Voltage-controlled magnetic anisotropy of Fe/Pd/MgO system

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The interfacial perpendicular magnetic anisotropy (PMA) of magnetic multilayer can be enhanced by inserting a large spin-orbit interaction material such as Pd [1]. Moreover, an attempt to find high PMA modulation by using voltage is very important for realizing high-density magnetic random-access memory [2]. We have reported the voltage-controlled magnetic anisotropy of Fe/Pd/MgO multilayer by analyzing spin-wave dynamics [3]. In the present study, we investigated post-annealing influences on voltage-controlled magnetic anisotropy (VCMA) of Fe/Pd/MgO.

The epitaxial multilayer stacks MgO (001) substrate/MgO(5 nm)/V(20 nm)/Fe(20 nm)/Pd(t_{Pd}=0-1 nm)/MgO(5 nm) was fabricated using the molecular beam epitaxy under ultrahigh vacuum. After that, the sample was encapsulated by sputtering of 50 nm SiO_2. Micro-sized antennas were prepared onto it to generate and detect spin-waves. An in-plane external magnetic field is applied normal to the spin-wave propagation direction to excite magneto-static surface spin-wave (MSSW). Using a vector network analyzer, the frequency shift of S_{21} signal under voltage was characterized. Figure 2 shows the voltage-induced interfacial magnetic anisotropy energy at several post-annealing temperatures. The result shows the increasing of Pd-thickness decrease the energy change. It is similar to sputter-deposited Co/Pd system [3] which can be explained by induced magnetic moment in Pd at MgO interface. Furthermore, the annealing treatment affected the VCMA, which should be correlated to the interfacial was attributed to Fe/Pd interfacial state change. The trend showed an increase by annealing for all Pd-thickness, where the maximum value reached ~40 fJ/Vm obtained at t_{Pd} = 0.2 nm (1 ML) annealed at 250 °C. Interestingly, the polarity change was observed for 1.2 nm Pd-insertion sample with 300 ˚C annealing.

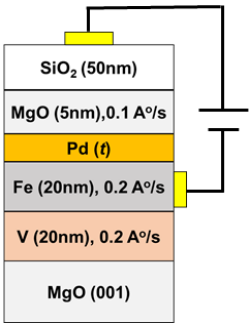

Fig. 1 Schematic of the sample structure

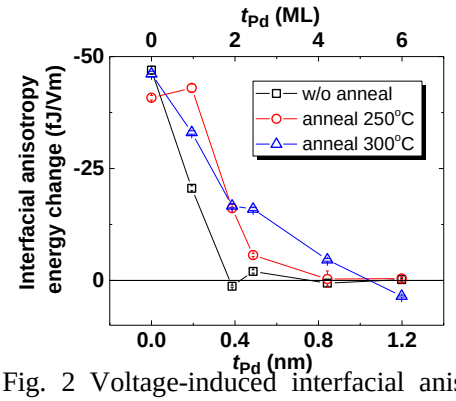

Fig. 2 Voltage-induced interfacial anisotropy energy change

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[3] J. Suwardy *et al.*, JSAP Spring Meeting 2017, ***. [4] Y. Hibino *et al.*, APEX **8**, 113002 (2015).