



# 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]

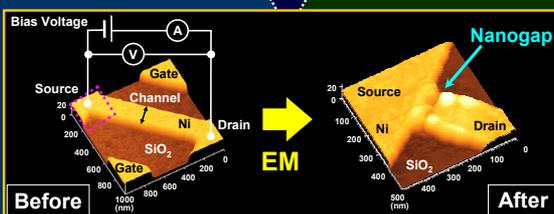
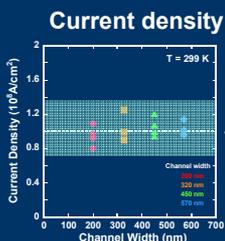
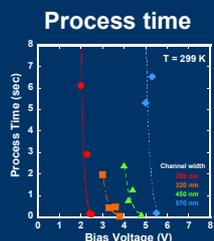
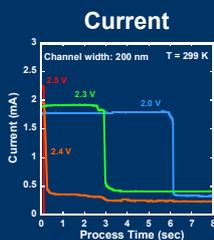
[1] H. Park, A. L. Lim, A. P. Alivisatos, J. Park, and P. L. McEuen, Appl. Phys. Lett. 75, 301(1999).  
 [2] Y. Noguchi, T. Nagase, T. Kubota, T. Kamikado, and S. Mashiko, Thin Solid Films 499 90 (2006).  
 [3] D. R. Strachan, D. E. Smith, D. E. Johnston, T.-H. Park, M. J. Therien, D. A. Bonnell, and 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

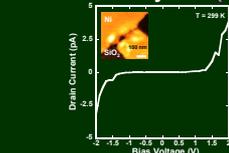
### Constant-voltage (CV) process

#### Performing CV process

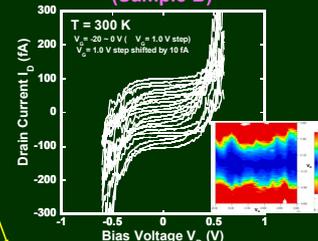


#### After EM

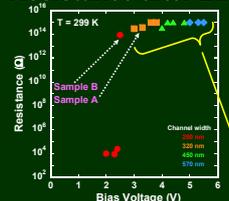
Ni-vacuum-Ni system (Sample A)



Single-electron transistor at 300 K (Sample B)



#### Resistance after EM



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

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

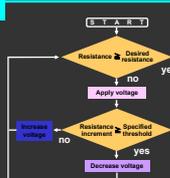
Improvement of the controllability on channel resistance

FCE procedure  
Step1

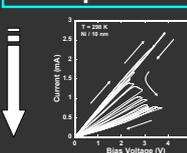
CV process  
Step2

#### FCE procedure

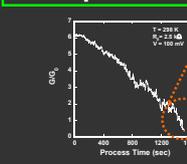
- Performing FCE procedure
  - Control of the applied voltage in response to the changing resistance [3]
  - Suppression of rapid EM



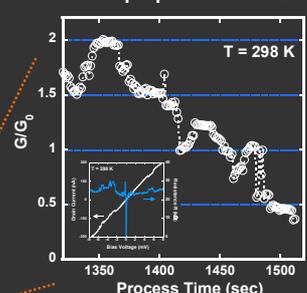
#### FCE procedure



#### 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