CMOS-COMPATIBLE Cr/Ru-SEEDED FePd THIN FILM WITH HIGH PERPENDICULAR MAGNETIC ANISOTROPY FOR STT-MRAM APPLICATION

Jinming LIU[1], Delin ZHANG[1], and Jian-Ping WANG[1]

1) Electrical and Computer Engineering, University of Minnesota, Minneapolis, MN 55455 USA, dlzhang@umn.edu

ABSTRACT

Magnetic materials with perpendicular magnetic anisotropy (PMA) have received the increasing attention because of their promising properties for the applications in ultra-low energy and ultra-high density spin memory devices, such as spin-transfer-torque magnetic random-access memory (STT-MRAM)[1]–[3]. For satisfying the demand of the reliable storage (>10 years) and ultralow switching current density, these materials should possess high magnetic anisotropy (K_u) and low damping constant (α). Most importantly, the materials need to maintain their PMA properties after the thermal treatment with the temperature as high as 400 °C, which is the essential requirement for spin memory devices integrated with complementary metal-oxide-semiconductor (CMOS) technique.

Among the bulk PMA materials, $L1_0$-phase FePd is a promising candidate due to its high PMA K_u~ 2×10^7 erg/cm^3 and low damping constant α~0.002 (4). The disadvantage of the FePd PMA material is the Pd diffusion after the high-temperature thermal treatment; this issue has been solved by inserting the diffusion barrier.[4] Besides, the seed layer also plays a significant role in obtaining the highly-textured FePd thin film with better performance. Previously the Cr/Pd or Cr/Pt bilayers are designed as a seed layer to develop highly-textured FePd thin films.[5], [6] However, the Pd or Pt can diffuse into the FePd layer after high-temperature thermal treatment, which will change its composition and further change the PMA property.

In this work, we have designed a new bilayer, Cr/Ru, as the seed layer for FePd thin films. We further investigate the magnetic and structural properties of the FePd thin films. All the samples were prepared by a magnetron sputtering system with the base pressure smaller than 5.0×10^{-8} Torr. The (001) MgO single crystalline substrate was used to induce the (001) texture. First, the Cr/Ru seed layer was deposited on the MgO substrate with the substrate temperature at 350 °C. Then FePd thin films were grown at the same substrate temperature by co-sputtering Fe and Pd. A Ta capping layer was deposited after the system cooled down to room temperature. After that, the FePd samples were post-annealed at 400 °C and 500 °C, respectively, using a high-vacuum furnace. The magnetic property and crystal structure of the FePd samples were investigated as a function of the post-annealing temperatures. The crystal structure of the FePd thin films was characterized by an x-ray diffraction (XRD), and the diffraction patterns are shown in Fig. 1. In Fig. 1, the (001) and (002) diffraction peaks are observed for all the FePd samples, which indicates that the Cr/Ru seed layer can induce the highly-textured structure in the FePd layer. The important thing is that the intensity of these two peaks slightly increases with the increase of the post-annealing temperature, suggesting the crystallinity of the FePd layer improves. Meanwhile, the magnetic properties of FePd samples were measured by a PPMS with the VSM mode. The results are plotted in Fig. 2. From Fig. 2, we can clearly find that the FePd thin film still possesses the PMA property after post-annealing at 500 °C. With the increase of the post-annealing temperature, the in-plane component of FePd thin films decreases and the effective anisotropy (H_{keff}) increases, which are observed from their magnetic hysteresis (M-H) loops, indicating that the PMA property of the FePd thin film becomes better. These results demonstrate that the Cr/Ru-seeded FePd thin films can be used to fabricate the spin memory devices, which can integrate with the current CMOS technology.

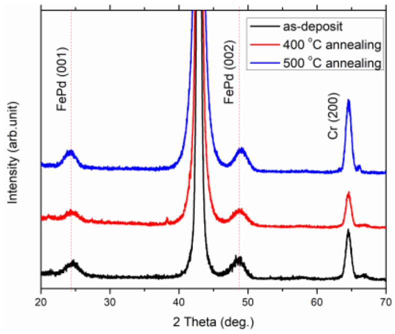

Fig.1 Out-of-plane XRD patterns of the Cr/Ru-seeded $L1_0$-phase FePd at the different annealing temperatures.

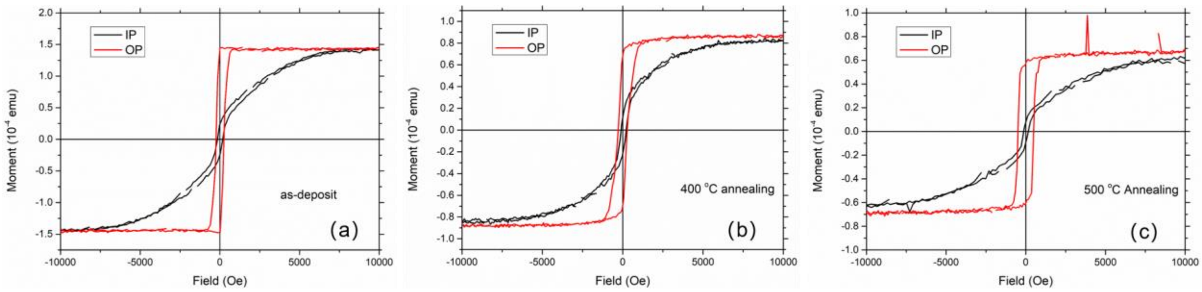

Fig. 2 Magnetic hysteresis (M-H) loops of the Cr/Ru-seeded $L1_0$-phase FePd samples at the different annealing temperatures.

REFERENCES

1) H. Meng and J.-P. Wang, "Spin transfer in nanomagnetic devices with perpendicular anisotropy," *Appl. Phys. Lett.*, vol. 88, no. 17, p. 172506, 2006.
2) S. Mangin, D. Ravelosona, J. A. Katine, M. J. Carey, B. D. Terris, and E. E. Fullerton, "Current-induced magnetization reversal in nanopillars with perpendicular anisotropy," *Nat. Mater.*, vol. 5, no. 3, pp. 210–215, Mar. 2006.
3) S. Ikeda, K. Miura, H. Yamamoto, K. Mizunuma, H. D. Gan, M. Endo, S. Kanai, J. Hayakawa, F. Matsukura, and H. Ohno, "A perpendicular-anisotropy CoFeB-MgO magnetic tunnel junction.," *Nat. Mater.*, vol. 9, no. 9, pp. 721–4, Sep. 2010.
4) D. Zhang, C. Sun, Y. Lv, K. B. Schliep, Z. Zhao, J. Chen, P. M. Voyles, and J. Wang, "Synthetic Antiferromagnet through an fcc Ru Spacer Utilized for Perpendicular Magnetic Tunnel Junctions," *Phys. Rev. Appl.*, vol. 9, no. 4, p. 044028, Apr. 2018.
5) D. Halley, Y. Samson, A. Marty, C. Beigné, and B. Gilles, "Surface morphology and chemical ordering in FePd/Pd(001) thin layers," *Surf. Sci.*, vol. 481, no. 1–3, pp. 25–32, Jun. 2001.
6) D.-L. Zhang, K. B. Schliep, R. J. Wu, P. Quarterman, D. Reifsnyder Hickey, Y. Lv, X. Chao, H. Li, J.-Y. Chen, Z. Zhao, M. Jamali, K. A. Mkhoyan, and J.-P. Wang, "Enhancement of tunneling magnetoresistance by inserting a diffusion barrier in L1 0 -FePd perpendicular magnetic tunnel junctions," *Appl. Phys. Lett.*, vol. 112, no. 15, p. 152401, Apr. 2018.

Jinming Liu
E-mail: liux1872@umn.edu
tel: +1-612-8689438