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ELSEVIER

High-field magnetization process of $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds

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Abstract

The high-field magnetization process of $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds ($x = 0–0.5$) has been investigated. Substitution of Ga for Fe leads to an increase of the spin reorientation temperature. A tentative spin phase diagram is proposed. The magnetization of magnetically aligned samples was measured at 4.2 K in quasi-static fields up to 21 T.

Since the discovery of the intermetallic compound $\text{Sm}_2\text{Fe}_{17}\text{N}_y$ produced by gas–solid reaction [1], a large improvement of intrinsic properties has been achieved by the introduction of interstitial nitrogen or carbon atoms into R_2Fe_{17} compounds. Besides this, substitution of many elements such as Nb and Al for Fe in R_2Fe_{17} compounds [2,3] also have significant influence on the magnetic properties. In the present investigation, we have focussed our attention on the crystal structure and magnetic properties of the $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ series, especially on the magnetization and magnetocrystalline anisotropy.

Alloys with composition $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ ($x = 0.0, 0.07, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4$ and 0.5) were prepared by arc melting, followed by annealing in argon atmosphere at 1200°C for 4 h.

X-ray diffraction patterns of randomly and magnetically aligned powder samples have been obtained.

The high-field magnetization was measured in fields up to 21 at 4.2 K at the University of Amsterdam [4]. The magnetic isotherms were recorded with the external field applied either parallel or perpendicular to the alignment direction of cylindrical samples.

The spin reorientation transition temperatures were measured in a SQUID magnetometer from 4.2 K to room temperature and in a magnetic balance from room temperature up to the Curie temperature.

The X-ray diffraction patterns show that all prepared samples are single phase with a $\text{Th}_2\text{Zn}_{17}$ -type of structure, except for a small amount of impurity in a few samples.

The X-ray diffraction patterns of aligned samples of the $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds (Fig. 1) show that the samples with $x = 0.15, 0.20$, and 0.25 exhibit uniaxial

Fig. 1. X-ray diffraction patterns with Co K α radiation for aligned samples of $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds.

anisotropy at room temperature. For $x = 0.1$ and 0.3 , the samples are isotropic. For $x = 0.4$, cone-type anisotropy appears. This result is consistent with the spin phase diagram in Fig. 2. From Fig. 2 one can see that up to $x = 0.2$ substitution of Ga for Fe in $\text{Sm}_2\text{Fe}_{17}$ compounds enhances the spin reorientation temperature. At $x = 0.2$, the spin reorientation temperature has a maximum value of

Fig. 2. Spin phase diagram of $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds.

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Fig. 3. Field dependence of the magnetization at 4.2 K of magnetically aligned samples with the field applied parallel (●) or perpendicular (■) to the alignment direction.

about 475 K. In $\text{Sm}_2\text{Fe}_{17}$ compounds, the anisotropy is determined by the competition between the *c*-axis anisotropy of the Sm sublattice and the planar anisotropy of Fe sublattice. Ga substitution for Fe at a sufficient content reduces the planar anisotropy of Fe sublattice.

The Curie temperature T_c of the $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds, also shown in Fig. 2, increases with Ga concentration up to $x = 0.2$, where T_c has a maximum at 592 K, then T_c decreases. It is interesting to note that both T_c and T_{sr} have their maximum at $x = 0.2$. In Fig. 3, the high-field magnetization of the $\text{Sm}_2(\text{Fe}_{1-x}\text{Ga}_x)_{17}$ compounds is shown. For $x = 0.1$ and 0.3 , the two magnetiza-

tion curves measured with the field parallel and perpendicular to the alignment direction coincide, which indicates that the anisotropy has disappeared. This is in good agreement with the results of the X-ray diffraction on aligned samples mentioned above. Values for the saturation magnetization were derived from the easy-direction magnetization by means of $\sigma-1/B$ plots. The saturation magnetization decreases linearly with Ga concentration, from 155.2 $\text{A m}^2/\text{kg}$ for $x = 0.0$ to 59.2 $\text{A m}^2/\text{kg}$ for $x = 0.5$, which is easy to understand because the Ga atoms have no magnetic moment. From the magnetization curves in Fig. 3 it can be seen that $\text{Sm}_2(\text{Fe}_{0.8}\text{Ga}_{0.2})_{17}$ has the largest anisotropy field B_a , amounting to 21 T. The Curie temperature and spin reorientation temperature have maximum values of 592 and 475 K, respectively, for 20% of the Fe substituted by Ga. These results suggest that these compounds may be used for practical application as starting material for permanent magnets.

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