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HCP-disordered CoPt electrode and exchange control layer for MgO based perpendicular magnetic tunnel junctions

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1. Introduction

Spin transfer torque magnetic random access memory (STT-MRAM) with perpendicular magnetic anisotropy is an attractive application as a new spintronic device. Recently several studies have shown that the perpendicular magnetic tunnel junctions (P-MTJs) present better data retention as well as lower critical switching current compared with the in-plane MTJs [1-2]. However, there are some issues that should be overcome in realizing perpendicular STT-MRAM. One of key issue is the enhancement of tunnel magnetoresistance (TMR) for the enough reading margin. Thus, the various perpendicular magnetic materials have been reported to improve the TMR ratio [3-5].

In this letter, the P-MTJs with HCP-disordered CoPt perpendicular magnetic materials were. The PMA of the (0001) oriented HCP-CoPt is 2×10^7 erg/cc [6], which is large enough for high density non-volatile data storage applications. Also, the narrow switching current and retention distribution are expected from a very narrow c-axis distribution of CoPt film. Therefore, we claim that HCP-CoPt is a promising electrode material and has potential to extend the scalability of STT-MRAM. Especially, we present that the insertion of exchange control layer (ECL) improves the PMA of CoPt/CoFeB as well as the TMR.

2. Experimental Procedures

The MTJs with CoPt perpendicular magnetic material are prepared on an amorphous TiN bottom electrode by DC/RF sputtering method at room temperature. The typical MTJ in this letter is structured with seed layers (Seed layer)/CoPt/ECL1(x)/CoFeB(y)/MgO/CoFeB/ECL2/CoPt/[Pd/Co]$_5$/Ta capping layer. The ECL1 thickness (x) in free layer is varied from 0 to 1 nm. In case of the pinned layer, the ECL2 layer is fixed at 0.7 nm. The CoFeB thickness (y) used as in-plane transition metal (TM) is changed from 0 to 1.5 nm. All samples are annealed in vacuum for 2hr at 275 °C after the deposition of MTJ. The width of patterned MTJ is changed from 200 nm to 3 μm. The magnetization curves of CoPt film are examined by vibrating sample magnetometer (VSM). The TMR and product of resistance and area (RA) of P-MTJs are estimated by measuring resistance as a function of applied perpendicular magnetic field.

3. Results and Discussions

To investigate the strength of exchange coupling between CoPt and CoFeB, the M-H curves for (Seed layer)/CoPt/MgO/Ta and (Seed layer)/CoPt/CoFeB/MgO/Ta is measured after annealing, as displayed in Fig. 1. For a single CoPt, H_n is about -377 Oe, whereas the double CoPt/CoFeB layers favor not the perpendicular magnetization but the in-plane magnetization as shown in the inserted figure of Fig. 1. This can be caused by the strong in-plane magnetization anisotropy (IMA) of CoFeB as well as the weak exchange coupling of CoPt/CoFeB.

We introduced a very thin TM as ECL at the interface of CoPt/CoFeB to improve the exchange. Fig. 1 shows the M-H curve taken from (Seed layer)/CoPt/ECL/CoFeB/MgO/Ta. In this case, H_n show a negative value of -92 Oe, contrary to CoPt/CoFeB mentioned above. This indicates that ECL insertion enhances the PMA property of CoPt/CoFeB. We also find that a negative H_n decreases as the CoPt thickness decreases, but does not display in this letter. Consequently, we think that the PMA improvement of P-MTJs with ECL is attributed to the surface magnetic anisotropy contribution and magnetostatic field from CoPt. Another effect of a thin ECL is to improve the texture of CoFeB/MgO and thus TMR, which will present in the following paragraph.

Fig. 2(a) shows the full R-H (resistance versus applied magnetic field) curve of P-MTJ without ECL, where the MTJ size is 0.3×1.0 μm^2. As displayed in Fig. 2, the magnetization of free layer does not show the sharp switching characteristics due to the weak PMA. This is consistent with the result shown in Fig. 1. In this sample, the TMR (R_{AP}-R_P/R_P) is about 25%, and the parallel resistance (R_P) is 8.5 kΩ (RA = 1.2 kΩ-μm^2). Especially, the RA is higher than that of in-plane MTJ designed at 1 nm MgO thickness. The origins of this low TMR and high RA are the weak PMA and the texture of CoFeB/MgO.

A very thin ECL is inserted at the interface of CoPt/CoFeB to exclude the template effect of CoPt as another effect in addition to the PMA improvement. Fig. 2(b) shows the minor R-H curve of P-MTJs with ECL. Contrary to the case of P-MTJ without ECL, the perfectly

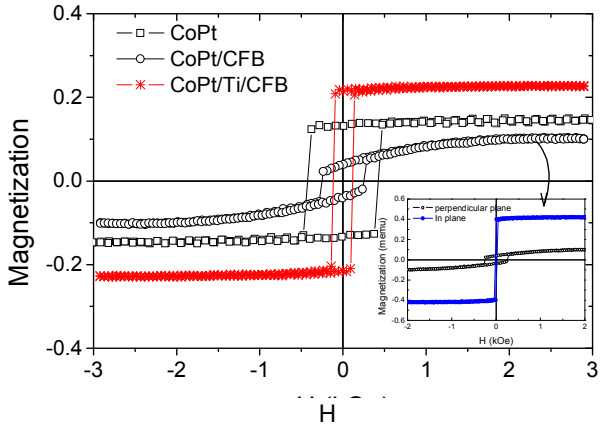

Fig. 1. Magnetization curves as function of perpendicularly applied magnetic field in CoPt, CoPt/CoFeB and CoPt/ECL/CoFeB. The insertion shows the perpendicular and in-plane M-H curves of CoPt/CoFeB.

square hysteresis loop is shown and the coercivity (*Hc*) is about 1650 Oe. This sharp transition of free layer is due to the PMA increase. In this sample, the TMR is 82% and the RA is 0.53 kΩ-μm^2, which is close to that of in-plane MTJ. From this result, we confirm that the ECL improves the PMA as well as the CoFeB/MgO texture.

4. Conclusion

The novel perpendicular MTJs with HCP-disordered CoPt and ECL were successfully developed, having the high TMR above 80%. Considering a flat film roughness, a narrow c-axis distribution and a large PMA, it is likely that the CoPt based P-MTJ with ECL has high potential for use of STT-MRAM at high density. An important aspect of ECL is that it can apply in various P-MTJ structures and perpendicular materials, hence allowing an engineering of the STT-switching and PMA.

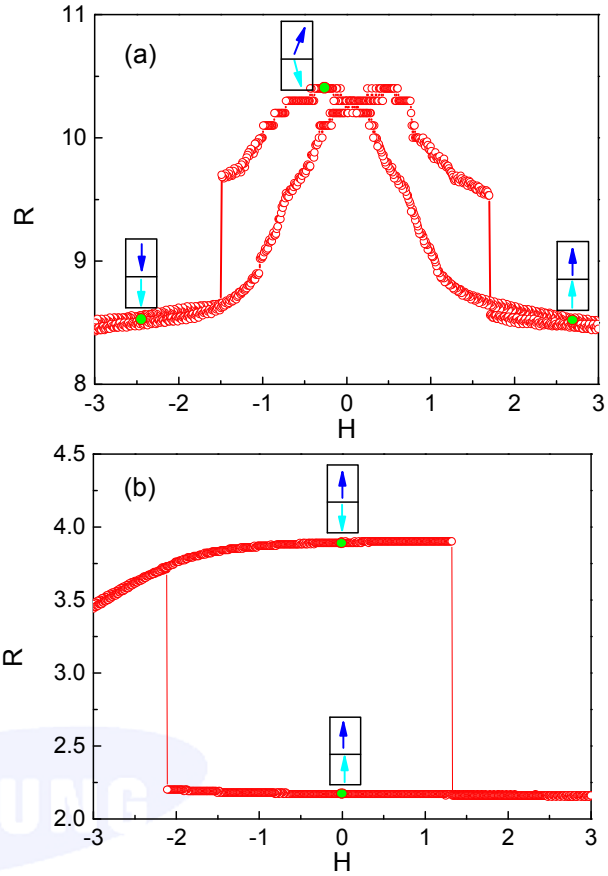

Fig. 2. (a) Full R-H curve of P-MTJ without ECL. (b) Minor R-H curve of P-MTJ with ECL

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