Effects of NiFe/Co Insertion at the [Pd/Co] and Cu Interface on the Magnetic and GMR Properties in Perpendicularly Magnetized [Pd/Co]/Cu/[Co/Pd] Pseudo Spin-Valves

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Perpendicularly magnetized $[Pd/Co]_2/Cu/[Co/Pd]_4$ pseudo spin-valves (PSVs) are promising in spintronic device applications. However, a large coercivity of the soft $[Pd/Co]_2$ ferromagnetic layer due to a high perpendicular anisotropy is revealed as a drawback for the device applications. In order to reduce the coercivity of the soft layer, a thin NiFe layer of 0–1 nm was inserted at the interface between the soft $[Pd/Co]_2$ layer and the Cu spacer. It was observed that the soft layer coercivity dropped dramatically from 250 to 40 Oe (85% reduction) by increasing the NiFe thickness. The main physical reason for this decrease is the reduction in perpendicular anisotropy caused by the in-plane anisotropy of the NiFe layer with a thickness larger than 0.4 nm. The interlayer coupling field was also increased mainly due to the increase in topological coupling induced by a rougher surface roughness attributed to Ni-Cu inter-diffusion. Due to this Ni-Cu intermixing, there is an increase in spin-independent scattering at the interfaces leading to an incidental decrease in the giant magnetoresistance (GMR). To improve the GMR performance in this structure, a thin Co layer of 0.1–0.6 nm was inserted at the interface between the NiFe layer and the Cu spacer while keeping the total NiFe/Co thickness constant at 0.5 and 0.7 nm, respectively. The Co insertion was found to be effective in protecting against the Ni-Cu intermixing leading to a 26% and 70% improvement in the GMR ratio up to 0.3 nm of Co insertion thickness with a further 65% and 75% reduction in the soft layer coercivity for a NiFe initial thickness of 0.5 and 0.7 nm, respectively. The experimentally confirmed results in this work demonstrate that NiFe/Co insertion at the interface between [Co/Pd] ferromagnetic layer and Cu spacer is effective in obtaining an optimum condition where the soft layer coercivity (anisotropy) is reduced while maintaining higher GMR ratio in the perpendicularly magnetized [Pd/Co]/Cu/[Co/Pd] PSVs.

Index Terms—**Control of perpendicular anisotropy and GMR, Co/Pd pseudo spin-valves, NiFe/Co insertion, perpendicular anisotropy.**

I. Introduction

RECENT developments in Co/Pd based spin-valves with perpendicular anisotropy have been driven by the expectation of promising properties such as high thermal and magnetic stabilities that allow for the realization of extremely low-dimensional, high-reliability devices for spintronic applications [1]–[4]. The development of spin-valves with perpendicular anisotropy for applications such as spin transfer switched magnetic random access memory (MRAM), ultra-high-density magnetic information devices, and low field spin oscillators are fueled by these promising advantages [5]–[11]. However, one of the major drawbacks with these spin-valves is the large coercivity of the free layer due to their large perpendicular anisotropy. In applications such as toggle or spin transfer switched MRAMs, the large coercivity (or switching field) necessitates a larger critical current density to be able to switch the magnetic elements. One approach to reduce the coercivity is to reduce the perpendicular anisotropy of the soft (free) layer. This can be achieved by introducing an in-plane anisotropy component by the insertion of thin layer of ferromagnetic material such as NiFe or CoFe. Previous works indicate that the NiFe grown on ferromagnetic materials with perpendicular anisotropy is able to introduce an in-plane anisotropy component while still maintaining the perpendicular anisotropy of the structure at controlled thicknesses [12], [13].

In this work, we investigated the effects of inserting a thin layer of NiFe between the soft $[Co/Pd]_2$ layer and the Cu spacer, on the anisotropy (H_K), soft layer coercivity (H_C), giant magnetoresistance (GMR) and interlayer coupling field (H_{INT}) in the $[Pd\ (1.2)/Co(0.6)]_2/Cu$ (t_{Cu} = 1.6 or 1.9)$/[Co\ (0.3)/Pd\ (0.6)]_4/Pd$ (3 nm) PSVs. It was revealed that the NiFe is effective in reducing the perpendicular anisotropy and coercivity of the soft [Co/Pd] layer. However, the GMR of the spin-valves is degraded due to the surface roughness induced increase in H_{INT} along with Ni/Cu intermixing [14]–[16]. In order to improve these undesirable effects, an ultrathin Co layer is introduced between the NiFe and Cu layers, and the changes in the magnetic and GMR properties due to this insertion are investigated. Finally, we aim to achieve an optimum condition where the soft layer coercivity (anisotropy) is reduced while maintaining higher GMR ratio in the perpendicularly magnetized [Pd/Co]/Cu/[Co/Pd] PSVs.

II. Experiment

The series of PSVs, Si/Pd (3)/$[Pd\ (1.2)/Co\ (0.6)]_2/Ni_{80}Fe_{20}$ (t_{NiFe})/Co (t_{Co})Cu (t_{Cu})/$[Co\ (0.3)/Pd\ (0.6)]_4$/Pd (3 nm), were deposited on Si (100) substrate using a dc-magnetron sputter at room temperature. The base pressure was maintained below 4×10^{-8} Torr. First, in order to investigate the effect of NiFe insertion on their magnetic and GMR properties, the Si/Pd (3)/$[Pd\ (1.2)/Co\ (0.6)]_2$/NiFe (t_{NiFe})/Cu (t_{Cu})/$[Co\ (0.3)/Pd\ (0.6)]_4$/Pd (3 nm) PSVs were fabricated with a Cu spacer thickness, t_{Cu}, of 1.6 and 1.9 nm,

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