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ABSTRACT

Magnetism or electron spin has always been important for information storage. Magnetic random access memory, using magnetic tunnel junctions (MTJ), has many advantages like non-volatility, unlimited write endurance and zero data retention power. The MTJ is a heterostructure consisting of two ferromagnetic layers namely, the pinned layer (PL) and the free layer (FL), with an insulating spacer between them.

In a spin transfer torque RAM (STTRAM), data is written into the FL by a torque produced by a current perpendicular to the plane of the structure. In addition, the tunneling current also gives rise to an Ampere torque. We have derived an expression for the Ampere torque and incorporated the same into the Landau Lifshitz Gilbert equation (LLGE) governing the magnetization dynamics of the FL.

We study the effects of inter layer exchange field between the FL and PL and also the spin torque as they are the significant factors in deciding the threshold current density. We use SPICE to model a MTJ within a square array of MTJs, making the compact magnetic models accessible to circuit design engineers. We study the FL switching currents required in the presence of various fields and torques in an STTRAM. We optimize the MTJ structure by means of varying the barrier thickness, barrier height and the insulating material using the compact SPICE model for the MTJ in an array.

Tunneling magneto resistance (TMR) is a figure of merit for an MTJ structure. Generally, to study tunneling characteristics of a multi layered structure, the transfer matrix (T matrix) method is used. Here, we prove that the scattering matrix (S matrix) method is numerically more stable for a thicker barrier or for a multibarrier structure. We derive the tunnel con-
ductance from the transition probability for a MTJ structure using perturbation theory and obtain an analytical expression for TMR by means of scattering matrix formalism. Finally, we propose a method for estimation of unoxidized metal layer formed in the growth of an MTJ from the experimental data, by means of the $S$ matrix.