646 CD
DOI: 10.1017/S143192760606510X
Microsc Microanal 12(Supp 2), 2006


# Influence of Beam Energy and Probe Size on the Process of Electron-Beam-Induced Deposition

Zhi-Quan Liu, Kazutaka Mitsuishi, Kazuo Furuya

High Voltage Electron Microscopy Station, National Institute for Materials Science (NIMS)
3-13 Sakura, Tsukuba 305-0003, Japan

Electron-beam-induced deposition (EBID) is a resistless method and can add desired materials on any position of substrate directly, which is suitable for three-dimensional fabrication [1]. This process includes the electron-solid interactions among three entities: electron beam, substrate, and gas precursor [2]. These interactions are so complicated that, so far, parts of them are still unknown and need to be studied further. The present study focuses on the entity of electron beam. By changing its energy and probe size, the influence on the process of EBID was investigated.

EBID was performed in a SEM with 20keV electrons, a STEM with 200keV electrons, and a TEM with 400keV electrons, respectively. Both SEM and STEM were equipped with a FE-gun, while the TEM uses a $LaB_6$ filament. The basic pressure is in the order of $10^{-5}$ Pa for SEM and STEM, and $10^{-6}$ Pa for TEM. During EBID the pressure did not change much after introducing $W(CO)_6$ gas into the chamber. Carbon thin film (about 100nm-thick) was used as substrate to deposit tungsten tip.

The profiles of tungsten tip deposited with 20keV, 200keV, and 400keV electrons were shown in Fig.1(a), (b), and (c), respectively, which shows the in-situ growth of tips. Fig.1(a) and (b) are secondary electron (SE) images, while Fig.1(c) is TEM images. The tip was deposited in a "spot mode" by focusing and fixing the electron beam on the top surface of carbon film for different seconds, and the images were taken by tilting the substrate 30 degree after deposition. With 20keV electrons tip grew on the top surface of substrate, and there was no tip on the bottom surface. Using 200keV electrons, deposition also happened on the bottom surface as indicated by an arrow in Fig.1(b). However, the size of the bottom tip is small and the growth of the top tip is still dominated. When 400keV electrons were used in EBID, the growth of the bottom tip was comparable to that of the top tip, as shown in Fig.1(c). (Dashed line indicates the position of the carbon film, which was transparent to electron beam in TEM images.) The length (or height) of top and bottom tips deposited with different electron energy was summarized in Fig.2. In order to differentiate from the top tip (open symbols), negative values were assigned to the bottom tip (solid symbols). In this time span (60s-2000s) the growth of the top tip is nearly linear, with a rate of about 1.01nm/s for 20keV electrons, 0.89nm/s for 200keV electrons, and 0.43nm/s for 400keV electrons. For 200keV electrons, the length of the bottom tip saturates quickly at the deposition time around 180s to a value of about 120nm. However, longer bottom tip can be fabricated using 400keV electrons. The bottom tip deposited at 1800s is about 745nm-long. Although the bottom tip length is also turning to saturation for 400keV electrons, it is still not saturated yet before the deposition time of 2000s. As a result, low energy electrons result in a shorter bottom tip. Fig.3 shows the tip deposited with different probe sizes using 400keV electrons in TEM. The diameter (full width at half maximum) of spot 8, spot 7, and spot 6 is about 70nm, 100nm, and 180nm, respectively. The tip length as a function of normalized electron dose was shown in Fig.4. Smaller probe size results in a higher growth rate, higher aspect ratio, and a longer bottom tip. These results can be understood considering the interactions between electron and solids.

References

[1] Z.Q. Liu et al., Appl. Phys. A 80 (2005)1437.
[2] H.W.P. Koops et al., J. Vac. Sci. Technol. B 13 (1995) 2400.

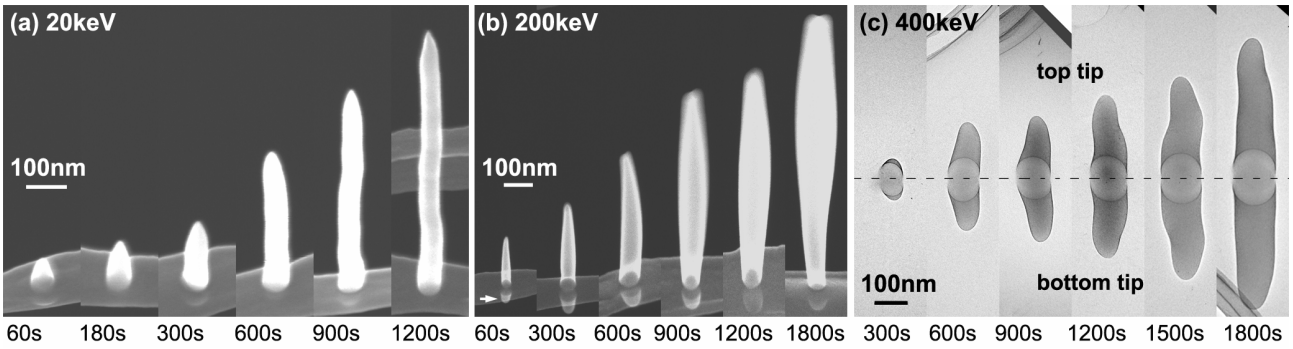


Fig. 1. Tungsten tips deposited on 100nm-thick carbon film using (a) 20keV electrons in a SEM with a probe size of 2nm; (b) 200keV electrons in a STEM with a probe size of 0.8nm; (c) 400keV electrons in a TEM with a probe size of about 70nm.

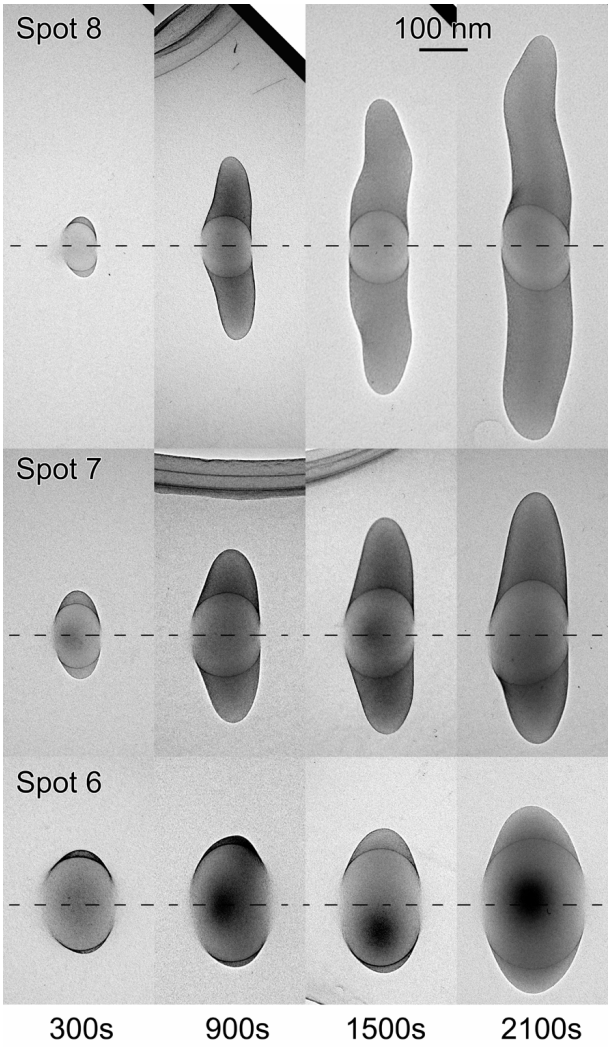


Fig. 3. Images of tungsten tips deposited with probe sizes of 70nm (spot 8), 160nm (spot 7), and 180nm (spot 6) using 400keV electrons in a TEM.

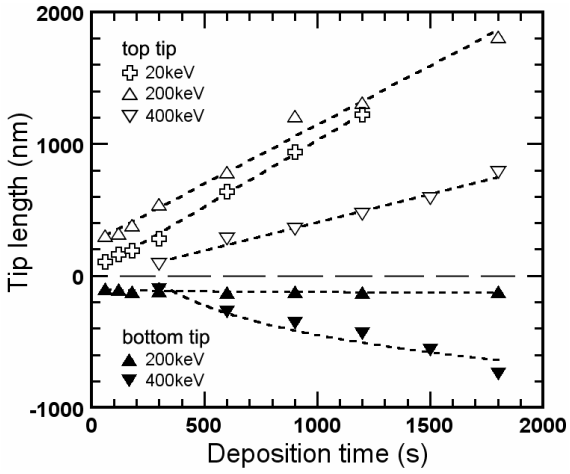


Fig. 2. Growth behavior of top and bottom tips showing the influence of electron energy.

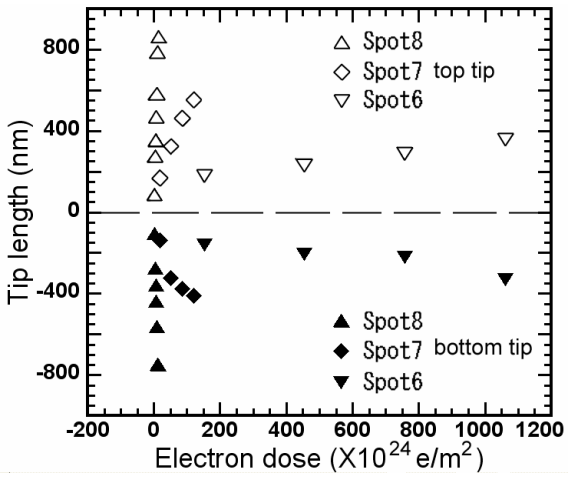


Fig. 4. The plots of top and bottom tip length summarized from Fig.3, showing the effects of probe size on the process of EBID.

https://doi.org/10.1017/S143192760606510X Published online by Cambridge University Press