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Nanometer Size Tungsten Markers Formation by a Helium Ion Microscope Equipped with Gas Injection System for Alignment of TEM Tomographic Tilt Series

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Transmission electron microscope (TEM) tomography is a useful technique for visualizing three-dimensional (3D) structures of materials and nano-devices, while it needs more accurate alignment in tilt series to acquire more accurate 3D images. Using nanoparticles as fiducial markers is a typical method for the alignment. A conventional process to form the markers involves placing a suspension of the markers on a specimen; however, it is difficult to get an even dispersion of markers on the specimen: in an extreme case, there might be no markers in the region of interest because of lack of the makers' position controllability. This paper describes a new method to form markers with position control.

An electron beam-induced deposition has been reported to form nanostructures of less than 100 nm size [1, 2], and they discussed a superiority of the electron beam to a gallium focused ion beam because of their minimum spot sizes, sub-nm and a few nm for the electron beam and the gallium ion beam, respectively, which limit the minimum size of the structures. Recently, a helium ion microscope (HIM) has been developed [3], and we equipped the HIM with a $W(CO)_6$ gas injection system (GIS) for the deposition. A beam spot size of the HIM is 0.25 nm, and a maximum distribution of secondary electrons energy was about 1 eV [4], so it is expected that the helium ion beam deposition brings about tungsten particles of less than a few nm diameter without any deposition at the periphery of a focused area due to secondary electrons of higher energy than a few eV which is generated in the gallium ion case. Figure 1a shows a SEM image of a tungsten nanoparticle and cross lines deposited on a Si substrate and an enlarged STEM image of the nanoparticle in fig. 1a is shown in fig. 1b. Diameter of the particle is approximately 8 nm so far. The deposition experiment using the HIM with the GIS is at a very early stage, and it needs further experiments to optimize beam currents, beam radiation time, and so on to get a smaller particle. The tungsten particles were also deposited on a rod-shaped specimen for the TEM tomography as

shown in fig2. Smaller particles and an automatic method of detecting the markers for alignment of TEM tomographic tilt series, which is a modified our previously developed method [5], will be presented

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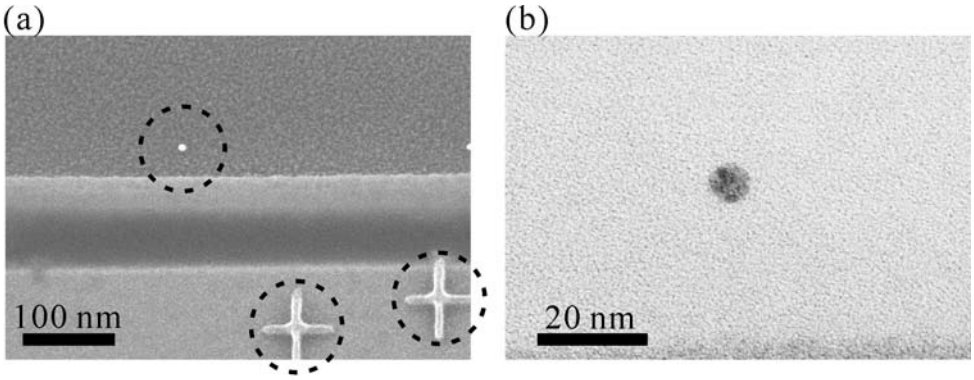

FIG. 1. (a) SEM image of tungsten nanoparticle and lines deposited on a Si substrate. (b) An enlarged STEM image of the nanoparticle in (a).

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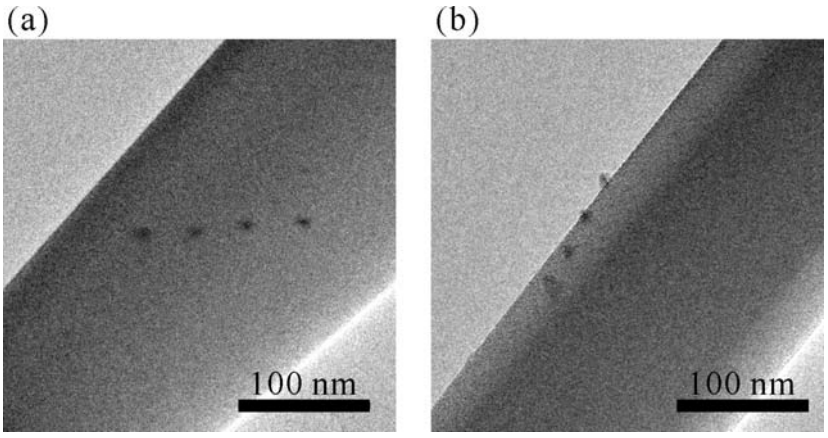

FIG. 2. The tungsten particles were also deposited on a rod-shaped specimen for the TEM tomography at a rotation angle of (a) 0° and (b) 90°.

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