Low Energy Performance of a SEM Using a New Monochromator with Double Offset Cylindrical Lenses

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The latest nanoelectronics industries demand continuous improvements in the performances of Scanning Electron Microscopy (SEM) such as critical dimension SEM, defect review SEM, and SEM for laboratories. These advanced SEMs have been operated at extremely low energy below 100 eV[1]. It leads to avoid beam damage and charge-up of sample materials and devices, and to reveal sub-surface and nano-scale information of specimens due to reduced interaction volumes. However, image resolutions are limited mainly by chromatic aberration. To solve this problem by narrowing energy spreads of electron beams, dedicated monochromators (MCs) have been developed[2,3].

Recently, we've proposed a new MC with double offset cylindrical lenses[4]. Fig. 1 shows its schematic. It has capability of energy filtering at the middle and forms stigmatic and non-energy dispersive images at the exit. Fig. 2 shows simulated beam profiles at energy selection plane and exit image plane. The expected energy resolution is better than 10 meV for 4 keV. Further, we investigate the MC's application to SEM especially in ex-low energy conditions. After calculating optical parameters and aberration coefficients of the MC, we derive beam diameters, energy spreads, and probe currents at its exit. Postulating ideal SEM optics with C_s and C_c of 1 mm, the beam diameters containing 50% of the current, FW50[5], are calculated at the position of the specimen. Fig. 3 shows the beam diameter dependency on the probe current at 100 eV. The use of the MC dramatically improves the beam diameter down to 4.4 nm from 19.7 nm at the probe current of 1 pA. The contribution of chromatic aberration become negligible. Even though increased Gauss image, which is caused by third order aperture aberration of the MC, deteriorates the performance in large current, the SEM with the MC shows superiority in middle current region (<160 pA).

From the quantitative estimation, we can conclude that this MC is effective to improve SEM performance in low energy region. The detailed discussion will be given in the conference.

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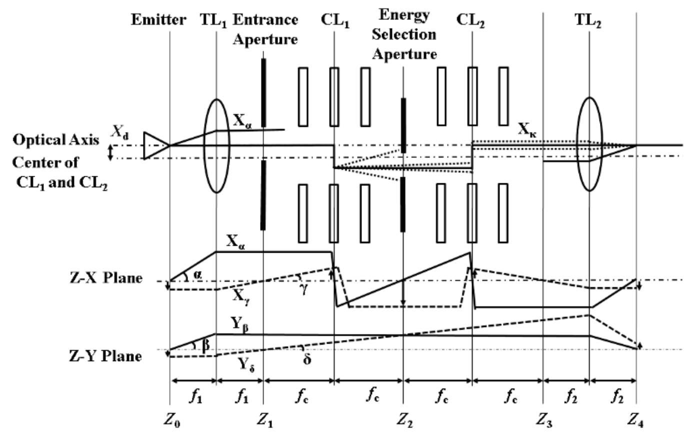

Figure 1: Schematic of the new monochromator: Two cylindrical lenses (CL_1 and CL_2) are offset to the optical axis by X_d. The configurations of emitter, transfer round lenses (TL_1 and TL_2), and apertures are shown.

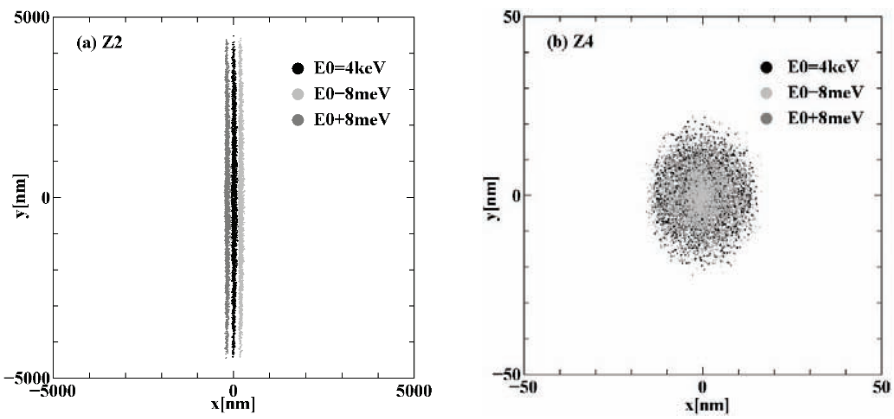

Figure 2: Beam profiles at the middle plane Z_2 (a) and the exit plane Z_4 (b): The simulation conditions are as follows: incident current of 300 pA, beam energy of 4 keV, energy differences of ±8 meV.

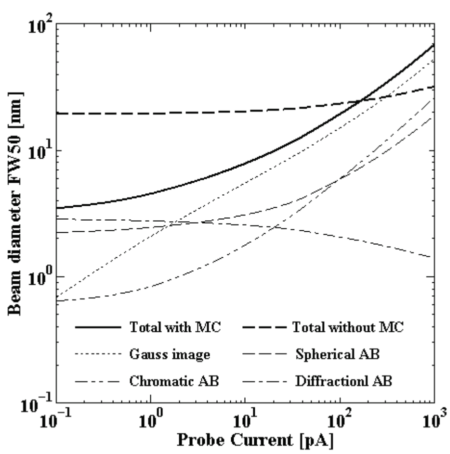

Figure 3: Beam diameter dependency on probe current for a SEM with the MC: The graph shows total beam diameters with/without the MC and aberration factors. The beam energy is 100 eV.