The Kondo effect in the presence of ferromagnetism in magnetic tunnel junctions

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We show that planar macroscopic magnetic tunnel junctions with a nanodot layer and MgO tunnel barriers [1] can exhibit zero bias anomalies as a double conductance peak and a single conductance peak for the parallel and antiparallel alignment of leads' magnetization, respectively. Such behavior leads to a suppression of the tunneling magnetoresistance (TMR) close to zero bias volatge. This double conductance peak structure can be interpreted as a splitting of the Kondo resonance similar to the usual magnetic-field-induced splitting but it appears due to exchange interaction with ferromagnetic leads [2]. This splitting can be compensated for in the antiparallel alignment of leads' magnetization and the strong coupling limit of the Kondo effect can be restored in the presence of ferromagnetism. The observation of the double peak in conductance at low bias voltages may seem in contrary to the expectation that ferromagnetism suppresses Kondo assisted tunneling, but it may be easily explained from the theoretical point of view by the predictions of the Kondo physics for the Anderson quantum dot coupled to ferromagnetic leads [3,4]. The structure does not appear in experiments with tunnel junctions with normal metallic electrodes, which indicates that the spin splitting of zero-bias anomaly is due to the exchange interaction between dots and ferromagnetic electrodes and that it is induced by spin dependent renormalization of the dot levels. The magnetic field effect observed in the experiment can be explained by the inelastic spin-flip cotunneling that is modified by the field, and which accounts for the details of the conductance line shape. All the observations strongly support the hypothesis of the coexistence of the Kondo effect and ferromagnetism in magnetic tunnel junctions [5]. The account of various parameters on the effect, such as tunnel barrier thickness, magnetic field, level position and temperature is discussed, according to the theoretical results, which are in a good agreement with the experimental data. The junctions were prepared using magnetron sputtering through a sequence of metal shadow masks at room temperature. The magnetic tunnel junctions without nanodots were fabricated with an exchange biased lower ferromagnetic electrode of CoFe (100Å Ta/250Å of $Ir_{22}Mn_{78}$/35Å $Co_{70}Fe_{30}$), an upper CoFe counter electrode (70Å CoFe/100Å Ta), and a 28Å MgO tunnel barrier on top of a 8Å Mg layer. MgO barriers are formed by reactive magnetron sputtering in an Ar-O2 mixture [1]. A thin subatomic CoFe layer of nominal thickness 5Å inserted in the middle of the MgO layer forms a discontinuous layer of nanodots.

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