



Multiscale SPM Lithography



S. Nishimura, T. Toyofuku, K. Miyashita, and J. Shirakashi
Graduate School of Engineering, Tokyo University of Agriculture and Technology



1. Introduction

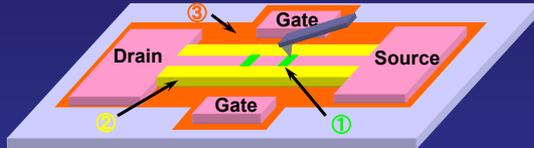
● SPM local oxidation lithography¹

→ Anodic oxidation within water meniscus formed between SPM tip and sample surface

[1] R. Garcia, M. Calleja, and H. Rohrer, J. Appl. Phys. 86, 1898 (1999).

● Fabrication of nanometer-scale tunnel devices such as planar-type tunnel junctions and single-electron transistors (SETs)²

[2] J. Shirakashi, K. Matsumoto, N. Miura, and M. Konagai, Jpn. J. Appl. Phys. 37 (1998) 1594.



composed of

Nanometer-scale structures (~ 10 nm)
Current confinement structures (μm)
Separation / isolation regions (μm)

→ We propose a new concept for the fabrication of such device by SPM local oxidation

2. Experimental

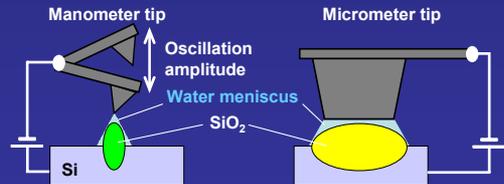
● SPM local oxidation with different size of SPM tip

→ A sharp tip, "Nanometer tip" (Tapping mode)

⇒ Applied for sub-10 nm resolution

→ A robust blunt tip, "Micrometer tip" (Contact mode)

⇒ Applied for large-scale regions



Under the SPM tip: $H_2O \rightarrow H^+ + OH^-$
Surface of the sample: $Si + 2H^+ + 2OH^- \rightarrow SiO_2 + 2H^+$ J. A. Dagata et al., Appl. Phys. Lett. 76 (2000) 2710.

3. Results and Discussion

Nanometer-scale SPM local oxidation

● Tapping-mode SPM local oxidation with amplitude modulation

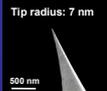
→ Amplitude: 72 nm ~ 432 nm

Voltage: 20 V

Scanning speed: 20 nm/s

⇒ Width: 31.3 ~ 18.3 nm

Height: 1.5 ~ 0.4 nm



Amplitude	Amplitude Modulation			
	72 nm	144 nm	288 nm	432 nm
SPM Image				

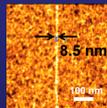
● Optimizing oxidation conditions

→ Amplitude: 292 nm, Voltage: 17.5 V

Scanning speed: 250 nm/s

⇒ Width: 8.5 nm

Height: 0.6 nm



● A larger amplitude of cantilever

→ Reducing lateral dimension of water meniscus

→ Decreasing average intensity of electric field strength

⇒ Smaller resolution in fabricated oxide

Micrometer-scale SPM local oxidation

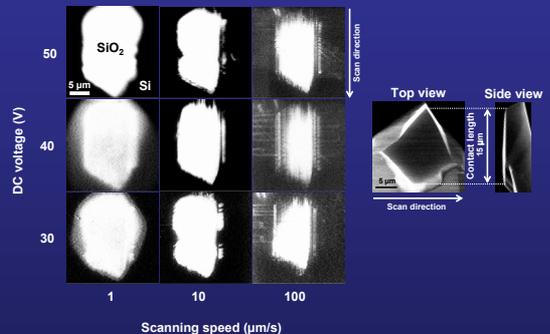
● Contact-mode SPM local oxidation with contact length of 15 μm tip

→ Voltage: 30 ~ 50 V, Scanning speed: 1 ~ 100 μm/s

⇒ Width: 15 μm

⇒ Throughput: 830 μm²/s [V = 50 V, S = 100 μm/s]

30,000 times larger than that of conventional SPM local oxidation



● Width of the Si oxide is completely determined by the contact length of the SPM tip

4. Conclusions

● Nanometer-scale SPM local oxidation: Realization of 8.5 nm in width of the Si oxide wire

● Micrometer-scale SPM local oxidation: Upscaled by using larger SPM tip (Width: 15 μm, Throughput: 830 μm²/s)