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Magnetic properties of Anisotropy HDDR $Nd_{13}Fe_{63.1-x}Co_{17}B_{6.6}Zr_{0.1}Ga_x$ Powders

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Introduction

Recently, the hydrogenation disproportionation desorption recombination (HDDR) phenomenon has been taken much into account to produce NdFeB-type permanent magnetic powders with good hard magnetic properties. The disproportionation reaction occurs at elevated temperatures and results in the formation of an intimate mixture of a-Fe, Nd-hydride ($NdH_{2\pm x}$) and Fe_2B, which can be represented as follows:

$$Nd_2Fe_{14}B \pm xH_2 \rightarrow 2NdH_{2\pm x} + Fe_2B + 12\alpha - Fe - \Delta H \quad \text{......................(1)}$$

x as a function of hydrogen pressure and temperature. $-\Delta H$ is exothermic heat of reaction.
Desorption recombination stage(under vacuum or low hydrogen partial pressure):

$$2NdH_{2\pm x} + Fe_2B + 12\alpha - Fe \rightarrow Nd_2Fe_{14}B \pm xH_2 + \Delta H \quad \text{...........................(2)}$$

ΔH is endothermic heat of reaction.

To improve the anisotropy of the HDDR powders, a little Zr, Ga [1, 2]elements were added to induce the magnetic anisotropy for the HDDR Nd(Fe, Co)B powders, hence, the hard magnetic properties of the bonded magnets can be improved. Small substutuions (<1%) of Zr increase the coercivity, which can be due to the formation of ZrB_2 phase[3]. Ga may increase the stability of the NdFeB compound locally, which leaves a few residual undecomposed NdFeB particles in the disproportionated alloy and helps to retain the orientation of original coarse grains, thus causing an orientational anisotropy in HDDR powder.

In present work, an investigation of HDDR powder based on the alloys $Nd_{13}Fe_{63.1-x}Co_{17}B_{6.6}Zr_{0.1}Ga_x$(x=0.1, 0.3, 1) has been carried out.

Experiments

The ingots with the composition of $Nd_{13}Fe_{63.1-x}Co_{17}B_{6.6}Zr_{0.1}Ga_x$(x=0.1, 0.3, 1) in atomic concentration were prepared by using an induction furnace in argon atmosphere. Then these ingots were crushed to small piece of less than 5 mm in diameter for the next process-HDDR. After HDDR processing, the alloy pieces were crushed into powders with less than 150 μm. The magnetic properties of the powders were obtained by vibrating sample magnetometer (VSM) with the magnetic field of 2.2 T after pre-aligned in a magnetic field of 2.2 T. The microstructure of the powders was obtained by X-ray diffraction (XRD).

Result and Discussion

Fig.1 shows magneto energy product $(BH)_{max}$, coercivity ($\mu_0 H_C$) and remanent magnetic polarization ($J_r(\|)$) of the HDDR powder under the disproportionation temperature (T_{disp}) of 800, 820, 840, 860 □. The magnetic properties of the HDDR powder of X=0.3 is a little higher than that of the HDDR powder of X=0.1. But for X = 1, good magnetic properties was obtained. The remanent magnetic polarization and magneto energy product increase sharply, which can reach 1.178T and 243.79 KJ/m_3. But its coercivity is lower than that of the HDDRpowders of X=1.

The remanent magnetic polarization ratio, $J_r(\|) / J_r$(□) for $Nd_{13}Fe_{62.3}Co_{17}B_{6.6}Zr_{0.1}Ga_1$ powder aligned in a magnetic field is 2.29 (see table 1). The comparison of results given in Table 1 shows that the Ga content of NdFeCoBZr alloys seems to an important influence on the formation of anisotropy structure.

Conclusion

High performance NdFeBCoZrGa powders can be prepared by HDDR process, which have high magneto energy product, high remanent magnetic polarization and high magnetic anisotropy, which are suitable to fabricate the bond magnet. Ga content does an important role on the formation of anisotropy.

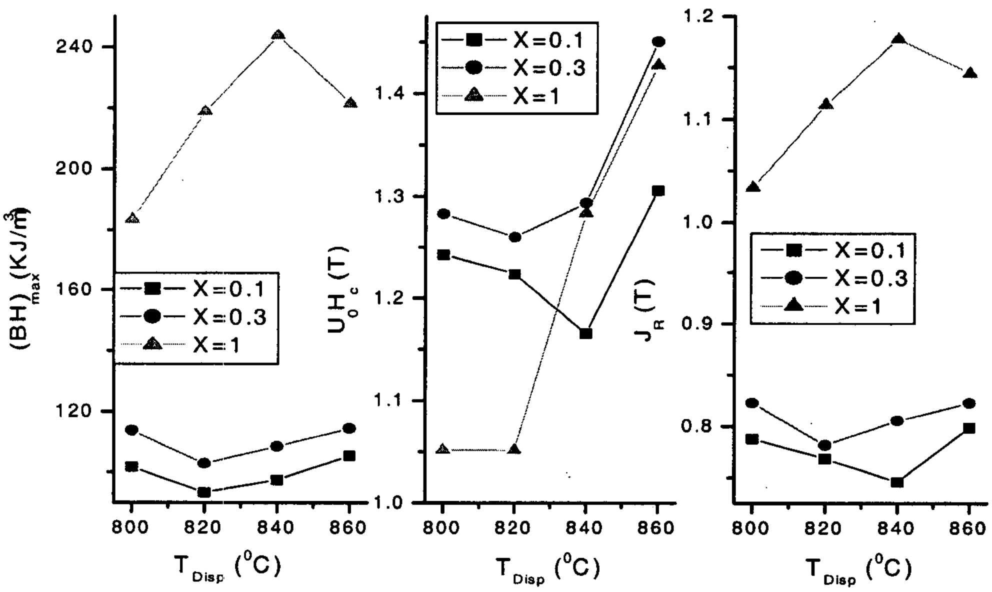

Fig. 1 Dependences of $\mu_0 Hc$, $J_r(\|)$ and $(BH)_{max}$ on T_{Disp} of the $Nd_{13}Fe_{63.1-x}Co_{17}B_{6.6}Zr_{0.1}Ga_x$(x=0.1, 0.3, 1) HDDR powders

Table 1 Remanent magnetic polarization J_r of HDDR(T_{Disp} = 840 □) processed powder measured parallel ($\|$) and perpendicular (□) to the direction of alignment

Composition	$J_r(\|)$	J_r(□)	$J_r(\|) / J_r$(□)
$Nd_{13}Fe_{63.2}Co_{17}B_{6.6}Zr_{0.1}Ga_{0.1}$	7.46	6.41	1.16
$Nd_{13}Fe_{63.0}Co_{17}B_{6.6}Zr_{0.1}Ga_{0.3}$	8.06	6.31	1.28
$Nd_{13}Fe_{62.3}Co_{17}B_{6.6}Zr_{0.1}Ga_1$	11.78	5.15	2.29

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