Switching probability analysis on epitaxial Co/Pt multilayer single nanodots

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Magnetization switching is a fundamental function of various magnetic devices, such as magnetic recording, spintronics, permanent magnets, and so on. Thus understanding the magnetization switching behavior in a single small magnetic particle is essentially important to develop the high performance magnetic devices. The underlying physics of magnetization switching has been discussed through various experiments and simulations in Co/Pd and Co/Pt multilayers [1-3], which are important materials for practical applications due to their tunable perpendicular magnetic anisotropy. Through these large number efforts, it has been widely accepted that a nucleation of a reversed domain with a dimension of domain wall width initiates the magnetization reversal of the dot. These previous experiments, however, were carried out in polycrystalline samples, many of intrinsic switching properties would be hidden behind some distributions of magnetic and geometric properties. In this study, we have investigated the magnetization switching behavior in a series of single nanodots of epitaxially grown Co/Pt multilayer.

The film structure is Sapphire(001)/Pt 20/[Co 0.8/Pt 0.5]$_4$/Pt 1.5 (in nm).All deposition processes are performed at room temperature after substrate annealing at 800 ^{o}C for 1 h. The epitaxial growth of Co/Pt film with fcc (111) structure is well confirmed by x-ray diffraction measurements. The Co/Pt film is patterned into single nanodots with diameters *d* varying from 120 nm to 1.6 μm by using electron beam lithography and Ar ion etching. Subsequently, the Pt underlayer is patterned into a cross-shaped electrode for anomalous Hall effect (AHE) measurements. An example of scanning electron microscope (SEM) image of a Co/Pt dot of *d* = 200 nm is shown in Fig. 1. The magnetization switching of the dots is detected by an AHE curve under a vertical dc field H_{dc} from an electromagnet.

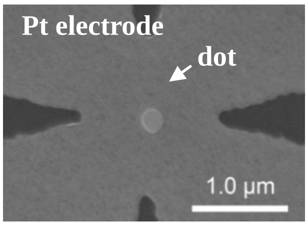

Fig.1. SEM image of a single dot with *d* = 200 nm with a Pt electrode.

Magnetization curves of the single Co/Pt dots exhibit a rectangular shape, and show a Stoner-Wohlfarth like angular dependence of coercivity, which suggesting a nucleation reversal mechanism in the dots with bi-stability magnetized states. To analyze the switching process, switching probability P_{sw} of the dot is evaluated by repetition of magnetization curve measurements. The P_{sw} plotted as a function of H_{dc} is well fitted by the Néel-Arrhenius law $P_{sw} = 1 - exp\{-tf_0 exp[-E_b/k_BT]\}$. The behaviors of P_{sw} changes drastically below and above *d* = 400 nm, indicating the change of energy barrier E_b. The fitting analysis on the P_{sw} by assuming a simple energy barrier function of $E_b = E_0(1 - H_{dc}/H_0)^n$ gives the intrinsic switching field H_0 and energy barrier height E_0/k_BT, as shown in Fig. 2. Note that these two parameters exhibit dramatic change at *d* ~ 400 nm, strongly indicating the change of reversal mechanism. For *d* < 400 nm, the value of E_0 can be well explained by the single barrier of reversed embryo. On the other hand, *d* > 400 nm, the evaluated value of E_0 by assuming simple energy barrier function is hard to be explained, suggesting the somewhat complicated reversal mechanism, such as multi-barrier.

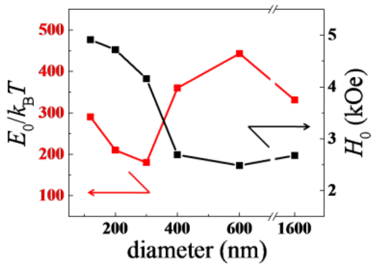

Fig.2. E_0/k_BT (black circle) and H_0 (red square) as functions of dot diameter *d*.

Reference

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