Critical dimension measurement using new scanning mode and aligned carbon nanotube SPM tip

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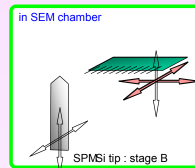
Abstract

We measured critical dimension of the shallow trench isolation using the new scanning mode and the aligned carbon nanotube.
The aligned carbon nanotube was assembled in the SEM camber. This tip was well controlled during fabrication. Tip diameter is uniform around 20nm and its attached angle is within +/-1.5deg. to the sample normal. Aspect ratio (length/diameter) is greater than 30.
New scanning mode is composed of two function, one is transporting the tip along the trench structure and the other is detecting the sample surface. This mode can faithfully trace the steep side wall using flexible CNT tip without tip damage.
Critical dimension (CD) measurement [1] of shallow trench isolation (STI) was performed using this tip.

Tip Fabrication

The fabrication process of the aligned CNT (A-CNT) tip is as follows. Silicon cantilever is introduced in the focused ion beam (FIB: SMI2050 SII NanoTechnology Inc.) chamber. Silicon tip is ground by fine focused ion beam and generates the flat surface which is precisely aligned normal to the sample surface. Next, using the 6-axis manipulator, CNT is carried on the aligned surface to assemble the A-CNT tip [2]. Fig.1 shows a schematic drawing of the A-CNT tip assembling process in the SEM chamber. Fig.2 shows a scanning electron microscope image of the A-CNT tip.



Two stages movable independently.
H. Nishijima, *et al*, APL74, 4061 (1999)

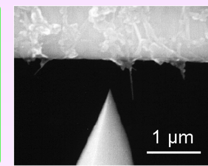


Fig. 1. Schematic drawing of the A-CNT tip assembling process in the SEM chamber.

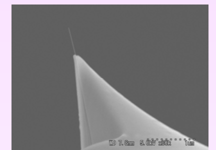


Fig. 2. SEM image of the A-CNT tip
length : 700 nm,
diameter : 20 nm,

Sampling Intelligent Scan (SIS) Mode:

New Scanning mode

We made the new scanning mode (Sampling Intelligent Scan : SIS mode) which can faithfully trace the steep side wall using flexible CNT tip. The cantilever vibrates small amplitude at its resonance frequency to detect the sample surface. Another large Z movement is superimposed on the small vibration at each sampling point to move the tip up and down along the steep side wall. In this way, dynamic range of the tip traceability is expanded. Fig.3 shows a schematic drawing of the tip trajectory of SIS mode. Table 1 is listed up advantages of SIS mode. Z resolution of this mode is around 0.05nm. Fig.4 shows an atomic sapphire step（Al_2O_3:Step height 0.21nm) image using SIS mode.

Table 1 SIS Mode's advantages

1. Little damage both sample and probe tip
2. Wide dynamic range tracing the deep structure
3. Accurate traceability even on the steep side wall
4. Good stability during the measurements

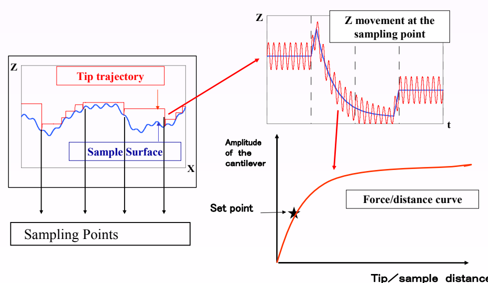


Fig.3 Schematic drawing of SIS mode of operation

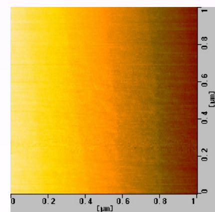


Fig.4 Atomic sapphire step（Al_2O_3: Step height 0.21nm) image using SIS mode.

CD Measurement

We used the SPM (SPA550, SII NanoTechnology Inc.) equipped with a voice coil motor linear scanner to measure shallow trench isolation (STI). The scanner linearity was better than 0.2 %. Length and height calibration was performed using VLST standard samples .

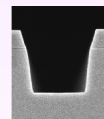


Fig. 5-a. Cross sectional SEM image of Shallow Trench Isolation.

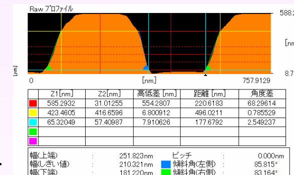


Fig. 5-b. Cross sectional SPM image of Shallow Trench Isolation

Scanning width is 1 μ m.
Scanning speed is 6sec/line.
Width 496.0nm, Depth 554.2 nm,
Sidewall angle 84 degrees.

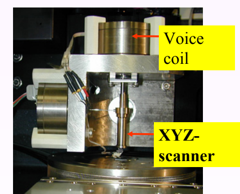


Fig. 6 Photograph of the voice coil motor linear scanner.

	Depth[nm]	Pitch[nm]	Angle left	Angle right
1	554.2	496.2	85.8	83.2
2	554.0	497.2	85.3	82.9
3	554.5	497.4	85.4	83.3
4	555.3	499.3	85.1	83.9
5	554.0	497.5	85.0	83.9
6	555.0	497.4	84.7	83.6
Average	554.5	497.5	85.22	83.5
σ	0.497	0.917	0.343	0.368

Fig7. STI CD measurement results

Depth σ ＝0.5nm Pitch σ ＝0.9nm

Summary

New Scan mode and well- Aligned-CNT tips were developed and applied to the CD measurements. The CD measurements obtained good repeatability because the tip can faithfully trace the steep side wall by the SIS mode and the A-CNT tip has high aspect ratio, robustness and precise control of the attached angle.

Reference

1. K.Miller, D.Fong, D.Dawson, B.Todd, SPIE Microlithgraphy 4689 (2002)
2. Y. Nakayama, S. Akita J. Phys. D32 1044 (1999)