High temperature annealing of flexible magnetic tunnel junction

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Formation of magnetic tunnel junctions (MTJs) on a flexible substrate is crucial for spintronics applications in internet of things society, *i.e.*, highly sensitive wearable sensors based on the magnetoresistance effect [1] as well as flexible non-volatile memories. Post annealing process over 300°C, however, is required to obtain high tunnel magnetoresistance (TMR) ratio in CoFeB/MgO-based MTJs. To avoid thermal damage to an organic flexible substrate, a transfer printing process [2,3] has been used so far (a CoFeB/MgO-based MTJs have been firstly formed on a rigid substrate and annealed, and then transferred to a flexible substrate). In contrast, here we report a direct formation of the CoFeB/MgO-based MTJ on a flexible substrate [4]. We use a polyimide substrate with high thermal endurance, which enables the post annealing process up to 500°C.

The MTJs formed on the polyimide and Si substrates were annealed at T_A (= 350-500°C) for an hour in vacuum. Dependences of the TMR ratio and resistance at parallel magnetization configuration (R_p) on T_A are summarized in Figs. (a) and (b), respectively. TMR ratio of ~100% is obtained with T_A = 350°C, which is higher than the upper limit expected by the Julliere's model. Higher annealing temperature leads to further increase in the TMR ratio. The dependences for the flexible MTJ are qualitatively similar to those in our MTJ formed on Si substrate or in previous rigid MTJs [5]. In addition, strong strain endurance of our MTJ is conformed in our flexible MTJ (T_A = 500°C) as shown in Fig. (c): almost no change in sample properties is confirmed before and after 1000 times stretching of more than 1% tensile strain.

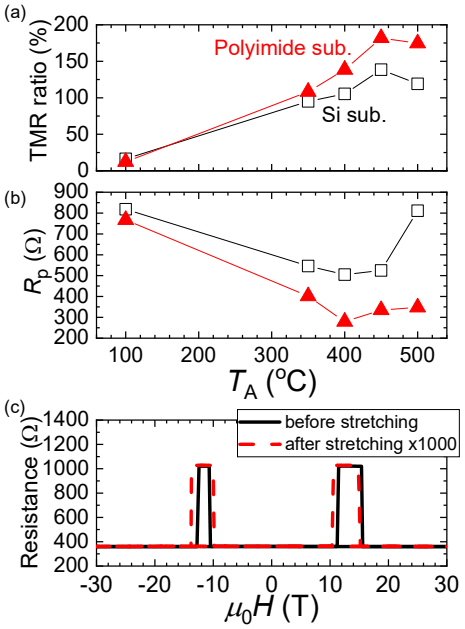

Figure (a) TMR ratio (b) R_p as a function of T_A. (c) TMR curves before and after 1000 times stretching.

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