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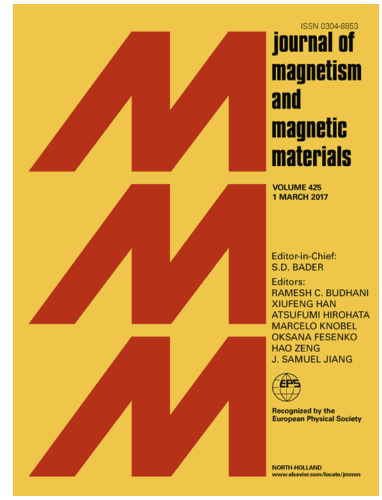

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Boundary conditions at the interface of finite thickness between ferromagnetic and antiferromagnetic materials

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Abstract: Systematic approach has been applied to obtain the boundary conditions for magnetization at an interface between ferromagnetic (FM) and antiferromagnetic (AFM) materials in the continuous medium approximation. Three order parameters are considered inside an interface of finite thickness magnetization $\mathbf{M}$ of FM, magnetizations of both sublattices $\mathbf{M}_1$ and $\mathbf{M}_2$ of AFM. The boundary conditions are defined in terms of some average properties of the FM/AFM interface. The interface has a finite thickness which is much less than spin wave length. This approach allowed to take into account the interface anisotropy, interface symmetric exchange coupling and interface coupling resulting from inversion symmetry breaking in the vicinity of the interface.

Keywords: antiferromagnetic spintronics, interface, boundary conditions, spin waves.

Introduction

Antiferromagnetic spintronics has emerged recently as a research area [1]. Neel considered AFMs as extremely interesting but useless and for the long time nobody has touched this topic [2]. Back in the days it was hard for the outside observer to visualize the magnetic structure of AFM, which was caused by the fact that magnetic sublattices are compensated in the ground state and it doesn't usually create scattering fields unlike FMs. AFMs requires strong magnetic fields for the transition into magnetized state.

But AFM have a number of advantages that make them very interesting nowadays. First, they allow to work within THz frequencies [3], which is much more rapid than the frequencies accessible in FMs. Second, ability to manipulate AFMs, namely to L-vector – Neel order, as with electric and spin currents has been shown recently [4]. It is possible to create L-vector excitation in the AFM layer through interface exchange interaction of neighboring FM layer, as well as manipulating L-vector with the help of this [5, 6] as it is illustrated in Fig. 1. Moreover, methods of detection of L-vector has been discovered which are rather simple, for example, on basis of anisotropic magnetoresistance effect [7]. Also, X-ray magnetic linear dichroism (XMLD) provides one of the few tools to measure AFM order [8]. As a result, there is a possibility as to manipulate L-vector without application of strong magnetic fields and to detect it. And this has become popular for devices in the fields of magnonics and spintronics [6].

The interface between FM and AFM materials is investigated intensively during last decades, both theoretically and experimentally. Number of papers is dedicated to research of boundary conditions on the interface between FM and various materials, for example, the interface of a FM layer and a non-magnetic metal [9], as well as at the FM/AFM interface [10]. In particular, the influence of interface properties on the phenomenon of exchange bias of the hysteresis loop in FM/AFM structures was discovered a long time ago [11-13]. However, at the present time, interest to these effects still persists in connection with practical applications. There are theoretical models of this effect, which consider the interfaces between FM and AFM as either uncompensated [13] or compensated [14]. Besides, FM/AFM interface attracts attention of researchers in view of the observed domain structures in the magnetic force microscopy (MFM) experiments supported by micromagnetic calculations and magneto-resistive measurements which confirmed difference of the magnetic states in these microstructures for both compensated and uncompensated cases [14]. Polarization-dependent XMLD spectro-microscopy has been presented that reveals the micromagnetic structure on both sides of a FM/AFM interface [15]. Remanent hysteresis loops, recorded for individual FM domains, show a local exchange bias. The alignment of the FM spins is determined, domain by domain, by the spin directions in the underlying AFM layer [15]. In any case, the quality of the interface influences on the magnetic parameters of FM/AFM layers. Besides, the investigation of magnetic ordering on the boundary of FM/AFM is important for development antiferromagnetic spintronics [1]. However, the latter type of boundary conditions is insufficiently investigated.