HEAT DISSIPATION EFFECTS ASSOCIATED WITH SPIN TRANSFER WRITING IN MRAM DEVICES

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The possibility to reverse the magnetic moment of a ferromagnetic layer by using the spin transfer effect of a polarized current pulse applied perpendicular to the layer plane, has recently received increasing attention due to the its potential applications in non-volatile Magnetic Random Access Memory (MRAM) devices. Although the spin transfer effect has been studied both theoretically and experimentally, the heat dissipation, intrinsic to the application of current pulses of density ~ $1x10^7$ A/cm^2, as required for spin transfer switching, has not yet received a quantitative interpretation. Thermal effects of current pulses may influence the reversal incubation delay [1] and also the current required for switching by spin transfer [2]. Previous studies of heat dissipation in Magnetic Tunnel Junctions (MTJ) have attempted to explain the writing mechanism of MRAM devices with thermal assisted switching (TAMRAM), where the Joule heating of the tunnel barrier by an electric current pulse is used for unpinning the adjacent Ferromagnetic/Antiferromagnetic storage layer [3]. However, these studies were restricted to a narrow temperature range, corresponding to the range of pulse widths 2 ns – 100 ns. Also, the relationship between the power of the current pulse and the temperature of the MRAM layers was not established. The purpose of this paper is to present a detailed investigation of heat dissipation in TAMRAM devices for a wide range of pulse widths, extending from 2 ns up to 1 s. The outcome of this study is the estimation of the thermodynamic parameters (heat capacity and thermal conductivity) of the layers comprised by the MRAM. The properties thus found are further used for calculating the temperature profile of a typical MRAM device used for spin transfer writing. For this purpose, measurements of cooling time, subsequent to the application of a current pulse, and of pulse power, required to set the exchange bias acting on the storage layer to a specific value, as a function of pulse duration, are presented. The results are consistently interpreted by both, a theoretical model of exchange bias and by thermodynamic simulations of heat diffusion in the MRAM device using the COMSOL 3D software. The heat capacities of the MRAM layers, used in the thermodynamic simulations, were measured by a standard calorimetric method.

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