Observation of Magnetic Field in STEM by using Blade-shape aperture with DeScan Function

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For observation of magnetic and electric fields in STEM (Scanning Transmission Electron Microscopy), DPC (Differential Phase Contrast) method is widely used [1]. However, specialized segmented detector is required for the DPC imaging. We have reported that a technique and some results of observation for magnetic field by using a CCD camera instead of a special detector in a conventional TEM [2-4].

In this study, we propose a new technique to observe magnetic field by using a blade-shape aperture, which is used for obtaining a DPC signal. The DPC signal is acquired by detecting displacement of STEM disk deflected due to magnetic field in a sample. By eclipsing the STEM disk with a static blade-shape aperture, the signal detected by the BF detector is modulated due to the magnetic field in a sample. To perform this technique in low magnification, STEM disk shift due to scanning is a problem. It is important to compensate the shift to distinguish the STEM disk displacement due to magnetic and/or electrostatic fields in a sample. Therefore, we developed a new scan generator that work along with descan function. The descan function enables us to realize a stationary STEM disk while an electron beam scans in vacuum, and to detect a small beam deflection originated from a weak magnetic and/or electrostatic field in a sample.

Figure 1 shows a scheme of the configuration of the blade-shape aperture and the STEM BF (Bright Field) detector. The blade-shape aperture is placed directly above a STEM BF detector. The signal of normal BF STEM image is acquired with a way shown in Fig. 1 (a) with no blade aperture. The DPC signal is acquired with a way shown in Fig. 1 (b) with eclipsed STEM disk. In Fig. 2 (a), an image of the scintillator on the standard STEM BF detector is shown. And an image of the scintillator eclipsed by the blade aperture is shown in Fig. 2 (b). Besides, in Fig. 2 (c), the other side of the scintillator on STEM detector is shown, which is calculated by subtracting the signals in Fig. 2 (a) with the signals in Fig. 2 (b). As a result, the static blade-shape aperture enables us to build virtual segmented detectors.

A normal STEM BF image and DPC images for a Ni thin film are shown in Fig. 3 (a), 3 (b) and 3 (c). The STEM images shown in Fig. 3 (a) and 3 (b) was acquired under the configuration shown in Fig. 2 (a) and 2 (b), respectively. The STEM image in Fig. 3 (c) is a remainder after subtraction of the image in Fig. 3 (b) from the image in Fig. 3 (a). In the Fig. 3 (b) and (c), contrasts of magnetic domains were clearly visible. In contrast, the standard STEM image shown in Fig. 3 (a) does not show the contrasts of magnetic domains.

As a result, we successfully observed DPC images with the conventional STEM instrument equipped without the special segmented detectors.

References
Figure 1. Scheme showing the configuration of a blade-shape aperture and a STEM BF detector. Standard BF STEM image is acquired under the configuration (a) and DPC STEM image is acquired under the configuration (b).

Figure 2. Images of the scintillator on STEM BF detector. (a) shows the image of full scintillator taken under the configuration shown in Fig. 1(a). (b) shows the image of eclipsed scintillator taken under the configuration shown in Fig. 1(b). (c) is the subtracted remainder of the image shown in (a) by the image shown in (b).

Figure 3. The normal STEM BF image (a) and the DPC images (b) and (c) of a Ni thin film. STEM image (a) and (b) were acquired under the configurations shown in Fig. 2 (a) and (b), respectively. STEM image (c) is remainder subtracted from the image (a) by the image (b).