

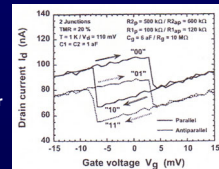
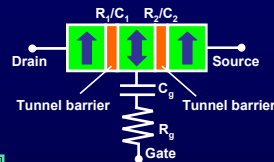
# Fabrication of Planar-Type Ferromagnetic Tunnel Junctions Using Electromigration Method and Its Magnetoresistance Properties

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## Introduction

- Ferromagnetic Single-Electron Transistors: FMSETs
  - RC-coupled FMSET<sup>[1]</sup>
    - Hysteresis of the Drain Current on Gate Voltage
    - Enhancement of Tunnel Magnetoresistance
- Interplay of Spin and Charge: Multivalued Functions
- DRAM + HDD + Low Power = Universal Memory**



RC-coupled ferromagnetic SET

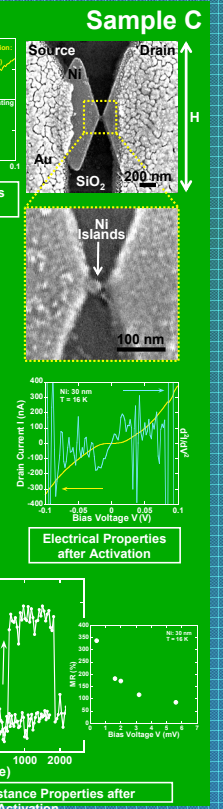
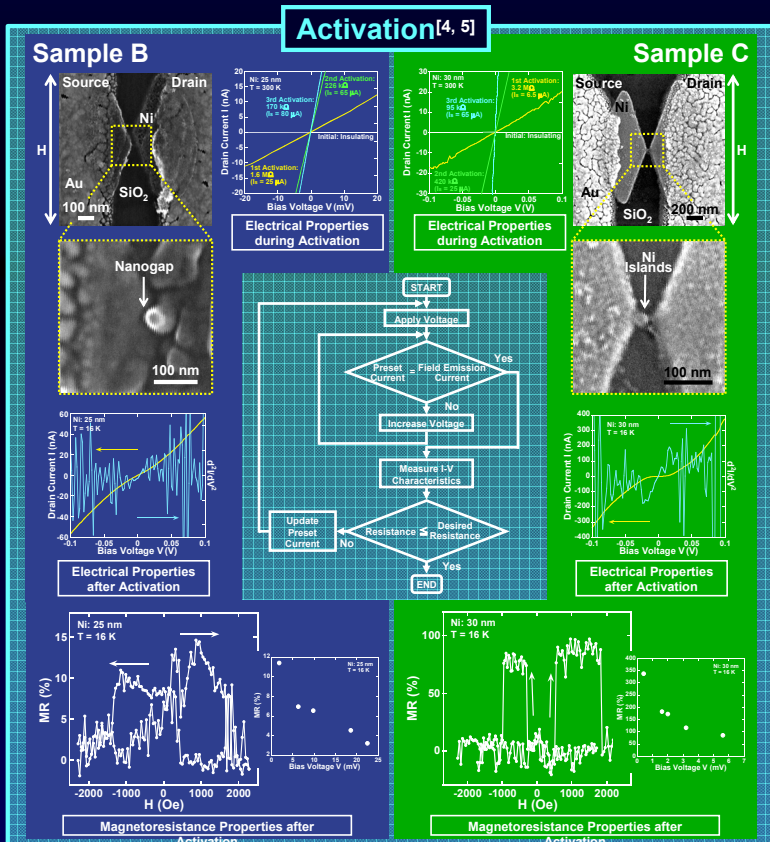
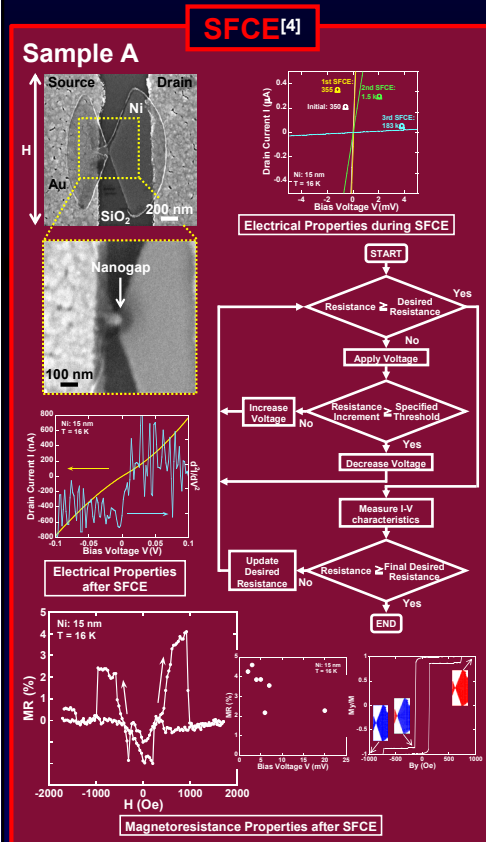
[1] J. Shirakashi and Y. Takemura, J. Appl. Phys. 93 6873 (2003).

## Experimental Method

- Planar-Type Tunnel Junctions with Ferromagnetic Nanogap System
  - EB Lithography and Lift-off Process
  - Asymmetrical Butterfly Shape: Induction of Magnetic Shape Anisotropy
  - Electromigration Method: **Stepwise Feedback-Controlled Electromigration (SFCE)**<sup>[2]</sup>
- Field-Emission-Induced Electromigration (Activation)**<sup>[3]</sup>

[2] K. Takahashi, et al., Int. Conf. Nanoscience + Technology (ICN+T 2008), Keystone, CO, USA.

[3] Y. Tomoda, et al., J. Vac. Sci. & Technol. B 27 813 (2009).



[4] Y. Tomoda, et al., IEEE Tran. Mag. (2009) in print

[5] Y. Tomoda, et al., J. Phys. Conf. Ser. (2009) in print

## Conclusions

- Stepwise Feedback-Controlled Electromigration (SFCE)**
  - Increase of the Resistance: 350  $\Omega$  → 183  $\text{k}\Omega$
  - Magnetoresistance of Planar-Type Ferromagnetic Tunnel Junctions: ~4 % @ 16 K
- Field-Emission-Induced Electromigration (Activation)**
  - Decrease of the Resistance: Insulating → 95  $\text{k}\Omega$
  - High MR ratio of Planar-Type Multiple Tunnel Junctions: ~300 % @ 16 K

## Acknowledgement

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