Giant MR Ratio by Using Metastable bcc-Cu Spacer Layer in Epitaxial Current In-Plane Giant Magnetoresistance Devices

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Current in-plane giant magnetoresistance (CIP-GMR) has been used in magnetic sensor applications because it has low noises, adjustable resistance and almost no bias voltage dependence of MR ratio. However, its magnetoresistance (MR) ratio has been saturated for long years although larger value is necessary to increase the signal output for various magnetic sensor applications. It is well known that good lattice and band matchings are necessary to obtain large MR ratio. Since previous study shows ideally perfect lattice match on bcc-Fe/bcc-Cu/bcc-Fe because of the formation of metastable bcc-Cu spacer [1], it is worth to investigate epitaxial bcc $Co_{1-x}Fe_x$-based CIP-GMR spin valves with thin Cu spacer. The stacking of MgO subs./$Co_{1-x}Fe_x$/Cu/$Co_{1-x}Fe_x$/IrMn/Ta were deposited by sputtering with x = 10, 25, 50, 67 and 100. We found a large enhancement of MR ratio from 4% in pure Fe (x = 100) to over 20% in bcc-CoFe (x = 25-67) as shown in Fig.1. The largest observed MR ratio of 26% in $Co_{50}Fe_{50}$ is close to the highest ever reported value (28%) [2]. We also fabricated antiferromagnetically exchange coupled MgO subs./$Co_{50}Fe_{50}$/Cu/$Co_{50}Fe_{50}$/MgO GMR stack, where the MgO capping layer is to introduce a specular reflection of conduction electron at the interface with CoFe. As a result, we observed giant MR ratio of 40% which is the highest MR in trilayer CIP-GMR ever reported. As shown in Fig.2, our TEM analysis confirmed $Co_{50}Fe_{50}$ and Cu layers coherently connected without any dislocation because of the formation of bcc Cu spacer as previously reported in Fe/Cu/Fe stack [1]. Our first principle calculation confirmed the improvement of band matching with bcc Cu from Fe to $Co_{50}Fe_{50}$ is the origin for observed giant MR ratio.

[1] B. Heinrich *et al.*, Phys. Rev. Let., 64 (1990) 673
[2] M. Seigler, IEEE Trans. Magn., 43 (2007) 651

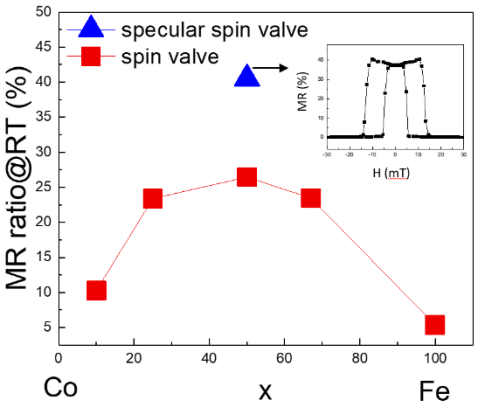

Figure 1. Composition (x) dependence of MR ratio of $Co_{1-x}Fe_x$-based CIP-GMR device.

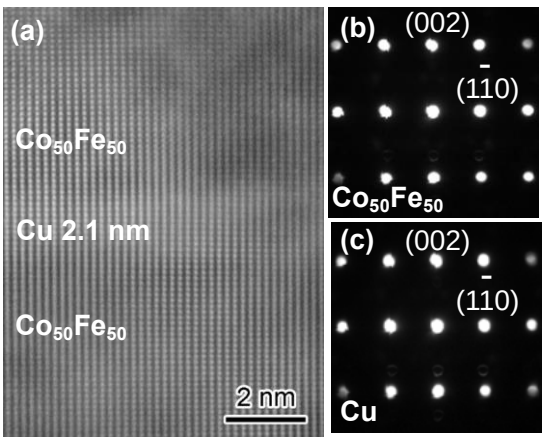

Figure 2. High-angle annular dark field STEM image of $Co_{50}Fe_{50}$/Cu/$Co_{50}Fe_{50}$ along with its electron diffraction pattern (b)-(c).