# Effect of interstitial hydrogen and nitrogen on the magnetocrystalline anisotropy of $Y_2Fe_{17}$

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## Abstract

Magnetocrystalline anisotropy of $Y_2Fe_{17}$ and of its nitride and hydrides has been measured on magnetically oriented samples. The anisotropy is defined by the local site anisotropy behavior and in a first approximation depends mainly on the lattice expansion along the $c$ axis. © 1997 Elsevier Science S.A.

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## 1. Introduction

It was shown that insertion of light elements such as hydrogen and nitrogen in the $R_2Fe_{17}$ alloys produce a drastic change in the magnetic properties of these compounds [1,2]. The changes in the Curie temperatures and saturation moments are nearly proportional to the increase in the cell volume. The behavior of magnetocrystalline anisotropy is more complicated. For instance, $Sm_2Fe_{17}N_3$ has a magnetic anisotropy of easy-axis type and an anisotropy field close to 22 T [3], whereas $Sm_2Fe_{17}$ hydrides are easy-plane at room temperature [4]. In order to study the differences in the effects of hydrogen and nitrogen insertion it is essential to separate their effects on the iron and rare earth sublattices. We report here on the determination of the magnetocrystalline anisotropy of $Y_2Fe_{17}$, $Y_2Fe_{17}H_{3.5}$, $Y_2Fe_{17}H_{5.5}$ and $Y_2Fe_{17}N_{3.2}$.

## 2. Experimental details

The starting alloy $Y_2Fe_{17}$ was produced by arc melting followed by a heat treatment at 1100 °C for 24 h. The $Y_2Fe_{17}$ nitride was produced at 450 °C under molecular $N_2$ atmosphere 10 bar pressure. The hydrides $Y_2Fe_{17}H_x$ were produced at 150 °C, 5 bar for $x=3.5$ and at 350 °C, 5 bar for $x=5.5$. X-ray diffraction indicates that all compounds have the $Th_2Ni_{17}$ crystal structure.

The magnetic measurements were made for aligned and free powder samples in the temperature range 100–300 K and magnetic fields up to 1.3 T using a pendulum magnetometer. Since our samples are easy-plane materials we used an alignment in a rotating magnetic field [5]. The mixture of sieved powder with epoxy resin was placed in a 0.7 T magnetic field, rotating with a frequency near 1 Hz. A proper choice of the viscosity and the hardening time of the resin has allowed to produce well-aligned samples with the hard axis oriented along the axis of rotation. The easy and hard magnetization curves for $Y_2Fe_{17}$ at 100 K are shown in Fig. 1.
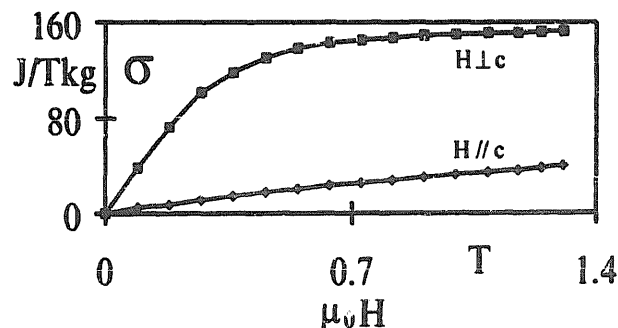


Fig. 1. Magnetization curves for the $Y_2Fe_{17}$ aligned sample measured in the easy and hard directions.

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## 3. Results and discussion

The saturation magnetic moments were deduced from the free powder magnetization curves. To do so we used the linear approximation of the magnetic moment versus reciprocal magnetic field to the higher field values. Effective anisotropy constants $R_1 = -(K_1 + 2K_2 + 3K_3)$ [6] were calculated from the saturation moments and the slopes of the linear part of the hard magnetization curves.

In Fig. 2 the $R_1$ values for the samples studied are plotted versus reduced temperature. From these data it follows that the $R_1$ behavior for $Y_2Fe_{17}H_{3.5}$ and $Y_2Fe_{17}$ is nearly identical, whereas the $R_1$ values for $Y_2Fe_{17}H_{3.5}$ and $Y_2Fe_{17}N_{3.2}$ are both notably smaller than the corresponding value for $Y_2Fe_{17}$.

From the general single-ion crystal field consideration of the 3d anisotropy it follows that the anisotropy is determined by the $c/a$ ratio [7]. On the other hand it is known [8] that in the hydrides with an hydrogen concentration under 3 the hydrogen fills the octahedral places leading to the expansion of the unit cell in the basal plane. For the higher hydrogen concentration the tetrahedral places are filled, which leads to increase the $c$ parameter. The maximum deviation of the $c/a$ ratio from the value for $Y_2Fe_{17}$ occurs for the hydrides with the concentration value near 3. So the 3d magnetocrystalline anisotropy is governed mainly by the local site anisotropy behavior.

In the reference [9] it was concluded that the basal plane expansion in 2–17 crystal structures leads to the amplification of positive interactions while the $c$ increase leads to the decrease of negative interactions of 'dumbbell' atoms. This supposition accounts for the main increase of the
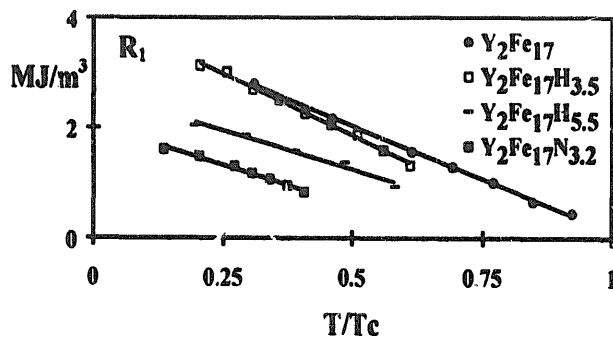
Table 1
Saturation magnetization at 80 K and Curie temperature for $Y_2Fe_{17}(N,H)_x$

| Compound | $\sigma_s$, (T=80 K) J/T kg | $T_c$ K |
|---|---|---|
| $Y_2F_{17}$ | 160 | 325 |
| $Y_2F_{17}H_{3.5}$ | 170 | 490 |
| $Y_2F_{17}H_{5.5}$ | 170 | 510 |
| $Y_2F_{17}N_{3.2}$ | 172 | 740 |

saturation moment in hydrides (Table 1) when octahedral places are occupied. Moreover our results agree with the assumption that the modification of the 'dumbbell' sites local anisotropy is preponderant.

## 4. Conclusion

The behavior of the iron sublattice anisotropy in the $Y_2Fe_{17}$ compounds charged with nitrogen and hydrogen agrees with the assumption that the anisotropy is very sensitive to the increase of the $c$ lattice parameter. For the hydrides the lattice expansion is anisotropic and the magnetocrystalline anisotropy changes only for the hydrogen concentrations higher than 3 when $c$ starts to increase.

## Acknowledgements

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Fig. 2. Dependence of the anisotropy constant versus the reduced temperature for $Y_2Fe_{17}(N,H)_x$.