COMSOL Implementation of Valet-Fert Model for CPP GMR devices

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Introduction

The Giant Magneto Resistance (GMR) effect is a quantum mechanical effect which can be observed in systems consisting of thin alternating ferromagnetic and non-ferromagnetic layers. The effect manifests itself as the change in electrical resistance as a reaction to a change in an applied external magnetic field. In the absence of an external field the magnetizations of two successive ferromagnetic layers are aligned anti-parallel to each other. The external field aligns the magnetic moments and saturates the magnetization of the multi-layers which leads to a drop in the electrical resistance of the multilayer stack.
The magnitude of the GMR effect depends furthermore on the exact geometry of the multi-layers. One distinguishes between the Current-In-Plane (CIP) and the Current-Perpendicular-to-Plane (CPP) geometry. In the CIP devices the current flows in the film plane whereas in CPP devices the current flow is perpendicular to the film plane. Due to different mechanisms the GMR ratio is higher in CPP devices and has therefore several advantages for high-density recording applications which can also be seen in the ongoing transition from CIP sensors to CPP sensors[1].
To develop CPP-GMR based sensors, theoretical predictions and analysis of the resistance and magnetoresistance of realistic CPP-GMR devices is crucial for further improvements. Due to the complicated boundary conditions in real devices, a numerical treatment based on the finite elements method is necessary.

Use of COMSOL Multiphysics

In 1993, T. Valet and A. Fert[2] developed a model based on the Boltzmann equation to calculate the transport properties of CPP multi-layers. In the limit were the spin-diffusion length is much longer than the mean-free-path, the spin dependent transport equation are reduced to a macroscopic model which results in two coupled second order differential equations for the spin dependent electrochemical potentials. The simple 1D model has been generalized to the 3D case and implemented into the COMSOL software package using the PDE general mode. This allows the evaluation of the magneto-resistance ratio and the electrical resistances of realistic CPP-GMR devices and opens the possibility to study new device materials and designs.

Expected Results

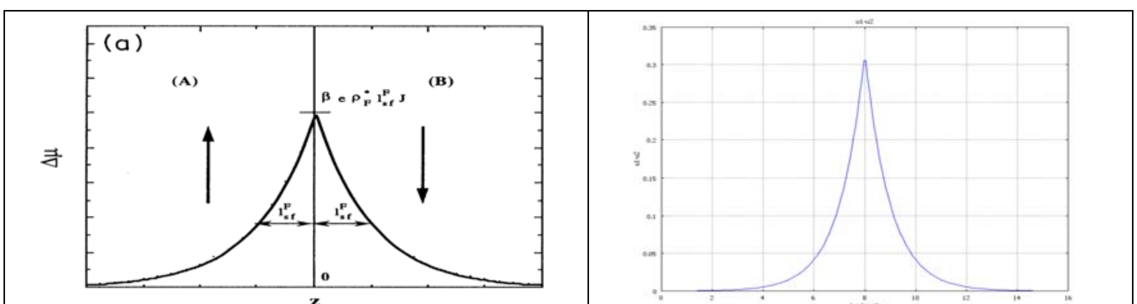

Figure 1. Distribution of chemical potential along the direction that perpendicular to the interface. Comparison between Valet and Fert's (left) [2] and our COMSOL model's (right).

Reference

1. J.A. Katine and E.E. Fullerton, J. Mag. Mag. Mat. **320**, 1217 (2008)
2. T. Valet and A. Fert, Physics Review B, **48**, 7099 (1993).