

Influence of vanadium impurities on the GMR and the magnetic properties of Fe/Cr/Fe

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Abstract

The giant magnetoresistance (GMR) of Fe/Cr_s/V_n/Fe sandwiches is investigated within the Kubo–Greenwood formalism, wherein the electronic and magnetic properties are obtained from the screened Korringa–Kohn–Rostoker method. The reduction of the GMR with increasing number of spacer layers becomes larger by replacing Cr with V. Furthermore, for $n = 2$ the magnetic configuration of the spacer changes significantly.

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1. Introduction

The giant magnetoresistance (GMR) of Fe/Cr/T multilayers with T being a thin layer of a third metal seems to be related to two different effects: the spin dependent scattering and the anti-ferromagnetic coupling of the Fe leads, whereby the differences in the spin-dependent resistivities of the impurities are mostly important for very thin layers [1]. With increasing thickness of the overlayer the GMR is dominated by the interlayer exchange coupling.

Here, we study the influence of V overlayers on the GMR of Fe/Cr/Fe systems in the current perpendicular to the plane geometry (CPP). The impurity layers consisting of one or two monolayers (ML) (i.e. 1.4 and 2.8 Å) of V are placed on top of the Cr spacer, whereby the Cr thickness ranges between 2 and 21 ML.

The fully-relativistic, spin-polarized version of the screened Korringa–Kohn–Rostoker method for layered systems [2] has been used to investigate the electronic and magnetic properties of the Fe/Cr/V/Fe systems. The transport properties have been obtained from the

Kubo–Greenwood formalism [3]. The GMR of a system with m spacer layers can be written as

$$R(m) = \frac{r(\text{AF}, m) - r(\text{FM}, m)}{r(\text{AF}, m)}, \quad R \leq 1, \quad (1)$$

in which $m = n + s$. The two magnetic configurations of the leads being either parallel or antiparallel are denoted by FM and AF, respectively. Due to numerical reasons the calculations have to be performed for a finite imaginary part of the Fermi energy (here: 2 mRy). Therefore, the present values of the GMR serve as lower limit for the actual value of the GMR for details see Refs. [4,5].

2. Results

From Fig. 1 it can be seen that the GMR decreases with increasing number of spacer layers. It has been already shown elsewhere that the small oscillations are related to the oscillations in the interlayer exchange coupling (IEC) [6]. Obviously, the GMR is also reduced if Cr layers are replaced by V. For systems with 8 and 9 ML of Cr the GMR decreases by 2% and 3%, respectively, which is in good agreement with the experimental observations [1]. Except for very thin Cr layers the GMR of the systems with a single monolayer of V behave very similar to the systems without V. This

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can be understood from the fact that V couples AF to Fe and Cr such that it acts as an additional layer of Cr. The systems with $n = 2$ show a slightly different behavior. The GMR seems to decrease faster and the oscillations are less pronounced. This can be partially understood from the fact that the addition of a second V layer leads to a shift in the IEC (not shown here) in order to keep the AF coupling of Cr at the interfaces. However, what seems to be even more important is that there is not only a shift in the magnetic coupling, but the magnetic structure also changes. This can be seen from the magnetic moments of the spacer layers displayed in Fig. 2. Systems with pure Cr spacers (Fig. 2 top row)

show the typical oscillations and knots due to the spin-density wave (SDW), whereby systems with even numbers of Cr have reduced moments in order to minimize frustration effects. If the outermost Cr layer is replaced by V the magnetic structure is only slightly changed at the V–Fe interface and the V seems to stabilize the SDW, i.e. the size of the Cr moments is increased. If two Cr layers are replaced by V the SDW is damped, i.e. the system starts to transform into a commensurate AF structure. Only on the left side of the spacer, i.e. far away from the V layers, a knot from the SDW can be observed. Similar observations have been made for one monolayer of Mn on the Cr spacer [5]. Due to the AF coupling between Fe, V, and Cr it takes two monolayers of V until the magnetic configuration starts to change. In summary, replacing Cr by V leads to a more rapid decrease of the GMR as compared to Fe/Cr/Fe. From the magnetic moments it turns out that one ML of V seems to stabilize the SDW, whereas in the case of two V layers the magnetic configuration transforms to a commensurate structure.

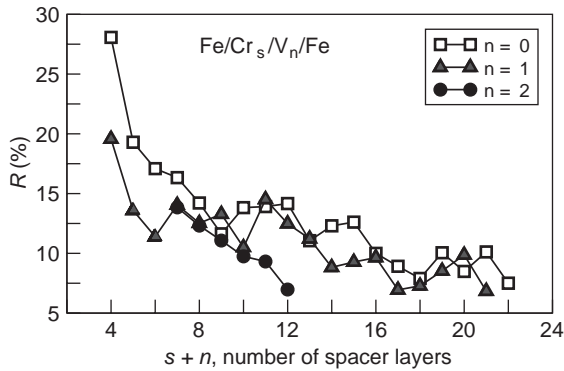


Fig. 1. GMR of Fe/Cr_s/V_n/Fe sandwiches vs. the number of spacer layers $s + n$. Symbols denote the thickness of the V layer.

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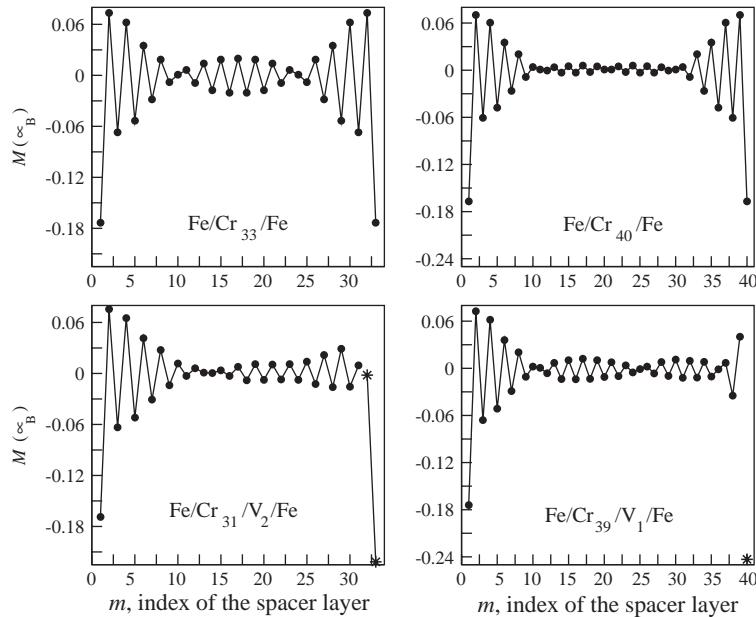


Fig. 2. Top: magnetic moments of the Cr layers in Fe/Cr_s/Fe systems with 33 (left) and 40 (right) spacer layers. Bottom: magnetic moments of the Cr and V layers for Fe/Cr_s/V_n/Fe having the same number of spacer layers, but one (right) or two (left) Cr layers replaced by V.

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