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The structure, intrinsic magnetic properties, and magnetic hardening of $L1_0$-$Mn_{1.15}Ga$ alloy

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ABSTRACT

Recently, we successfully prepared $L1_0$-ordered $Mn_{1.15}Ga$ alloy with space group P4/mmm by induction melting high purity Mn and Ga followed by annealing the as-melt ingot at 465 ℃ for 2 days. The highest experimental room-temperature saturation magnetization, Ms, of 92 emu/g, is reported, and the Curie temperature and anisotropy field are estimated to be 595 K and 6.3 T, respectively. Based on the compound, low-energy ball milling technique, along with size-selection and annealing treatment are utilized to study the magnetic hardening and magnetic anisotropy inducement. It was found that milling can effectively improve the coercivity. With increasing the milling time to 210 min, the coercivity gradually increases from 0.8 kOe to a maximum value of 4.71 kOe for powders milled for 120 min, and then decrease. After classifying the powders milled for 120 min into different sizes, the coercivity is caused varying degrees of improvement and up to 5.03 kOe for the particles less than 10 μm. However, the remanence and magnetization are getting worse with long ball-milling time. After annealing at 465℃ for 1 min, remanence and magnetization are recovered without losing too much coercivity, leading to a great promotion of energy product, and the $(BH)_{max}$ of 2.96 MGOe is achieved for the $L1_0$-$Mn_{1.15}Ga$ powders with particle size in the range of 20~37 μm. In addition, the annealed powder shows possible magnetic anisotropy. The degree of alignment reaches 0.47 for the $L1_0$-$Mn_{1.15}Ga$ powder, which is 18 % higher than the as-milled powders with same size distribution.

1. Introduction

Mn-Ga based alloys have attracted increasing attention because of their multiple phase structures and potential applications in magnetism [1-9]. For example, $D0_{22}$-Mn_3Ga with high spin polarization and compensated ferromagnetic properties is widely studied for spintronic application [10-12], while $L1_0$-MnGa with high anisotropy constant (Ku) and saturation magnetization (Ms) is predicted as a promising candidate for rare-earth free permanent magnetic materials. In theory, the $L1_0$-MnGa compound possesses Ku of 26 Mergs/cm^3 and Ms of 116 emu/g, which yields a maximum energy product, $(BH)_{max}$, of 28 MGOe [13], the enthusiasm for $L1_0$-MnGa is therefore aroused in the last several decades. Cui et al. [3] reported the magnetic properties of $L1_0$-$Mn_{1.27}Ga$ isotropic particles prepared by high energy ball milling and subsequent annealing. Coercivity of 6.2 kOe, Ms of 61 emu/g, Mr of 42 emu/g, and $(BH)_{max}$ of 2.5 MGOe were obtained for the sample annealed at 600 ℃ for 20 min. Huh et al.[6] prepared nanostructured Mn_xGa ($1.2 \leq x \leq 1.9$) ribbons using arc-melting and melt-spinning followed by a heat treatment, and a maximum Ms of 85 emu/g was achieved in $L1_0$-$Mn_{1.2}Ga$. Mix et al. [2] studied the formation and magnetic