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TUNNEL MAGNETORESISTANCE IN ASYMMETRIC PLANAR DOUBLE-BARRIER MAGNETIC TUNNEL JUNCTIONS

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Currently, layered magnetic nanostructures FM/I (ferromagnet/insulator) is one of the most exciting and rapidly developing areas of spintronics. Effects of tunneling magnetoresistance and magnetization switching in such structures are used in magnetic field sensors, nonvolatile magnetoresistive memory (MRAM, ST-MRAM), resonant tunneling diodes, spin transistors [1, 2]. In this report, we investigate theoretically the asymmetric double-barrier magnetic nanostructures $FM^L/I_1/FM^W/I_2/FM^R$. They consist of three ferromagnetic layers separated by dielectric layers. As the ferromagnetic layers material, Fe, Co, Ni and their alloys (CoFeB, FeNi) are considered. Insulating layers are usually AlO_x or MgO. Magnetization of the outer sheets (FM^L , FM^R) are co-directed and pinned by the exchange bias effect. Magnetization of the middle layer (FM^W) can be changed by an external magnetic field. One of such structures is shown in Fig. 1.

Usually, one considers two situations referring to relative orientations of the ferromagnetic layer magnetizations. P-orientation (parallel) is referred to the case when the magnetizations of all ferromagnetic layers are parallel, AP- orientation (anti-parallel), when the magnetization of the middle layer is directed opposite to the magnetizations of the side layers. If we apply a bias voltage to the external electrodes, a current flows across the structure. It is due to quantum mechanical tunneling of electrons through the barriers. Resistance of the structure depends on relative orientations of the ferromagnetic layers. The relative difference between resistances in the P and AP alignments may reach $\sim 1000\%$ at room temperature.

Analysis of the electron tunneling is based on the model of spin-conduction channels. Current calculation is performed using the quasiclassical theory [4]. The ferromagnetic layers are discussed in the framework of two-band model. Transmission coefficients of the structure are calculated quantum-mechanically in the effective-mass approximation for the conduction electrons [5]. As a result, we obtain the dependence of spin-polarized current and magnetoresistance on applied voltage.

The theory can be used for explanation of the experimental data, and searching for condition of softening the requirements to the magnitude of current necessary for switching of the tunnel magnetic structures between high and low resistance states.

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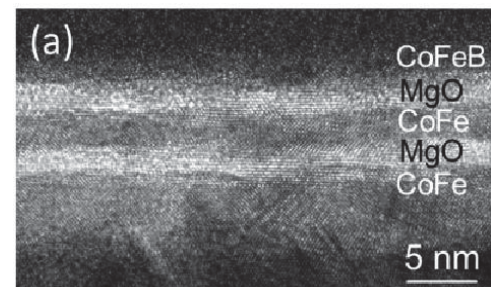


Fig. 1. Cross-sectional transmission electron microscopy image of the double-barrier magnetic tunnel junction (taken from Ref. [3]).