Effects of Annealing on the Magnetic Dead Layer Thickness of CoFeB Relevant to a Synthetic Ferrimagnetic Free Layer Structure

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1. Introduction

It is of great importance to precisely determine themagnetic dead layer (MDL) thickness in the magnetic thin films used for high density MRAM, because the MDL does not contribute to the magnetic volume and hence the thermal stability. MgO-based magnetic tunnel junctions (MTJs) show a very high tunneling magnetoresistance (TMR) and are most promising for use as a memory cell. A synthetic ferrimagnet (SyF), consisting of two ferromagnetic layers separated by a very thin non-magnetic spacer such as Ru, is being used increasingly as a free layer structure in an MTJ. Several advantages over a conventional single magnetic layer are expected with the use of a SyF as the free layer structure and some of them include small cross-talk effects, a coherent magnetization switching, and a high magnetoresistance ratio.

2. Experimental

The unit structures were deposited by using a UHV sputtering system under a base pressure of 1-5*10-8 Torr. An oxidized Si layer with a thickness of 500 μm and lateral dimensions of 10*10 mm^2 was used as the substrate. The samples were annealed at 473 K and 623 K. The magnetic moment (*m*) was measured using a vibrating sample magnetometer.

3. Results and Discussion

Magnetic moment was measured for four different model systems (see Fig. 1) having various thicknesses of CoFeB in the as-deposited state and also after annealing. The MDL thickness was then determined by linearly fitting the measured data. Fig. 1 summarizes the results for the MDL thickness for the samples in the as-deposited state [1] and for those annealed at two different temperatures of 473 and 623 K. The results for the MDL thickness at constituent interfaces, which are necessary to obtain the effective thickness of magnetic layers, were then extracted from these experimental results. In this process, it was assumed that no MDL is formed at the MgO (bottom)/CoFeB interface because the bond strength of MgO is very high [1]. With this assumption, the MDL thicknesses at the constituent interfaces were obtained and the results (at an annealing temperature of 623 K) are: 0.08 nm for the Ru (bottom)/CoFeB, 0.29 nm for the CoFeB/Ru (top), and 0.49 nm for the CoFeB/Ta (top). These results can be well explained by related thermodynamic properties. The MDL thickness in the Ru(bottom)/CoFeB interface, for example, is diminished by annealing from 0.20 to 0.08 nm, because bcc (Co, Fe) has a limited terminal solubility in Ru. Additionally, the change in the saturation magnetization (M_s) of CoFeB was determined as a function of annealing temperature. A large increase in M_s is particularly noted in the presence of a Ta layer, possibly due the role of the Ta layer as a B sink during annealing [2].

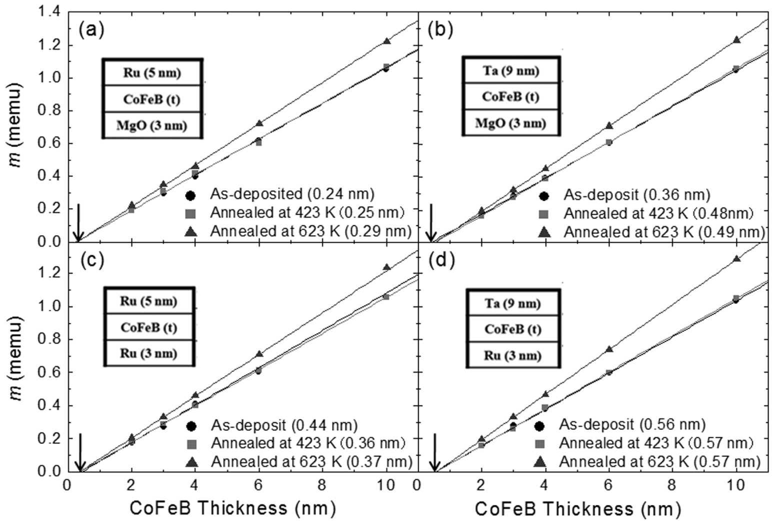

Fig. 1. The ms vs. t curves for the four different unit structure, which were annealed at different temperatures. The stack structures are also shown the insets of the figures.

[1] S. Y. Jang *et al*., J. Appl. Phys. (In the press).

[2] Miyajima *et al.*, Appl. Phys. Lett. 94, 122501 (2009).