10 Micrometer-Scale SPM Local Oxidation Lithography

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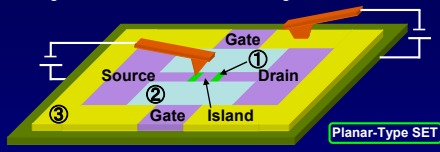
① Introduction

● Fabrication of Single-Electron Transistors (SETs) Using SPM Local Oxidation Lithography[1]



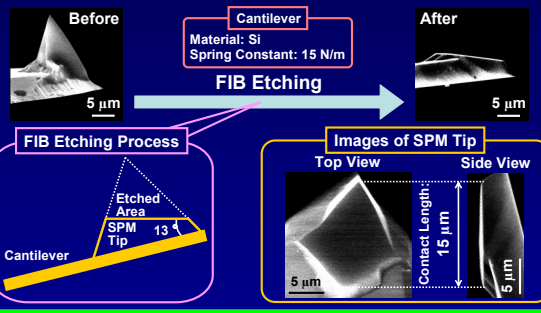
Planar-Type SET

Nanometer-Scale Oxidation[2]
① Tunnel Junctions

Micrometer-Scale Oxidation[3]
② Current Confinement Structures
③ Separation / Isolation Regions

[1] J. Shirakashi, K. Matsumoto, N. Miura and M. Konagai, Jpn. J. Appl. Phys. 37, 1594 (1998).
[2] S. Nishimura, T. Ogino, Y. Takemura and J. Shirakashi, J. Phys. Conf. Ser. 100, 052021 (2008).
[3] S. Nishimura, T. Ogino and J. Shirakashi, Jpn. J. Appl. Phys. 47, 715 (2008).

② Modification of SPM Tip Using Focused-Ion-Beam (FIB) Process



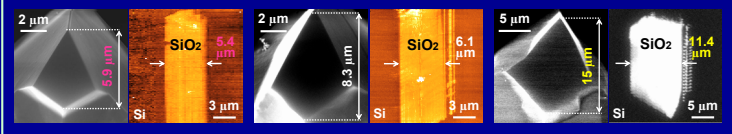
③ Fabrication of Si Oxide Structures

Experimental Conditions

Parameter
Humidity: 70 %
Bias Voltage: 5, 50 V
Scanning Speed: 0.5 ~ 200 μm/s
Number of Scan Cycles: 1 cycle
Contact Force: 0.1 ~ 2.8 μN
Contact Length: 5.9 ~ 15 μm

Sample
Material: p-type Si (100)
Resistivity: 1kΩ•cm

Large-Scale SPM Local Oxidation Lithography

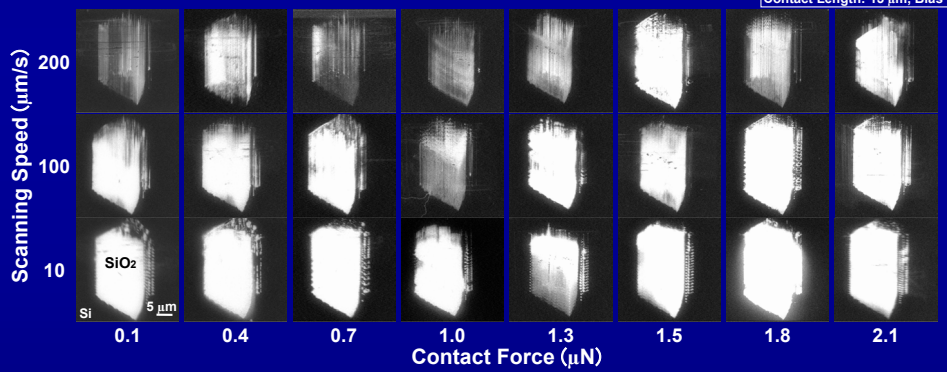


Contact Length [μm]	5.9	8.3	15
Bias Voltage [V]	5	50	50
Scanning Speed [μm/s]	0.5	10	10
Contact Force [μN]	2.8	1.5	1.5
Width [μm]	5.4	6.1	11.4
Height [nm]	0.6	2	※

※: Too Large to Measure by Our SPM

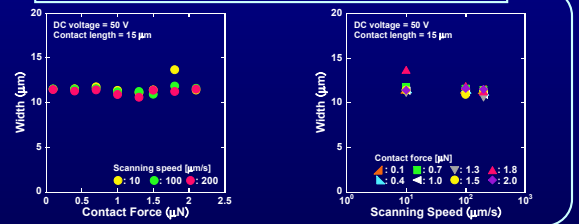
Influence of Contact Force on Large-Scale Oxidation

Contact Length: 15 μm, Bias Voltage: 50 V

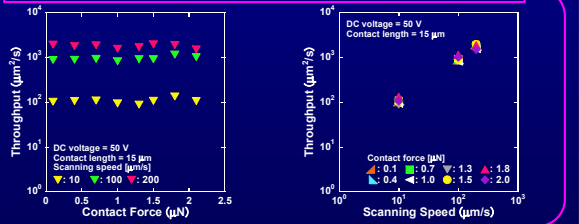


● Si oxide with good size uniformity was obtained at high contact forces above 1.5 μN.
→ The average distance between the etched surface of the SPM tip and the sample surface decreases at high contact forces.
→ The intensity of electric field is stronger than at contact forces below 1.3 μN.

Width of Si Oxide vs Contact Force and Scanning Speed



Throughput of Si Oxide vs Contact Force and Scanning Speed



④ Conclusion

○ 10 Micrometer-Scale SPM Local Oxidation on a Si Surface with a SPM Tip Having a Large Contact Length
→ Si oxide region over 11 μm width was produced by SPM tip with contact length of 15 μm.
→ Width of Si oxide depended on contact length of SPM tip with sample surface.

○ Influence of Contact Force on Size of Si Oxide
→ Si oxide with good size uniformity was obtained with a high scanning speed of 200 μm/s at high contact forces above 1.5 μN.
→ Throughput of 10 micrometer-scale SPM local oxidation reached about 10^3 $\mu m^2/s$ (scanning speed: 200 μm/s, contact force: 1.5 μN).