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Electrodeposition of Ferromagnetic Metal Nanowires

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Abstract
Ni, Co, Fe and their alloys were electrodeposited from aqueous solution into cylindrical nanochannels to synthesize an array of numerical ferromagnetic metal nanowires. The shape of nanowires was precisely transferred from the nanochannel template and the aspect ratio reached to around 150. Magnetic hysteresis loops revealed that Ni, Co and Fe nanowires were spontaneously magnetized to the long axis direction and the coercive force reached to ca. 1000 Oe.

Keywords: nanowire, nanochannel, electrodeposition, magnetic material, coercive force

Introduction
The array of numerous metallic nanowires with straight shape has much attention due to their shape anisotropy and extremely large surface area. Metallic nanowires can be fabricated by electrochemically depositing metallic atoms into a nano-well template such as anodized aluminum oxide films with high density of nanochannels (about $10^8$ - $10^{10}$ cm$^{-2}$) [1-5]. On the other hand, lithographic galvanoforming (LIGA) process using laser, UV, X-ray, electrons and ions is also promised technique to obtain the wide range order of nanochannels and nanowires. Especially, ferromagnetic metal nanowires array is the best candidate to be applied for magnetic storage media with high density domain. In this study, Iron-group metals such as Ni, Co, Fe and Ni-Fe alloy were potentiostatically electrodeposited into ion-track etched polycarbonate membrane filters with numerical cylindrical nanochannels to synthesize the ferromagnetic metal nanowires array.

Experimental
Ion track-etched polycarbonate membrane filters with pore-diameter of 40, 80, 160 and 300 nm, pore-length of 6000 nm and pore-density of $10^8$ pore$\cdot$cm$^{-2}$ were used as a template for growing metallic nanowires. On a surface of the membrane filter, a gold layer was sputter-deposited to cover the pores and make a cathode. Aqueous solution containing metal sulfate was used as electrolyte. After the growing nanowires, polycarbonate membrane filters were dissolved in organic solvent (dichloromethane and chloroform) and the remains consisted of nanowires and a gold layer was served as a
sample for SEM observation. Magnetic hysteresis loops of electrodeposited nanowires were obtained using VSM with increasing the magnetic field up to 10 kOe.

**Results and Discussions**

Magnetic hysteresis loops were investigated using the sample of Ni, Co and Fe nanowires with pore-diameter of 40, 80, 160 and 300 nm. Magnetic field was applied to perpendicular directions to the film plan, which corresponds to the parallel direction to the long axis of nanowires. Coercive force of the nanowires was increased in decreasing the pore-diameter. Figure 1 shows the magnetic hysteresis loops of Ni, Co and Fe nanowires electrodeposited into polycarbonate templates with pore-diameter of 40 nm. As shown in these figures, magnetization switching was observed at around 1 kOe and residual magnetization was almost equal to the saturated magnetization. The coercive force of Co nanowires reaches up to 1084 Oe and the magnetic hysteresis loop shows typical perpendicular magnetization behavior. This is resulting from the uni-axial magnetic anisotropy and single magnetic domain structure of the nanowires with large aspect ratio.

![Fig.1 Magnetic hysteresis loops of Ni, Co and Fe nanowires electrodeposited into polycarbonate templates with channel-diameter of 40 nm.](image)

**Conclusions**

The cylindrical shape was precisely transferred from the nanochannels to the nanowires and the aspect ratio reached up to ca. 150. The each nanowire was consisted of single crystalline domain. Basis on the uni-axial magnetic anisotropy and single magnetic domain structure of the ferromagnetic metal nanowires, the magnetic hysteresis loops showed typical perpendicular magnetization behavior and the coercive force reached up to around 1 kOe.

**References**