A New Method for the Calculation of the Thermal Stability Parameter of Nanostructured Exchange-Coupled Trilayers

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An exchange-coupled trilayer with antiparallel magnetization alignment (often called synthetic antiferromagnet, composed of two magnetic layers separated by a nonmagnetic spacer) finds its increasing use as a free layer structure in advanced device applications. Recently, exchange-coupled trilayers were used as a free layer structure in the current-induced magnetization switching (CIMS) of MgO-based magnetic tunnel junctions (MTJs) [1]. This indicates that exchange-coupled trilayers show significant potential for use as a high-density spin-transfer torque (STT) magnetic random access memory (MRAM) [2]. Although the thermal stability of high density MRAM is of critical concern, it is somewhat difficult to estimate the thermal stability parameter of exchange-coupled trilayers. This is mainly due to the poor definition of their anisotropy and magnetic volume. The main aim of this talk is to develop a new method for the calculation of the thermal stability parameter of exchange coupled trilayers. The key to this approach is the use of the total energy, including the magnetostatic energy expressed in an *analytical* form. When the total energy is in an analytical form, it is a relatively straightforward task to obtain the magnetic energy (and hence the thermal stability parameter). The magnetic energy is simply the energy barrier along the *lowest* energy path linking the two energy minima (or two stable or metastable states). Since magnetostatic fields such as the self-demagnetizing field and interlayer magnetostatic field are very non-uniform, it will be difficult to express the total energy in a simple analytical form. This difficulty was overcome with the use of the *effective* magnetostatic fields by averaging over the entire magnetic volume. In this sense, the present approach is a hybrid one, combining an analytical method with a numerical method. The present was applied to a nanostructured exchange-coupled trilayer, Co-Fe-B (2 nm)/Ru (0.6 nm)/Co-Fe-B (2 nm) with lateral dimensions of 160 nm x 80 nm, as a free layer structure in MgO-based MTJs, where the experimental result for the thermal stability parameter is available [1]. Micromagnetic simulation is performed in order to obtain the equilibrium magnetic configuration, from which the effective magnetostatic fields are obtained. These are acquired by averaging over the entire magnetic layers and they are then used as inputs in an analytical equation for the total energy. Systematic calculations are performed, even considering the effects of edge rounding during nanofabrication and the thermal stability parameter is calculated to be within the range of 62 ~ 69, which concurs with the value of 68, as reported in the literature from the current induced magnetization switching experiments obtained by using the Slonczewski equation.

The Korea Science and Engineering Foundation (KOSEF) supported this work through the National Research Laboratory program, which is funded by the Korean Ministry of Science and Technology (Project No. M10600000198-06J0000-19810).

References

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