MAGNETIC PROPERTIES OF SOME $Er_2Fe_{14}BH_x$ HYDRIDES

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Introduction

The $R_2Fe_{14}B$ (R - rare-earth) compounds absorb copious amounts of hydrogen readily and form stable hydrides at room temperature. The changes in magnetic characteristics of these compounds which occur due to hydrogen absorption are of great fundamental and technological interest.

The intrinsic magnetic properties of the $Er_2Fe_{14}B$ intermetallic compound have been previously investigated [1]. According to literature data the magnetic ordering temperature of this compound is $T_C = 554$ K and it exhibits one successive spin reorientation transition at about 325 - 327 K. The aim of this work is to study the effect of hydrogenation of the magnetic phase transitions in the $Er_2Fe_{14}B$ compound using magnetization investigations. The important feature of these investigations is that the measurements were carried out in situ in a hydrogen atmosphere.

Results and discussion

The $Er_2Fe_{14}B$ samples were prepared by arc melting under purified argon gas from starting materials of at least 99.99 % wt purity. After melting the as-cast samples were wrapped in a tantalum foil, sealed in quartz tubes and annealed in an argon atmosphere for 14 days at 900^0 C. X-ray diffraction have been used to check the purity of the samples.

A volumetric type experimental set-up was used to study the hydrogen absorption-desorption properties at hydrogen pressure up to 4 atm in the temperature range from 300 to 700 K.

The magnetization measurements were carried out in the temperature range 300-700 K in permanent magnetic fields up to 12 kOe using an apparatus for magnetic measurements under gas pressure up to 12 atm, constructed on the principle of a vibrating-sample magnetometer.

The effect of hydrogenation on the Curie temperature of these compounds has been studied. Fig. 1 shows hydrogen pressure dependence of the T_C for $Er_2Fe_{14}BH_x$.

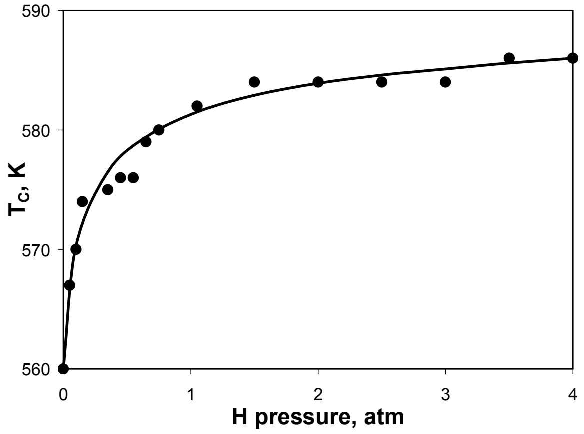

Fig. 1. Curie temperatures for $Er_2Fe_{14}BH_x$ versus the hydrogen pressure.

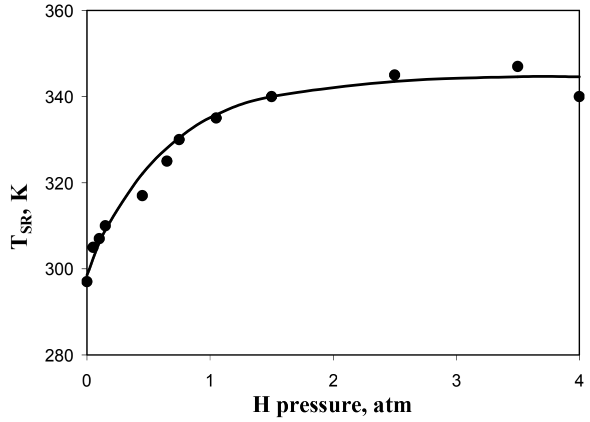

Fig. 2. Spin reorientation transition temperatures for $Er_2Fe_{14}BH_x$ versus the hydrogen pressure.

As it shown in figure, the Curie temperature strongly depends on hydrogen content: at small concentrations of hydrogen a sharp rise of the Curie temperature occurs. This increase is related to an expansion of the lattice parameters and may be attributed to a reduction of the negative exchange interactions between iron atoms.

The spin-reorientation transition in $Er_2Fe_{14}B$ compound can be attributed to the competing of the uniaxial Fe sublattice and the planar rare-earth sublattice anisotropy, with the former being dominant at higher temperatures and the latter being dominant at lower ones.

Fig. 2 shows the dependence of the spin-reorientation transition temperature on the hydrogen pressure. As one can see, there is a correlation between $T_C(p)$ and $T_{SR}(p)$ curves. It should be mentioned, that according to our results in $Er_2Fe_{14}B$ compound the $T_{SR} = 297$ K that is considerably less (by 30 K) than in literature data. This fact can be explained as follows: since these compounds could absorb hydrogen at room temperature and atmosphere pressure, the host compounds $Er_2Fe_{14}B$ contain some amount of hydrogen.

Having studied of SRT temperature of $Er_2Fe_{14}BH_x$ and K_{1Fe} [2] we calculated a B_{20} crystal field parameter before and after hydrogenation using a formula obtained by Kuz'min et al. [3].

$$B_{20} = \frac{20K_{1Fe}}{J(J+1)(2J-1)(2J+3)}\left(\frac{k_B T_{SR}}{\Delta_{ex}}\right)^2$$

where $\Delta_{ex} = 2\,|g_J - 1|\, m_B\ B_{ex}$– is the exchange splitting between two successive energy levels, $J = 15/2$ – quantum number of the full moment of Er^{3+} ion. Values of the exchange field B_{ex} and exchange splitting Δ_{ex} were determined using temperature Curie data for $Lu_2Fe_{14}BH_x$ and $Er_2Fe_{14}BH_x$ in terms of molecular field theory.

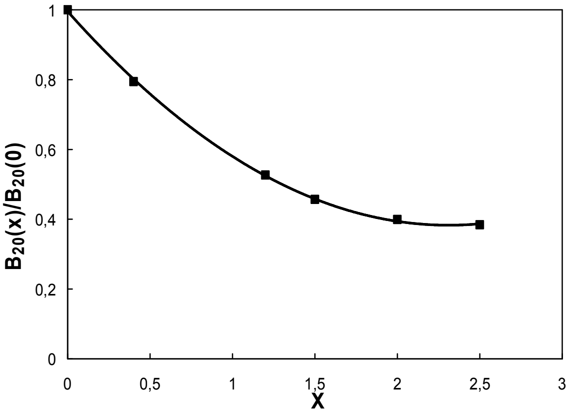

Fig. 3. Dependence of the CF parameters in $Er_2Fe_{14}BH_x$ on the amount of interstitial hydrogen x.

A B_{20} crystal field parameter decreases as hydrogen atoms concentration increases and, therefore, the rare-earth sublattice magnetic anisotropy constant K_{1R} ($K_{1R} \sim -J^2B_{20}B_J^2(x)$, where $B_J^2(x)$ is the 2nd order generalized Brillouin function) also decreases. Hydrogenation leads to a decrease of the uniaxial contribution to the anisotropy K_{1Fe} from the Fe sublattice [2]. Compensation of rare-earth and iron sublattices constants for the host compound takes place at temperature $T = 297$ K, and for the hydrides it takes place at higher temperature. The increase in spin-reorientation transition temperature was caused by strengthening of iron-iron and rare-earth - iron exchange interactions.

Conclusions

We have synthesized and studied the $Er_2Fe_{14}B$ intermetallic compounds and its hydrides. The dependencies of the Curie temperature and spin-reorientation temperature on the hydrogen pressure were investigated. It has been found that T_C and T_{SR} increase monotonically with increasing hydrogen pressure. The obtained experimental results are useful for understanding of the change in magnetocrystalline and exchange interactions upon hydrogen absorption.

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References

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