

Magnetostriction in some Laves phase pseudobinaries

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Abstract Magnetostriction and magnetization measurements are presented for two series of Laves phase pseudobinaries: $(Zr,Hf)Fe_2$ and $(Zr,Y)Fe_2$. The results are briefly discussed in terms of the model of Heine et al.

1. Introduction

We have made studies of the magnetostriction in the following series of Laves phase pseudo binaries: $(Zr_{1-x}Hf_x)Fe_2$ and $(Zr_{1-x}Y_x)Fe_2$. The choice of the first series of compounds was dictated by the possibility¹, in these Laves phase series, of selectively modifying the strength of the spin-orbit coupling interaction at the A sites. In the case of Y doped compounds, although with quasi identical spin-orbit coupling strength¹, Y atoms introduce perturbations in the electronic structure of the material.

Recently, Heine et al.² described the magnetostriction in terms of a second order perturbation theory on the spin-orbit coupling interaction. The result of the calculation is written in terms of the one electron propagators for the itinerant d electrons, responsible for the magnetic properties of the material. These propagators in turn are affected by the chemical disorder introduced by the impurities. Then two effects are present: the changes in the strength of the spin orbit coupling and the electronic structure modifications associated to chemical

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disorder. The last effect directly modifies the magnetization of the material and thus competitive effects may occur.

The intermetallic compounds were prepared by arc melting and several fusions were made in order to ensure homogeneity of the samples. The series of compounds $(Zr_{1-x}Hf_x)Fe_2$ had been previously prepared in our laboratory, and we carefully verified the quality of the samples through X-ray diffractometry. The Hf series show cubic C15 structure for all concentrations, except near $x=1.0$.

We prepared the $(Zr_{1-x}Y_x)Fe_2$ series following the same procedures as in the previous case. X-ray studies show however the existence of small quantities of another phase, except at the ends of the series. This fact has been previously reported in reference 3. The magnetization and magnetostriction measurements were performed in as cast samples.

The magnetization of the Y and Hf compounds was measured with a vibrating sample magnetometer at room temperature and the results are shown in Fig.1. The results for the magnetization in Y series, made at room temperature are consistent with those reported in ref. 3. Magnetization data for the $(Zr,Hf)Fe_2$ series is, to the authors knowledge, not available in the literature.

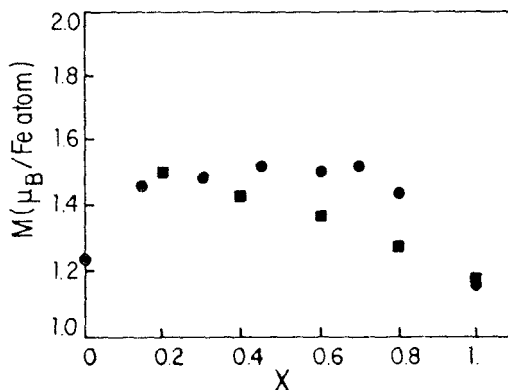


Fig. 1 - Magnetization in μ_B per Fe atom for $(Zr,Hf)Fe_2$ and $(Zr,Y)Fe_2$. Circles denote Hf compounds and squares correspond to Y pseudobinaries.

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These results for $(\text{Zr,Hf})\text{Fe}_2$ open another question, now of theoretical nature, which consists in extending a previous model for these pseudobinaries⁴. This model, called the "reservoir model" assumed a charge transfer from the A sites to the B ones, keeping unchanged the $3d$ local density of states. In that work, a model density of states was assumed, with a **negative** slope around the Fermi level. In the **presence** of increasing charge transfer with impurity concentration, the density of states at the Fermi level decreases and so does the magnetization. Our experimental data for the magnetization disagrees with such a picture. Corrections to that model are currently being introduced.

The magnetostriction was measured using the strain gauge technique, and using the classical Wheatstone bridge coupled with a lock in amplifier⁵. The measurements were performed at room temperature and the results are shown in Fig 2.

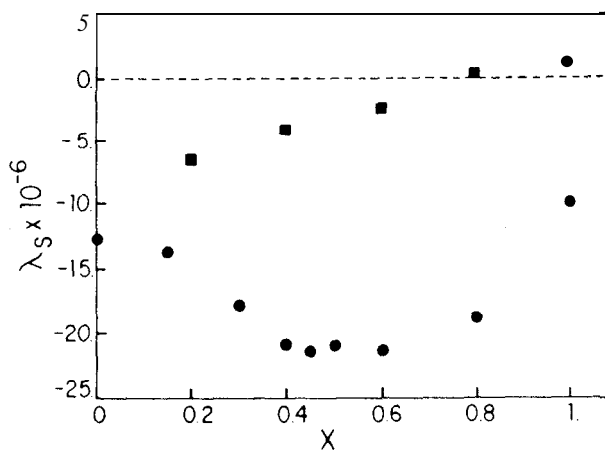


Fig. 2 - Magnetostriction for the series $(\text{Zr,Hf})\text{Fe}_2$ and $(\text{Zr,Y})\text{Fe}_2$. Circles denote Hf compounds and squares correspond to Y pseudobinaries.

In the case of Hf pseudobinaries, and for increasing concentrations, firstly the magnetostriction decreases (increases in absolute value) to approach smaller absolute values near the end of the series. The behaviour for concentrations up to around .60 of Hf is consistent with the dominating role of the increasing strength

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of the spin orbit coupling, the magnetization remaining almost constant. For higher concentrations, the magnetization decreases and thus dominates over the spin-orbit, decreasing A , in absolute value.

The behaviour in the case of $(Zr,Y)Fe_2$ pseudo binaries is quite unexpected since A , changes sign at Y concentrations around 0.80, in a way quite similar to binary transition metal alloys like $FeNi$ and $FePd$ ⁶. Since the strength of the spin orbit coupling is almost constant along the series, we attribute these effects to changes induced by the Y impurities in the electronic structure of the pseudobinary. In a LMTO-TB description of the electronic structure, one expects that the local d-band centers associated to Y atoms to lie higher than those associated to Zr atoms'. This implies that hybridization effects between the 3d states associated to Fe B sublattice and states connected to the A atoms (Zr or Y) will modify the one-electron propagators that appear in Heine's et al.² description of the magnetostriction.

It remains to clarify the role of the existence of coexisting phases in the results for the magnetostriction. It is tempting to assume that the extra phases are not magnetic and thus attributing all the measured effects to the changes in the electronic structure of the C15 phase. A good experimental test for this assumption, besides Curie temperature measurements, is to measure the NMR response of Y atoms. Work in this direction is in progress.

References

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Resumo

Medidas de magnetostricção e magnetização são efetuadas em duas séries de compostos pseudo binários: $(Zr, Hf)Fe_2$ e $(Zr, Y)Fe_2$. Os resultados são qualitativamente discutidos em termos do modelo de Heine et al.