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Mechanical Properties of Spark Plasma Sintering Nd-Fe-B Permanent Magnets

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Sintered Nd-Fe-B magnets have been widely used in the last two decades due to their excellent magnetic properties[1]. However, their undesirable mechanical property is still a major concern. It has been reported that the poor mechanical strengthof sintered Nd-Fe-B magnet is attributed to the complex microstructure, in particular, the size and distribution of the Nd-rich grain boundary phase[2]. In present study, Spark Plasma Sintering (SPS) technique was applied to prepare Nd-Fe-B sintered magnets with modified microstructure, and the mechanical properties of the magnets were evaluated.

Sintered Nd-Fe-B magnets with nominal composition of $Nd_{12.2}Pr_2Dy_2Fe_{bal}Al_1Nb_{0.3}Cu_{0.2}B_6$ were prepared by both SPS and conventional sintering technique. Impact toughness and bending strength of the alloys were investigated Microstructure and fracture morphology of the alloys were observed by scanning electronic microscopy (SEM).

Mechanical property investigation on both conventional sintered and SPS Nd-Fe-B magnets showed that the latter bore better properties than the former, in detail, the impact toughness of conventional sintered and SPS Nd-Fe-B magnets are 0.709J/m^2 and 0.955J/m^2, and the bending strength are 278.97 MPa and 402.25 MPa, respectively. A remarkable increase around 40% of mechanical property in SPS Nd-Fe-B magnets was observed. SEM observation showed that the microstructure of SPS Nd-Fe-B alloy is composed of fine and uniform main phase grainsas well as fine and even distributed Nd-rich phase. Further observation of the fracture morphology of both two kinds of the magnets (Fig. 1) showed that typical cleavage face, which indicates intro-granular fracture, was observed in SPS Nd-Fe-B magnet. However, the microstructure of conventional sintered Nd-Fe-B is composed of coarse grains, and its fracture morphology shows a typical inter-granular fracture. It is concluded, therefore, that obviously improved mechanical property of SPS Nd-Fe-B magnet resulted mainly from the unique morphology of Nd-rich in the magnet, which greatly restrained the inter-granular fracture of the magnet.

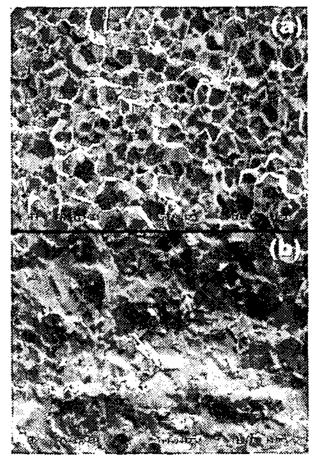

Fig. 1. SEM fracture morph-ology of both conventional sintered (a)and SPS (b) magnets.

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Structure and Magnetic Properties for Bulk $Fe_{73-x}Zr_2Y_4B_{21}Nd_x$ (x=0, 2, 5, 7) Alloys Prepared by Suction Casting

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Recently, Fe-based bulk metallic glasses (BMG) have become an important researching topic for their potential magnetic and mechanical applications [1-3]. Among this, the preparation of hard magnetic amorphous alloys and the study of their magnetic properties have provided the greatest stimulus for research of permanent magnets. Such fully dense magnets have the advantage that can be cast in precise dimensions and potentially cheaper than conventionally manufactured magnet obtained by consolidation of alloy powders produced by melt spinning or mechanical alloying. In this paper, the structure and magnetic properties for bulk $Fe_{73-x}Zr_2Y_4B_{21}Nd_x$ (x=0, 2, 5, 7 at.%) alloys are investigated.

$Fe_{73-x}Zr_2Y_4B_{21}Nd_x$ (x=0, 2, 5, 7 at.%) ingots were prepared by arc melting the mixture of pure metals Fe, Zr, Y, Nd and Fe-B alloy in an Ar atmosphere. Bulk Sheet specimens (0.8mm×10mm×50mm) were prepared by suction casting of the molten alloy into a copper mold under argon atmosphere. The annealing processes were performed in vacuum furnace with 2×10^{-3}Pa at different temperatures for 30min. Structural investigations were monitored by X-ray diffraction (XRD) in a Siements D5000 diffractometry using Cu-Kα radiation. The thermal stability was measured using differential thermal analysis (DTA) under Ar atmosphere at heating rates of 0.33K/s. Magnetic measurements were performed using a vibrating sample magnetometer (VSM) with a maximum applied field of 1.8T.

The results showed that Nd addition increase the crystallization temperature and decrease the melting temperature, which indicated that Nd addition could enhance the amorphous stability. Especially, the addition of Nd (5%) was very effective in improving glass-forming ability (GFA) for Fe-Zr-Nd-Y-B alloys. The reasonis that it satisfies the empirical rules for the achievement of Fe-based BMGs with high GFA [4,5]. On Nd addition, the crystallization behavior changes from a three-step to a single-step process. The as-cast $Fe_{68}Zr_2Y_4B_{21}Nd_5$ alloy presented soft magnetic behavior. However, the alloy showed the hard magnetic behavior after annealing at 963K for 30min. The existence of the $Nd_2Fe_{14}B$ phase is the main reason for exhibiting hard magnetic behavior. It can provide one promising way for the bulk magnet produced by the simple process of copper mold casting and subsequent heat treatment.

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