Perpendicular magnetic anisotropy of Fe/cubic CrO/MgO heterostructures

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Single-crystalline Fe/MgO interfaces show large perpendicular magnetic anisotropy (PMA) of 2 mJ/m^2.[1)] The hybridization of Fe-3d_{z^2} and O-2p_z orbitals plays an important role for PMA at Fe/MgO interface.[2)] Moreover, the magnetic anisotropy at Fe/oxide interface can be tuned by the electric field,[3)] and large voltage control magnetic anisotropy (VCMA) coefficients of 290 fJ/Vm at Fe/MgO interface were reported.[4)] Experimental and theoretical approaches have also been performed for enhancing PMA and VCMA by inserting heavy metals into Fe/MgO interface.[5,6)] Thus, Fe/MgO based magnetic tunnel junctions (MTJs) are promising for voltage-control magnetoresistive random access memory. In this study, we investigated structure and magnetic properties of Fe/MgO heterostructures formed by a sputtering process and found the formation of rock-salt-type CrO at the Fe/MgO interface, which shows interface PMA energies of 1.55 mJ/m^2.

The multilayered stacks of MgO substrate (001)//MgO(5 nm)/Cr(30 nm)/Fe(0.7 nm)/MgO(2 nm) were prepared by rf-sputtering. MgO substrate and Cr buffer were annealed at 500 ºC. After the deposition, post-annealing was performed at T_a = 300, 400, 500 ºC, and an as-deposited sample was also prepared for comparison. The structural analyses were performed using aberration corrected scanning transmission electron microscopy (STEM) with energy dispersive X-ray spectroscopy (EDS). In as-deposited samples, the oxidation of Fe layer was confirmed, suggesting that it was oxidized during the sputter-deposition of MgO layer. After the post-annealing with T_a = 500 ºC, Cr-oxide was segregated between Fe and MgO layers. From the nanobeam electron diffraction (NBD) patterns, the Cr-oxide layer was characterized as the rock-salt type structure. In addition, it was found that the Fe oxide was reduced by Cr and returned to pure Fe.

The magnetic properties were investigated using a vibrating sample magnetometer. Saturation magnetizations increased with the post-annealing temperatures. The stacks with T_a = 400, 500 ºC show effective PMA energies of 0.82 and 0.77 MJ/m^3, respectively. Interface PMA energies of 1.55 mJ/m^2 were achieved in the samples with T_a = 500 ºC, suggesting that the PMA occurs at the Fe/CrO interface. Our demonstration revealed that the diffusion of Cr leads to the well-controlled flat heterostructure, resulting in a cubic CrO ultrathin layer stabilized at Fe/MgO interface.

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