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Non-Destructive Examination of Carbon Nanotube AFM Probes by HRTEM

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Carbon nanotubes (CNTs) are mechanically stiff and have very large aspect ratios in morphology. These characteristics make carbon nanotubes very attractive as atomic force microscope (AFM) probes by attaching a nanotube on the commercial Si or Si_3N_4 tips [1-3]. Theoretical studies have suggested that the resolution of an atomic force microscope (AFM) is very much dependent on the characteristics of cantilever tip, in which the tip diameter and the aspect ratio are most crucial in improving the performance of the AFM. Structural and functional characterization has shown that the microstructure of the attached nanotubes on an AFM cantilever tip will greatly influence its function and performance [4]. However, limited by its resolution, the details of the cohesion between the nanotube probe and the cantilever tip are usually not revealed when the structure is examined in an optical microscope or even scanning electron microscope (SEM), as shown in FIG. 1a, though SEM offers an efficient method to observe the morphology of the tip. On the other hand, these AFM tips do not fit the commercial TEM sample holders for direct examination without alteration.

We have developed a custom-designed TEM sample holder that allows us to examine the AFM cantilever directly without any alteration. The CNTs were assembled on the commercial AFM single crystal Si cantilever by dielectrophoresis using a similar method as that used to assemble single-walled carbon nanotubes (SWNTs) on tungsten tips [5]. Using this special-purpose sample holder, we observed the microstructure of the CNTs probe and the contacting area of CNTs and Si tip by TEM (JEM-2010F).

FIG. 1b shows a typical image of the nanotube adhered to a commercial AFM tip (shown in FIG. 1a). The surface of the SWNT bundle is smooth and the diameter is quite uniform. The SWNT bundle attaches to the Si tip along an edge of the tip rather than on the tip's flat surfaces. The aspect ratio of this bundle is about 400 with length of 8.5 μm. High resolution transmission electron microscopy (HRTEM) image of Si tip, FIG. 2a, shows that there is an amorphous layer of about 10 nm thickness on the outer surface of the Si tip. FIG. 2b shows the high resolution image of the SWNT bundle, which is coupled with amorphous carbon. The selected-area electron diffraction pattern and enlarged image of the squared area, shown as insets, indicate that the nanotubes are well aligned. It is also suggested that the amorphous carbon around the SWNTs and the amorphous layer on the Si tip might enhance the adhesion between the nanotube bundle and the Si tip.

References

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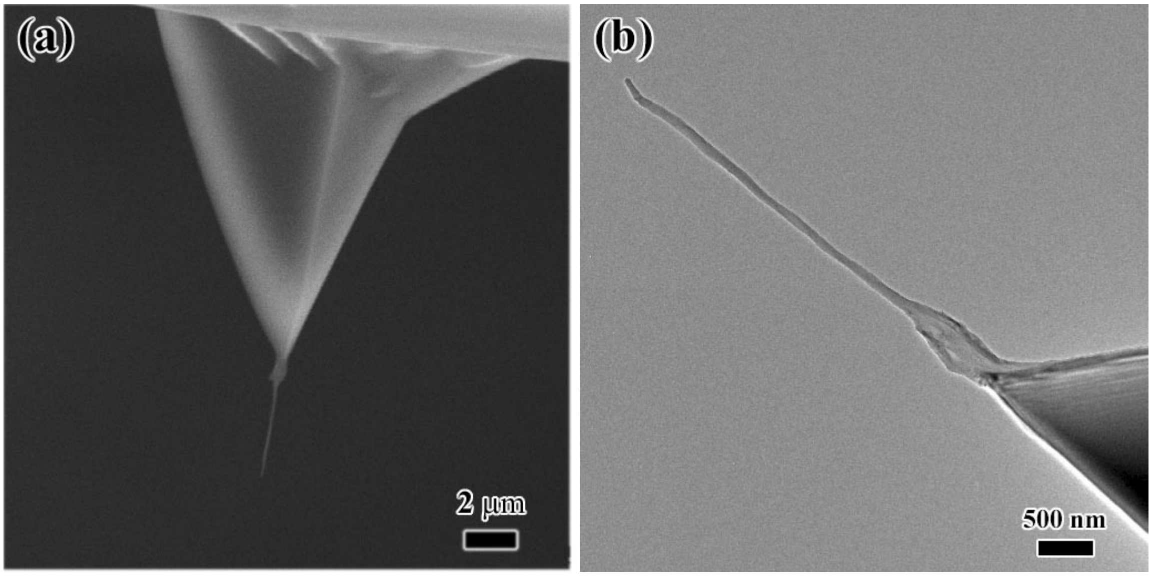

FIG.1 SEM (a) and TEM (b) morphology of carbon nanotube AFM probe, in which SWNT bundle is attached to the commercial AFM Si tip. The aspect ratio of this carbon nanotube AFM probe is about 400 with length of 8.5 μm

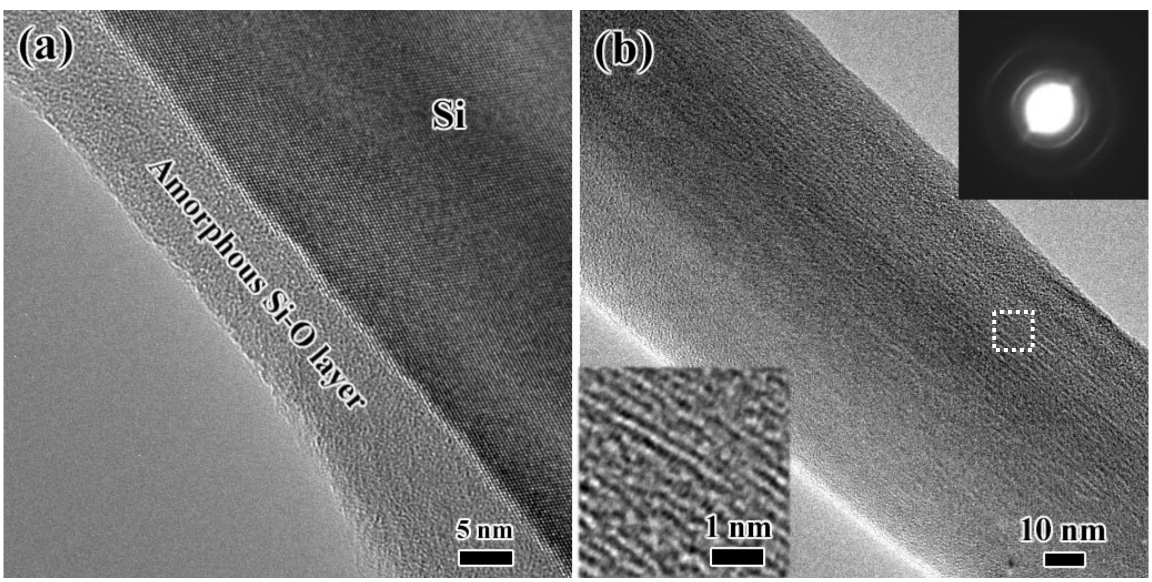

FIG.2 (a) HRTEM image of AFM Si tip showing crystalline region and the amorphous layer of about 10 nm thick. (b) Well aligned SWNT bundle with amorphous carbon. The amorphous carbon helps cement the nanotube bundle and further stabilize the nanotube probe.