

## Fabrication and Investigation of Supertips on Tungsten AFM Probe

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In order to improve the imaging quality, a fine supertip with small lateral size is needed in scanning tunneling microscope (STM) or atomic force microscope (AFM) [1,2]. As electron-beam-induced deposition (EBID) is a method of additive lithography with a resolution down to several nanometers [3,4], it was often used to fabricate supertips on the probe of STM [5] and AFM [6], which is one important aspect of nanofabrication. In the present study, supertips were successfully fabricated on conventional tungsten probes using EBID in scanning electron microscope (SEM). The property-related microstructures were investigated in transmission electron microscope (TEM). Efforts were made to improve the crystallization of the supertip, hence to improve its properties.

EBID was carried out in a JEM-6700F SEM using  $W(CO)_6$  as gas precursor. The probe size of electron beam was 2nm, and the chamber pressure during deposition was about  $2 \times 10^{-4}$  Pa. TEM observations were done in a JEM-ARM1000 TEM operated at 1000kV with a basic pressure of  $3-5 \times 10^{-6}$  Pa. Annealing of supertip was also done in TEM with a Gatan heating holder.

Fig.1(a) shows an image of a tungsten AFM probe, which was used as substrate for EBID. Its end/apex was cleaned by focused-ion beam (FIB) before deposition. Two methods were used to fabricate supertips. One is scan deposition of self-supporting tip using the “scan mode” of SEM. With this method, a small lateral size can be obtained, and the aspect ratio of supertip is determined by the scan distance of electron beam. The other method is stationary deposition of self-standing tip using the “spot mode” of SEM. The tip diameter turns to saturation, and the aspect ratio of tip is determined by the deposition time. Fig.1(b) shows the self-supporting supertip fabricated on AFM probe by scanning electron beam along the axis of probe (scan deposition method). The beam scan speed is 2.72nm/s, and the obtained supertip has a lateral size of 20nm and an aspect ratio of 50 (length/width). The as-deposited microstructure of this supertip was characterized as amorphous

phase. After annealed in the vacuum of TEM at 1173K for 6 hours, many nanocrystallites in size of 2-3nm precipitated from the original amorphous substrate. The supertip fabricated with stationary deposition method was shown in Fig.1(c). Its original microstructure consists of nanocrystallites in size of 2-4nm. After annealing, these nanocrystallites grew up with an increased size of more than 5nm. These crystals were identified as pure tungsten, tungsten carbides, and tungsten oxides. It is expected that improvement of crystallization of the supertip can improve its properties like conductivity. This will be presented and discussed at the conference time.

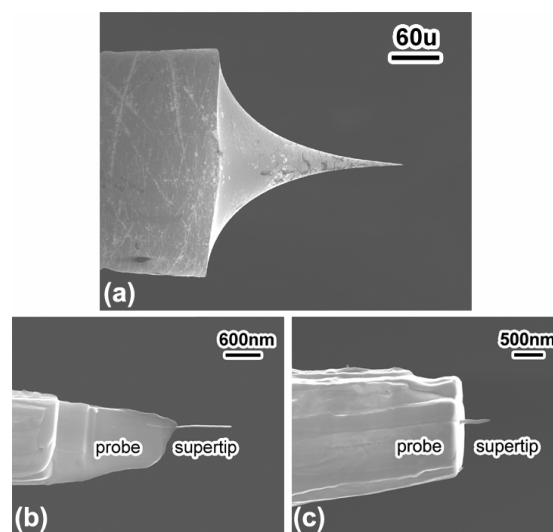


Fig. 1 (a) Conventional tungsten AFM probe. (b) Self-supporting supertip fabricated with scan deposition method. (c) Self-standing supertip fabricated with stationary deposition method.

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