Novel Magnetic Nanostructures

Unique Properties and Applications

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Spin and Charge Tunneling Transport in Magnetic Tunnel Junctions With Embedded Nanoparticles

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11.1 Introduction

Various multilayer systems such as magnetic tunnel junctions (MTJs) and their modifications attract attention due to their promising applications: magnetic field sensors, magnetic memory, memristors, nano spin-valves, and resistance generators. The current progress in studying giant magnetoresistance (GMR), tunnel magnetoresistance (TMR), and spin-transfer torque (STT) can provide successful solutions of the problems related to energy consumption and thermal stability factor of magnetic random access memory (MRAM, STT MRAM). Moreover, spintronic devices have a unique advantage against semiconductor devices that they are nonvolatile. In addition, they are expected to be more scalable than semiconductor-based devices, because magnetic nano-domain is much more stable groundwork for the information storage in contrast to a charged micro-capacitor. It is well-known that the leakage current rapidly increases with a capacitor dimension reduced down to the nano-scale.

In this review we show how quasiclassical theory for point-like contacts can be adapted for spintronic device physics explaining mean free path and GMR effects in nano-scale heterocontacts, asymmetric voltage dependences of TMR in MTJs, as well as applied to modeling of zero bias TMR anomalies in MTJs with embedded nanoparticles (NPs). The dependence of in-plane component of STT on the applied voltage for various size of NPs in the case of the different barrier asymmetry can be also calculated.

GMR is a change in electric resistance of a magnetically inhomogeneous material when an applied magnetic field modifies magnetic configurations in the system. The magnetically inhomogeneous system usually consists of a magnetic multilayer in which the layers are