電界放射電流誘起型EMにより作製した単電子トランジスタの特性制御

Simple and Easy Control of Electrical Properties of Single-Electron Transistors Using Field-Emission-Induced Electromigration

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① Introduction

Field-Emission-Induced Electromigration (Activation)

- Simple and Easy Technique
  - ⇒ Application of The Current Only Passing Through The Nanogap
- Novel Technique for The Fabrication of Tunnel Devices
  - ⇒ Ferromagnetic Tunnel Junctions
  - ⇒ Single-Electron Transistors (SETs)

Previous Reports Using Activation

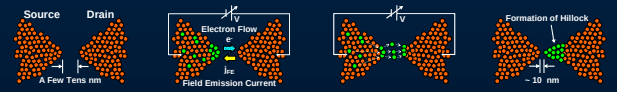
Wide-Range Control of Tunnel Resistance of Nanogaps[1-3]
[1] S. Kayashima et al., Jpn. J. Appl. Phys. 46 (2007) L907.
[2] S. Kayashima et al., J. Phys. Conf. Ser. 100 (2008) 052022.
[3] Y. Tomoda et al., J. Vac Sci. & Technol. B 27 (2009) 813.

Magnetoresistance Properties of Ni/Vacuum/Ni System[4,5]
[4] Y. Tomoda et al., IEEE Trans. Mag. 45 (2009) 3480-3483.
[5] Y. Tomoda et al., J. Phys. Conf. Ser. 200 (2010) 062035.

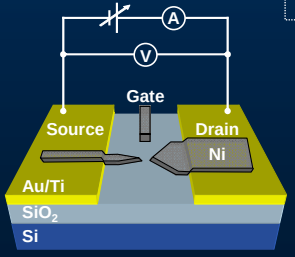
② Activation Procedure

Experimental Conditions

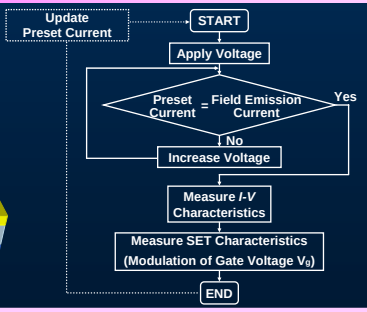
Control Parameters	Samples
Temperature: 300 K	Material: Ni
Environment: Vacuum	Thickness: 20 ~ 30 nm
Preset Current I_S: 1 ~ 150 μA	Initial Gap Width W: 21 ~ 68 nm



① Before Activation ② Activation of Atoms ③ Migration of Atoms ④ After Activation



Setup for Activation Process



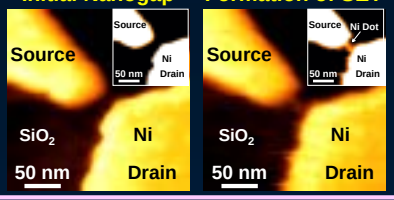
③ Fabrication of SETs

Conditions

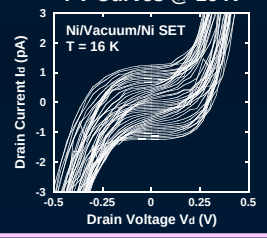
- Preset Current: I_S = 500 nA
- Initial Gap Width: W = 27 nm
- Temperature: T = 16 K
- Gate Voltage: V_G = -50~50 V, ΔV_G = 2 V Step

Before — Initial Nanogap

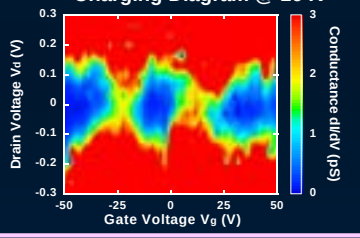
After — Formation of SET



I-V Curves @ 16 K

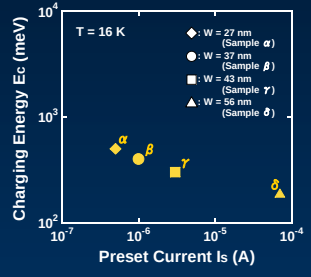


Charging Diagram @ 16 K

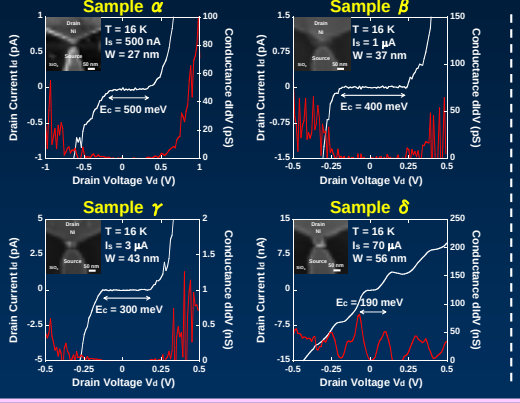


④ Control of SET Properties

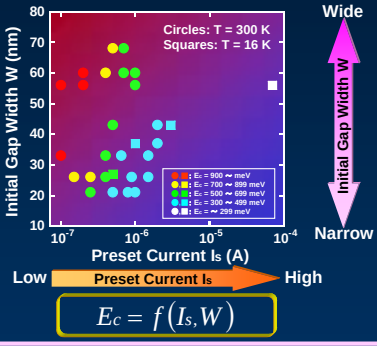
Preset Current vs. Charging Energy



$I_S \propto E_C^{-1}$



Charging Energy of SETs as Functions of Preset Current and Initial Gap Width



$E_C = f(I_S, W)$

⑤ Conclusions

➢ Fabrication of SETs by Field-Emission-Induced Electromigration (Activation)
- Periodic Modulation of Coulomb Blockade Voltage @ Is: 500 nA, W: 27 nm, Ec: 500 meV
  - ⇒ Fabrication of SETs with Single Island / Double Tunnel Junctions

➢ Control of SET Properties Using Field-Emission-Induced Electromigration (Activation)
- Ec: 1030 ~ 190 meV @ { Is: 100 nA ~ 70 μA, W: 21 ~ 68 nm }
  - ⇒ Control of Charging Energy Ec by Preset Current Is and Initial Gap Width W