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Fabrication of Fine Electron Biprism Filament by Focused-Ion-Beam Chemical-Vapor-Deposition

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The combination of the FIB and CVD is a promising method to fabricate any kind of three-dimensional nanostructures with various materials[1, 2]. Using this method, we have produced a fine diamond-like carbon (DLC) nanowire as the biprism filament[3]. The DLC nanowire is generally fabricated as follows. First, phenanthrene ($C_{14}H_{10}$) molecular gas is absorbed on substrates. Second, a DLC nano-scale terrace is grown up by decomposing the carbon molecular that is captured by low-energy secondary electrons from the focused Ga^+ beam. Finally, the DLC nanowire is produced by continuous growth of the DLC nanoterrace[4]. The DLC nanowire has a Young's modulus of over 100 GPa, which means that the DLC nanowire has mechanical durability[5]. The DLC free-space nanowiring was made with a commercially available FIB apparatus (SMI2050MS2: SII NanoTechnology Inc.) and using a Ga^+ ion beam of 30 keV. The beam was focused to a 5-nm spot in a phenanthrene ($C_{14}H_{10}$) gas environment. Supplying the phenanthrene gas gave a pressure of 1 x 10^{-4} Pa in the chamber. The beam current was 1 pA. The Ga^+ beam was scanned horizontally between the W rods for 90 seconds by using a computer-pattern generator, which enabled us to control both the scanning speed and direction. To enhance its conductivity, the Pt/Pd layer was sputter-coated onto the biprism filament holder.

Scanning-electron microscopy (SEM) micrographs of the DLC biprism filament are shown in Fig. 1(a), and an enlarged image of the middle of the DLC nanowire is shown in Fig. 1(b). To demonstrate the practical advantages of the finer biprism filament, we compared the electron interference region and the fringe contrast between the 80 and the 400 nm diameter filaments. The 400-nm filament, which was close to the common diameter used in the conventional electron biprism, was prepared by Pt-sputter coating onto the 80-nm DLC filament. With the exception of those for the filament diameter, the electron-optical conditions were identical. The interference experiments were done using in a transmission electron microscope (Hitachi, HF2000 field emission TEM) that was operated at an accretion voltage of 200 kV.

As shown in Fig. 2, the electron-interference fringes and the corresponding line profiles were obtained using a biprism filament with a diameter of 80- and 400- nm, respectively. The scale bar in the images indicates the length in a TEM sample plane. The fringe intensity was normalized with the intensity of the non-interference area. The applied biprism voltages were 20 V. Clear interference fringes without distortions were obtained using these biprisms. The interference region with the 80-nm-diameter filament was 240 nm, and that with the 400-nm-diameter was 200 nm. The contrasts obtained using the diameter of 80 and 400 nm were 0.29 and 0.21, respectively. Using the higher contrast fringes enabled us to measure the reconstructed waves more accurately. The measured fringe spacing of both filaments was almost the same value, 9.0 nm. The spatial resolution of the reconstructed waves is generally determined by the fringe spacing and corresponded to 2 or 3 times the fringe spacing. Thus, using the finer biprism filament does not deteriorate the spatial resolution.

In conclusion, we developed a fine electron biprism filament using free-space nanowiring with FIB-CVD. The FIB-CVD finer filament (80 nm in diameter) improved both the interference region and the contrast of the interference fringes with the same fringe spacing. Using the FIB-CVD filament would provide more accurate measurements than the conventional biprism filament in electron holography.

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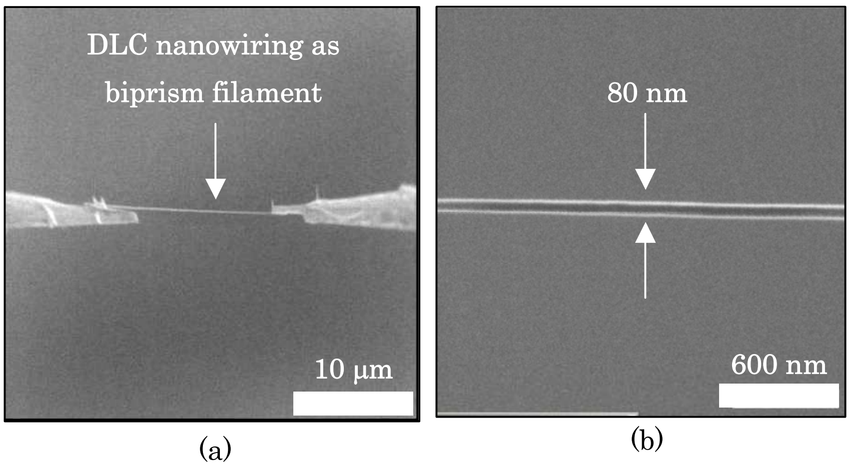

Fig. 1. SEM micrographs of DLC nanowire with 80-nm-diameter fabricated by FIB-CVD. (a) Nanowire bridged between W rods, (b) Enlargement of middle of the nanowire.

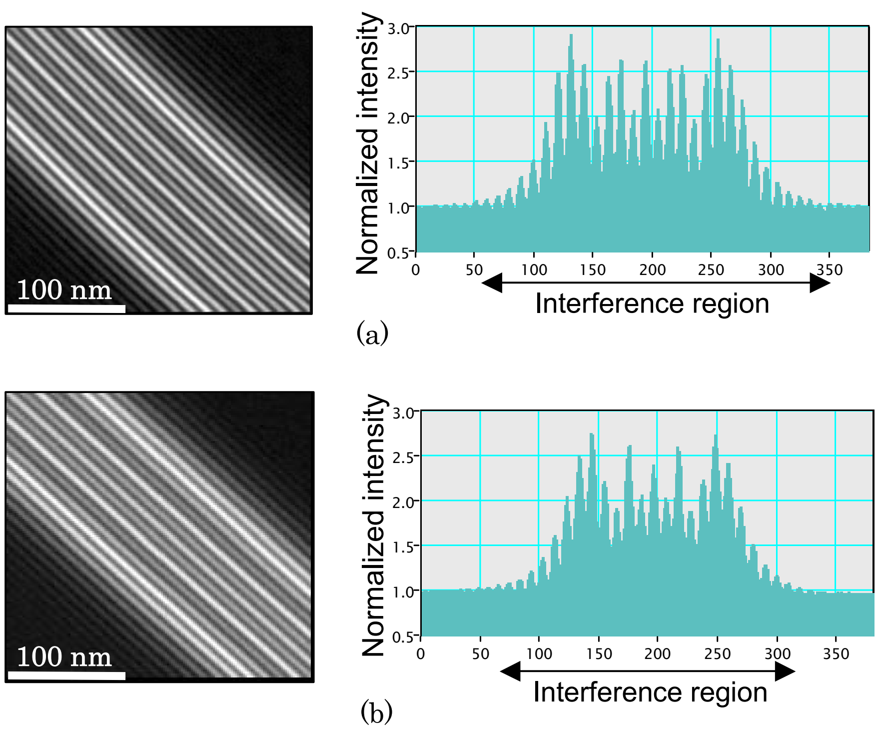

Fig. 2. Interference fringes obtained using DLC biprism filament with (a) 80-nm diameter and (b) 400-nm diameter, and corresponding line profiles of fringe intensity.

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