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Attenuated Oscillation of the Tunneling Magnetoresistance in a Ferromagnet-metal-insulator-ferromagnet Tunneling Junction

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We apply the spin-polarized free-electron model [1] to study the tunneling magnetoresistance (TMR) in a ferromagnet-metal-insulator-ferromagnet (FM_1-M_2-I_3-FM_4) tunneling junction. Firstly, our calculation shows that the effective spin polarization $P_{FM_4\text{-}I_3}$ of the FM_4-I_3 bilayer is the same as Slonczewski's, but $P_{FM_1\text{-}M_2\text{-}I_3}$ of the FM_1-M_2-I_3 trilayers is modified by $P_{FM_1\text{-}M_2\text{-}I_3} = P_{FM_1} \times \cos(2k_{\xi,2}t + \phi_{M_2\text{-}I_3} + \pi)$ under one reasonable approximation. The trem P_{FM_1} is the spin polarization of the FM_1 layer, $k_{\xi,2}$ within the M_2 layer is the out-of-plane wave vector, t is the thickness of the M_2 layer, and the phase change $\phi_{M_2\text{-}I_3}$ is from the phase difference between the incident and the reflected electrons at the M_2-I_3 interface. Clearly, $P_{FM_1\text{-}M_2\text{-}I_3}$, and also the TMR ratio, oscillates with the amplitude of P_{FM_1} and with the period related to $2k_{\xi,2}t$. Secondly, our calculation finds that not only electrons with the out-of-plane energy E_ξ close to the Fermi energy E_F but also electrons with E_ξ below E_F can tunnel sufficiently through the FM_1-M_2-I_3-FM_4 tunneling junction. This is due to the coherence multiple reflective scatterings within the M_2 layer; therefore, the range of E_ξ is bounded between E_F and Elow. Thirdly, Fig. 1 in our calculation indicates that the out-of-plane energy dispersion ΔE_ξ of tunneling electrons both attenuate the TMR amplitude and increase the oscillatory period, which is in good agreement with the reported experimental data [2].

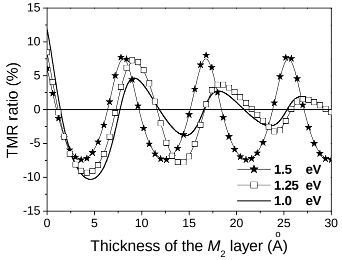

Fig. 1. The TMR ratios with the thickness of the M_2 layer in three E_{low} and E_F=1.5 eV.

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The Shape Dependency of Magnetic Energy Barrier in Nanostructured Magnetic Thin Film

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As the lateral dimension of the magnetic cell in the MRAM approaches to nano scale range, thermal stability (E_M/kT) of magnetic cell is of significant importance, as the magnetic energy barrier (E_M) of nanostructured cell approaches to the thermal energy (kT). Recently, Ikeda et al. reported the results for E_M/kT in single magnetic thin films and an exchange coupled trilayer [1]. The value of E_M/kT is much smaller in single magnetic thin films than that in exchange coupled trilayers. In an effort to understand the origin which causes the large difference in E_M/kT, we calculated E_M/kT in nanostructured single magnetic thin films.

The thin films having lateral dimensions of 160 × 80 nm^2, which are similar to those reported in the literature, was considered [1]. The thickness (t) is varied within 2 to 2.5 nm. In order to consider the effect of edge rouding during fabrication, the shape of thin film was varied from the complete rectangle to complete ellipse by changing the values of a, b ($a = 2b$) as seen in Fig. 1. The magnetic parameters used were: a saturation magnetization of 1034 emu/cc, an induced anisotropy of 10 Oe.

The results for the E_M are shown in Fig. 2 as a function of t and b. Expectedly, E_M increases with increasing t over the whole rangle of b. More importantly, there is a significant difference of E_M depending on the shape of the cell. This result indicates that the E_M/kT can be largely changed with fabrication process condition in the mass production. The shape dependency of E_M/kT in magnetic thin film can acts as another demerit in actural device application.

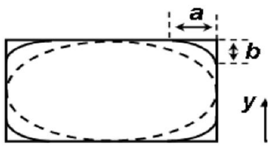

Fig. 1. The shape of thin films.

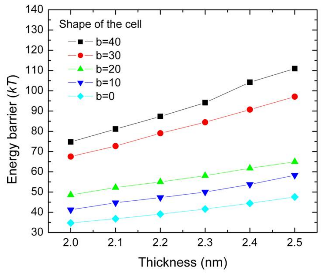

Fig. 2. The E_M as a function of the shape and thickness of thin film.

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