Wide-dynamic-range magnetic sensor based on magnetic tunnel junction with perpendicularly magnetized [Co/Pd]-based reference layer

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Magnetic tunnel junctions (MTJs) have been attracting much attention for application to magnetic sensor. The application requires a linear tunnel magnetoresistance (TMR) curve to a magnetic field, which can be demonstrated by utilizing perpendicular magnetic anisotropy (PMA) materials as a reference layer [1]. A Co/Pd multilayer is one of PMA materials, showing a high PMA energy (~3×10^6 erg/cm^3) and a large coercivity H_c (~1.5 kOe) [2]. Since a dynamic range of magnetic sensor based on an MTJ is confined to an H_c value of a reference layer in principle, a Co/Pd multilayer is a promising PMA material for a reference layer to achieve a wide dynamic range. In addition, it is predicted that sensitivity and nonlinearity in such systems are correlated to magnetic properties of a sensing layer [3]. In this study, we systematically investigated sensor performance of MTJs with a [Co/Pd]-based reference layer.

MTJ films were prepared by dc/RF magnetron sputtering: Si substrate/buffer layers/[Co 0.2/Pd 0.8]$_{10}$/insertion bilayer (IBL)/CoFeB 1.0/MgO 2.0/CoFeB t_{CoFeB} = 1.5, 1.6, 1.7/capping layers (unit in nm). Here, the IBL consists of Co 0.2/Ta 0.3. The films were processed into circular devices of 80-100 μm in diameter, afterwards annealed in a vacuum for 1 h at 225°C-300°C. MR measurement was performed by a dc four-probe-method under an out-of-plane magnetic field.

Fig. 1 shows TMR curves for various t_{CoFeB} annealed at 225°C. For t_{CoFeB} = 1.5 nm, the MTJ with the IBL exhibited a TMR ratio of 50% much higher than that without IBL (10%). This is attributed to the separation of the crystallinity between the [Co/Pd] and CoFeB layer [4]. As the t_{CoFeB} increased, the PMA of the CoFeB sensing layer decreased, which resulted in linear TMR curves near the zero magnetic field for t_{CoFeB} = 1.6 nm and 1.7 nm. The dynamic range is confined to the sharp drops of TMR ratio around ±650 Oe corresponding to the H_c value of the [Co/Pd]-based reference layer. This value is much larger than that in previous report [1]. Furthermore, by varying the annealing temperature, it is clarified sensitivity and nonlinearity are associated with intrinsic TMR ratio and anisotropy field of a sensing layer. This provides us a guideline to design sensor performance for adequate application.

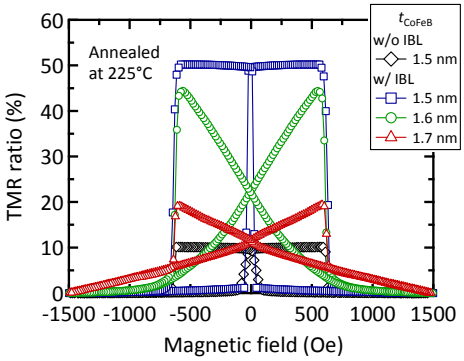

Fig. 1. TMR curves for various t_{CoFeB}.

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