

Sub-10 nm-thick-carbon nanotube tip for AFM

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Abstract

Atomic force microscopy (AFM) is a powerful tool for dimensional metrology at the nanometer scale, while linewidth metrology in the semiconductor industry is one of the most important applications. Though ITRS dictates more and more aggressive application of AFM to 3D nano structures, in some cases, the high aspect ratio tips cannot even enter the narrow trenches, beyond the region where we can at least estimate the tip-induced artifact. The limitations come from not only geometrical considerations but also tip-sample interactions at the vertical sidewall. Researches are necessary obviously in both the tip control and tip itself. As to the tips, carbon nanotube (CNT) has been regarded as one of the ideal tips, and several companies already sell the multi-walled nanotube (MWNT) tips. MWNT are thicker than 10 nm, becoming too large for the future devices. We may need thinner tube to decrease tip width while increasing tip overhang. In this work, the double-walled carbon nanotube (DWNT) tip was fabricated and employed in AFM to study the behavior at the vertical sidewalls.

Nanomanipulation in FESEM

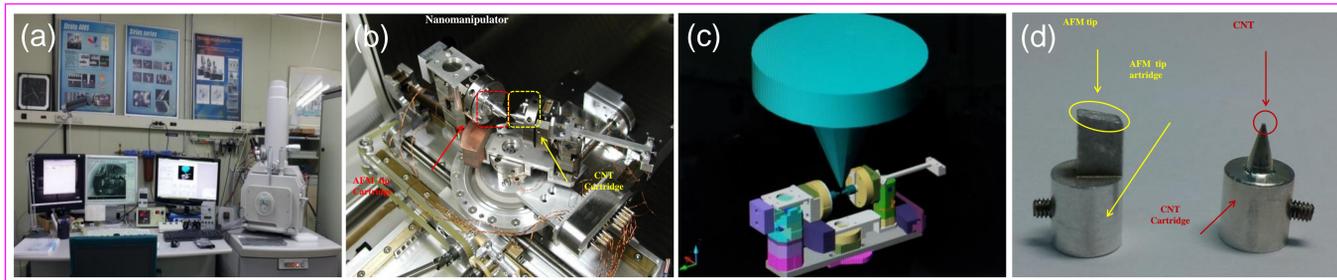
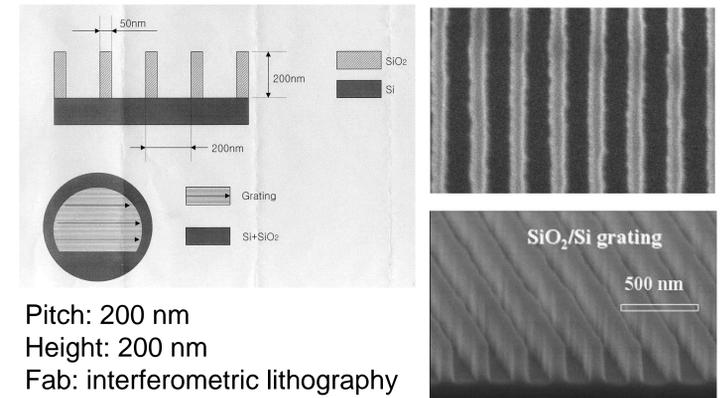
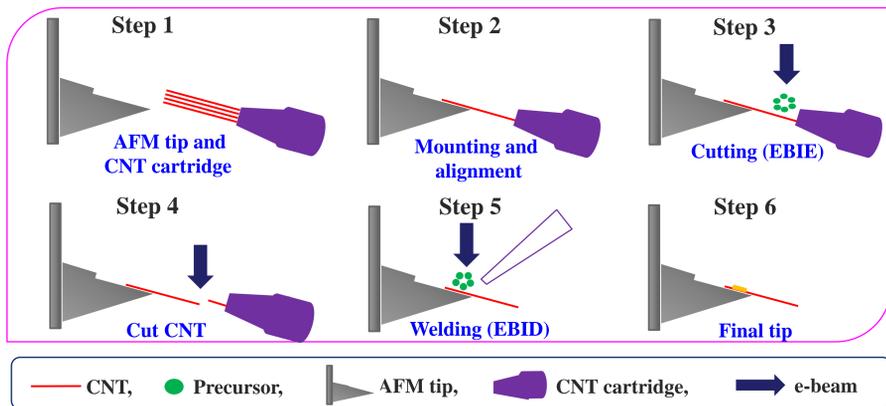


Fig. (a) FESEM, (b) nanomanipulator inside SEM chamber, (c) Configuration of electron beam, CNT cartridge and AFM tip cartridge. (d) AFM tip cartridge and CNT cartridge.

Grating sample



Fabrication of CNT tips for AFM



AFM tips used

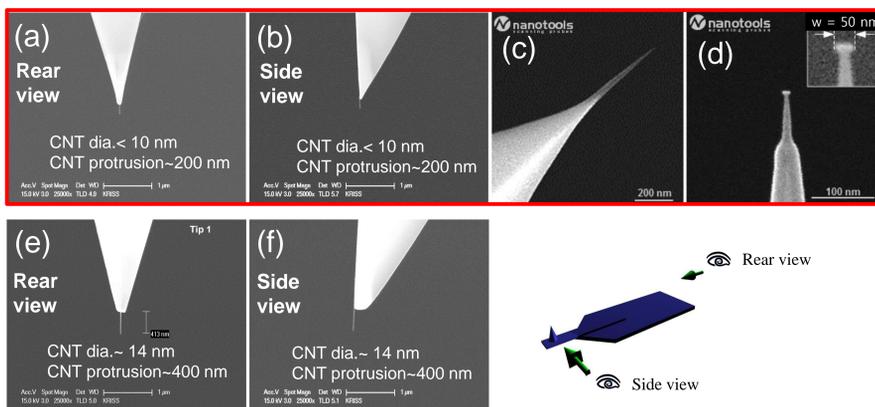


Fig. (a) & (b) DWNT tip (home-made), (c) conical tip (MSS-FMR, Nanotools), (d) flared tip (CDR50, Nanotools), (e) & (f) MWNT tip (home-made) for comparison.

Results & Discussion

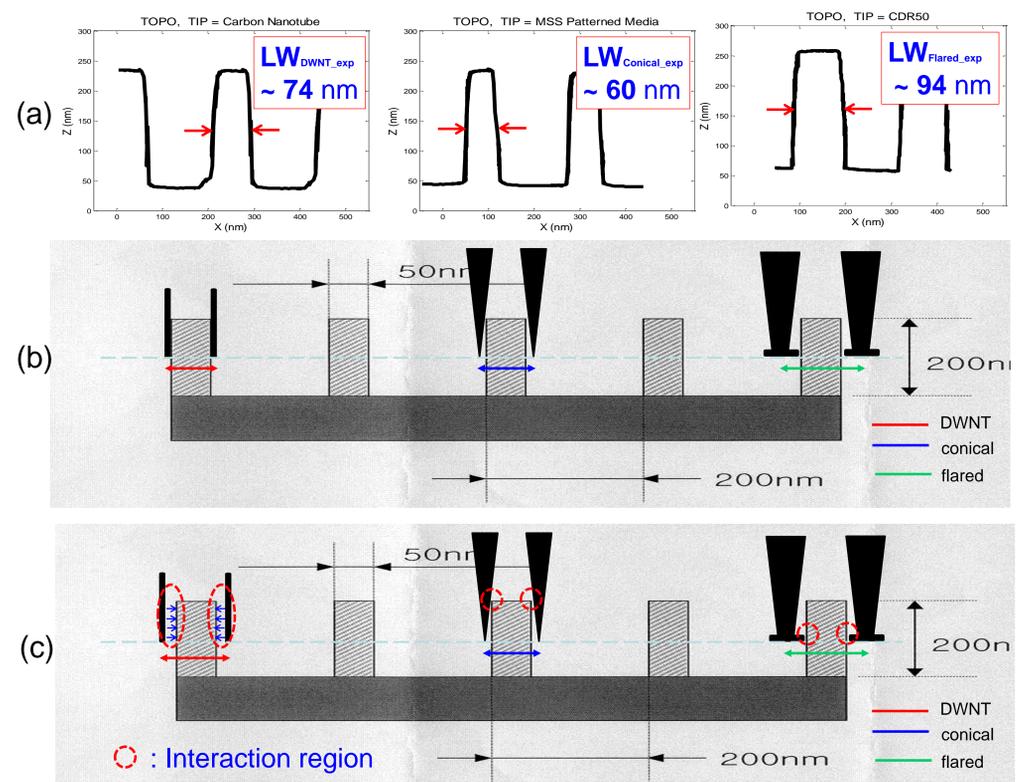


Fig. (a) Linewidth at the middle height from the profiles obtained under the adaptive scan mode of AFM (Autoshot, Nanofocus) without tip -correction (b) consideration of tip geometry only (c) Consideration of the assumed tip-sample interaction as well as the tip geometry.

Summary

- DWNT tip (dia. < 10 nm from the SEM image) was fabricated using nano-manipulation and electron beam-induced deposition and etching in SEM.
- Using the DWNT tip, a nano scale grating was measured under the adaptive scan mode of AFM to reduce the tip chattering at the sidewall.
- The sample was also measured with other high aspect ratio conical and flared tips commercially available, and then compared.
- DWNT tip-measured linewidths are much greater than expected from the geometrical consideration only.
- On the while, conical/flared tip-measured linewidths are roughly the same as those expected from geometry of the tips and line.
- The results are considered to show the case where the effect of the tip-sample interaction dominates the tip geometry.
- Unlike the conical/flared tips, DWNT in parallel to the vertical sidewall is delocalized(wall-to-wall interaction). Either or both of tube bending and other interactions(shear, for example) will impact the measurements. The exact mechanism, however, still remains unclear.
- The least we can say is that, in equilibrium at a given set point, the DWNT tip (more exactly mother tip) stay farther from the wall than the flared/conical tips, so the lines may have been measured thicker.
- Our next step is to deposit a Pt-ball at the DWNT tip end, and then re-measure the same grating to compare with the straight DWNT tip.