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HIGH FIELD MAGNETIZATION OF $(R_xY_{1-x})Fe$ COMPOUNDS*

by

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ABSTRACT

The magnetization of the pseudo-binary intermetallic compounds $(Dy_xY_{1-x})Fe_2$ and $(Er_xY_{1-x})Fe_2$ was studied in high magnetic fields (up to 20 T). The saturation magnetization shows a minimum as a function of concentration, due to the anti parallel coupling of the R and Fe moments. From the magnetization curve in the high field region we derived the spontaneous magnetization and high field susceptibility, as a function of concentration. The susceptibilities, coercive fields and the anisotropy terms show maxima in the 20 - 40% concentration range.

Keywords: rare earth transition metal compounds, high field magnetization

REF 20/011

1. Introduction

The pseudo-binary intermetallic compounds $R_xY_{1-x}Fe_2$, where R is a rare earth, crystallize with the C15 cubic Laves phase structure and exhibit magnetic order with ordering temperatures that increase from about 550 K to 800 K with increasing R content [1]. NMR studies at 4.2 K with the ^{89}Y resonance in the $R_xY_{1-x}Fe_2$ compounds have revealed a distinct behavior for the compounds containing R = Dy or Er; this behavior was related to the reduced mobility of the domain walls [2]. The easy direction of magnetization in the Dy compounds changes, with increasing Dy concentration, from [111] to [100].

To obtain further information on these compounds we had their magnetization studied under magnetic fields of up to 20 T.

2. Experimental

The compounds were prepared in an arc furnace and homogenized at 900 ^{0}C for 100 hours; the X-Ray patterns showed the standard crystal structure (C15).

The magnetization measurements were made with a Bitter magnet, using polycrystalline samples at 4.2 K, in fields of up to 20 T. The experiments were performed at the Francis Bitter National Magnet Laboratory, MIT, in Cambridge, USA.

The experimental (M x H) curves in the high field region were computer analyzed by least squares fits to the function [3]

$$M = M_0\left[1 - \frac{A}{H^2}\right] + \chi H$$

where M_0 is the spontaneous magnetization, χ is the high field susceptibility and A is a parameter proportional to $(K_1/M_0)^2$, where K_1 is the anisotropy constant at saturation.

3. Results and Discussion

The curves of |M| versus |H| are shown in Figs. 1 and 2; the data are from the third quadrant of the hysteresis cycle. The most obvious change from sample to sample is the variation of the magnetization attained at high fields, as a function of concentration (Fig. 1 and Fig 2). This magnetization goes through a minimum at about 20 % Dy or Er, reflecting the partial compensation of R and Fe moments, arising from their anti-parallel coupling. The same trend is observed with the parameter M_o (spontaneous magnetization) obtained from the fit. This is shown in Fig. 3, where the experimental points were fitted to a linear dependence with x.

The parameter A shows a maximum around 20 % (Dy) or 40 % (Er), corresponding to a peak in the ratio K_1/M_0; the maximum value attained for the Dy samples is 20 times that value for the

Er series. This difference reflects mainly the higher anisotropy associated to the Dy atoms. The high field susceptibility, which appears as the slope of the magnetization curve in the high field limit, is also maximum at x = 0.20 or x = 0.40. A maximum is also observed for the coercive field H_c in both series at 40 %. The parameters obtained from the magnetization curves are given in Table I.

The magnetic moment per formula unit derived from M_0(Fig. 3) shows a compensation point at x = 0.31 for the Er and Dy series; the Er value is in agreement with an earlier result obtained with H = 30 kOe [4].

Some of the curves exhibited unusual features (wiggles), more evident in the data for the 80 % Dy compound (Fig. 1). After annealing at 400 ^{0}C in vacuo for 5 minutes (curve 80 A) the same sample did not show these features.

4. Acknowledgements

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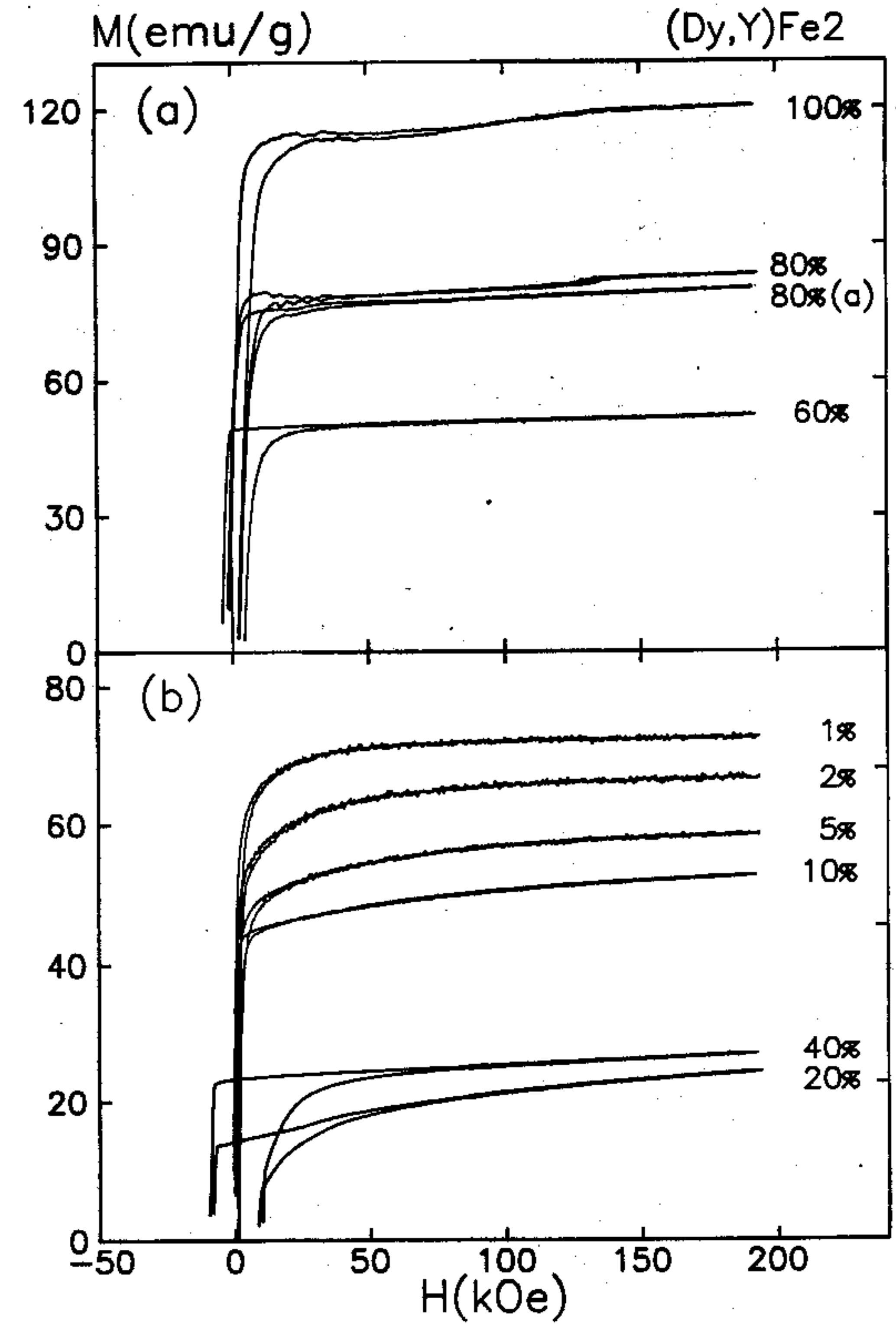
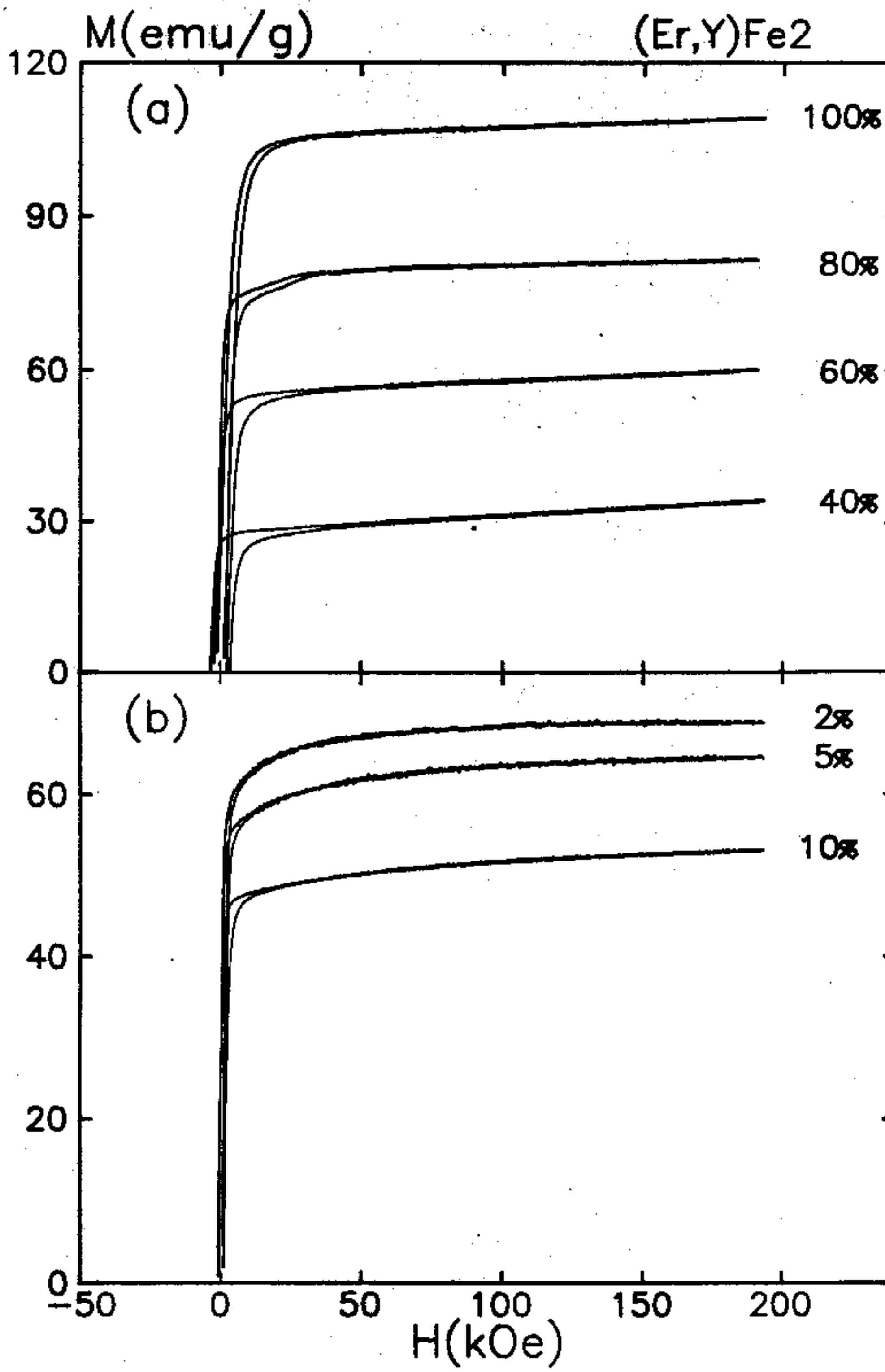
FIGURE CAPTIONS

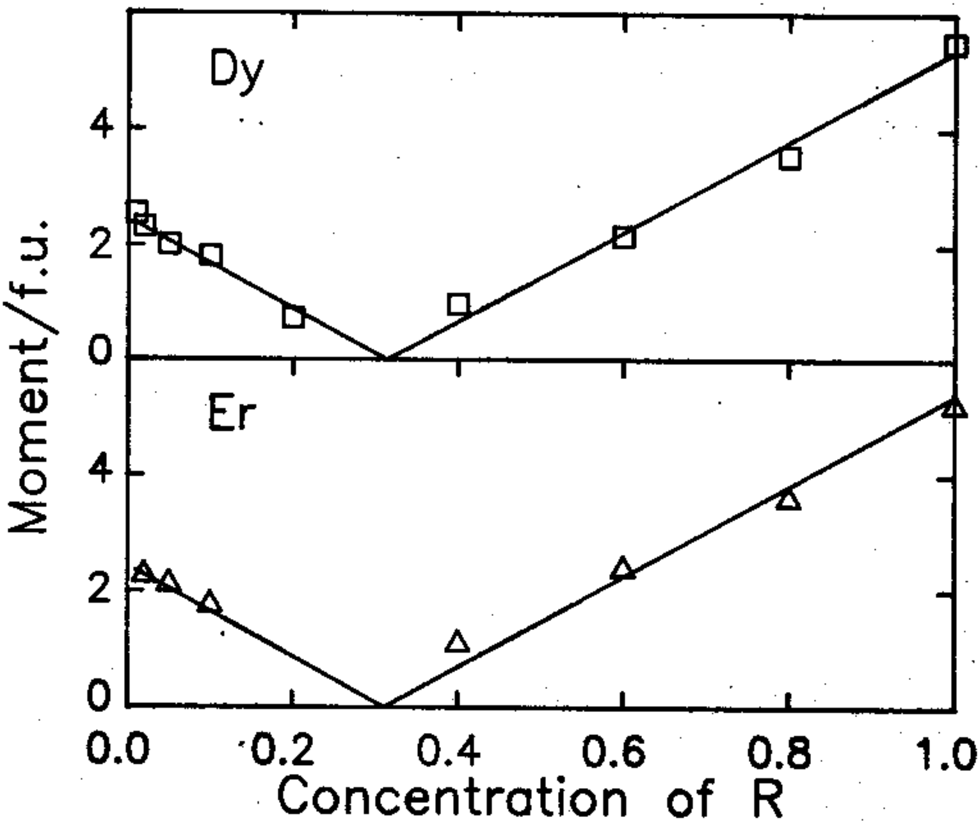
Fig.1 Magnetization versus applied magnetic field of the pseudo-binary intermetallic compounds $Dy_xY_{1-x}Fe_2$ at 4.2 K. The curves are labelled with the Dy concentration. The curve 80A was obtained after annealing the x = 0.80 sample (see text).

Fig.2 Magnetization versus applied magnetic field of the pseudo-binary intermetallic compounds $Er_xY_{1-x}Fe_2$ at 4.2 K. The curves are labelled with the Er concentration.

Fig.3 Saturation magnetization M_0 (in Bohr magnetons per formula unit) versus rare earth concentration in the $R_xY_{1-x}Fe_2$ (R = Dy and Er) intermetallic compounds at 4.2 K. The lines are computer fits to the experimental points, obtained by assuming a linear dependence with x.


M(emu/g)
(Dy,Y)Fe2
(a)
100%
80%
80%(a)
60%
(b)
1%
2%
5%
10%
40%
20%
120
90
60
30
0
80
60
40
20
0
-50
0
50
100
150
200
H(kOe)


M(emu/g)
(Er,Y)Fe2
(a)
100%
80%
60%
40%
(b)
2%
5%
10%
120
90
60
30
0
60
40
20
0
-50
0
50
100
150
200
H(kOe)


Dy
Er
Moment/f.u.
0
2
4
0
2
4
0.0
0.2
0.4
0.6
0.8
1.0
Concentration of R

	$(Dy_xY_{1-x})Fe_2$			$(Er_xY_{1-x})Fe_2$		
x	χ	A	H_c	χ	A	H_c
0.01	0.012	12	0.48			
0.02	0.016	41	0.50	0.039	1.2	0.47
0.05	0.021	42	1.03	0.036	1.4	0.68
0.10	0.021	30	1.30	0.029	1.9	0.97
0.20	0.029	256	8.40			
0.40	0.017	120	9.98	0.036	11.6	3.42
0.60	0.013	19	4.40	0.027	8.4	2.40
0.80	0.039	8	2.39	0.026	5.0	1.58
1.00	0.049	12	1.89	0.018	11	1.15

Table I. Parameters obtained from the high field magnetization curves for the $(Dy_xY_{1-x})Fe_2$ and $(Er_xY_{1-x})Fe_2$ series of intermetallic compounds: $\chi(10^{-3}cm^3/g)$, $A(kOe^2)$ and $H_c(kOe)$.

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