Deconvolution Method used in Improving the Depth Resolution of Three-Dimensional Images Taken by Scanning Confocal Electron Microscopy

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Scanning confocal electron microscopy (SCEM) is a new imaging mode for electron microscopy, which provides three-dimensional (3D) information of the sample. Frigo et al. first demonstrated SCEM imaging of an inner structure of thick samples [1]. They employed a scan-descan system that was not capable of 3D scanning. Takeguchi et al. have developed a stage scanning system to carry out 3D-scan with high resolution under a fixed electron optics configuration [2]. Using this system, not only lateral (XY) sliced images but also vertical (XZ) sliced images are obtained directly without computer tomography process that requires acquisition of a tilt-series of images. Recently, Hashimoto et al. demonstrated that the use of an annular dark field (ADF) aperture improved the depth resolution of SCEM images. They showed a reconstructed 3D image of a nano-coil with the depth resolution of about 100nm, which was close to the vertical probe size determined by a spherical aberration (Cs=1.0mm) and convergence angle (about 10mrad) [3].

Figure 1 shows the ray diagram and components of ADF-SCEM with the stage scan system, while Figs.2 (a) and (b) show lateral and vertical sliced ADF-SCEM images from a carbon film, on which 5nm Au particles were distributed. Images of both the carbon film and Au particles are elongated along z-direction in the vertical sliced image. In this study, we applied an image processing technique to improve the depth resolution of ADF-SCEM images. Vertically sliced ADF-SCEM images were deconvoluted with a modeled point spread function. Wiener filter was adopted to minimize the effect of noise included in the image. Resultantly, the elongation along z direction was reduced by 35-40%, as shown in Fig.2 (c).

References
[1]   S.P. Frigo, Z.H. Levine, N.J. Zaluzec, *Appl. Phys. Lett.* 81 (2002) 2112.
[2]   M.Takeguchi et al., J. Electron Microsc. 57 (2008) 123.
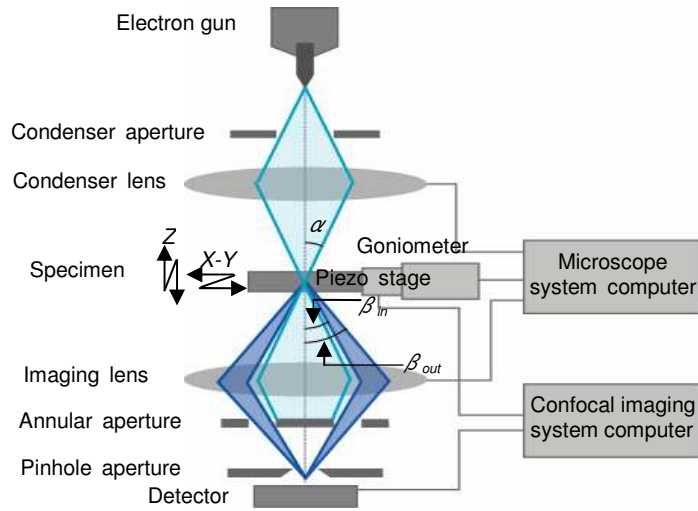[3]   A. Hashimoto et al., J. Appl. Phys. 106 (2009) 086101.

FIG. 1.   Schematic diagram of ADF-SCEM equipped with a stage-scanning system.
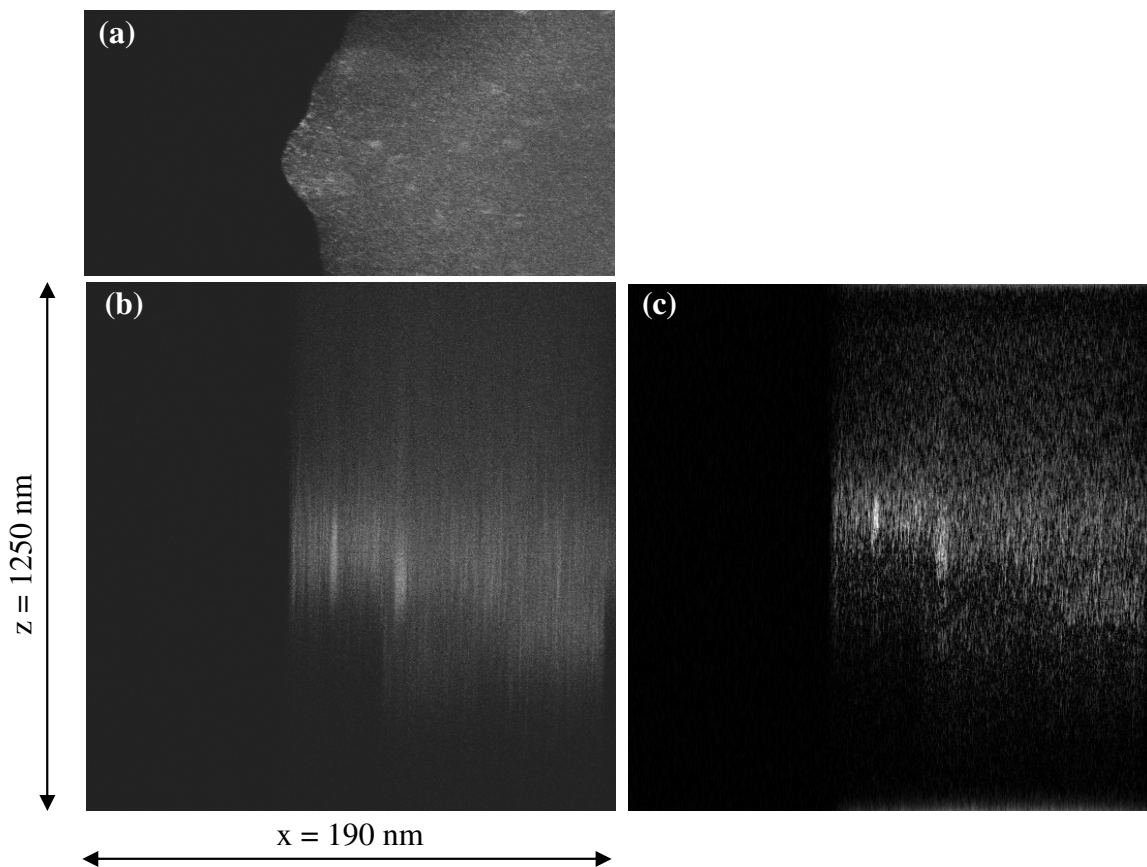

FIG. 2.   X-Y scan (a) and X-Z scan (b) of ADF-SCEM from 5nm Au particles; (c) is the deconvolution result of (b).