



Control of Channel Resistance on Metal Nanowires by Electromigration Patterning Method

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➤ Introduction

• Electromigration-induced nanogaps

- ➔ Breaking metal nanowires by electromigration (EM) is a useful technique for making nanogaps [1]
- ➔ It is achieved by only passing a current through a metal nanowire
- ➔ However, nanogaps formed with a single voltage ramp tend to exhibit high tunnel resistance [1~3]

[1] H. Park, A. L. Lim, A. P. Alivisatos, J. Park, and P. L. McEuen, Appl. Phys. Lett. 75, 301 (1999).

[2] Y. Noguchi, T. Nagase, T. Kubota, T. Kamikado, and S. Mashiko, Thin Solid Films 499, 90 (2006).

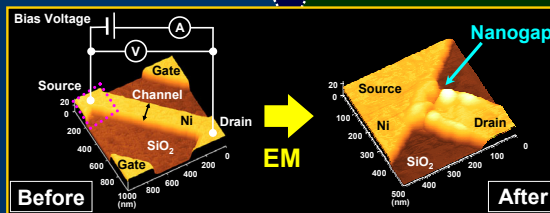
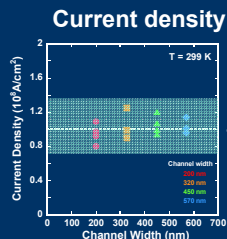
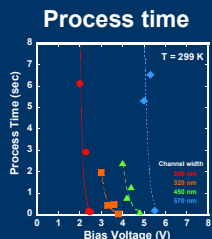
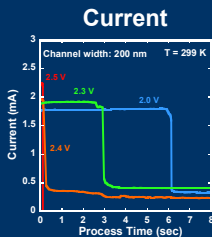
[3] D. R. Strachan, D. E. Smith, D. E. Johnston, T.-H. Park, M. J. Therien, D. A. Bonnell, and A. T. Johnson, Appl. Phys. Lett. 86, 43109 (2005).

We propose a new approach for the fabrication of nanogaps with atomic-scale constriction

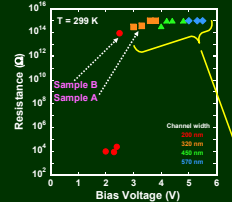
➤ Fabrication of EM-induced nanogaps

Constant-voltage (CV) process

Performing CV process



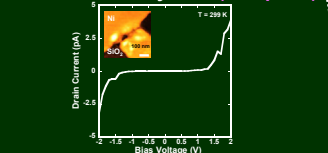
Resistance after EM



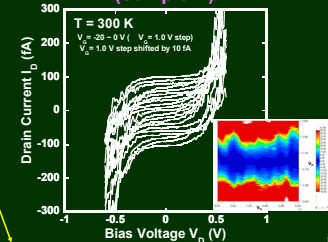
Nanowires with >300 nm width is not well controlled due to Joule heating

After EM

Ni-vacuum-Ni system (Sample A)



Single-electron transistor at 300 K (Sample B)



CV process in addition to feedback-controlled electromigration (FCE) procedure

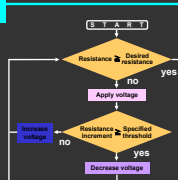
Improvement of the controllability on channel resistance

FCE procedure
Step1

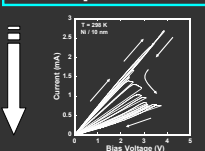
CV process
Step2

FCE procedure

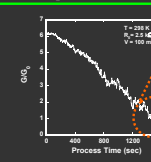
- Performing FCE procedure
 - ➔ Control of the applied voltage in response to the changing resistance [3]
 - ➔ Suppression of rapid EM



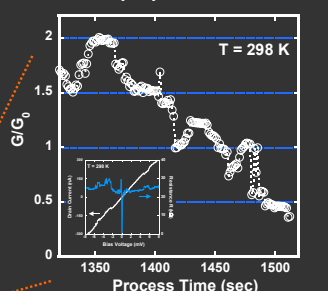
FCE procedure



CV process



Conductance plateau at 298 K and I-V properties after EM



Discrete steps in units of $G_0 = 2e^2/h$ [4]

[4] T. Ono, Y. Ooka, H. Miyajima, and Y. Otani, Appl. Phys. Lett. 75, 1622 (1999).

➤ Conclusion

- Control of channel resistance in CV process
 - ➔ Nanowires with >300 nm width is not well controlled due to Joule heating
- Improvement of the controllability on channel resistance
 - ➔ Control of the channel resistance by performing CV process in addition to a FCE procedure
 - ➔ Conductance quantization → **Fabrication of nanogap with atomic-scale constriction**
- This technique can easily control the channel resistance of metal nanowires

