

Study on the Microstructure of Single Stage Hot Deformed Anisotropic Nd-Fe-B Magnets

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Anisotropic Nd-Fe-B magnets were fabricated by the single stage hot deformation (SSH) method which is a more effective method that simplifies the traditional hot-pressing and die-upsetting process as one step hot press and replaces the sample die with copper tube. In previous work [1, 2], we have researched much about the magnetic properties affected by raw materials, the fabrication process, etc. This study will focus on the microstructure of the single stage hot deformed NdFeB magnets in order to understand the origin of anisotropy in SSHD magnets.

Fig. 1-3 are the SEM images of SSHD magnet fabricated at 650°C, 700°C and 750°C, respectively.

In Fig. 1, it is observed that randomly oriented grains with the diameter of 40-60nm at 650°C without Nd-rich liquid phase.

Fig. 2 shows the platelet-shaped Nd₂Fe₄B grains formed at 700°C. They are about 0.8 μm long and 0.2 μm wide on the average. At the boundary of the flake, the grain size is much bigger than the typical platelet-shaped Nd₂Fe₄B grains. While the temperature of hot deformation was increasing up to 750°C, the coarse grains grown larger, shown in Fig. 3.

EDS analysis results shows that the ratio of Fe to Nd in the coarse grain zone is lower than that in platelet-shaped Nd₂Fe₄B grains zones, and also lower than that in raw material, MQPA powder. It means Nd is enriched and the large amount of Nd-rich liquid phase formed between the powder flakes, which is good for hot deformation, but at the same time promotes the formation of coarse grains leading to low coercivity. The reason for coercivity decreasing may relate with coarse grain. And the intergranular Nd-rich liquid phase plays key role in the alignment growing of the NdFeB grains and improving magnetic anisotropy.

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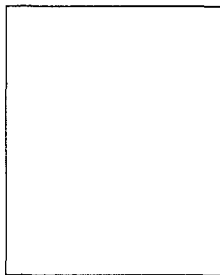


Fig. 1. SS hot deformed at 650°C

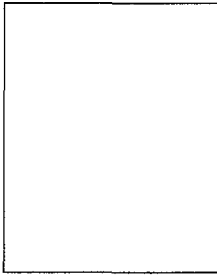


Fig. 2. SS hot deformed at 700°C

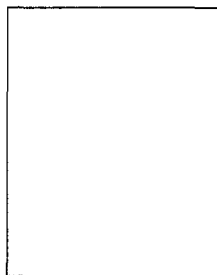


Fig. 3. SS hot deformed at 750°C

Magnetic Properties of Melt-spun (Nd_{62.5}Ni_{37.5})₈₅Al₁₅ Alloy

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Since the bulk amorphous Nd-Fe-Al alloy with hard magnetic properties was reported by Inoue, Nd-based bulk amorphous alloys have gradually attracted the interest of researchers [1]. In the previous work, Ni and Cu were selected to substitute Fe and form (Nd_{62.5}Ni_{17.5-x}Cu_x)₈₅Al₁₅ metallic glasses, which have a certain glass-forming ability [2].

In the present work, the magnetic properties of (Nd_{62.5}Ni_{17.5})₈₅Al₁₅ are further studied. The ribbon samples were prepared by melt-spinning method. XRD pattern shows that the as-quenched sample is amorphous. The magnetic properties were characterized with SQUID. The hysteresis loops measured at 5K show that for the as-quenched sample, the sample annealed to T_g (glass-transition temperature, 240°C) and the sample annealed to T_x (onset temperature of crystallization, 275°C), the magnetic coercivities are 290±100e, 334±50e, 570±100e, respectively. The magnetization of the sample didn't reach saturation even at 70 kOe. This indicated that the sample has a complicated magnetic structure, a kind of speromagnetism, which possibly originates from the RE-TM alloy [3]. The thermomagnetic relations indicate Curie temperature is as low as about 15K, and it is also increased by annealing, especially when annealed to T_x.

The ZFC-FC thermomagnetic relations under 1000e show the typical bifurcations of spin-glasses. The spin-glass behavior is further supported by AC susceptibility spectra. The AC susceptibility spectra measured at different frequencies (from 0.02 Hz to 1488 Hz) are shown in Fig. 1. The freezing peak moves to higher temperature with increasing frequency. In order to estimate the dynamical parameters characterizing the SG state the obtained T_f data are fitted to the standard expression $\tau_{max} = \tau_0 [(T_f - T_g)/T_g]^{z/\nu}$ (the critical slowing down), with $\nu = 1.2 \times 10^{-4}$ was kept fixed, the fit yields the static freezing temperature T_f = 10.2384K and the critical dynamical exponent z/ν = 12.9. When the temperature is higher than the freezing temperature, the spectra follow the Curie-Weiss Law. This is a very typical character of spin glass.

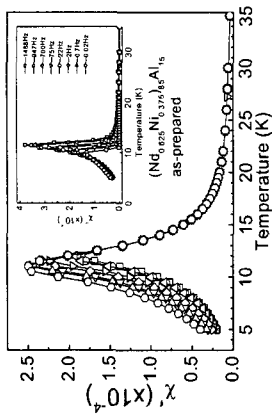


Fig. 1. AC susceptibility spectra at different frequencies under 100 Oe.

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