Enabling Nanometrology for High Aspect Ratio Structures with Carbon Nanotube AFM Probes

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ABSTRACT

Atomic force microscopy (AFM) and carbon nanotube (CNT) are two cornerstones in the emerging field of nanoscience and nanotechnology. This paper discusses recent progress in combining CNT probes with the industrial AFM tool to measure depth, sidewall angle, pitch of narrow and deep space features in nanoscale semiconductor micro-chip manufacturing processes. As the technology roadmap advances to the 45nm node and below, the narrow space features with high aspect ratio (trench or hole) pose a difficult challenge for optical, e-Beam, or even conventional AFM dimension metrology. Data in this paper demonstrated that AFM with CNT tips shows a great potential to provide a gauge capable metrology solution for STI etch, contact etch, metal trench etch, and via etch for logic, DRAM, or flash memory devices. The inline etch depth metrology by AFM is critical for production inline process monitoring, engineering process experiments, or calibrating scatterometry simulation models. CNT probes equally apply for metrology needs in other similar nanoelectronic manufacturing such as photomask and magnetic thin film head.

Traditional AFM probes are of conical shape made of silicon materials by focused ion beam (FIB) processing. Shown in Figure 1, CNT probes are cylindrical profile and inherently suitable for high-aspect narrow trench measurements. Figures 2-3 show that the CNT tip is capable to measure the bottom trench width and total depth more reliably than a FIB tip. The precision for sidewall angle measurement is shown in Figure 4. Besides the superior metrology capability, CNT probes have been proved to have a greater lifetime than most of other AFM probes because of the excellent mechanical properties of carbon nanotube. Figure 5 shows a CNT tip shape changed a little after over 2000 measurements.

Keywords: atomic force microscopy (AFM), AFM tips, carbon nanotube (CNT) probes, depth metrology, high aspect ratio trench and hole, semiconductor manufacturing

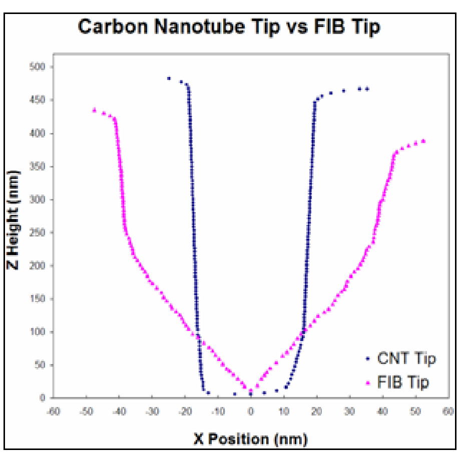

Figure 1 Compare the tip shapes for FIB and CNT probes. The CNT cylindrical shape is more prone to reach down to high aspect ration holes or trenches.

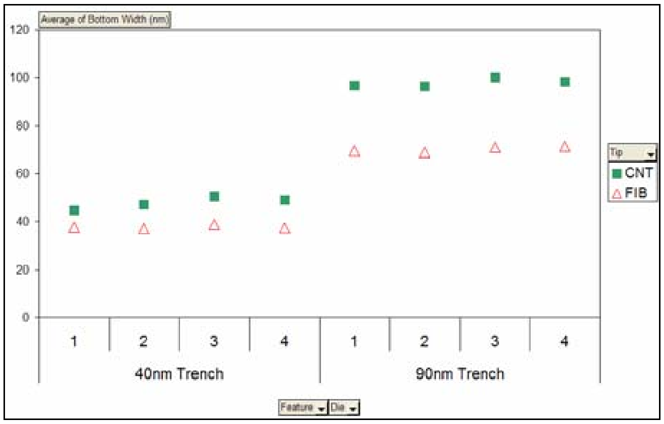

Figure 2 Superior capability of CNT probes for bottom trench width measurements.

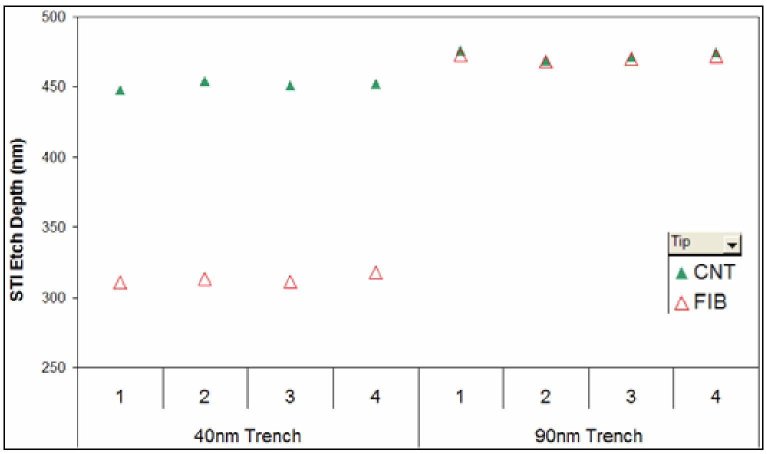

Figure 3 Superior capability of CNT probes for trench depth measurements.

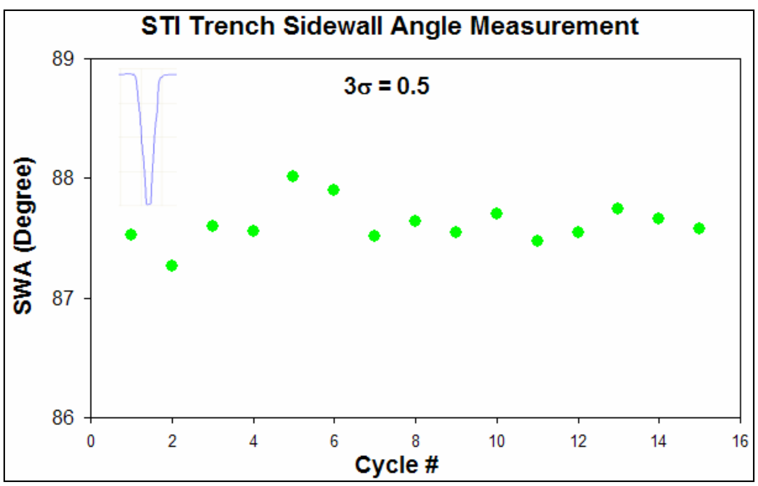

Figure 4 The sidewall angle measurement precision by CNT tip.

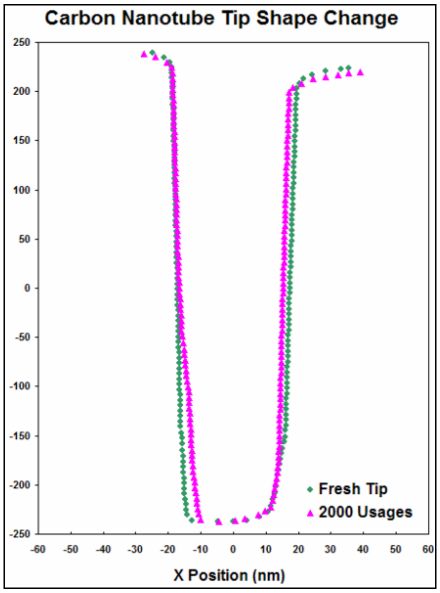

Figure 5 The CNT probe shape hardly changes after over 2000 usages.