THE INFLUENCE OF HYDROGEN ON MAGNETIC AND MAGNETOELASTIC PROPERTIES OF Lu_2Fe_{17} SINGLE CRYSTAL

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Introduction

The specific feature of the rare earth – iron intermetallic compounds with the R_2Fe_{17} stoichiometric formula is that their magnetic properties strongly depend on the unit cell volume and interatomic distances. It results in considerable shift of the magnetic ordering temperature T_C value under the hydrostatic pressure [1].

Among the R_2Fe_{17} compounds the Lu_2Fe_{17} compound is less studied because of difficulty to obtain big high-pure single crystals. It was established [2] that small uncontrolled dashes lead to suppression of the antiferromagnetic state and remove the T_C toward the higher temperatures. But the magnetic properties of Lu_2Fe_{17} single crystal obtained from the high-pure components provide complete information about the iron sublattice behavior in R_2Fe_{17} compounds. The purpose of the present work is to investigate the influence of hydrogenation on magnetic and magnetoelastic properties of Lu_2Fe_{17} single crystal.

Results and discussion

The intermetallic Lu_2Fe_{17} compound crystallizes in disordered variant of hexagonal structure of Th_2Ni_{17} type with the $P6_3/mmc$ space group [2]. It is known [3] that the R_2Fe_{17} compounds could absorb up to 5 H at./f. u. and form stable hydrides. The hydrogen occupies octahedral positions for $x \leq 3$ (x – the concentration of absorbed hydrogen atoms).

Fig. 1 shows the temperature dependence of magnetization $\sigma(T)$ for the Lu_2Fe_{17} compound. There are some features on the $\sigma(T)$ curve: 1) a sharp slump of the magnetization at T = 180 K (the transition from the ferromagnetic (FM) to the antiferromagnetic (AFM) state), which accompanied by the considerable hysteresis; and 2) a weak maximum typical for the AFM – PM (paramagnetic) transition with Néel temperature T_N = 275 K, which is in good agreement with literature data [4]. The hydrogenation also leads to suppression of the AFM and induces FM state in the Lu_2Fe_{17} single crystal. As a result of hydrogenation, the Curie temperature increases and reaches a value of T_C = 400 K (see Fig. 2).

This effect can be explained within both the localized and collectivized electrons models.

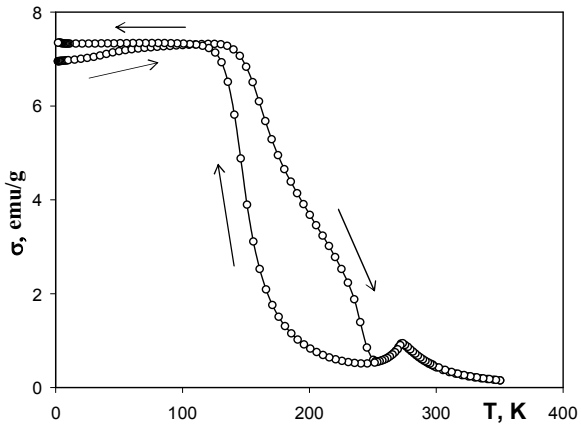

Fig. 1. Temperature dependence of magnetization of Lu_2Fe_{17} single crystal in magnetic field of H = 100 Oe.

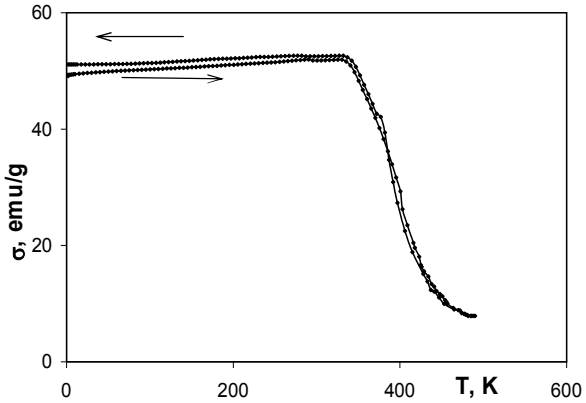

Fig. 2. Temperature dependence of magnetization of $Lu_2Fe_{17}H_{1,5}$ single crystal in magnetic field of H = 500 Oe.

Assuming that the increase in the Curie temperature value of the $Lu_2Fe_{17}H_{1,5}$ single crystal mainly connected with the increase of the exchange integrals as a result of increase in the unit cell volume, we could calculate a change in the T_C using the following formula:

$$\Delta T_C = -\frac{T_C}{\chi}\frac{\Delta V}{V}\frac{d\ln T_C}{dp}$$

where χ – compressibility. The values are $\chi = 1.03\cdot10^{-3}$ kbar^{-1} and $d\ln T_N/dp = -19\cdot10^{-3}$ kbar^{-1} for the Lu_2Fe_{17} [1]. It was found that the calculated value of $\Delta T_C = 55$ K is smaller than the observed one - $\Delta T_C = 125$ K. The calculation of the Curie temperature increase in terms of the spin-fluctuations theory [5] provides a higher value - $\Delta T_C = 175$ K.

The host Lu_2Fe_{17} compound has a metamagnetic transition from AFM to the induced by the internal magnetic field FM state in case when the magnetic field applied along the c axis. The temperature dependence of the critical field $H_{CR}(T)$ is shown in the Fig. 3.

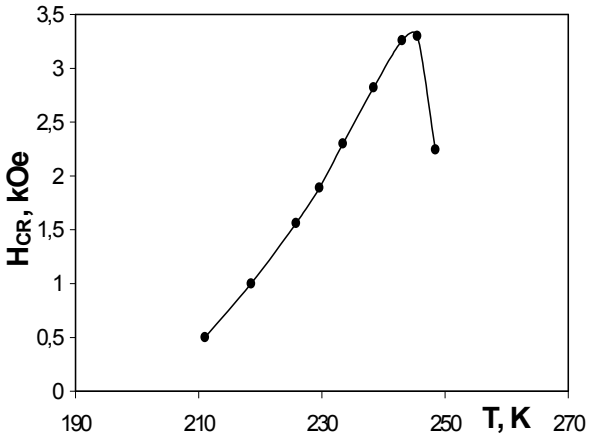

Fig. 3. Temperature dependence of the critical field for Lu_2Fe_{17} single crystal.

As one can see from the Fig. 3 the H_{CR} rises with temperature increase, has a narrow maximum and abruptly decreases when approaching the Néel temperature. Thus, the magnetic field of $H \geq 3{,}5$ кOe suppresses the AFM state in Lu_2Fe_{17} compound.

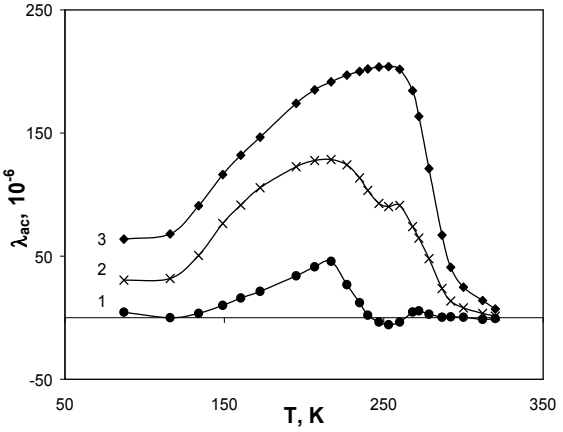

Fig. 4. Temperature dependence of transverse λ_{ac} magnetostriction for Lu_2Fe_{17}, measured in magnetic fields: 1 – 2; 2 – 6,5; 3 – 12 кOe.

To obtain the information about magnetostriction of the Lu_2Fe_{17} single crystal the temperature and field dependencies of longitudinal magnetostriction in the temperature range of 77 – 300 K and magnetic fields up to 12 кOe applied along and across the hexagonal c-axis [001] were investigated (see Fig. 4). With temperature increase and approaching to the magnetic ordering temperature (where the para-process plays the most important role) the values of magnetostriction λ_{cc} and λ_{ac} significantly rise approaching theirs maximum values.

Hydrogenation of the Lu_2Fe_{17} single crystal leads to decrease of magnetostrictive deformations to zero value in the whole investigated temperature range of 77-300 K.

Conclusions

Thus, we established that hydrogenation leads to a change of magnetic state of Lu_2Fe_{17} compound – suppression of the AFM and induction of the FM state; and moreover to a change of the magnetoelastic interactions as a result of the interatomic distances increase.

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