SHIRAKASHI GROUP

Nanoelectronics, Nanofabrication and Nanolithography

http://www.tuat.ac.jp/~nanotech/index.htm

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Keywords

Nanofabrication:

- Scanning Probe Microscopy (SPM)
  - Atomic Force Microscopy (AFM) ⇒Local Oxidation, Scratching
  - Electron-Beam Lithography

Devices:

- Single-Electron Transistor (SET) ⇒ Si, Ferromagnet, Superconductor
- Ultra-Small Tunnel Junction ⇒ Planar-Type / Lateral
- Quantum Point Contact (QPC) ⇒ Quantized Conductance @ RT
- Ferromagnetic Nanostructure ⇒ Ferromagnetism (Ni, NiFe, Co)

Physical Properties:

- Single-Electron Charging Effects
- Electromigration (Voltage-Controlled / Field-Emission-Induced)
- Magnetoresistance (MR) / Anisotropic Magnetoresistance (AMR)
- Tunnel Magnetoresistance (TMR)
- Domain Wall Magnetoresistance (DWMR)

Research Topics

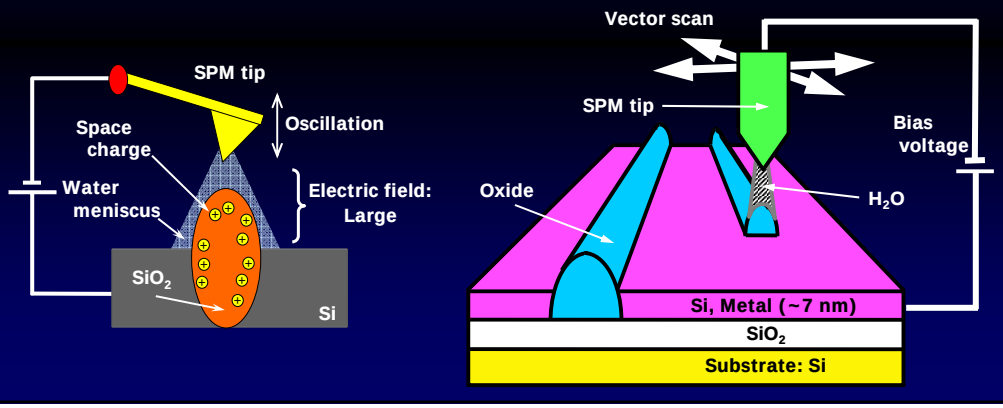
Our group's research focuses on:
fabrication of nanometer-scale devices and measurement of their electronic and magnetic properties at low temperatures - RT.

Our primary research areas include:
new nanofabrication techniques, magnetoresistance properties in ferromagnetic nanodevices, transport through Si and metallic quantum dots and ferromagnetic and superconducting devices.

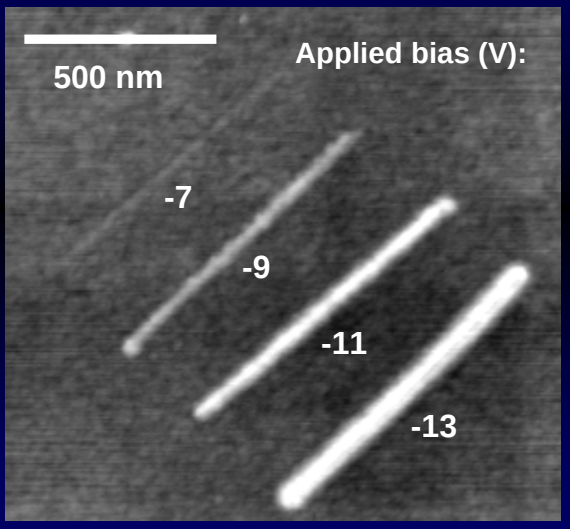
We also have active collaborations with TAKEMURA group @ YNU.

SPM Local Oxidation

SPM local oxidation
SPM using contact, noncontact and tapping modes
→ Anodic oxidation on the metal/semi. surfaces under the SPM tip
→ Parameters: bias voltage, scanning speed and ambient humidity



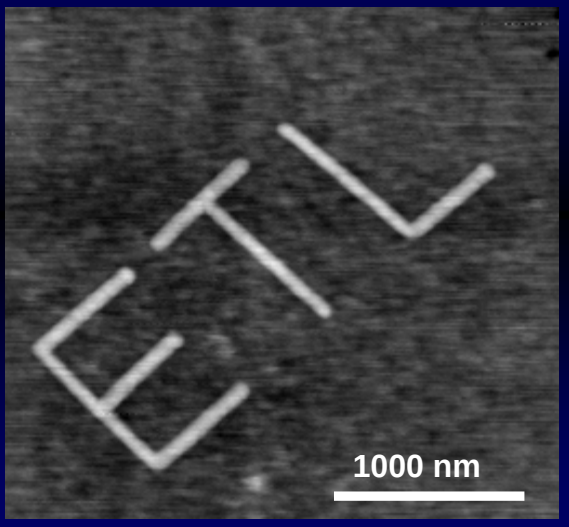
SPM Local Oxidation: Nb



Nb, 1996

J. Shirakashi et al., Jpn. J. Appl. Phys. 35 (1996) L1524.

SPM Local Oxidation: Nb



Nb, 1996

J. Shirakashi et al., Jpn. J. Appl. Phys. 36 (1997) L1120.

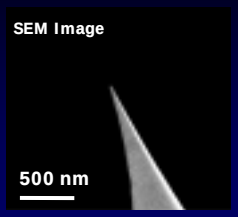
SPM Local Oxidation: Si

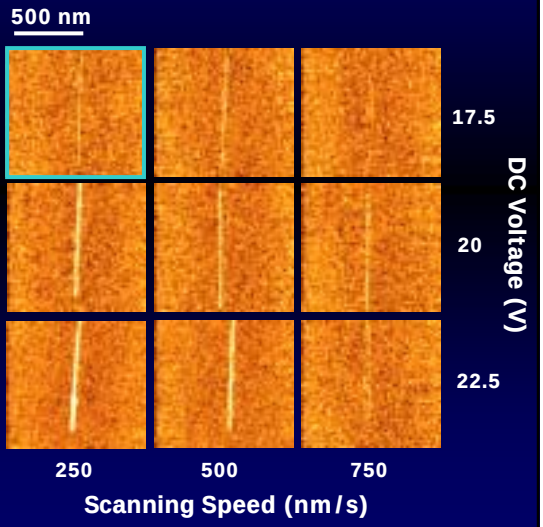
Size Controllability

Conditions

In Ambient Air
Substrate: Si (p-type, ~1kΩ·cm)
Humidity: 30 %
Oscillation Amplitude: 292 nm

Cantilever

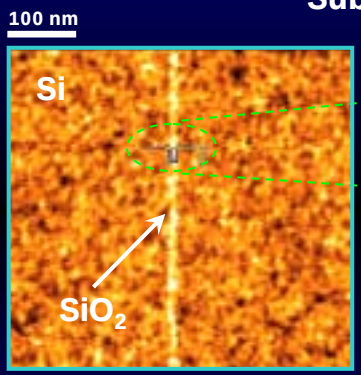




S. Nishimura et al., J. Phys. Conf. Ser. 100 (2008) 052021.

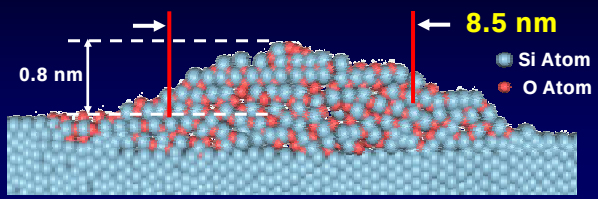
SPM Local Oxidation: Si

Sub-10 nm Resolution



Cross Section of Si Oxide Wire

Atomic Image of Si Oxide Wire



Conditions

Voltage: 17.5 V
Oscillation Amplitude: 292 nm
Scanning Speed: 250 nm/s

S. Nishimura et al., J. Phys. Conf. Ser. 100 (2008) 052021.

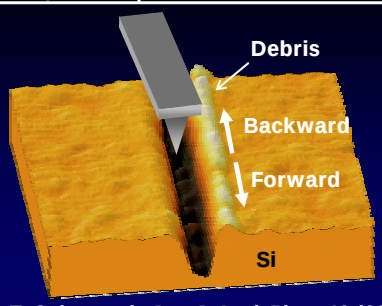
SPM Scratching

Sample

Si (100), Surface Roughness (R_a): ~0.08 nm
Treatment: Sonication in Organic Solvents → HF (10 %)

Cantilevers

	Materials	Spring Constant (N/m)	Tip Radius (nm)
Patterning	Diamond	46	100~200
Imaging	Si_3N_4	0.08 / 0.02	10~20



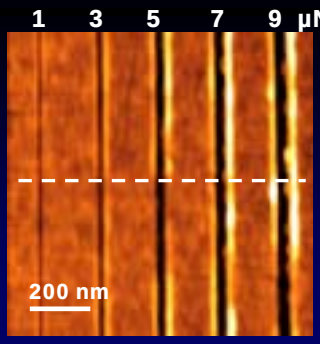
Room Temperature
Humidity: 33~46 %

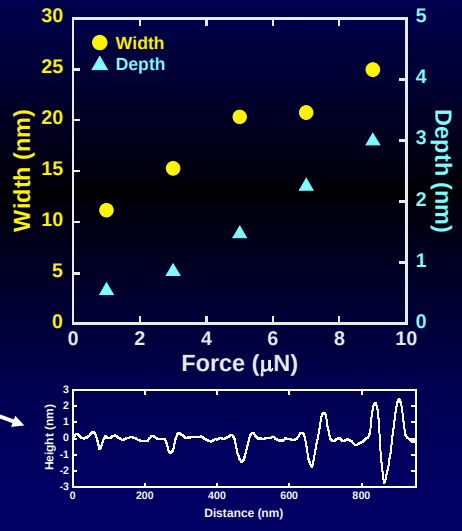
T. Ogino et al., Jpn. J. Appl. Phys. 46 (2007) 6908.

SPM Scratching: Si

Groove Size vs Force

Scan Parameters
Applied Force: 1~9 μN
Scan Speed: 10 nm/s
Scan Cycle: 1 cycle
Scan Direction: Forward

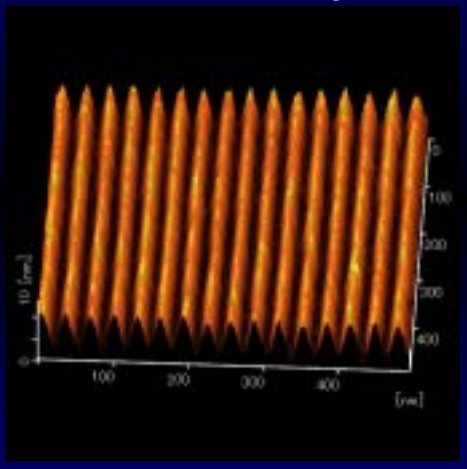


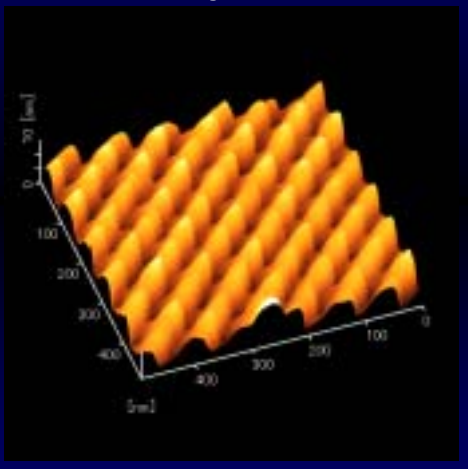


T. Ogino et al., Jpn. J. Appl. Phys. 46 (2007) 6908.

SPM Scratching: Si

Line & Space Patterns, Dot Arrays



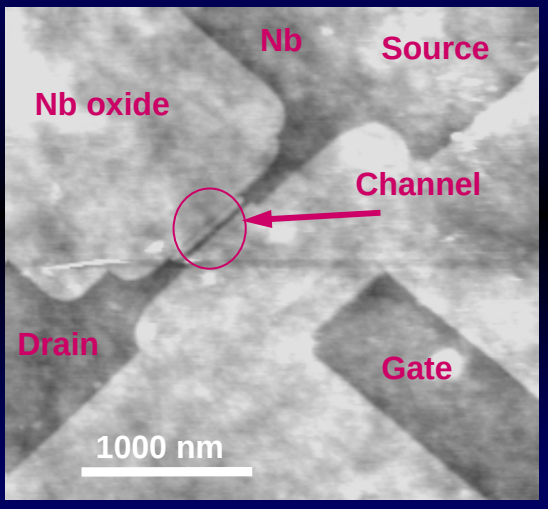


Pitch: 30 nm

Dot Density: 2.6×10^{10} cm^{-2}

T. Ogino et al., Jpn. J. Appl. Phys. 47 (2008) 712.
T. Ogino et al., J. Phys. Conf. Ser. 100 (2008) 052020.

Nb-Based SET by SPM L. O.

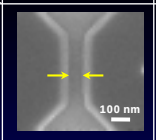
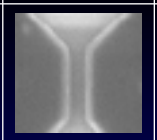
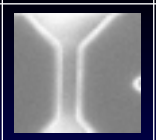
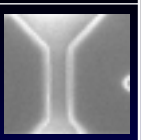
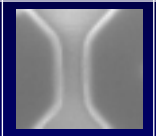
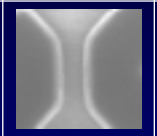
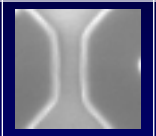
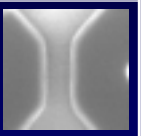


J. Shirakashi et al., Jpn. J. Appl. Phys. 37 (1998) 1594.
J. Shirakashi et al., Appl. Phys. Lett. 72 (1998) 1893.

EB Lithography

Resist Patterns

Resist: ZEP520A
Thickness: 220 nm
Dose: 125~140 μC/cm²

Width \ Dose	125 μC/cm²	130 μC/cm²	135 μC/cm²	140 μC/cm²
20 nm (Designed)	 71 nm	 75 nm	 77 nm	 81 nm
30 nm (Designed)	 115 nm	 113 nm	 119 nm	 131 nm

Conclusions

Nanolithography/Patterning Techniques in Our Group:

- ☺ SPM Local Oxidation: ~8.5 nm
- ☺ SPM Scratching: ~11 nm
- ☺ Electron Beam: ~70 nm
- ☺ Controlled Electromigration: ~10 nm

Nanodevices in Our Group:

- ☺ Ferromagnetic Single-Electron Transistors (Enhanced TMR)
- ☺ Metal-Based Single-Electron Transistors (Beyond CMOS)
- ☺ Si-Based Single-Electron Transistors (Beyond CMOS)
- ☺ Ferromagnetic Quantum Point Contacts (TAMR, DWMR)
- ☺ Ferromagnetic Nanoconstrictions (DWMR, AMR)

For More Information:

☞ http://www.tuat.ac.jp/~nanotech/publication/publication.htm