分割型電圧フィードバックエレクトロマイグレーションによるNiナノチャネルの磁気抵抗特性制御

Magnetoresistance Properties of Ni Nanochannel Using Stepwise Feedback-Controlled Electromigration

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1. Introduction

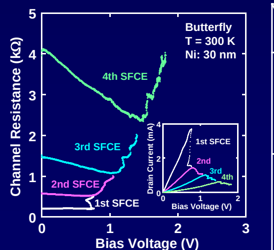
- Fast Progress and Development of Nanoelectronics
  - ➔ Intensive Studies in Fundamental Physical Properties of Metallic Nanocontacts and Nanogaps[1]
- Electromigration Method for the Fabrication of Nanogaps
  - ➔ Simple Method Achieved by Only Passing a Current Through a Metal Nanowire[2,3]
  - ➔ Stepwise Feedback-Controlled Electromigration (SFCE) Scheme[4]

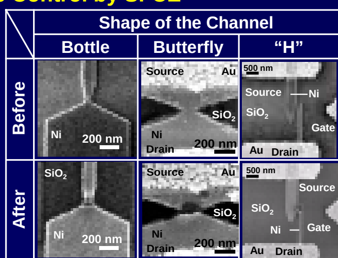
[1] K. I. Bolotin, et al., Nano Lett. 5 1685 (2005). [2] D. R. Strachan, et al., Appl. Phys. Lett. 86 43109 (2005). [3] K. Takahashi, et al., J. Vac. Sci. Technol. B 27 805 (2009). [4] S. Itami, et al., J. Nanosci. Nanotechnol. (2010) in print.

SFCE: A New Approach to Control the Resistance of Metal Nanowires @ Room Temperature

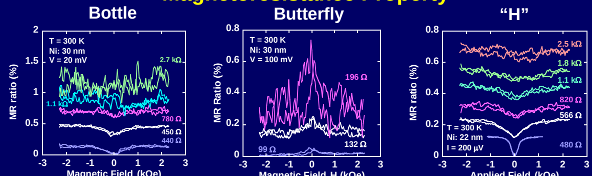
2. Magnetoresistance Properties of Ni Nanochannels Obtained during SFCE

Resistance Control by SFCE

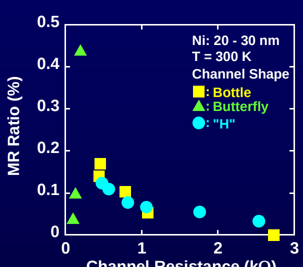




Magnetoresistance Property



- Observation of Anisotropic Magnetoresistance (AMR)
- Increase of Coercive Field with Increase of Channel Resistance[6]



	Resistance (kΩ)	AMR Ratio (%)
Bottle	0.4 → 2.7	0.14 → ~10^{-5}
Butterfly	0.1 → 0.2	0.04 → 0.44
"H"	0.5 → 2.5	0.12 → 0.03

Bottle & "H" (R > 400 Ω):
- Decrease of MR Ratio[5, 6]

Butterfly (R < 400 Ω):
- Increase of MR Ratio[1, 7]
- Resistance of Domain Walls

$$\frac{\Delta\rho}{\rho_0} = \frac{K}{S^{\alpha}}$$

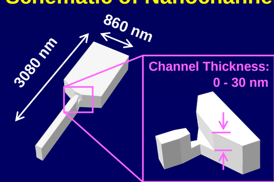
K: Constant
S: Cross-Sectional Area

[5] Y. Osawa, IEEE Trans. Magn. 43 3007 (2007). [6] G. Watanabe, et al., J. Vac. Sci. Technol. B 23 2390 (2005). [7] S. Lapadatu, et al., Phys. Rev. Lett. 92 127201 (2004).

3. Micromagnetic Simulations[8] of the Magnetization of a Ni Nanochannel

[8] Micromagnetic Simulations Using Object Oriented Micromagnetics Framework (OOMMF) Package ,http://math.nist.gov/oommf/

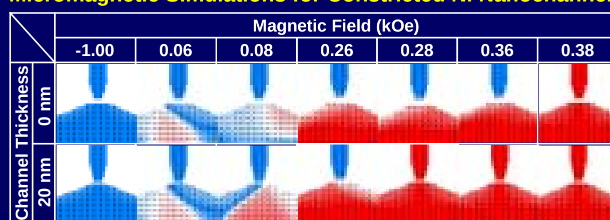
Schematic of Nanochannel

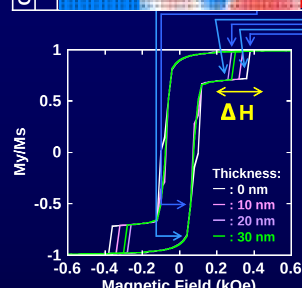


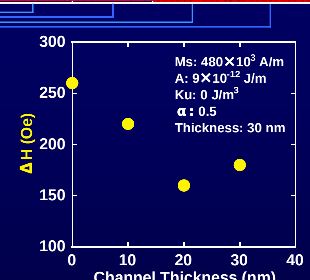
Simulation Parameters

Material Name	Nickel
Saturation Magnetization (Ms)	480×10^3 A/m
Exchange Stiffness constant (A)	9×10^{-12} J/m
Anisotropic Constant (Ku)	0 J/m³
Damping Constant (α)	0.5
Thickness	30 nm

Micromagnetic Simulations for Constricted Ni Nanochannels







- Domain Wall is pinned at the constriction of Ni nanochannel[7].
- Switching field increases with decreasing the channel thickness[6].

→ Good Agreement with the Experimental Results

Control of Magnetoresistance Properties Using SFCE Scheme

4. Conclusions

- Magnetoresistance Properties of Ni Nanochannels Obtained during SFCE
  - ➔ Observation of Anisotropic Magnetoresistance (AMR) Effects
  - ➔ Increase of Coercive Field with Increase of Channel Resistance of Ni Nanochannels
  - ➔ Bottle & "H": Decrease of MR Ratio with Increase of Channel Resistance of Ni Nanochannels
    Butterfly: Increase of MR Ratio during SFCE Process
- Micromagnetic Simulations of the Magnetization of Ni Nanochannels Using OOMMF Package
  - ➔ Pinning of Domain Wall at the Constriction of Ni Nanochannels
  - ➔ Increase of Switching Field with Decrease of Channel Thickness of Ni Nanochannels