EFFECTS OF DISORDER IN MAGNETIC TUNNEL JUNCTIONS

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The influences of random disorder in the barrier on tunnel conductance (TC) and magnetoresistance (TMR) in ferromagnet (FM) / insulator (semiconductor) (I(S)) / FM junctions are investigated theoretically taking into account spin-orbit (SO) coupling. The TMR decreases significantly due to the spin-flip (SF) scattering caused by the SO coupling. We have found that the SF scattering is much stronger for anti-parallel configuration of magnetization due to the reversal of the spin dependence of final DOS in the spin-flip processes and the TMR can even be inverted when the SF scattering is beyond some critical point. The numerical calculations are performed within the single-orbital tight-binding model using the recursive Green's function method based on the extended Landauer-Buttiker formula [1,2].

FIG.1. TMR vs the thickness of nonmagnetic impurity barrier, α_{so} : spin-orbit coupling parameter, ϵ_i : impurity on-site energy.
 α_{so} : 0 (solid line, uniform barrier); 0.2 (dashed line); 0.3 ($\epsilon_i = 3.0|t|$, dot-dashed line; $\epsilon_i = 1.5|t|$, dotted line).

FIG.2. TMR vs thickness of magnetic impurity barrier.
 α_{so} : 0 (solid line, uniform barrier); 0 (dotted line); 0.2 (dot-dashed line).

- [1] Y. Li and C. R. Chang, Phys. Lett. A 287 (2001) 415.
 [2] S. Datta, 1990 J. Phys.: Condens. Matter 2 (1990) 8023.

TRANSPORT IN MAGNETICALLY-DOPED MAGNETIC TUNNEL JUNCTIONS

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Introduction

We report striking transport features in high quality magnetic tunnel junctions (TMR $\geq 40\%$ at room temperature). These features are presumed to be associated with well-localized magnetic impurities (Co^{+2}) inside the tunnel barriers, which diffuse out from the bottom CoFe electrode during the high power plasma oxidation of the tunnel barriers.

Results and Discussion

Highlights of the transport features of our MTJs can be summarized as following:

- (1) Dynamic conductance ($G \equiv dI/dV$) of the junctions reveals anomalies, manifesting a huge dip at zero bias (Figure 1(a)). These anomalies *logarithmically* decrease with increasing temperature (T) and bias (V).
- (2) Such conductance anomalies accompany severe suppression of TMR, indicating that they involve spin-flip scattering. As a consequence, the junctions exhibit *striking bias and temperature dependencies* of TMR (Figure 1(b)).

These features conform well with Applebaum's theory describing *s-d* exchange interaction between the tunneling electrons and the localized spins, ensuring the presence of magnetic impurities in the tunnel barriers. These junctions may be a unique experimental platform for probing correlated electron transport in tunnel junctions.

Figure 1: Transport highlights. (a) Typical dynamic conductance of the junctions measured at 1.4 K. (b) Bias dependence of the junction at various temperatures. Inset shows the temperature dependence of zero bias TMR.