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LETTER TO THE EDITOR

Enhancement of remanence in $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ magnets

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Abstract. In the present work, hard magnetic behaviours of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ magnets are investigated. Remanence enhancement is observed when some of the Sm atoms are replaced by Pr atoms in the compounds, which is due to the larger saturation magnetization of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ than of pure $Sm_2Fe_{17}N_x$. Meanwhile the coercivity of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ decreases with increasing Pr content in the compounds, which corresponds to the decrease of the anisotropy field in the compounds. In order to obtain a combined good effect on the remanence and the coercivity, the Pr content y should be no more than 0.4 in $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ nitrides.

Recently it has been found that the $Sm_2Fe_{17}N_x$ phase has a large anisotropy field, a reasonable saturation magnetization and a relatively high Curie temperature [1]. Different methods have been used to develop a hard $Sm_2Fe_{17}N_x$ magnet. A possible method to increase the remanence in mechanically alloyed powder is to use nanocrystalline material with a two-phase structure comprising a hard magnetic phase coupled to a soft phase [2]. In this letter, hard magnetic behaviours of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ nitrides are investigated. Remanence enhancement occurs when some of the Sm atoms are replaced by Pr atoms, which may be due to the larger saturation magnetization of $(Sm_{1-7}Pr_y)_2Fe_{17}N_x$ than of pure $Sm_2Fe_{17}N_x$. Meanwhile the coercivity of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ decreases with increasing Pr content in magnets, which corresponds to the decrease of anisotropy field in $(Sm,Pr)_2Fe_{17}N_x$ nitrides.

Primary $(Sm_{1-y}Pr_y)_2Fe_{17}$ alloys were prepared by arc melting under argon atmosphere and subsequent vacuum annealing at 1050 °C for 8 h. X-ray analysis indicated that alloys were of a single phase. The samples were then crushed and nitrogenated at 500 °C for 4 h. The nitride powders were ball-milled, and then mixed with epoxy resin and bonded in a magnetic field. The hard magnetic behaviours were measured by VSM and a pulsed high magnetic field.

The Pr content y dependence of the remanence for $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ at room temperature is listed in table 1. It can be seen that the remanence first increases and then decreases with replacement of Sm atoms by Pr atoms in the compounds. The remanence is 117.5 emu g^{-1} for $y = 0$ and 123.4 emu g^{-1} for $y = 0.2$. The error bars for the values of

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Table 1. The Pr content y dependence of the remanence, the coercivity, the anisotropy field at room temperature, the saturation magnetization at 4.2 K and room temperature and the Curie temperature.

	B_r (emu g^{-1})[a]	M_s (emu g^{-1})		H_c (kOe)[b]	H_a (kOe)	T_C
y	RT	4.2 K	RT	RT	RT	(K)
0	117.5	159	140.0	6.10	15.0	745
0.2	123.4	162	143.2	4.84	12.3	730
0.4	110.1	169	149.5	2.0	9.6	723

[a] Error bar, ±5 emu g^{-1}.
[b] Error bar, < 0.05 kOe.

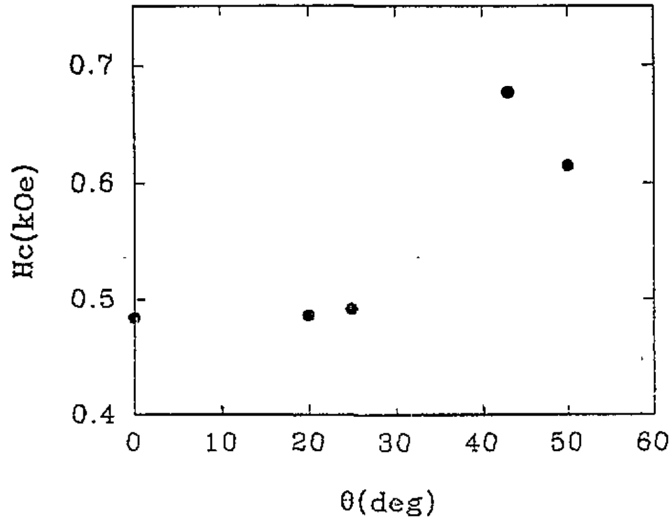

Figure 1. The angular dependence of the coercivity for the magnet $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ with $y = 0.2$ at room temperature (with the error bar of the measured deviation angle ±5°).

measured remanence are about ±5 emu g^{-1}, and mainly originate from the measurement of the (Sm, Pr)–Fe–N powder weight in the magnetically aligned magnet bonded with epoxy resin. The Pr content dependences of the saturation magnetizations for $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ at 4.2 K and room temperature are also listed in table 1. The saturation magnetization of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ increases with the increase of the Pr content y in the compounds. This remanence enhancement may be attributed to the larger saturation magnetization of $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ than of pure $Sm_2Fe_{17}N_x$. Such results imply that the remanence of an SmFeN type nitromagnet can be also improved by replacing some of the Sm atoms with Pr atoms in the compound.

The Pr content y dependences of the coercivity and anisotropy field for $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ at room temperature are also listed in table 1. It can be seen that the coercivity decreases with replacement of Sm atoms by Pr atoms in the compounds. The coercivity is 6.1 kOe for $y = 0$ and 4.84 kOe and 2.0 kOe for $y = 0.2$ and 0.4 respectively. The error bar for the coercivity of a magnetically aligned magnet is less than 0.05 kOe. Meanwhile the anisotropy field decreases with the increase of Pr content y in $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ from 15.0 kOe for $y = 0$ to 9.6 kOe for $y = 0.4$. The remanence of the nitride with $y = 0.4$ is 110.1 emu g^{-1}, which is smaller than the remanence of the pure $Sm_2Fe_{17}N_x$ nitride. This may correspond to another fact, that the coercivity of nitride $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ with $y = 0.4$ is much smaller than that of pure $Sm_2Fe_{17}N_x$ nitride.

Different from the remanence enhancement in mechanically alloyed powder where nanocrystalline structure with two hard–soft magnetic phases is required, the remanence enhancement in $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ is obtained from the state of one single phase, which has a larger saturation magnetization. The size of the particles in the $(Sm, Pr)_2Fe_{17}N_x$ magnet may reach 1 μm, which is easy to prepare using many methods.

The angular dependence of the coercivity for the magnet $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ with $y = 0.2$ has also been measured. The results are shown in figure 1. The coercivities with a large deviation angle θ between the aligned direction of the magnet and the direction of the external magnetic field are larger than that with $\theta = 0$. The error bar of the measured data may originate from the measurement of the deviation angle, which is about $\pm 5°$. No minimum coercivity has been found in this magnet, which is similar to the case in the NdFeB magnet [3, 4].

The Pr content dependence of the Curie temperature for the $(Sm_{1-y}Pr_y)_2Fe_{17}N_x$ phases is also listed in table 1. It can be seen that the Curie temperature decreases slightly with increasing Pr content in the compounds.

In conclusion, remanence enhancement of a 2:17 type nitromagnet can be obtained by replacing some of the Sm atoms R = Pr or/and Nd in the $(Sm, R)_2Fe_{17}N_x$ nitride.

References

[1] Coey J M D and Sun H 1990 *J. Magn. Magn. Mater.* **87** L251
[2] Ding J, Street R and McCormick P G 1992 *J. Magn. Magn. Mater.* **115** 211
[3] Kronmuller H, Durst K D and Martinek G 1987 *J. Magn. Magn. Mater.* **69** 149
[4] Givord D, Tenaud P and Viadieu T 1988 *IEEE Trans. Magn.* **MAG-24** 1921