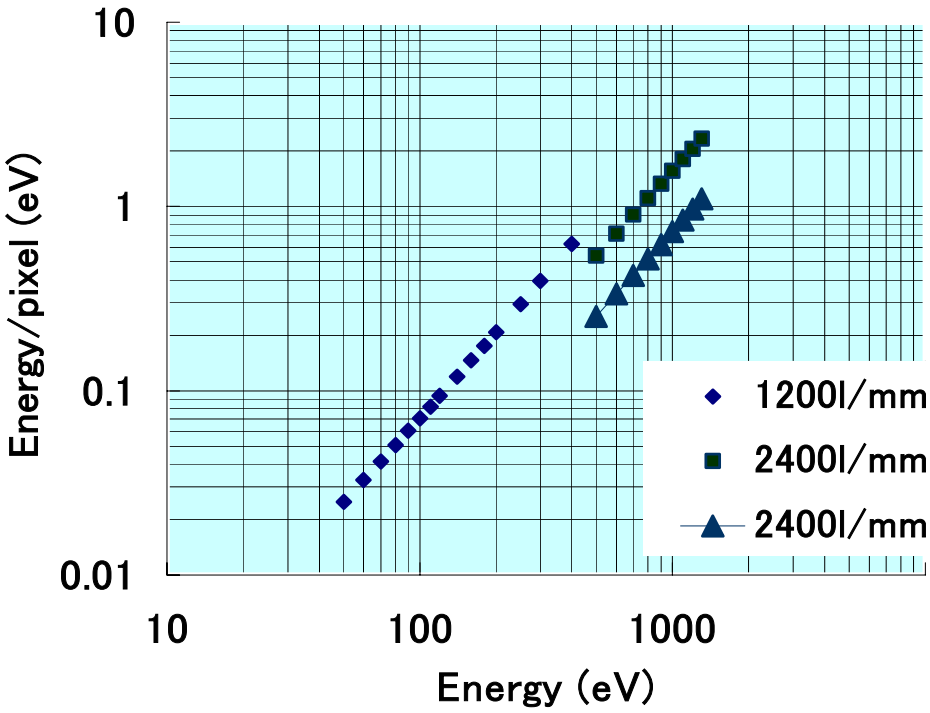


FIG.1 Energy dispersions (energy / CCD pixel) of the gratings of 1200 l/mm (◆), 2400 l/mm (■) already used and the newly designed grating of 2400 l/mm (▲).

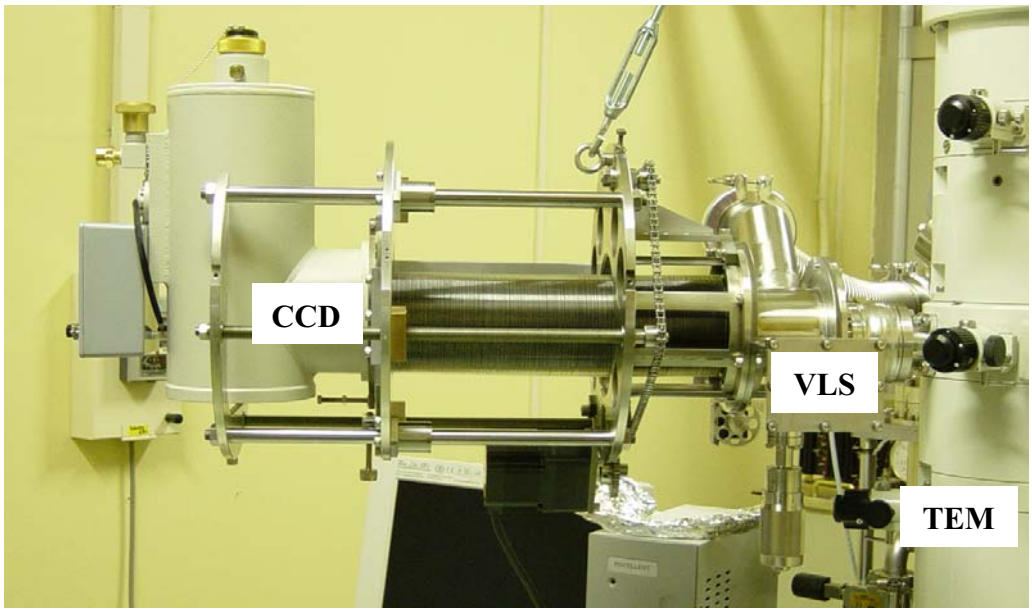


FIG.2 Photo of the spectrometer (3rd version) attached to a transmission electron microscope of JEM2000FX.

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