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Magnetostriction of $RFe_{11}Ti$ and $RFe_{10}Cr_2$

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The magnetostriction of polycrystal $RFe_{11}Ti$ (R=Nd, Sm, Gd, Tb, Dy, Ho, Er and Y) and $RFe_{10}Cr_2$ (R=Tb and Dy) compounds with $ThMn_{12}$-type structure have been investigated at 77 K and room temperature in magnetic fields up to 20 kOe. The values of magnetostriction $\lambda_t = \lambda_{\parallel} - \lambda_{\perp}$ in H=20 kOe at 300 K are 180×10^{-6} for $TbFe_{11}Ti$ and 106×10^{-6} for $TbFe_{10}Cr_2$. The magnetostrictions for compounds with R=Nd, Sm, Dy, Ho and Er are very small. The signs of λ_t for all these compounds are in agreement with that predicted by the single-ion crystal field theory. All studied samples show a volume magnetostriction feature. Their forced magnetostrictions $\Delta\omega/\Delta H$ have a value which is close to that of $YFe_{11}Ti$, 27×10^{-10}/Oe. It reveals that the Fe sublattice is responsible for the volume magnetostriction.

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The magnetostrictions of some R-T (R: rare earth, T: transition metal) intermetallic compounds with different structures, including RT_2, RT_3, R_6T_{23}, R_2T_{17} and $R_2Fe_{14}B$, were systematically investigated by Clack[1] *et al.*, and Ibarra[2] *et al.*, Recently a new group of compounds with $ThMn_{12}$ structure have been attracting interest as potential permanent-magnet materials. No magnetostriction study about it has been seen so far. In this paper we report some magnetostriction results of polycrystal $RFe_{11}Ti$ and $RFe_{10}Cr_2$ compounds.

The polycrystal $RFe_{11}Ti$ (R=Y, Nd, Sm, Gd, Tb, Dy, Ho and Er) and $RFe_{10}Cr_2$ (R=Tb and Dy) compounds were prepared by arcmelting the starting metals with purity better than 99.9%. The ingots were annealed in vacuum at 900°C for 2 weeks and confirmed by x-ray diffraction to be the $ThMn_{12}$ structure. Some of them contain a small amount of α-Fe. The ingots were cut into flakes of 1.5 mm in thickness and about 8 mm in width. The parallel and perpendicular magnetostrictions, ($\lambda_{\parallel}$) and ($\lambda_{\perp}$), have been measured using standard strain gauge technique in magnetic fields up to 20 kOe at 77 K and room temperature. The anisotropic magnetostriction $\lambda_t = \lambda_{\parallel} - \lambda_{\perp}$ and volume magnetostriction $\omega = \lambda_{\parallel} + 2\lambda_{\perp}$ were calculated directly from the measurement results. The forced magnetostriction $\Delta\omega/\Delta H$ was derived from a linear part of the $\lambda - H$ curve in the field region higher than 10 kOe.

The contribution of the magnetism of R-T compounds originates from both rare earth ions and Fe sublattice. In order to ascertain the contribution of Fe sublattice to the magnetoelastic coupling, it is useful to consider the magnetostriction in $YFe_{11}Ti$ compound. Figure 1 shows the magnetostrictions for $YFe_{11}Ti$ as a function of applied field at 77 K and room temperature, separately. At the room temperature both $\lambda_{\parallel}$ and $\lambda_{\perp}$ are positive and nearly equal, so the values of λ_t are very small. This is a

remarkable characteristic of the volume magnetostriction. The forced magnetostriction $\Delta\omega/\Delta H$ amounts to 27×10^{-10}/Oe at room temperature, which is very close to that of $Y_2Fe_{14}B$ (28×10^{-10}/Oe), although they have quite different Fe sublattices. For other $RFe_{11}Ti$ and $RFe_{10}Cr_2$ and their $\Delta\omega/\Delta H$ values are very close (see Table 1). It can be considered to be due to the contribution of Fe sublattice, because they have same Fe sublattice. At 77 K both $\lambda_{\parallel}$ and $\lambda_{\perp}$ are negative in the field range lower than 20 kOe, the $\lambda(H)$ curves decrease with field H, reaching a broad minimum, then increase, indicating that the volume magnetostriction characteristic might be more obvious in higher magnetic field region. The result of $GdFe_{11}Ti$ is similar to the situation of $YFe_{11}Ti$.

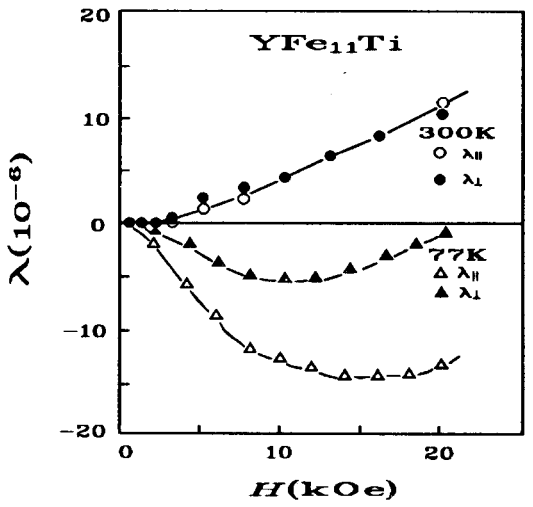

Fig. 1: Paralell and perpendicular magnetostrictions of $YFe_{11}Ti$ as a function of applied fields at 77 K and room temperature.

Table 1: Magnetostrictions for $RFe_{11}Ti$ and $RFe_{10}Cr_2$ compounds.

	$RFe_{11}Ti$								$RFe_{10}Cr_2$	
R	Y	Nd	Sm	Gd	Tb	Dy	Ho	Er	Tb	Dy
$\lambda_t(10^{-6})$ 300 K	0	27	−15	0	180	18	10	−15	106	23
(20 kOe) 77 K	−13	−13	−19	0	502	26	27	−6	201	10
$\Delta\omega/\Delta H(10^{-10}$/Oe)	27	32	10	21	36	26	27	18	23	10
Sign of α_j		−	+		−	−	−	+	−	−

The magnetic field dependences of λ_t for $TbFe_{11}Ti$ and $TbFe_{10}Cr_2$ are plotted in Fig. 2. The λ_t values are nearly saturated in a magnetic field of about 20 kOe. The values of λ_t for $TbFe_{11}Ti$ and $TbFe_{10}Cr_2$ were found to be 180×10^{-6} and 106×10^{-6} at room temperature, and 502×10^{-6} and 201×10^{-6} at 77 K, respectively. These values are much larger than those of the other compounds in these series. It may be ascribed to a contribution of Tb ion which devotes to a larger magnetostriction in the most rare earth-transition metal compounds and to a easy-plane anisotropy, leading to the

domain rotation to take place easily. Only $TbFe_{11}Ti$ and $TbFe_{10}Cr_2$ have easy-plane anisotropies at room temperature in $RFe_{11}Ti$ and $RFe_{10}Cr_2$ series.[3,4]

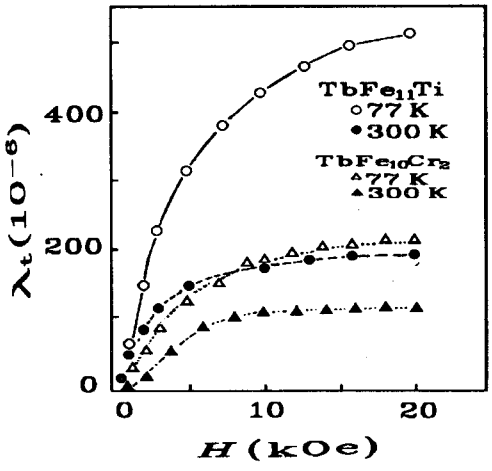

Fig. 2: Magnetic field dependences of anisotropic magnetostriction for $TbFe_{11}Ti$ and $TbFe_{10}Cr_2$ at 77 K and room temperature.

$RFe_{11}Ti$ with R=Nd, Dy and Ho, and $DyFe_{10}Cr_2$ have positive λ_t values, whereas the λ_t values for $RFe_{11}Ti$ with R=Sm and Er are negative (see Fig. 3 or Table 1). Their λ_t values are small and the absolute values increase continuously even in the fields up to 20 kOe at both room temperature and 77 K. So it is difficult to compare their λ_t with those predicted by single-ion crystal field theory,[5] according to which the relative values $\lambda_t(0)$ of the saturation magnetostriction at T=0 K for the various rare earth ions are proportional to $\alpha_J J(J-1/2) < r_f^2 >$, where α_J is Stevens factor, J is the angular momentum of rare earth ion, and $< r_f^2 >$ the average $4f$ electron quadratic radius, but the signs of λ_t are in agreement with that predicted by theory. The results mentioned above are very similar to the situation of RFe_2, RFe_3 and R_6Fe_{23} compounds. From the obtained results it can be considered that this theory may be valid for the $ThMn_{12}$-type compounds investigated here.

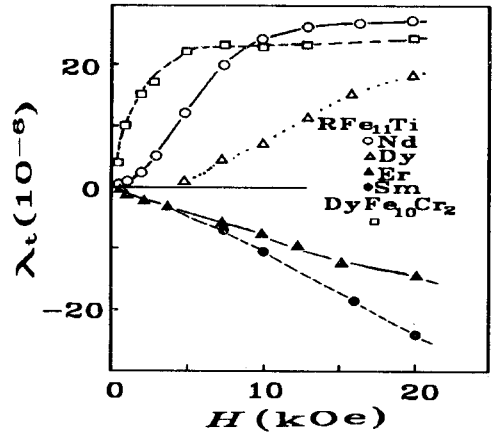

Fig. 3: Magnetic field dependences of anisotropic mangetostriction for $RFe_{11}Ti$ (R: Nd, Dy, Er and Sm) and $DyFe_{10}Cr_2$ at room temperature.

For studied $ThMn_{12}$-type compounds the magnetostriction are mainly dominated by the contribution of rare earth ion. The single-ion crystal theory is still valid. The Fe sublattice shows a volume magnetostriction, so the contribution to the linear magnetostriction can not be negligible especially in higher magnetic fields. The forced magnetostriction values for all samples are close to that of $YFe_{11}Ti$, 27×10^{-10}/Oe, which is close to that of $Y_2Fe_{14}B$ (28×10^{-10}/Oe). In the $RFe_{11}Ti$ series the $TbFe_{11}Ti$ has the largest λ_t value, being 180×10^{-6} at room temperature and 502×10^{-6} at 77 K.

References

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