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Structure Change under 1 MeV Electron Beam Irradiation of Amorphous-contained Nano-sized W-dendrites Fabricated on Alumina Substrates with Electron-beam-induced Deposition

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Electron-beam-induced deposition (EBID) is a promising technique to fabricate small-sized structures on substrates and is expected to be applied in technology [1]. Compact structures are usually fabricated with this technique. Recently, nanometer-sized W-dendritic and other branched structures were fabricated on insulator substrates with EBID in a 200 kV transmission electron microscope (TEM) [2]. However, one problem is that the nanodendrite usually contains amorphous. It is desirable to fabricate crystalline nanodendrite structures for their potential applications. In the present work, W-nanodendrite structure is fabricated on Al_2O_3 substrate in a 200 kV TEM, then irradiated with 1 MeV electron beam (EB) in a high voltage transmission electron microscope (HVTEM). Further more, nanodendrites are fabricated with EBID using higher energy EB. Structure and morphology of the nanodendrite are characterized.

EBID is performed using a TEM, JEM-2010F operated at 200 kV, with tungsten hexacarbonyl ($W(CO)_6$) powder as a precursor. After preparation of the nanodendrite on a substrate, crystalline Al_2O_3 thin film, the sample is set in an HVTEM, JEM-ARM1000, operated at 1 MV. The nanodendrite was irradiated with 1 MeV EB at a current density of about 6.4 A cm^{-2} at room temperature. Nanodendrites are also fabricated with 400 and 1000 eV EB. The structure change is characterized with JEM-ARM1000 before and after the EB irradiation.

Fig. 1 shows a high resolution electron microscopy (HREM) micrograph and a fast Fourier transformation (FFT) pattern of as-prepared W-nanodendrites. The lattice spacing shown in the figure is close to that of {110} of bcc W crystals. Combined with electron diffraction (ED) analysis, it is clarified that these crystals are in bcc W structure. Preferential lattice orientation is observed from fig. 1b. Lattice fringes can not be observed in many places, indicating that a part of them is in amorphous state. After irradiated with 1 MeV EB for 100 minutes, some small changes are observed at some tips, as shown with B in fig. 1 and 2. However, almost all the grains crystallized, and the preferential lattice orientation does not exist anymore as observed in fig. 2. The results evidence that the irradiation makes the structure change in morphology and fulfilled a crystallization of almost all part of the structure. The crystallization is considered to be attributed to irradiation enhanced diffusion of W-atoms. 1 MeV for electrons is not enough to displace a W-atom in W-crystals but is enough to displace one in W-amorphous. Based on the above results, W-nanodendrites are fabricated with 400 and 1000 keV EB. These nanodendrites have much better crystallinity than those fabricated with 200 keV EB. The present work suggests a method to fabricate W-nanostructure with a better crystallinity.

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[2] M. Song, K. Mitsuishi, M. Tanaka, M. Takeguchi, M. Shimojo and K. Furuya, Appl. Phys. A, (2005), in press.

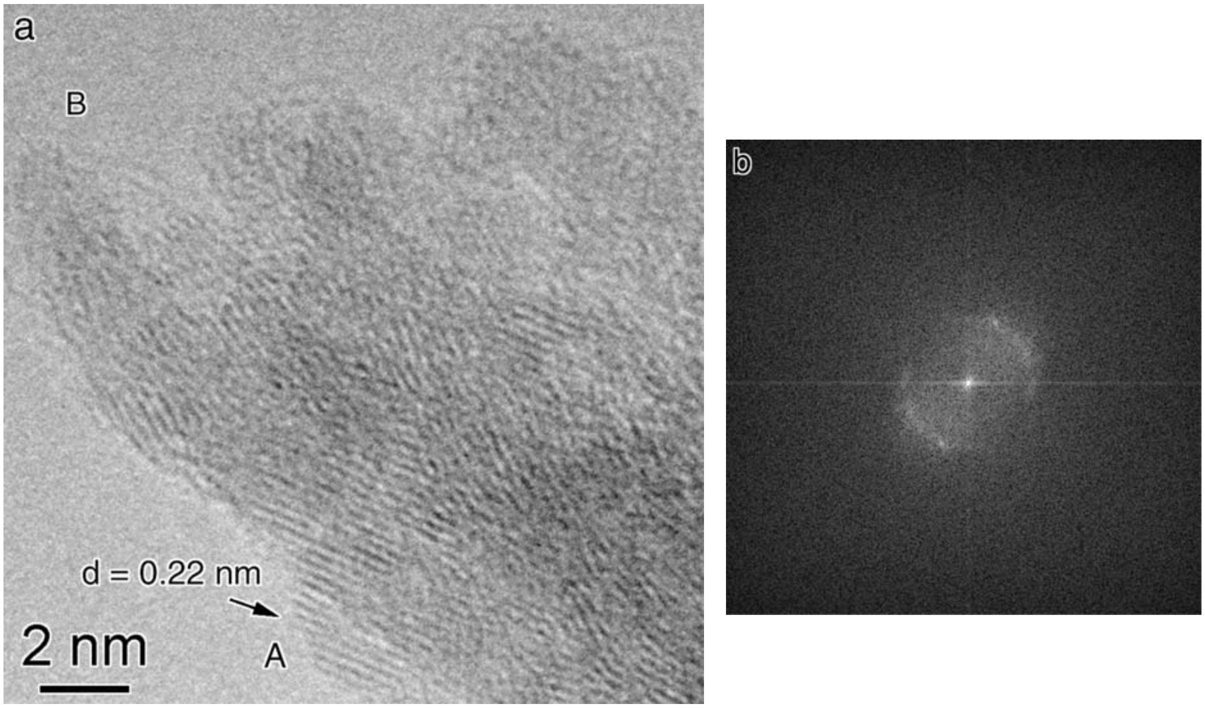

Fig. 1. An HREM micrograph (a) and fast Fourier transformation (FFT) pattern (b) of a dendrite structure. Lattice spacing is indicated in grain A. Arrow B indicate a tip of the structure.

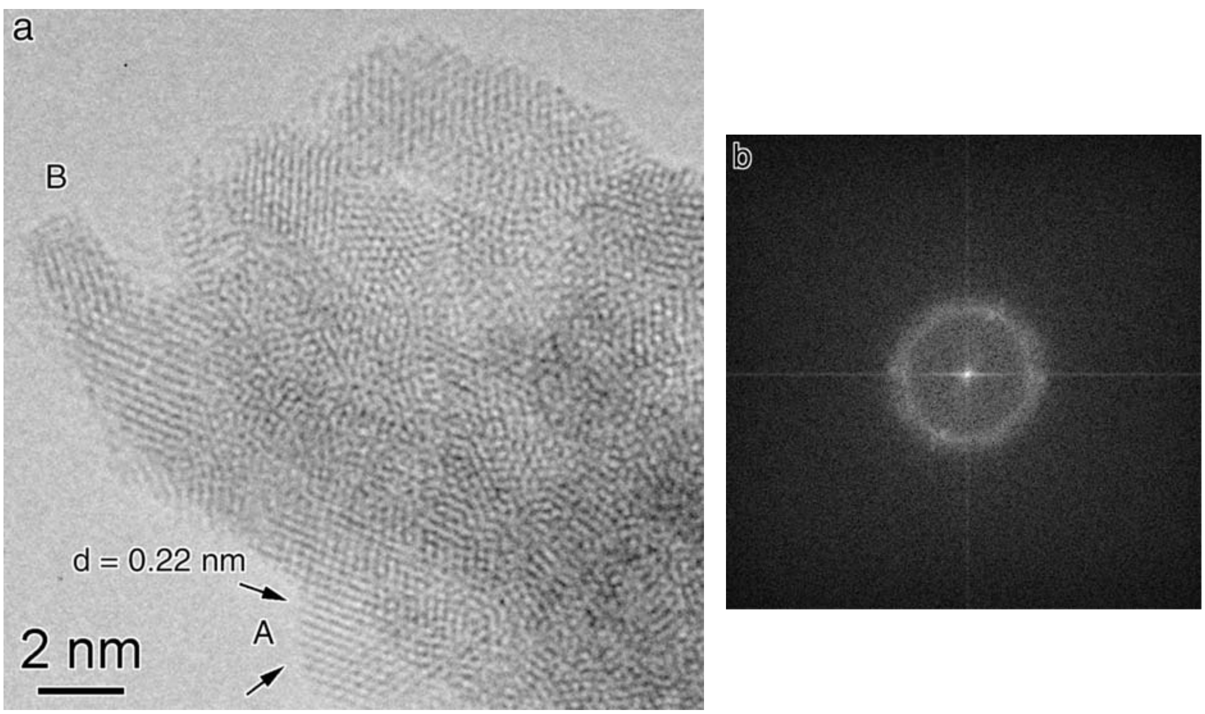

Fig. 2. An HREM micrograph (a) and an FFT pattern (b) of a dendrite structure after 1 MeV EB irradiation for 100 minutes. Lattice spacing is indicated in grains A. Arrow B indicates a tip.

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