# Magnetoresistance Properties of Planar-Type Ferromagnetic Nanostructures

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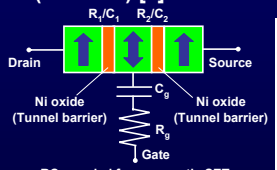
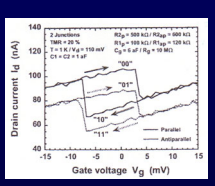
## Introduction

- Ferromagnetic nanostructures having tunnel barriers
  - → Single tunnel barrier: Tunnel magnetoresistance (TMR)
  - → Double tunnel barriers: Ferromagnetic single-electron transistors (FMSETs) [1]
- Ferromagnetic nanostructures having nanoconstriction
  - → Nanoconstriction: Enhancement of AMR, TAMR
  - → Formation of domain wall at constriction: Domain wall magnetoresistance (DWMR) [2]
  - → Reduction of constriction width: Enhancement of DWMR [3]

[1] J. Shirakashi and Y. Takemura, J. Appl. Phys. 93 6873 (2003).
[2] M. Tsoi, R. E. Fontana and S.S. Parkin, Appl. Phys. Lett. 83 2617 (2003).
[3] P. M. Levy and S. Zhang, Phys. Rev. Lett. 79 5110 (1997).

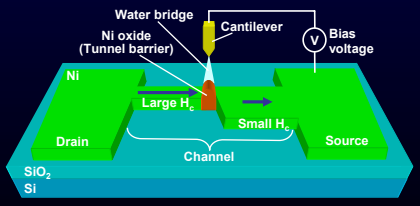


RC-coupled ferromagnetic SET

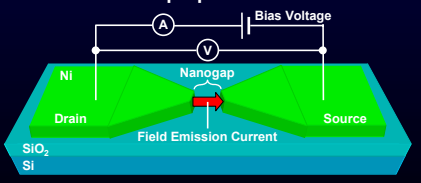



## Experimental

- Planar-type ferromagnetic tunnel junctions
  - → Photolithography and etching process
  - → Induction of magnetic shape anisotropy
  - → Ni oxide formed using SPM local oxidation



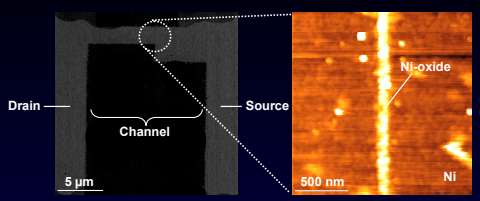

- Planar-type ferromagnetic nanogaps
  - → EB lithography and lift-off process
  - → Field-emission-induced electromigration
    - i) Measurement of I-V properties before activation
    - ii) Applying ramp voltage to preset current (Activation)
    - iii) Measurement of I-V properties after activation

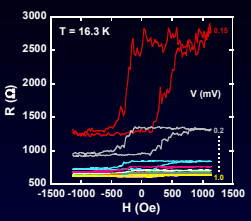


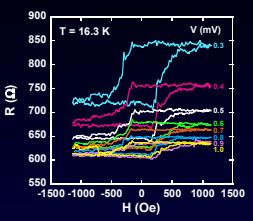

## Results and discussion

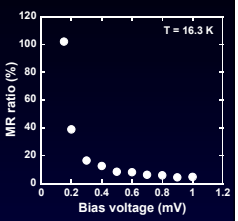
- MR properties of planar-type ferromagnetic tunnel junctions [4]
  - → Observation of magnetoresistance minor loop
  - → Dependence on applied bias voltage

[4] Y. Tomoda, S. Shibata, J. Shirakashi and Y. Takemura, J. Appl. Phys. 99 08T312 (2006).



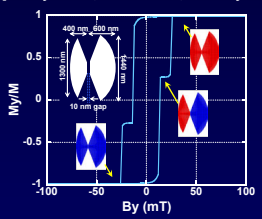



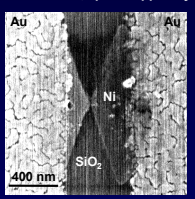



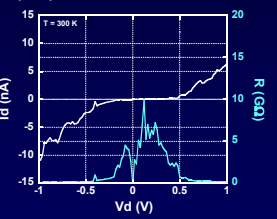



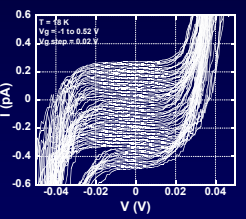

- Asymmetrical butterfly shape with tunnel barrier
  - → Clear observation of antiparallel state from B-H curve
  - → Fabrication of asymmetrical butterfly shape using EB lithography
  - → Control of tunnel resistance [5]

[5] S. Kayashima, K. Takahashi, M. Motoyama and J. Shirakashi, Jpn. J. Appl. Phys. 46 L907 (2007).




## Conclusions

- Planar-type ferromagnetic tunnel junctions
  - → Fabrication of planar-type Ni/Ni oxide/Ni tunnel junction by SPM local oxidation
  - → Magnetic shape anisotropy by asymmetrical constricted channel
  - → Magnetoresistance: ~100 % @ 16.3 K
- Planar-type ferromagnetic nanogaps
  - → Control of tunnel resistance by activation process
  - → Modulation of Coulomb blockade → Operation of single-electron transistors @ 18 K
- Asymmetrical butterfly shape could be suitable for planar-type ferromagnetic nanostructures

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