パッシベーション処理を施したナノギャップ電極における電界放射電流誘起型EMによる特性制御の検討

Control of Electrical Properties of Passivated Nanogaps Using Field-Emission-Induced Electromigration

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Introduction: Novel Technique for the Formation of Nanogaps

■ **Field-Emission-Induced Electromigration: Activation**

➢ Excellent Controllability of the Tunnel Resistance of Nanogaps [1-3]

- With the passivation layer, it is possible to protect surface of devices from chemical, electrical and mechanical damages
  ⇒It is necessary to use passivation technique for wide application of the activation method

➢ Simple and Easy Fabrication of Single-Electron Transistors (SETs) [4-5]

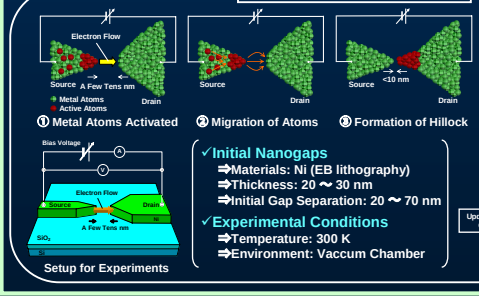
- Electrical properties of planar-type SETs can be controlled by only adjusting the applied preset current to the nanogaps

⇒ Control of Electrical Properties of Passivated Nanogaps Using Activation Based on Electromigration Induced by Field Emission Current

[1] S. Kayashima et al., Jpn. J. Appl. Phys. 46 (2007) L907.
[2] 花田他: 第69回応用物理学会学術講演会 4a-H-5 (2008).
[3] Y. Tomoda et al., J. Vac. Sci. Technol. B 27 (2009) 813-816.
[4] 友田他: 電子情報通信学会 信学技報, ED2008-232 (SDM2008-224), 2009, 47-51.
[5] W. Kume et al., J. Nnosci. Nanotechnol. (2010), in print.

Fabrication of Ni Nanogaps Using Activation Method

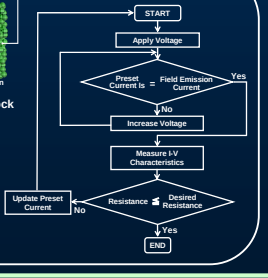
Activation Procedure



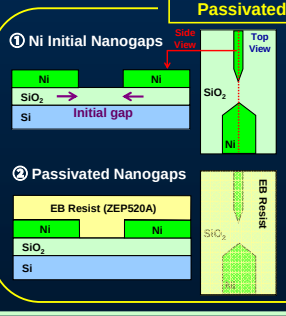
✓Initial Nanogaps
⇒Materials: Ni (EB lithography)
⇒Thickness: 20 ~ 30 nm
⇒Initial Gap Separation: 20 ~ 70 nm

✓Experimental Conditions
⇒Temperature: 300 K
⇒Environment: Vaccum Chamber

Flowchart of Activation

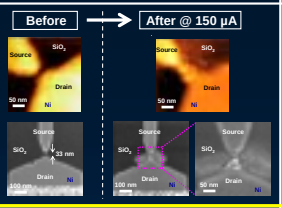
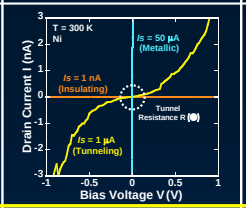
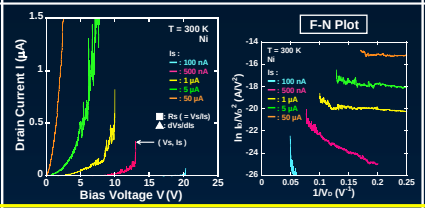
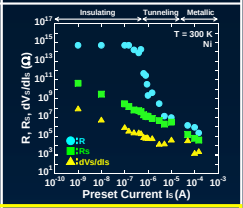
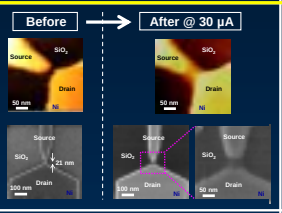
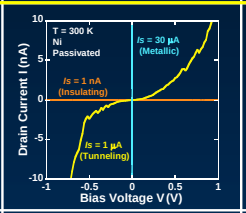
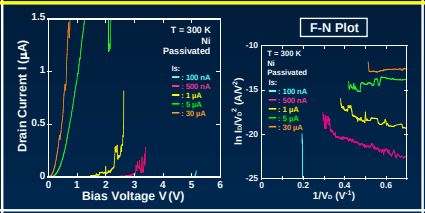
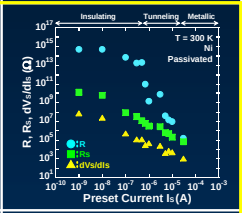
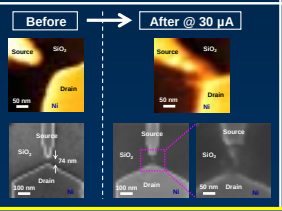
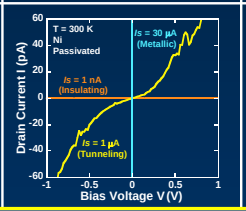
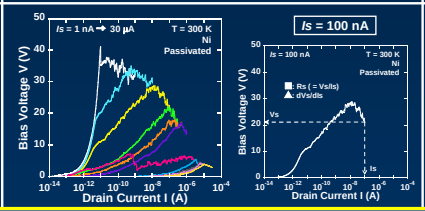
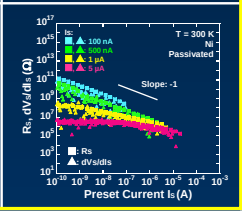


Passivated Nanogaps



Passivation Layer	ZEP520A
Thickness	300 nm ~ 400 nm
Bake Condition	10 Sec @ 180 ℃

Control of Electrical Properties of Passivated Nanogaps

		AFM and SEM Images of Nanogaps	I-V Characteristics After Activation	I-V Characteristics During Activation	Dependence of Resistances on *Is*
Voltage Source Mode	Without Passivation *Is* = 1 nA ➞ 150 μA				
	With Passivation *Is* = 1 nA ➞ 30 μA				
Current Source Mode	With Passivation *Is* = 1 nA ➞ 30 μA				

Conclusion

■ **Wide-Range Control of Electrical Properties of "Passivated Nanogaps" Using Voltage- and Current-Source-Mode Activation**

➢ AFM and SEM Images of Nanogaps Before and After Activation
⇒ Separation of Nanogaps: A Few Tens nm (Before) ➞ Less Than 10 nm (After @ *Is* = 30 μA)

➢ Transition of I-V Characteristics After Activation
⇒ Insulating ➞ Tunneling ➞ Metallic @ *Is* = 1 nA ➞ 30 μA

➢ Dependence of Resistances on Preset Current *Is*
⇒ ① Tunnel Resistance R: 100 TΩ ➞ 100 kΩ, ② Rs (= Vs/Is), dVs/dIs: A Slope of -1

These results are quite similar to nanogaps without passivation layer