Bulk Amorphous and/or Nanocrystalline Finemet Alloy Prepared by Super-high-pressure Consolidation

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Abstract

Microstructure and soft magnetic properties of bulk amorphous and/or nanocrystalline $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloys prepared by consolidation at 5.5GPa were investigated. The relative density of the bulk sample 1 (from amorphous powders) was 98.5% and the grain sizes were about 10.6nm. While the relative density and grain sizes of bulk sample 2 (from nanocrystalline powders) are 98% and 20.1nm, respectively. Particularly, the bulk samples exhibited a good combined magnetic property: for Sample1, M_s=125emu/g and H_c=1.5Oe; for Sample2, M_s=129emu/g and H_c=3.3Oe. The success of synthesizing the nanocrystalline Fe-based bulk alloys will be encouraging for the future development of bulk nanocrystalline soft magnetic alloys.

Keywords: Bulk nanocrystalline alloy; Ultra-high-pressure consolidation; Magnetic property

1. Introduction

Amorphous and nanocrystalline Fe-based alloys are technologically important materials due to their good magnetic properties and low cost [1]. However, the limitation in dimensions and shapes of these materials seriously restricts their applications in many engineering devices in which a big size or a desired shape may be required. Thus, generating bulk materials with good soft magnetic properties is of great interest.

This paper aims to produce bulk amorphous and nanocrystalline $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ soft magnetic alloys using ultra-high-pressure consolidation technique by compacting amorphous powders obtained from short-time ball milled amorphous ribbons and nanocrystalline powders obtained from mechanically alloying. In addition, the characterization of the bulk alloys was studied as well.

2. Experimental and Results

The amorphous Finemet powders were prepared by milling the as-quenched amorphous ribbons using a planetary ball machine while the nanocrystalline Finemet powders were prepared by mechanical alloying from elemental powders. Super-high-pressure consolidating was conducted on a multiaxial hydro-forming machine (HTDS-032A) with WC anvils. All the samples were consolidated into cylinders with an outer diameter 22mm and thickness 10mm at input current powers (P_w) of 580W~1150W at 5.5GPa for 3min depending on other experiments [2,3].

The XRD patterns of the bulk alloys prepared from amorphous and nanocrystalline powders at different input current powers are represented in Fig.1 and Fig.2. The grain sizes of bulk samples were calculated from the X-ray diffraction data by Scherer equation. It is shown that for sample 1 the grain sizes ranged from 9.6nm~11.4nm while for sample 2 the grain sizes ranged from 18.2nm~21.3nm.

The relative densities of bulk samples were determined by Archimedes' principle using water immersion. The relative densities ρ of sample 1 (consolidated at 980W) and sample 2

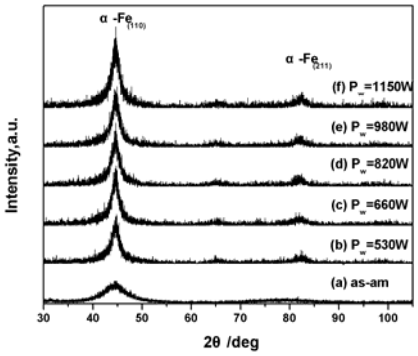

Fig. 1. XRD patterns of bulk amorphous Finemet alloys (Sample 1)

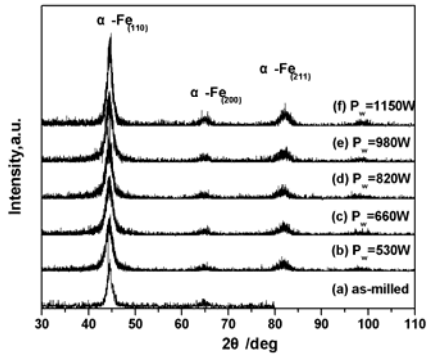

Fig. 2. XRD patterns of bulk nanocrystalline Finemet alloys (Sample 2)

(consolidated at 980W) were about 98.5% and 98%, respectively, far higher than that appeared in common fabrications of sintering and pressing [4,5]. Such a high relative density is mainly due to the super-high consolidating pressure.

Fig.3(a) and (b) gives the TEM micrographs and the selected area electron diffraction (SAED) pattern of bulk alloys. The average sizes of the nanocrystalline particles were about 14.3 nm (Sample 1) and 24.7nm (Sample 2).

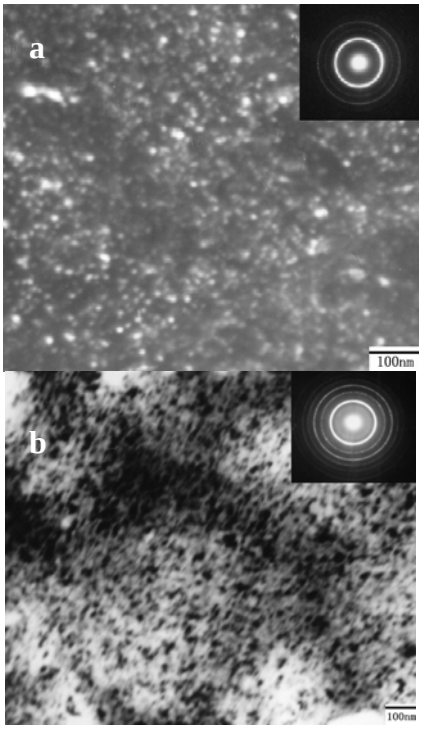

Fig. 3. TEM micrographs and SAED pattern of the bulk alloy consolidated at 980 W

The room temperature magnetic property of the bulk alloys consolidated at 980W under 5.5 GPa for 3 min was determined by a vibrating sample magnetometer under an applied field of 15000 Oe. The bulk samples exhibited a good combined magnetic property: for Sample1, M_s=125emu/g and H_c=1.5Oe; for Sample2, M_s=129emu/g and H_c=3.3Oe. The higher coercivity of the bulk Sample2 may be mainly attributed to the internal stresses and anti-size defects developed during mechanical alloying.

3. Summary

In this paper, the amorphous Finemet powders were prepared by milling the as-quenched amorphous ribbons while the nanocrystalline Finemet powders were prepared by mechanical alloying from elemental powders. The milled powders were consolidated into bulk samples with an outer diameter 22mm and thickness 10mm at 5.5GPa for 3min. The relative density of the bulk sample 1 (from amorphous powders) was 98.5% and the grain sizes were about 10.6nm. While the relative density and grain sizes of bulk sample 2 (from nanocrystalline powders) are 98% and 20.1nm, respectively. Particularly, the bulk samples exhibited a good combined magnetic property: for Sample1, M_s=125emu/g and H_c=1.5Oe; for Sample2, M_s=129emu/g and H_c=3.3Oe. What is more important, there will be no restriction in the size and shape of the bulk alloy prepared by this process. The success of synthesizing the nanocrystalline Fe-based bulk alloys will be encouraging for the future development of bulk nanocrystalline soft magnetic alloys.

4. References

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