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Uniaxial Perpendicular Magnetic Anisotropy of Co/Ni Multilayers

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According to a recent theoretical study, a perpendicular magnetic anisotropy can reduce the critical current density of the current-induced magnetic domain wall motion in a metallic nanowire [1]. We employ two magnetic elements, Co and Ni, to obtain the perpendicular magnetic anisotropy as they have a lower spin-flip scattering rate than other combinations of ferromagnetic and non-ferromagnetic materials such as Co/Pd or Co/Pt. A simulation study shows that the tuning of width and thickness can reduce the critical current density with a combination of various parameters such as suitable magnetic saturation field and perpendicular magnetic anisotropy. To find out the feasibility of theoretical hypothesis, a series of multilayer films consisting of Si/SiO_2/Au underlayer(10~200 Å)/ Ni(8 Å)/[Co(2Å)/Ni(8 Å)] × N (N = 2, 4, 8, 12, 16) are prepared. The magnetic anisotropy of the Co/Ni multilayer is controlled in two different ways: (i) the thickness of the Au underlayer, and (ii) the number of Co/Ni bilayer stacks. We observe that the perpendicular magnetic anisotropy energy (K_u) of Co/Ni multilayers ranges from 3.0×10^5 to 1.8×10^6 erg/cm^3 with the variation of those two factors.

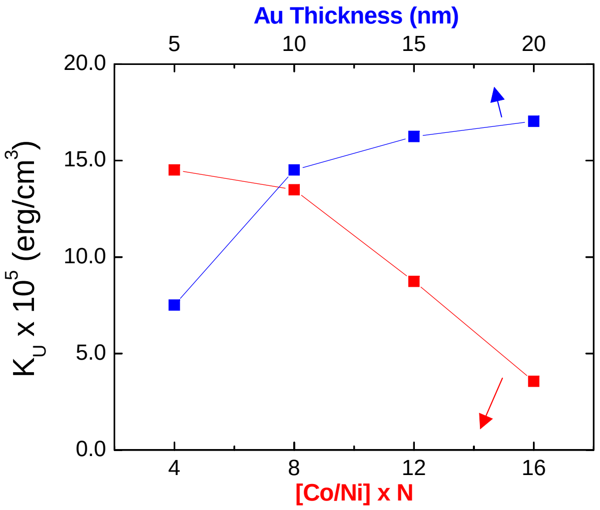

Fig. 1. Evaluated K_u value at various conditions.

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Anisotropy-dominated Magnetic Interactions in Semiconductor Nanostructures

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Nanostructured semiconductors showing novel electronic, optical, and magnetic properties have attracted intensive attention. Germanium, among others, is getting more important noticeable due to providing an uncomplicated system for research as well as its compatibility with Si-based technology. For instance, germanium nanocrystals buried in SiO2 matrix have been found to show size-dependent photoluminescence [1]. Recently, room temperature ferromagnetism has been reported for germanium nanostructures [2]. Here, we focus on the magnetic couplings occurring in the magnetized germanium nanostructures.

Germanium nanostructures buried in a silicon oxide thin film were formed by sputtering deposition on Si(100) substrates, followed by a thermal annealing at 900 °C. X-ray diffraction and energy dispersive spectroscopy were taken to confirm the phase of the nanostructures in the samples. Conventional and high-resolution transmission electron microscopy has been used for microstructural investigations. Magnetic measurements were performed using a superconducting quantum interference device, revealing at room temperature a superparamagnetic behavior of the ferromagnetically ordered germanium nanostrctures. Magnetization has been found to emerge due to size effects for temperatures up to 350 K, which is surpassed by the diamagnetic contributions from the silicon substrate and the oxide matrix in the high field regime. The temperature dependence of the magnetization showed that the germanium nanostructures were superparamagnetic down to 230 K, below which the couplings between magnetic domains cannot be ignored. Thermal excitation of the domain reorientation process was observed at temperatures below 60 K. Anomalous magnetic hysteresis with negative remanences was observed at 5 K, revealing the effects of the inter-domain couplings on the domain rotation driven by a changing magnetic field. These results will be discussed based on the comparison with the simulation results of a spin reorientation model, taking into account the anisotropy of individual domains and the interactions between them. An antiferro- or ferrimagnetic interaction can be concluded. Furthermore, the role of the distribution of easy axis in the observed hysteresis behaviors will be discussed in relation with the anisotropy effects, which are in general conspicuous in an assembly of spin-polarized nano-objects.

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