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Voltage Controlled Magnetic Anisotropy at $Fe_{1-x}Co_xPd$/MgO Interface

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Abstract

We study the interfacial magnetic anisotropy and its voltage induced change on a fully epitaxially grown Fe/$Fe_{1-x}Co_xPd$/MgO sample. It has been investigated using a spin-wave spectroscopy. We obtained the anisotropy energy change around 200 fJ/Vm in the cobalt rich region.

1. Introduction

In last few decades, an electric field controls the magnetic anisotropy at ferromagnetic/MgO interface [1,2]. It has been attracted with a great attention. This is called voltage controlled magnetic anisotropy (VCMA). The VCMA effect is sensitively measured by the spin-wave spectroscopy [3]. Interfacial anisotropy of the Fe/MgO interface can be engineered by inserting ultrathin layer [4,5], and by employing different underlayer materials [6-8]. Moreover, it is reported that FePd/MgO [9] and Co/Pd/MgO [10-12] systems show larger VCMA effect. Hence, in this study, we investigated the interfacial anisotropy and the VCMA on the $Fe_{1-x}Co_xPd$/MgO interface.

2. Fabrication and measurement

An epitaxial multilayer of MgO(5 nm)/V(20 nm)/Fe(20 nm)/$Fe_{1-x}Co_xPd$(3 monolayer)/MgO (5 nm) was deposited on the MgO(001) substrate using an electron beam deposition. Ultrathin $Fe_{1-x}Co_x$ layer was prepared by alternate deposition of Fe and Co as shown in Fig. 1(a). After that one monolayer (ML) Pd layer was deposited on the $Fe_{1-x}Co_x$ layer. Subsequently, a 50-nm-SiO_2 was encapsulated as an additional insulating layer by the sputtering. Then, the film is patterned in a 100 × 400 μm^2. Microsized antennae and an intermediate gate were fabricated with Cr (5 nm)/Au (200 nm) by a conventional microfabrication technique with an electron beam lithography and a lift off process. Figure 1 (b) shows the schematic of spin-wave device and measurement setup. We study the spin-wave property by measuring the scattering (S) parameter by a vector network analyzer. We excite the magnetostatic surface spin-wave (MSSW) by applying a radio frequency signal of −15 dBm. The fourfold crystalline anisotropy field ($H_{crystal}$) of 20-nm-Fe layer and the interfacial magnetic anisotropy (H_{surf}) between the $Fe_{1-x}Co_xPd$ and the MgO layers are estimated from the resonant frequency of MSSW, shown in Figs. 2 (a) and 2 (b), respectively. The fourfold crystalline anisotropy field is slightly changing with the different composition of Fe and Co as shown in Fig. 2 (a) and its average value is 680 Oe. However, the interfacial anisotropy is changing with the different composition of Fe and Co as shown in Fig. 2 (b).

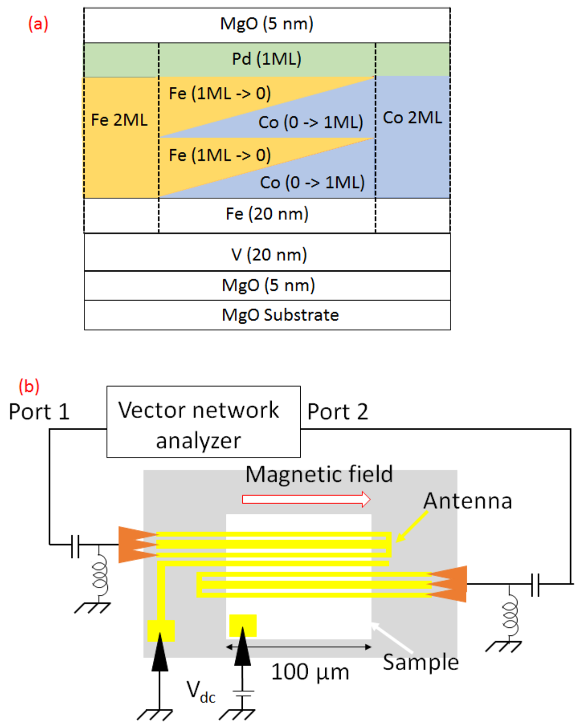

Fig. 1. (a) Schmatic of epitaxially grown films. (b) Schmatic of the fabricated sample and measurement setup. The yellow colour shows the antenna and gated contact pad. The ground-signal-ground (GSG) probe are shown by orange colour. The dc voltage are applied on sample.

To study the VCMA effect, we applied a dc voltage (V_{dc}) on the sample as shown in Fig. 1 (b). The applied voltage shifts the resonant frequency of the spin-wave propagation signal. This voltage-induced shift is correlated to the VCMA effect. Figure 3 shows the VCMA effect as a function of *x*. It shows that VCMA increases as the Co fraction increases in the composition.

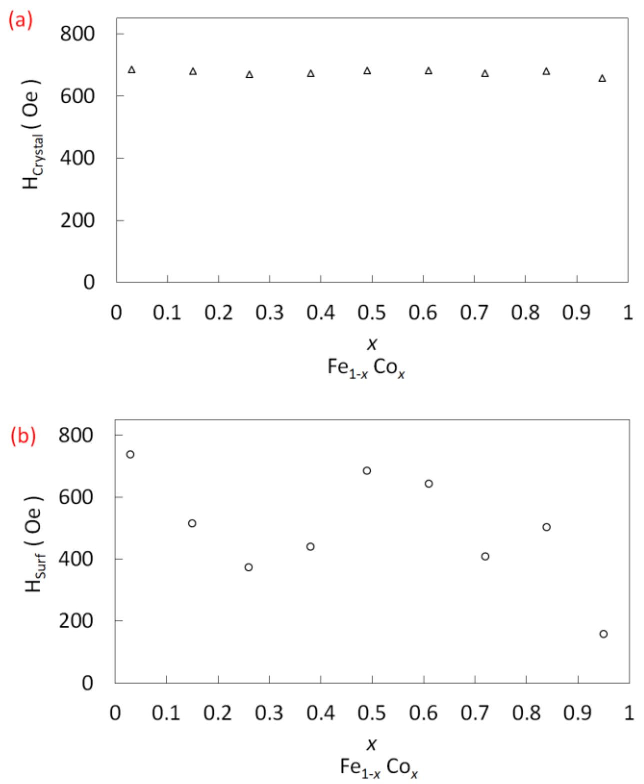

Fig. 2 (a) A fourfold crystalline anisotropy field. (b) Interfacial magnetic anisotropy. The *x* shows the fraction of Co in $Fe_{1-x}Co_x$.

3. Conclusion

The influence of ultrathin $Fe_{1-x}Co_xPd$ insertion between Fe and MgO interface on the interfacial magnetic anisotropy and its voltage-induced change has been studied by spin-wave spectroscopy. We found that VCMA effect is increasing by insertion of cobalt layer. We obtained VCMA effect around 200 fJ/Vm in cobalt rich region. Higher VCMA is useful for voltage-induced magnetization switching [13] to realize a nonvolatile memory.

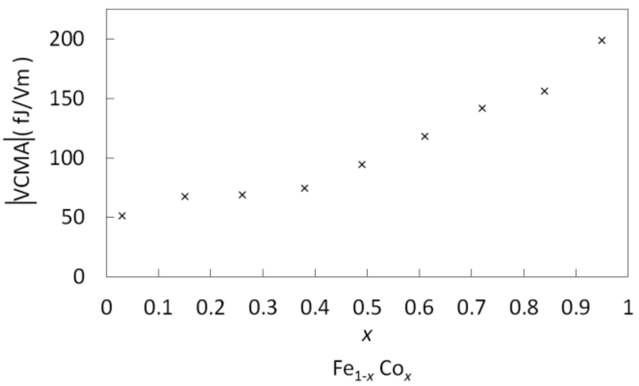

Fig. 3.The VCMA versus the composition of Fe and Co. The *x* shows the fraction of Co in $Fe_{1-x}Co_x$.

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