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Prediction and Confirmation of Perpendicular Magnetic Anisotropy in Pt/Co/Ni/Co/Pt Multilayers

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Introduction

Very recently, it has been suggested that perpendicular magnetic anisotropy (PMA) systems might be excellent candidates for race track memory based on current induced domain wall motion (CIDWM), since the critical current density can be small compared to in-plane magnetized thin film [1]. PMA films have three contrasting domain evolution patterns [2]: nucleation, stripe-growth and wall-motion phases. Among these evolution patterns, wall-motion is necessary for CIDWM. However, generally, wall motion phase can be achieved with an ultra-thin magnetic layer due to large magneto static energy [2]. It is advantageous to have a thick magnetic layer and a small number of interfaces for spin transfer torque effect. We have predicted and confirmed a single structure PMA sample showing the wall motion phase with inserting a thick Ni layer between Co layers.

Experiments

Pt (2.5 nm)/Co (0.3 nm)/Ni (x)/Co (0.3 nm)/Pt (1 nm) samples were deposited by dc magnetron sputtering onto bare Si substrates with changing the thickness of the Ni layer from 1 to 7 nm. The magnetic domain images and hysteresis loops were then monitored by a time-resolved MOKE microscope, capable of up to ×1,000 magnification with an objective lens having the numerical aperture 0.75 with the spatial resolution 0.45 μm. The films were first saturated under a sufficiently large magnetic field and then, the reversed domains were formed by applying short reversed magnetic field pulses. The captured domain images were analyzed by the background subtraction to extract the distinct domain evolution patterns.

Results and discussion

Fig. 1 illustrates the domain evolution patterns of samples with respect to the thickness of the Ni layer. Wall motion phase was dominant from 1 nm to 4 nm, and then, the wall motion phase was changed gradually to stripe growth (5-6 nm) and nucleation phase (7 nm). Fig. 1(a) shows the representative hysteresis loops of the each domain evolution patterns. The coercivity and switching time changes with respect to the thickness of the Ni layer.

The wall motion samples have stable magnetic properties showing a short switching time and high coercivity. Our samples maintained wall motion phase until the thickness of total magnetic layer was increased up to 4.6 nm. That is about four times thicker than that in the sample using a single Co layer. An ultra-thin Co layer (typically 0.2-1 nm) sandwiched between Pt is known to show the wall motion phase. However, the PMA begins to become weaker when the magnetostatic interacton becomes stronger with increasing the thickness of magnetic layer and thereby the total magnetic moment. Repeating the Co/Ni/Co structure can be the one way to increase the total thickness of the magnetic layers, but a lot of interfaces may result in complicated effects in terms of the spin transfer torque efficiency. We were able to extend the critical thickness of the magnetic layer to 4.6 nm by inserting a Ni layer with a very low saturation magnetization (450 emu/cc) without repeating the structure.

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References

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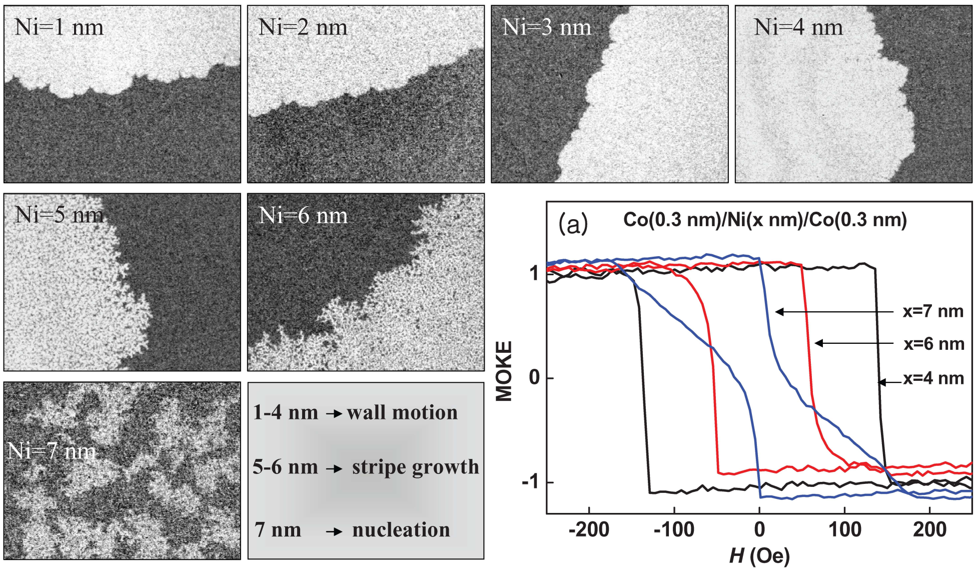

Fig. 1. MOKE images of the domain evolution patterns with respect to the thickness of Ni layer. (a) MOKE hysteresis loops of 4, 6, and 7 nm samples.