



Control Parameters for Fabrication of Single-Electron Transistors Using Field-Emission-Induced Electromigration

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① Introduction

■ Single-Electron Transistors (SETs) Is a Potential Candidate for Next Generation Electronic Devices.

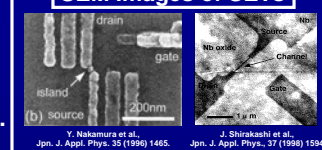
- Low Power Consumption and High Integration Density

■ Fabrication of SETs

- Main Technological Challenge Is to Position Islands in Nanoscale Gap between Source and Drain Electrodes.
- Fabrication Techniques Have Been Generally Known to Be Complicated and Require Special Techniques.

We Have Proposed a Simple and Easy Method for Fabrication of SETs Using Field-Emission-Induced Electromigration ("ACTIVATION").

SEM Images of SETs



② "ACTIVATION" Procedure: Our Previous Results

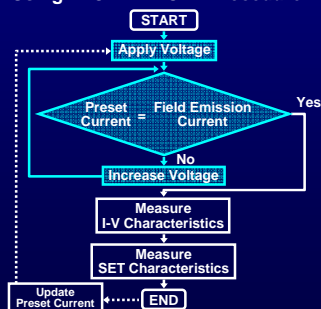
Fabrication Sample

Ni Thickness: 20 ~ 30 nm
Initial Gap Separation W : 20 ~ 70 nm

Experimental Condition

Temperature T : 16 K, 300 K
Environment: Vacuum
Preset Current I_s : $10^{-9} \sim 10^{-4}$ A

II Fabrication Processes of SETs Using "ACTIVATION" Procedure

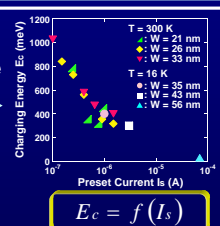


Previous Reports Using "ACTIVATION"

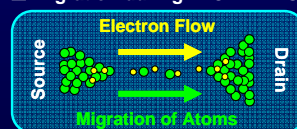
- Fabrication of SETs Operating at Room Temperature
W. Kume et al., *J. Nanosci. Nanotechnol.* 10, 7239 (2010).

- Integration of SETs
S. Ueno et al., *J. Nanosci. Nanotechnol.* in print.
S. Ueno et al., *Appl. Surf. Sci.* in print.

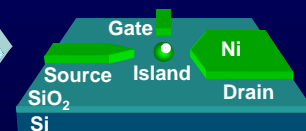
- Control of Charging Energy of SETs
W. Kume et al., *J. Nanosci. Nanotechnol.* 10, 7239 (2010).



III Migration during "ACTIVATION"



IV Formation of SET



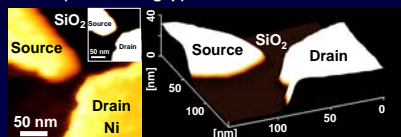
③ Fabrication of SETs

SET with "SINGLE" Island

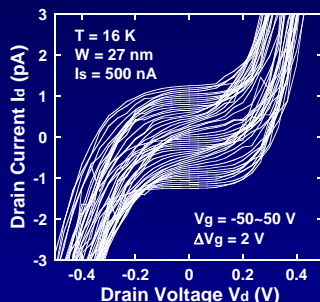
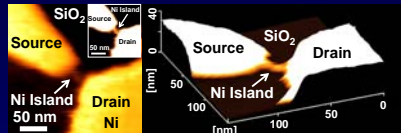
Initial Gap Separation $W = 27$ nm

Preset Current $I_s = 500$ nA, Temperature $T = 16$ K

Before (Initial Nanogap)



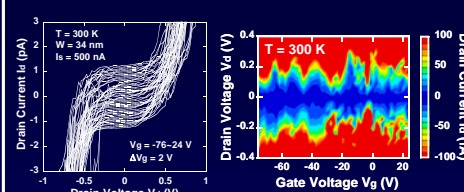
After Performing "ACTIVATION" (Activated Nanogap: SET)



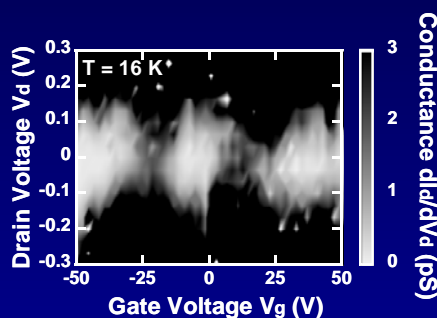
SET with "MULTIPLE" Islands

Initial Gap Separation $W = 34$ nm

Preset Current $I_s = 500$ nA, Temperature $T = 300$ K



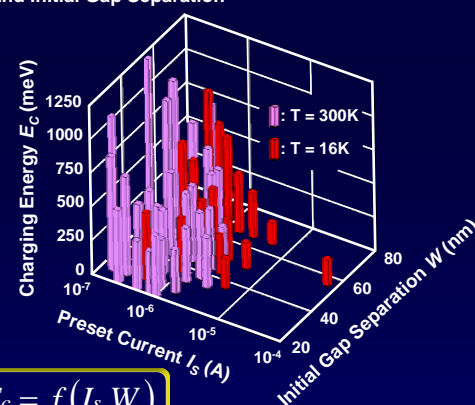
Charging Energy $E_c = 470$ meV
→ Charging Energy E_c Is Much Greater Than Thermal Energy at Room Temperature (26 meV).



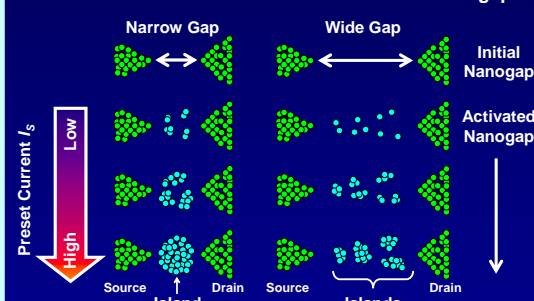
It Is Suggested That The Number of Islands in SETs Formed by "ACTIVATION" Is Reduced by Narrowing Initial Gap Separation.

④ Control of SET Characteristics

➢ Charging Energy of SETs As Function of Preset Current and Initial Gap Separation



➢ Schematic of Island Formation of Activated Nanogaps



- The Number of Moving Atoms Is Increased with Increasing Preset Current.
- Islands Easily and Rapidly Tend to Grow As Initial Gap Separation Narrows.

④ Conclusions

◆ Fabrication of SETs Using "ACTIVATION"

- Coulomb Blockade Voltage Is Modulated by The Gate Voltage

Periodically.

@ $W = 27$ nm, $I_s = 500$ nA ⇒ SET with "SINGLE" Island

Quasi-Periodically.

@ $W = 34$ nm, $I_s = 500$ nA ⇒ SET with "MULTIPLE" Islands

◆ Control of SET Properties Using "ACTIVATION"

- The Electrical Characteristics of SETs Can Be Widely Controlled by Adjusting Preset Current in Combination with Initial Gap Separation.

"ACTIVATION" Is a Simple and Easy Method for Control of Electrical Characteristics of SETs.

