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Origin of MR enhancement in CPP-GMR spin valves with ultra-thin Cu inserted Fe-Co layer

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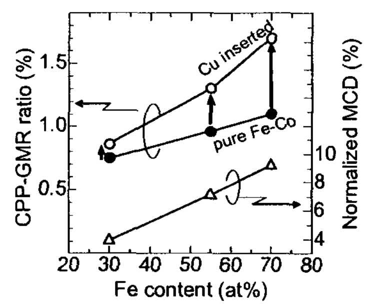
In order to utilize CPP-GMR elements for HDD-head-sensors, large MR ratio is required. As one approach for MR enhancement in CPP-GMR elements, ultra-thin Cu insertion technique into Fe-Co layers has been reported [1]. It was experimentally confirmed that the ultra-thin Cu insertion enhances the spin dependent bulk scattering factor and results in the MR enhancement [1]. However, the microscopic origin and/or mechanism of this phenomenon are not yet fully clarified. In the present work, quantitative measurement of spin polarization of inserted Cu atoms in the Fe-Co layers was performed with using x-ray magnetic circular dichroism (XMCD) technique and the correlation with the CPP-MR ratio was discussed.

Using UHV-DC magnetron sputtering system, the CPP-GMR spinvalve films of bottom electrode / MnIr (7.5) / $Co_{70}Fe_{30}$(3.5) / Ru (0.9) / Ref. / Cu spacer (3) / Free / Cap (thickness in nm unit) were fabricated. The Ref. and Free layer are composed of the Fe-Co (0.5) / Cu (0.2) bi-layers which are stacked 4 times via alternative deposition and Fe-Co (1) which is inserted at the interface with Cu spacer. The crystalline structure and MR performances are investigated at room temperature by means of XRD and AC-4 probe method, respectively, after field annealing at 270°C for 3 hrs with 8 kOe. CPP-GMR devices are fabricated using EB lithography and Ar ion milling with 200×300 nm^2 range. For MCD measurement, thick laminated layer of [Fe-Co (0.5) / Cu (0.2)]×40 are fabricated. MCD is measured with transmission mode by using a 1Hz helicity switching technique of left and right circularly polarized soft x-rays at BL25SU of SPring-8.

Figure shows CPP-GMR ratio and normalized MCD magnitude by *resonant absorption at Cu-L_3 edge as a function of Fe content of Fe-Co* based FM. The normalized MCD correspondsto the magnitude of spin polarization of Cu. The enhancement of CPP-GMR ratio by ultra-thin Cu insertion is clearly observed as indicated with thick arrows, and such the enhancement is remarkable with increasing Fe content. The normalized MCD also increases with increasing Fe content. Based on these experimental findings, we conclude that the enhancement of CPP-GMR ratio is originated from the enlarging spin polarization of inserted Cu atoms in Fe-Co FM, that might act as spin dependent scattering centres for conduction electrons.



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Ru-mediated interlayer exchange coupling in Co/Pd and Co/Au multilayers with perpendicular magnetic anisotropy

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A perpendicular magnetic anisotropy (PMA) multilayer is known to show little magnetoresistance. This is because a general PMA multilayer is energetically stable if the magnetization directions of ferromagnetic layers are aligned parallel to each other. One way to control this magnetic alignment inside the multilayer is to utilize interlayer exchange coupling (IEC) layers [1][2]. In this study, a Ru-mediated IEC was introduced in Co/Pd(111) and Co/Au(111) multilayers to induce antiferromagnet (AF) alignment inside them. The effects of the IEC layers on the magnetic properties were investigated.

Samples were grown by MBE. The Co/Pd(111) and Co/Au(111) multilayers were prepared follows the procedure described in Ref. [3]. $\{[Co(0.6\ nm)/Pd(2.0\ nm)]_3/Co(0.6\ nm)/Ru(0.85\ nm)\}_{N-1}/[Co(0.6\ nm)/Pd(2.0\ nm)]_3$ multilayers and {[Co(0.6 Zwere subsequently deposited on buffer layers at 100 °C, where N is the repetition number of the submultilayers. A submultilayer was defined as an area sandwichedbetween two Ru layers. The magnetization curves were obtained by *M-H* measurement using a VSM. The resistivities were then measured by four-lead magnetoresistance measurements.

Figure 1 shows the results of the VSM measurements for the samples with and without Ru layers. On inserting the Ru layers, the resulting magnetic coupling between the Co layers changes the shape of the magnetization curve. One shows a hysteretic behavior (< 7 kOe), while the other indicates a nonhysteretic behavior (> 10 kOe). We found that even within the stacks, the individual ferromagnetic layers switch separately, such that the AF configurations are present during reversal even within the same multilayer stack. On considering the magnetic reversal and transport properties of the Co/Pd multilayers, the IEC was found to cause AF alignment inside a multilayer stack that was sandwiched between two Ru layers.

In Co/Au(111) multilayers case, total changes of the resistivity are decreased for all of the samples using Ru layer. It is because the rates of changes after the magnetization saturation indicate smaller value than that of the sample without Ru layer. This is caused by the spin dependent scattering at Co/Ru interface.

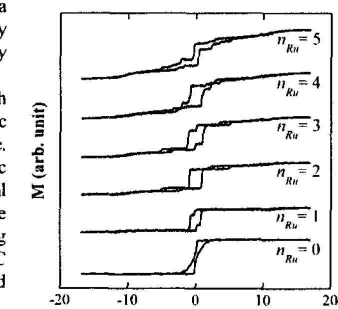

Fig. 1. Results of the VSM measurements for samples of Co/Pd multilayers with and without Ru layers (n_{Ru}: the number of Ru layer inserted in a sample). The magnetic field was applied perpendicular to the plane.

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