High Post-annealing Stability in [Pt/Co] Multilayers

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1. Introduction

The [Pt/Co] multilayers with a very thin Pt layer of 0.2 nm are presented that exhibits strong perpendicular magnetic anisotropy (PMA) even after annealing up to 500°C. The observed post-annealing stability is in significant contrast to that previously shown for conventional multilayers with a thicker Pt layer than Co, where good PMA properties are obtained in the as-deposited state but they deteriorate significantly at moderate annealing temperatures below ~300°C. The reason for the high post-annealing stability is a low level of intermixing during sputtering due to the very thin Pt layer. In this study, a new attempt was made to minimize the intermixing by using a very thin Pt layer. This approach is based on the idea that the magnitude of intermixing is proportional to the duration of sputtering. [Pt/Co] multilayers with a very thin Pt layer of 0.2 nm (~1 monolayer) were fabricated and their magnetic properties were investigated. A major difference with this scheme is that in conventional [Pt/Co] multilayers, the thickness of the Pt layer is usually ~1.5 nm, which is thicker than that of the Co layer [1, 2].

2. Experiment details

The multilayer structure that was the main focus of this study was [Pt (0.2 nm)/Co (t_{Co})]$_6$, where t_{Co} was varied from 0.2 to 0.6nm. The entire stack consisted of the following: Si substrate (wet-oxidized)/Ta (5 nm)/Pt (10 nm)/Ru (30 nm)/[Pt (t_{Pt})/Co (t_{Co})]$_6$/Ru (3 nm). The stack was fabricated using an ultra-high-vacuum dc magnetron sputtering system with a base pressure of 7×10^{-8} Torr. All layers were deposited at a constant Ar pressure of 2×10^{-3} Torr, and no specific substrate cooling or heating was applied during process. The thickness of the constituent layers was measured with a surface profiler, and in some cases, it was also measured with a high-resolution transmission electron microscope. The deposition rate of the Pt and Co, from which the thicknesses of the layers were calculated, was adjusted to approximately 0.03 nm/s by varying the sputtering power. The samples were annealed at different temperatures ranging from 300 to 500°C for 1 h at a vacuum of 1×10^{-6} Torr. m–H or M–H loops (where m, M, and H denote the magnetic moment, magnetization, and applied magnetic field, respectively) were measured with a vibrating sample magnetometer. The value of M was obtained by dividing m by the total volume of the multilayers.

3. Results and discussion

A systematic investigation was conducted that involves varying the Co layer thickness (t_{Co}) in [Pt(0.2 nm)/Co(t_{Co})]$_6$ multilayers and the annealing temperature and the results are shown in Fig. 1 where the effective PMA energy density (K_{eff}) is plotted as a function of t_{Co} at various annealing temperatures ranging from 300 to 500°C as well as in the as-deposited state. The value of K_{eff} increases significantly as t_{Co} increases from 0.2 to

0.28 nm, and then, it becomes almost saturated with further increases in t_{Co}. The window where strong PMA is evident is quite wide, with large values of K_{eff} observed in t_{Co} range of 0.28 to 0.6 nm, although the optimum occurs at t_{Co} = 0.5nm. The value of K_{eff} is slightly reduced at the highest Co thickness, t_{Co} = 0.6 nm, which can be explained by the fact that PMA is attributed to the interface anisotropy. Another important feature is that K_{eff} is not affected substantially by post-annealing unless the temperature exceeds 500°C, where a large decrease in K_{eff} is observed for all t_{Co} values. This post-annealing stability, which is significantly higher than that reported recently for similar samples [3, 4], indicates that these [Pt/Co] multilayers with a very thin Pt layer are compatible with the post-processing temperature for integration with complementary metal oxide semiconductor transistor [5].

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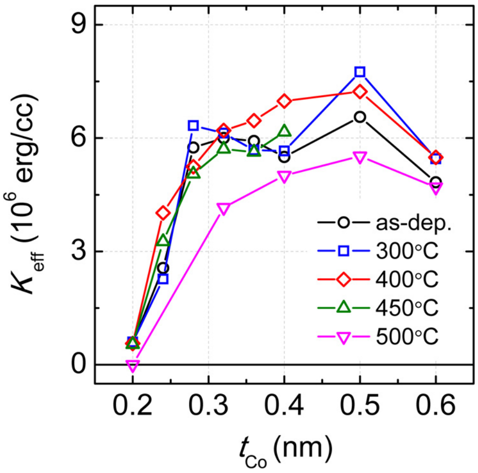

Fig. 1. Results for K_{eff} as a function of t_{Co} for the [Pt(0.2 nm)/Co(t_{Co})]6 multilayers at various annealing temperatures as well as in the as- deposited state.

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