The Modification of Aperture System for Atomic Image Projection Electron-Beam Lithography (AIPEL)

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We proposed a projection type electron-beam lithography using the image signal of high-resolution transmission electron microscopy (HRTEM) as a mask, which technique is named by atomic image projection electron-beam lithography (AIPEL).[1] For the formation of quantum dot and wire through the AIPEL process, we modified the transmission electron microscope with a field emission gun (JEM-2010F, JEOL Ltd.). The wafer stage was inserted at the image plane of objective lens and the patterning lens was introduced between objective lens and wafer stage, which control the patterning magnification from 50 to 300 times at the wafer stage. The proof of concept equipment was installed and successfully has been operated at the Seoul National University.

The most uniqueness of AIPEL is the using a HRTEM signal from crystalline materials as a mask. Consequently, the uniformity of quantum dot and wire from AIPEL process highly depends on the mask quality. Now, we use the conventional TEM sampling method using polishing, dimpling, and ion-milling for the AIPEL mask preparation. Therefore, there exists the nonuniformity of mask signal due to the surface amorphous layer, thickness variation of mask material and so on.

We introduce the noise reduction objective aperture (NR aperture) at the back-focal plane of objective lens for the reducing the noise and nonunifomity of mask signal. The origin of NR aperture is the same as an image filtering by Fourier transform. The NR aperture only passes through the transmitted and diffracted spot with phase information of mask signal at the back focal plane of objective lens. We fabricated the NR aperture by focused ion-beam (FIB) etching of Mo thin sheet with 10 μm thickness. Fig. 1 (a) shows the SEM image of NR aperture and Fig. 1(b) shows the image of NR aperture with diffraction spot of mask signal in AIPEL. The etch hole diameter was 10 μm. Fig. 2 clearly shows a noise reduction effect on the mask signal after using NR aperture.

In this presentation, I will present the origin and fabrication of NR aperture and the nano-patterning results using NR aperture in detail. Additionally, I will introduce about the modification of selected area aperture with square shape for the patterning with step and repeat process.

[1] H.-S. Lee, B.-S. Kim, H.-M. Kim, J.-S. Wi, S.-W. Nam, K.-B. Jin, Y. Arai, K.-B. Kim, *Adv. Mater.* **19**, 4189 (2006)

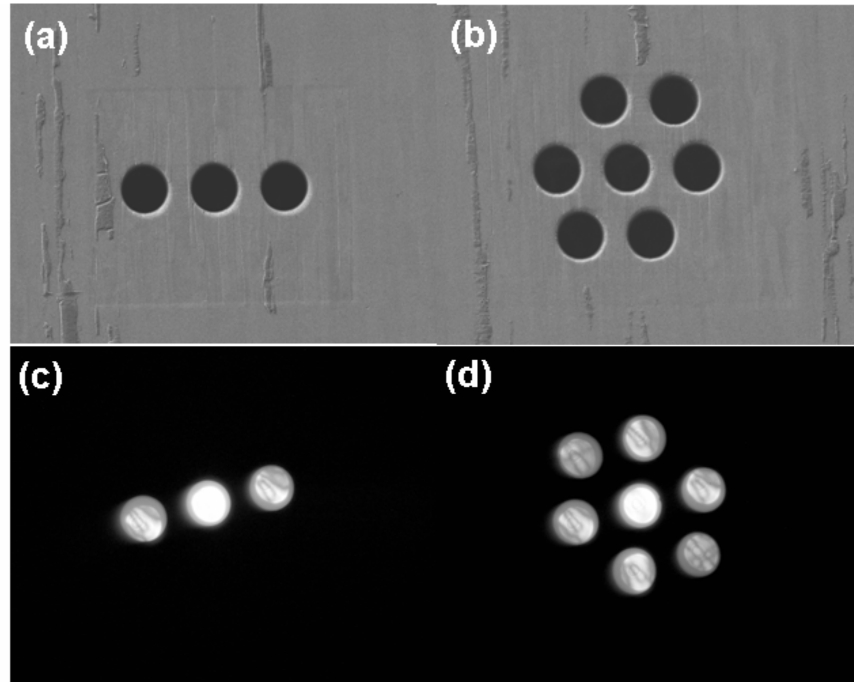

Fig. 1. SEM image of noise reduction aperture for (a) line pattern and (b) dot pattern and TEM diffraction pattern image with NR aperture for (c) line pattern and (d) dot pattern.

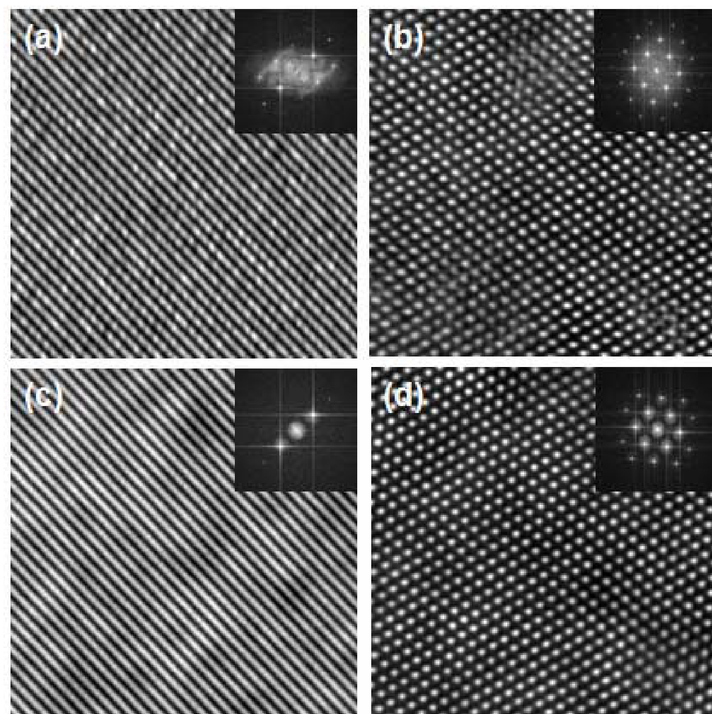

Fig. 2. TEM images and their FFT images; (a) and (b) before using NR aperture, (c) and (d) after using NR aperture.