



Nanoscale Patterning of NiFe Surface by SPM Scratch Nanolithography

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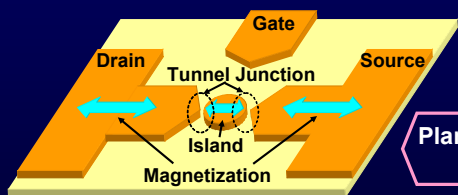


Fabrication of Nanoscale

Tunnel Junction Devices

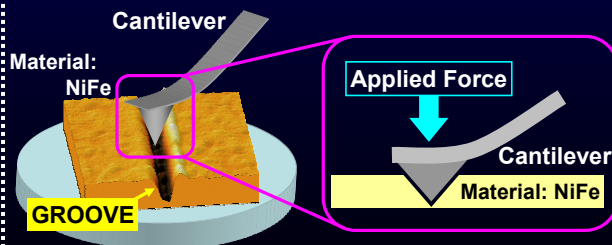
Ferromagnetic Single-Electron Transistors (FMSETs) [1]

[1] J. Shirakashi and Y. Takemura, J. Appl. Phys. 93 6873 (2003).



Planar-Type FMSET

SPM Scratch Nanolithography



SPM Scratching [2]

- Resistless Lithography and No Bias Voltage
- Metals, Semiconductors and Insulators
- Sub-20 nm Scratch Nanolithography on Si [3]

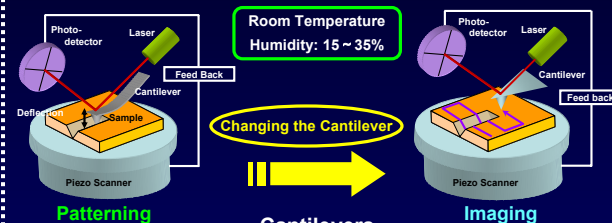
[2] X. Jin and W. N. Unertl, Appl. Phys. Lett. 61 657 (1992).

[3] T. Ogino, S. Nishimura and J. Shirakashi, Jpn. J. Appl. Phys. 42 712 (2008).

③ Experimental Conditions

Samples

NiFe	30 nm (Surface Roughness (Ra): ~0.2 nm)
Ni	20 nm (Ra: ~0.2 nm)
Si(100)	Bulk (Ra: ~0.08 nm)



Cantilevers

	Materials	Spring Contact (N/m)	Tip Radius (nm)
Patterning	Diamond	46	100~200
Imaging	Si ₃ N ₄	0.02~0.08	~20

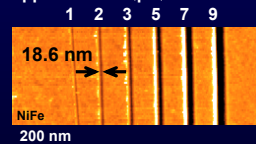
Patterning of NiFe by SPM Scratching

Groove Size of NiFe vs Applied Force, Number of Scan Cycles and Scan Speed

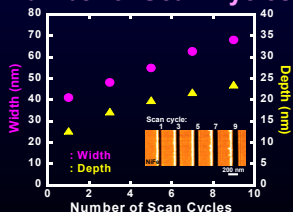
Scanning Parameters

Applied Force: 1~9 μ N
Number of Scan Cycles: 1~9 cycle
Scan Speed: 10^{-2} ~ 10^1 μ m/s

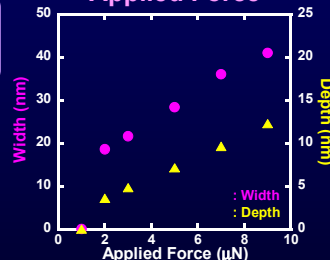
Applied Force (μ N):



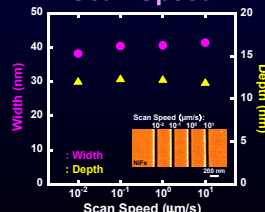
Number of Scan Cycles



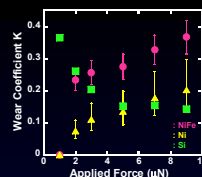
Applied Force



Scan Speed



Wear Coefficient of NiFe, Ni and Si vs Applied Force



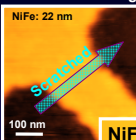
Archard's Wear Law [4]

$$V = k \frac{Lx}{H}$$

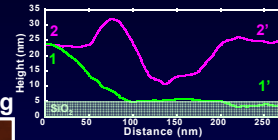
V = Wear Volume (m^3) L = Normal Load (N)
x = Sliding Distance (m) H = Hardness of Worn Material (Pa)
k = Wear Coefficient [4] J. F. Archard, J. Appl. Phys. 24 (1953) 981.

Fabrication of NiFe Nanoconstriction

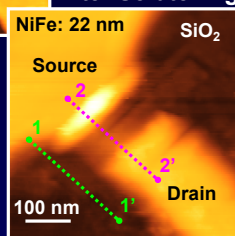
Before Scratching



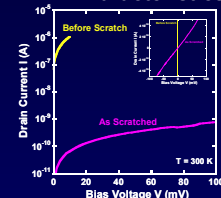
Cross Section of Nanoconstriction



After Scratching



I-V Characteristics



Increase of the Channel Resistance by SPM Scratching

CONCLUSION

- ◆ Scratch Nanolithography for NiFe Using SPM
 - Groove Size Depends on Applied Force, Number of Scan Cycles and Scan Speed.
 - Width: 18.6~68.0 nm, Depth: 3.6~23.6 nm (1~9 μ N, 1~9 cycle and 0.01~10.0 μ m/s)
- ◆ Fabrication of NiFe Nanoconstrictions by SPM Scratching
 - The Current Through the Channel Decreased from the Order of μ A to nA After SPM Scratching.

