Influence of ageing processes on the structure and physical properties of amorphous-crystalline films of Gd–Fe system

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Received July 20, 2012

Structural and electrophysical studies of thin amorphous and polycrystalline films of Gd–Fe system just after evaporation as well as after 3 years ageing were carried out. The high time stability of these materials has been established.

Проведены структурные и электрофизические исследования тонких аморфных и поликристаллических пленок системы Gd–Fe сразу после их получения и через 3 года. Обнаружено высокую временную стойкость данных материалов.

1. Introduction

Thin layers of intermetallic compounds of a rare-earth element — iron type are interesting for researchers 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 studied recently [1, 2]. It is necessary to note also that methods and conditions of evaporation of the films influence significantly on formation of the structure [3].

2. Experimental technique

Thin 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 thickness of 50–60 nm were evaporated on splitting of NaCl, and then NaCl was dissolved in water. The part of the films was picked up at once on copper electron diffraction grids. The second series of the films was transplanted on copper grids preliminarily coated by thin collodion films and in such way was maintained during 3 years. Then recurring researches were carried out. For electrophysical measurements the films were condensed on glass-ceramics substrates. A thickness of the films changed within 100–200 nm. The films thickness was measured by means of an optical interferometer MIO-1. The temperature of the substrates had two values 300 and 500 K. For structural investigations an electron microscope UEMV-100K and high-temperature attachment PRON-2 were used. Electron diffraction patterns were scanned photometrically using a microphotometer MF-4. Angle dependence of atomic factors of electron scattering on atoms of gadolinium and iron was considered. Specific resistance measurements in vacuum were carried out in special cryostat on the basis of VUP-5 unit. All measurements were repeated in 3 years after the first stage of the investigation.

3. Discussion

Structural investigations of $GdFe_2$ films have been already performed by us [1, 2]. It has been revealed that $GdFe_2$films condense in structural type $MgCu_2$ (face-centered cubic lattice) which is characteristic for the massive samples. In Table 1 the intensity of

Table 1. Intensities of diffraction peaks and values d_n for $GdFe_2$ films which has been evaporated at T_s = 500 K before and after a three-year ageing

$GdFe_2$ film			$GdFe_2$ film (recurring research)			Bulk sample		
I, r.u.	d_n, nm	(hkl)	I, r.u.	d_{hkl}, nm	(hkl)	I, r.u.	d_n, nm	(hkl)
63	0.266	(022)	63	0.266	(022)	63	0.261	(022)
100	0.217	(113)	100	0.217	(113)	100	0.223	(113)
12	0.186	(222)	13	0.186	(222)	16	0.213	(222)
12	0.164	(224)	13	0.164	(224)	3	0.170	(133)
10	0.145	(333)	10	0.145	(333)	20	0.151	(224)
11	0.132	(044)	10	0.132	(044)	19	0.142	(333)
						18	0.131	(044)
						7	0.117	(026)
						7	0.113	(335)
a = 0.750 nm			a = 0.750 nm			a = 0.740 nm		

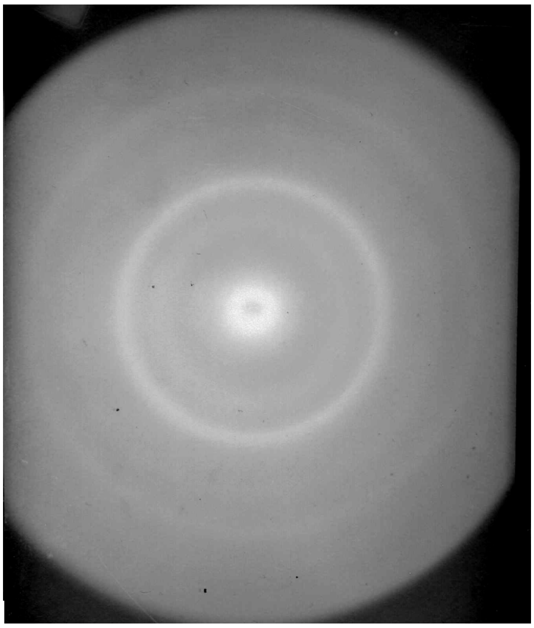

Fig. 1. Electron diffraction patterns of amorphous Gd_2Fe_{17} film ($T_{substrate}$ = 300 K).

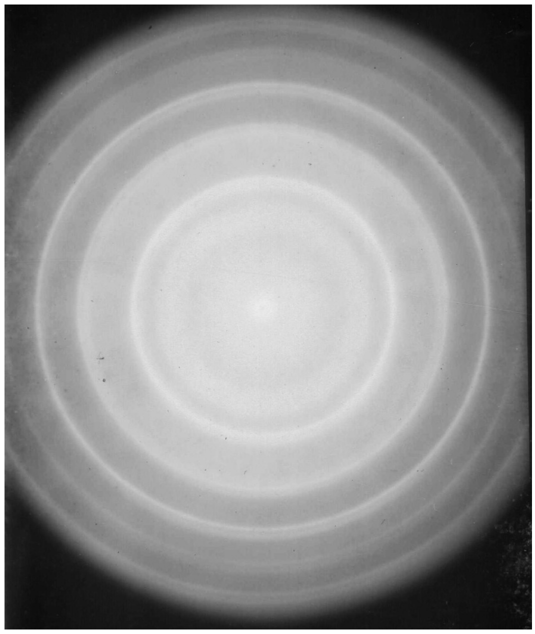

Fig. 2. Electron diffraction patterns of amorphous-crystal Gd_2Fe_{17} film ($T_{substrate}$ = 500 K).

diffraction peaks and value of d_{hkl} for amorphous-crystalline films $GdFe_2$ condensed at T_s = 500 K as-obtained and aged during 3 years as well as for massive $GdFe_2$ are listed. No any structural changes are observed. Especially it is necessary to note the lack of processes of an oxidizing.

In Fig. 1, 2 it is shown the electron diffraction patterns of Gd_2Fe_{17} compounds at the different substrate temperatures. In Fig. 3 the photomicrography of amorphous-crystalline Gd_2Fe_{17} film is preserved. Under identification of structure of the films for Gd_2Fe_{17} compounds it is necessary to consider that this compound crystallizes in two structural types [4]. Gd_2Fe_{17} films which were condensed at temperature of a substrate T_s = 500 K consisted of an intermixture of three compounds — hexagonal Gd_2Fe_{17} with structural type Th_2Ni_{17}, rhombohedral Gd_2Fe_{17} with structural type Th_2Ni_{17} and hexagonal $GdFe_5$ with structural type $CaCu_5$ (Table 2). In Table 2 also are shown the data of intensity of the diffraction peaks, values d_n and parameters S ($S = 2\pi/d_n$, nm^{-1}) for the films gained at T_s= 500 K as-obtained and after 3 years ageing at room conditions. The positions of the diffraction peaks have not changed. It testifies to the fact that the formed struc-

Table 2. Intensities of diffraction peaks, values d_n and parameters S ($S = 2\pi/d_n$, nm^{-1}) for Gd_2Fe_{17} films which has been evaporated at T_s = 500 K before and after a three-year ageing

Gd_2Fe_{17} film			Gd_2Fe_{17} film (recurring research)		
I, r.u.	d_n, nm	*S*, nm^{-1}	*I*, r.u.	d_n, nm	*S*, nm^{-1}
70	0.297	21.1	71	0.297	21.1
55	0.245	25.6	55	0.245	25.6
100	0.211	29.8	100	0.211	29.8
35	0.208	30.2	35	0.208	30.2
45	0.188	33.6	45	0.188	33.6
40	0.148	42.4	51	0.148	42.4
55	0.133	47.2	56	0.133	47.2
30	0.122	51.9	30	0.122	51.9
25	0.105	59.8	24	0.105	59.8
25	0.090	69.8	24	0.090	69.8

Bulk sample Gd_2Fe_{17} (structural type Th_2Ni_{17})			Bulk sample Gd_2Fe_{17} (structural type Th_2Zn_{17})			Bulk sample $GdFe_5$ (structural type $CaCu_5$)		
I, r.u.	d_n, nm	hkl	I, r.u.	d_n, nm	hkl	I, r.u.	d_n, nm	hkl
30	0.298	112	82	0.297	113	40	0.298	101
43	0.245	030	73	0.247	030	26	0.245	110
46	0.212	220	26	0.238	024	35	0.213	200
100	0.211	032	100	0.214	220	100	0.211	111
28	0.209	004	97	0.212	033	30	0.208	002
22	0.189	222	53	0.207	006	22	0.159	112
35	0.187	114	32	0.190	223	21	0.150	211
17	0.134	332	24	0.149	226	30	0.149	202
15	0.123	060	27	0.135	333	34	0.134	301
			23	0.123	060	25	0.123	220
						26	0.121	113
						37	0.106	222
						20	0.099	303
						45	0.091	411

tures have not changed with ageing, and also oxidizing process has not been observed. If to compare an intensity of the maxima it is possible to observe an insignificant redistribution of the phase's percentage content. The content of hexagonal Gd_2Fe_{17} compound with the structural type Th_2Ni_{17} has decreased (60 % $\rightarrow$ 50 %). The content of rhombohedral Gd_2Fe_{17} compound with the structural type Th_2Ni_{17} has increased (30 % $\rightarrow$ 40 %). The only phase which has not changed the percentage content is hexagonal Gd_2Fe_5 with the structural type $CaCu_5$ (10 %).

As a whole, the trend to the further crystallization of amorphous-polycrystalline films is observed. Electron diffraction studies confirm this suggestion (peaks become of the higher resolution).

We also carried out the repeated electrophysical investigations of the films of these compounds. In Table 3 values of a specific

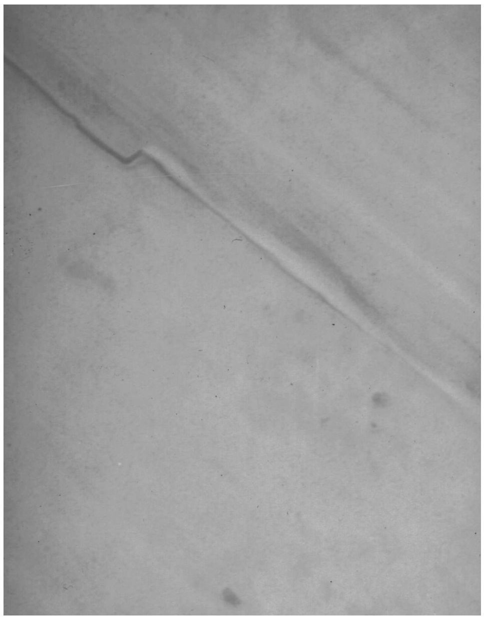

Fig. 3. Microscopic structure of amorphous-crystalline Gd_2Fe_{17} film ($T_{substrate}$ = 500 K).

Table 3. Electrophysical properties of the films

	$GdFe_2$	$GdFe_5$	Gd_2Fe_{17}
Specific electroresistance (mkOm·cm) at $T_{measuring}$ = 300 K and $T_{substrate}$ = 300 K			
as-obtained	$3.75 \cdot 10^4$	$1.09 \cdot 10^4$	$2.12 \cdot 10^3$
after 3 years aging	$3.77 \cdot 10^4$	$1.04 \cdot 10^4$	$2.14 \cdot 10^3$
Specific electroresistance (mkOm·cm) at $T_{measuring}$ = 300 K and $T_{substrate}$ = 500 K			
as-obtained	$5.63 \cdot 10^4$	$4.03 \cdot 10^4$	$9.26 \cdot 10^3$
after 3 years aging	$5.60 \cdot 10^4$	$4.08 \cdot 10^4$	$9.31 \cdot 10^3$

resistance for $GdFe_2$, $GdFe_5$, Gd_2Fe_{17} films are given at temperature 300 K (films have been evaporated at the substrate temperature T_S = 500 K). These effects confirm the fact that mechanisms of charge transfer and the concentration of carrying agents remain invariable.

4. Conclusion

The high time stability of physical characteristics of Gd–Fe films and lack of their oxidizing have been revealed. It is known also that these materials belong to a class of magneto-soft materials [4]. This fact uncloses major prospects for using the films of these compounds as magnetization reversal systems in the information magnetic recording systems.

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Вплив процесів старіння на структуру та фізичні властивості аморфно-кристалічних плівок системи Gd-Fe

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Проведено структурні та електрофізичні дослідження тонких аморфних та полікристалічних плівок системи Gd-Fe зразу після отримання і через 3 роки. Встановлено високу часову стійкість даних матеріалів.