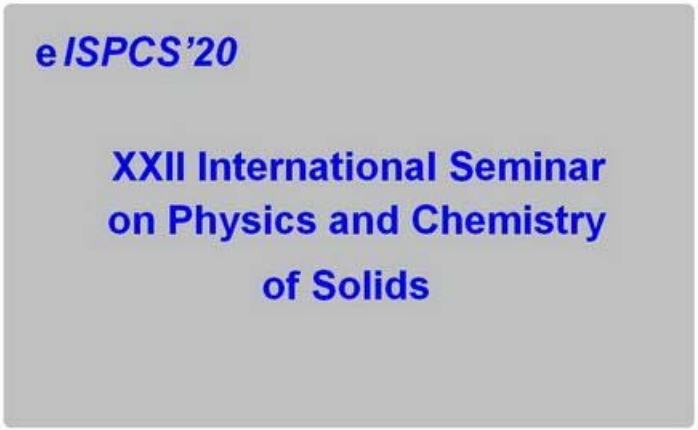

THE Gd-Fe CONDENSED FILMS (STRUCTURE & PROPERTIES)

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Introduction

Thin layers of intermetallic compounds of type a rare-earth element - iron are interesting due to their magnetic properties. These properties are influenced strongly by structural features of these compounds. For example, in Gd-Fe system there are many structural types which were have studied recently. It is necessary to note also a significant influence on formation of structure of methods and conditions of evaporations of films.

An interest to the investigations of structure of Gd_2Fe_{17} films is caused by their pecularity among other compounds of tne type of rare-earth metal – iron (R_2Fe_{17}). This pecularity consists in existence in equilibrium of two different by structure phases quite close by composition to Gd_2Fe_{17}. Moreover one of these phases exists at the excess of Fe in equilibrium with *a-Fe*, and another – at deficiency of Fe in equilibrium with compound similar to $GdFe_5$. The posibility of the existence of many phases in

equilibrium prompts for a variety of structure and substructure formation of processes of the films depending on technological conditions of their deposition.

Experiment

Films of binary compounds of Gd-Fe system were obtained by means of a thermal vacuum evaporation of polycrystalline mix material of a corresponding composition. The films with by thickness of 5-50 nm. were evaporated on splitting of NaCl, then NaCl dissolved in water. The part of films was picked up at once on copper electron diffraction grids. The temperature of substrates had two values 300 and 500 K. For structural investigation the electron microscope UEMV-100K and high-temperature attachment PRON-2 were used. Angle dependence of atomic factors of electron scattering was considered by atoms of gadolinium and iron.

Results & discussion

The electron diffraction investigations of the Gd_2Fe_{17} films precipitated at T_s=300K prove, that these condensates are amorphous [1]. It is determined, that at heating of such films the initial phase of crystallization consist of *a-Fe* crystallites with sizes increasing with temperature. This is proved by reduction of a half-width of the diffraction peaks in electron diffraction patterns and as well indicated by estimations of the sizes of crystallites on the electron-microscopic images. At further increase of temperature (more 100K higher than temperature of an initial *a-Fe* crystallization) the crystallization of Gd enriched amorphous matrix starts and as result Gd_6Fe_{23} crystallites are formed (structural type Gd_6Fe_{23}, space group Fm-3m). Crystallization of amorphous Gd_2Fe_{17} films completed by forming of polycrystalline film *a-Fe* and Gd_6Fe_{23}.

The appereance of Gd_6Fe_{23} phase is not strange, as far as this compounds is one of the most in Gd-Fe system. Furthermore even in a massive state in Gd-Fe system at the attempts to synthesize compounds with high abundance of Fe ($GdFe_5$, Gd_2Fe_{17}) without special technologies the phase of Gd_6Fe_{23} is always present.

The significantly different picture is observed in phase formation kinetics in mode of films of Gd_2Fe_{17} alloy, precipitations on heated substrate. In the range from room temperature to the T_s=400 K the amorphous films are observed. At T_s=500 K these films become amorphous-crystalline. At the further increase of the substrate temperature the fraction of a polycrystal phase increases. The interpretation of electron diffraction patterns has shown, that the polycrystalline films consists of three phases: Gd_2Fe_{17} (60 %) with Th_2Ni_{17} structural type (φ_1-phase), Gd_2Fe_{17} (30 %) of Th_2Zn_{17} structural type (φ_2-phase) and some (about. 10 %) $GdFe_5$ of $CaCu_5$ structural type. The unit cell of hexagonal modification of Gd_2Fe_{17} compound is presented constructed on the basis of the diffraction data using of computer code PowderCell (a = 8.50 And, c =8.35 A).

The apperance of these phases in Gd_2Fe_{17} films indicates on possibility of origination in a precipitation process of microareas enriched and depleted of iron. Such mechanism of formation of films leads to the mutual blocking of growing of crystallites of φ_1-

and φ_2 phases. This predetermines a possibility amorphous state of the formation in intermetallic Gd_2Fe_{17} compound and predetermines high thermal resistance of amorphous state in films precipitated on substrates at ambient temperature. At the precipitation of films on heated substrates the diffusive length of adsorbed atoms increases and decreases the density of seeds in which formation of the long-range order, and crystalline structure of phases φ_1 and φ_2 is possible.

Positions of diffraction peaks has not changed. It testifies that the generated structures have not changed in due course, and also oxidizing process is not observed. If to compare intensity of maximums it is possible to observe insignificant disproportionation of phases content. The content of hexagonal Gd_2Fe_{17} compound has decreased (60%→50%). The content of rhombohedral Gd_2Fe_{17} compound it was reduced (30%→40%). The only phase which has not changed the percentage is hexagonal $GdFe_5$ (10%).

We gain loops of a magnetic hysteresis for volume and thin-film samples (Fig.1-4). They confirm that fact that explored materials belong to the class of magnito-soft ferromagnetics [2,3]. They are characterised by a narrow loop of a magnetic hysteresis and small operation of an external field for magnetisation reversal. Also it is necessary to pay attention to differences in character of hysteresis curves for volume and thin-film samples of all compounds of the given system.

In the table 1 it is given a coercive force for amorphous and polycrystalline films and also for volume samples. The coercive force decreases at formation of amorphous films in comparison with volume samples. It is caused by lack of the long-range order in amorphous materials and accordingly much more a smaller magnetic anisotropy. Formation of a polycrystalline phase in films leads to magnito-hardness magnification. This results from the fact that magnetisation was measured lengthways their surfaces. It is known that in films there are flat domains which is much easier for magnetising lengthways rather than perpendicularly to a surface [4]. Influence of the relative content of iron in compound on magnetic properties of films is traced also. For terrain clearance value of a coercive force does not matter how there is a crystallisation, or in the course of film formation on the warmed-up substrate or during annealing amorphous films.

Table 1

Compound	$GdFe_2$	$GdFe_5$	Gd_2Fe_{17}
Coercive force	H, KA/m	H, KA/m	H, KA/m
Volume sample	2.1	3.0	4.1
Amorphous film	1.2	1.5	2.1
Polycrystalline film (the warmed-up substrate)	3.5	5.2	6.1
Polycrystalline film (annealing)	3.6	5.1	6.0

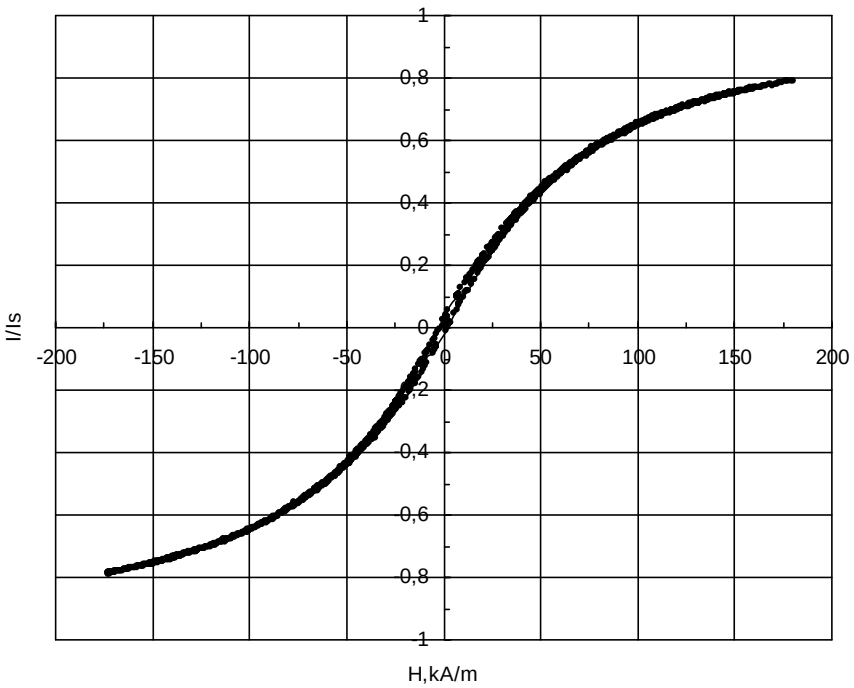

Fig.1
Hysteresis curve
for volume $GdFe_2$

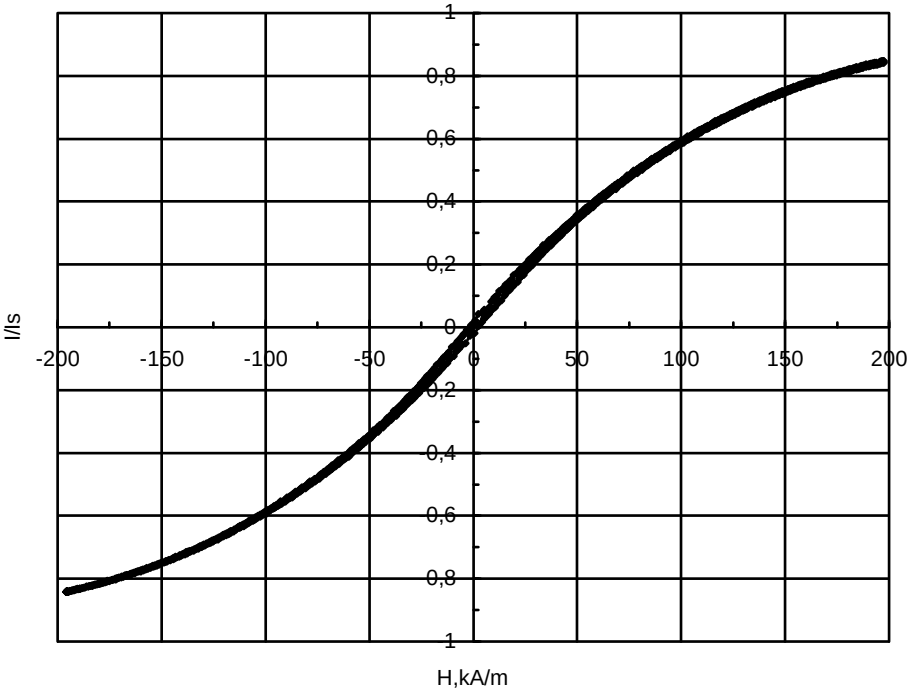

Fig.2
Hysteresis curve
for volume $GdFe_5$

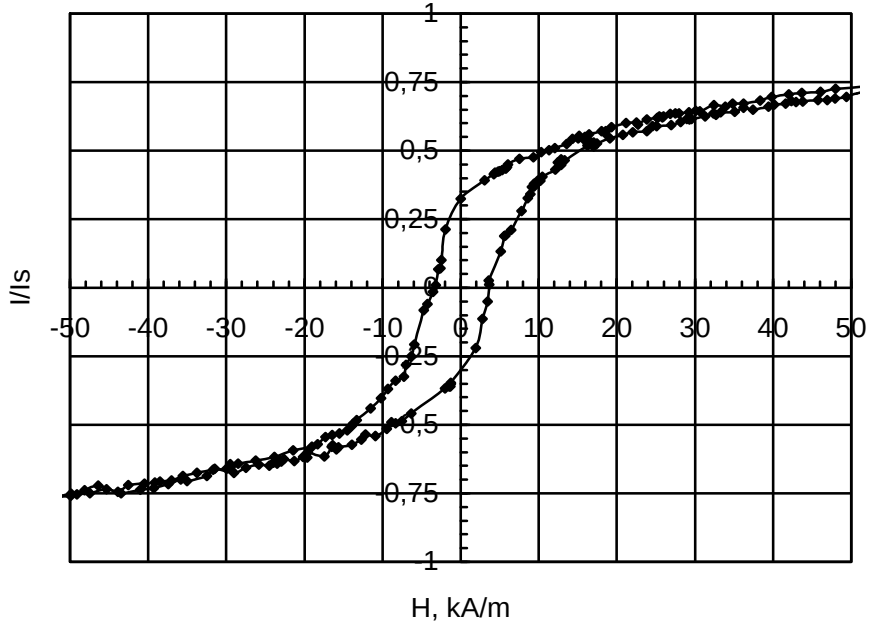

Fig.3
Hysteresis curve
for polycrystalline film $GdFe_2$

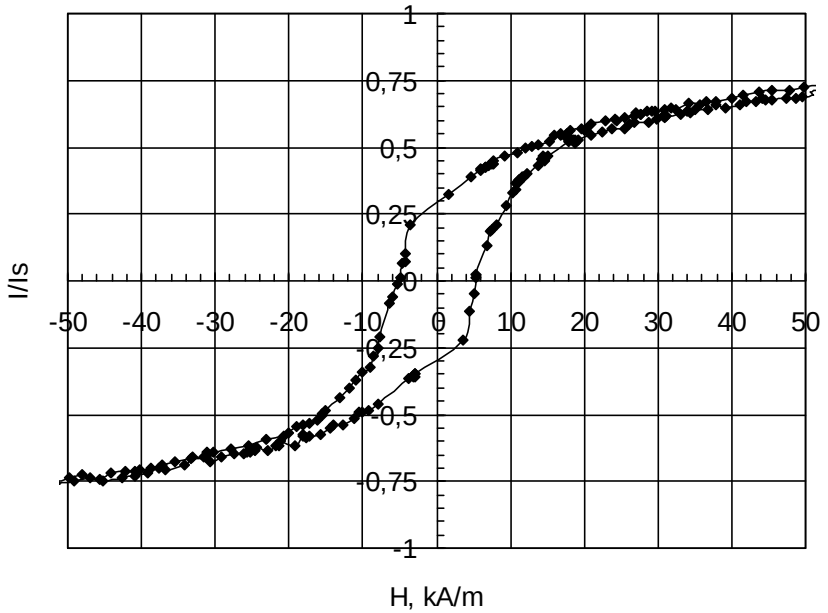

Fig4
Hysteresis curve
for polycrystalline film $GdFe_5$

Conclusions

- Explored compounds and their films belong to the class soft magnetic materials
- Coercive force decrease at formation of amorphous films in comparison with volume samples
- Formation of a polycrystalline phase in films leads to magnification of hard-magnetic

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