

# Tungsten Deposited SPM Tips for Critical Dimension and Electric Property Measurements

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## Abstract

We fabricated a robust and high aspect ratio tungsten deposited tip (TD tip) using a Focused Ion Beam (FIB). This tip was well controlled during fabrication. Tip diameter is uniform at around 90nm and its growing length is proportional to the irradiation time of the ion beam. Tip shape is a cylindrical pillar and aspect ratio (length/diameter) is greater than 10. Growing angle of the tip is identical to the incident angle of the ion beam. Critical dimension (CD) measurement [1] of shallow trench isolation (STI) and conductivity evaluation was performed using this tip.

## Fabrication

We used a FIB system (SMI2050 Seiko Instruments Inc.) for tip fabrication. A Ga<sup>+</sup> ion beam was injected at 30keV. Beam diameter was about 5nm at an ion beam current of 1pA. Hexacybonyltungsten (W(CO)<sub>6</sub>) was stored in a reservoir heated at 58 to 64 °C in order to adjust the pressure of the FIB chamber to about 1.2 x10<sup>-3</sup> Pa during gas injection. The distance between the gas nozzle and ion beam center was adjusted to 500 μm. Fig.1 shows a schematic drawing of the deposition mechanism. Adsorbed gases were decomposed by both scattered ions and secondary electrons, and then metal tungsten was deposited as a cylindrical pillar. (W(CO)<sub>6</sub> → W + 6 CO) The radius of the pillar was about 40 nm, the sum of the ion scattered radius (20nm at 30kV) and secondary electron scattered radius (20nm). Growing speed was 12 to 20 nm/second, or about 14% of the total injected gas molecules contributed to the deposition [2]. The growing length was proportional to the irradiation time of the ion beam.

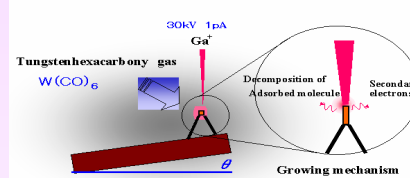


Fig. 1. Schematic diagram of TD tip fabrication in the FIB chamber. Hexacybonyltungsten gas at about 1.2 x10<sup>-3</sup> Pa was decomposed by the ion beam (1pAat30kV) and deposited in the shape of a cylindrical pillar. Theta (θ) shows mounting angle of the cantilever.

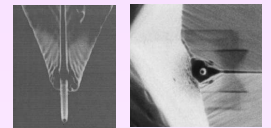


Fig. 2. SIM image of the TD tip (Side View, TOP view)

length of 822 nm,  
diameter of 90 nm,  
Sidewall angle 89 °

## CD measurement

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

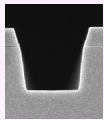


Fig. 4-a. Cross sectional SEM image of Shallow Trench Isolation.  
Width 505 nm  
Depth 520 nm.

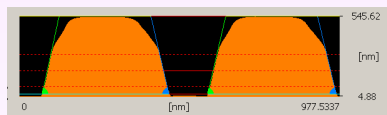


Fig. 4-b. Cross sectional SPM image of Shallow Trench Isolation Scanning width is 1 μm. Scanning speed is 6sec/line.  
Width 508.6 nm Depth of 546 nm, Sidewall angle of 84 degrees.

Fig. 5. 30 frame repeatability of pitch and depth of Shallow Trench Isolation

Pitch repeatability  
502.9nm±0.78 nm(1 %)  
depth repeatability  
550.4 nm±0.53 nm(1 %).

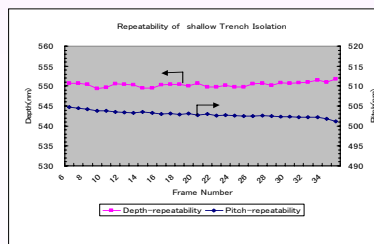


Fig. 6. 30 frame repeatability of angle of Shallow Trench Isolation

Angle repeatability  
83.9° ±0.05° (1 %)

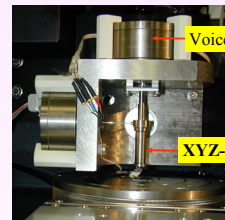
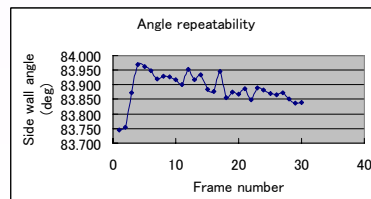


Fig. 3. Photograph of the voice coil motor linear scanner.

$X = F_x/k_x$   
(F<sub>x</sub> : Driving force X, k<sub>x</sub> Spring constant :Magnification factor)

$Z = F_z/k_z$   
(F<sub>z</sub>:Driving Force, k<sub>z</sub> Spring constant)

The displacement is linearly proportional to the driving force.

## Electric property measurement

A silicon cantilever was coated by gold using the sputter coater and tungsten deposition process was followed. The Bottom part of the Tip is reinforced by additional deposition.

Measured the I/V curve and observed continuous current mapping images proved that the TD-Tip holds good and stable conductivity against long-term abrasion (219frame:112mm : 2 μm x 2561 line).

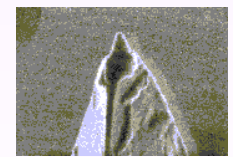


Fig. 7 Photograph of the conductive TD Tip.  
Length 300 μm, 6.33 X 10<sup>-3</sup> m

## Summary

Well-controlled TD tips were fabricated using the FIB. The CD measurements obtained good repeatability because of the high aspect ratio of the TD tip and robustness and precise control of the attached angle.

## Reference

1. K.Miller,D.Fong,D.Dawson,B.Todd, SPIE Microlithography 4689 (2002)
2. T.Kaito J. Vac. Soc. Jpn Vol46 , No2, 2003