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Calculation of Electrical Conductivity and Giant Magnetoresistance within the Free Electron Model

X.-G. Zhang* and W. H. Butler *
*Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6114

ABSTRACT

We use the model of free electrons with random point scatterers (FERPS) to calculate the electrical conductivity and giant magnetoresistance (GMR) for FeCr multilayer systems and compare our results with the experimental values. Our analysis suggests that the primary cause of the GMR in FeCr systems is regions of interdiffusion near the interfaces. We find that in the samples analyzed, these regions of interdiffusion occupy about 8.5Å of the magnetic layer near each interface.

Introduction

Previous calculations of the conductivity and Giant Magnetoresistance in magnetic multilayers have generally employed the model of Free Electrons with Random Point Scatterers (FERPS) and have approximated the conductivity within this model by using either a semi-classical approximation[1, 2, 3] or an approximate solution[4] to the Kubo formula[5, 6]. In a previous study[7] we evaluated the Kubo formula exactly within the FERPS model with a local self-energy, and compared it with the other methods. We investigated the relationships among the various approaches and found that under most circumstances the semi-classical approach agrees surprisingly well with the numerical solution, while the solution of Zhang, Levy and Fert[4] (ZLF) generally yields a conductivity which is lower than the numerical solution when the mean free path is comparable to the layer thicknesses[8].

In light of these results, the question arises as to whether the past analyses of experimental data using ZLF and the conclusions based on them should be re-examined. Specifically, since ZLF theory tends to give results that are closer to the thin limit, it usually over-emphasizes the effects of regions with strong scattering, e.g., interface regions. Therefore, one needs to reconsider the conclusion drawn from these studies that the dominant effect in these GMR systems is the interfacial scattering.

In this paper we calculate the conductivity and GMR exactly within the FERPS model for FeCr multilayer systems, and compare the results with previous studies[9]. Our study suggests that although interface roughness can be important, there may also be a region of interdiffusion that is larger than the rough regions near the interfaces, and this interdiffusion may be an important contributor to GMR. We further speculate that GMR may be significantly increased if this interdiffusion region can be increased while maintaining spin alignment.

Conductivity in the Free Electron Model

Our model of the multilayer is described by a complex local self-energy $\Sigma(z)$ that is constant in the xy directions (parallel to the layers), and is assumed to be constant in the