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Thermo-magnetic analysis study of mechanically alloyed Co-Zr system alloys

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Introduction

Since the discovery of the Nd-Fe-B-type material over two decades ago, a great demand for a new and superior hard magnetic phase has been increased. The Co-Zr phase has been investigated as a one of many promising candidate materials for an application of permanent magnetic material [1,2,3]. Although some intensive research works have been made, the hard magnetic properties of the Co-Zr phase is not yet quite promising for the application of permanent magnet. Further systematic studies are yet needed to understand the magnetic properties of the hard phase and to exploit this phase as a promising permanent magnetic material. In the present study, a thermomagnetic analysis (TMA) was carried out for the mechanically alloyed Co-Zr material in order to see the crystallisation of the mechanically alloyed amorphous material. The TMA was also carried out for the annealed materials in an attempt to examine the phase relation in the material. The knowledge of phase relation obtained by the TMA was related to the coercivity origin of the mechanically alloyed Co-Zr material.

Experimental procedure

Nano-structured $Co_{100-X}Zr_X$ (x = 10 - 40) alloys were prepared by using a mechanical alloying technique using the high purity component elements. The mass ratio of steel balls and the elemental materials was 20:1. The milling pot was evacuated and then filled with a high purity argon gas. The charged material was milled for 20 hrs in a shaker mill. The milled powder was retrieved in a glove box filled with high purity argon gas. The retrieved milled powder was annealed in a vacuum at the temperature range of 500 ℃ - 800 ℃. The TMA was performed for the milled and annealed materials in order to examine the crystallisation and phase relation of the milled and annealed materials. The crystallization of the milled powder was also studied using a differential thermal analyzer (DTA). The phase study of the materials at various conditions was also performed using an X-ray diffractometer (XRD) (Cu Kα radiation) and the results were correlated with the TMA results. Magnetic characterization of the materials at various conditions was carried out using a vibrating sample magnetometer (VSM) with maximum magnetic field of 15 kOe. Prior to the VSM measurement, the specimen was pre-magnetized using a pulsing field of 4.5 T. Self demagnetizing field was not corrected in this measurement.

Results and discussion

Fig. 1 shows the swift TMA tracings of the $Co_{82}Zr_{18}$ alloys annealed at 550 ℃ and 800 ℃. As can be seen two magnetic transitions are observed in both the materials annealed at 550 ℃ and 800 ℃. The Curie temperature observed at lower temperature may be corresponding to the $Co_{23}Zr_6$ phase and the one at higher temperature (around 665 ℃) to the Co_5Zr phase. It is noted that the Curie temperature of the $Co_{23}Zr_6$ phase is somewhat different in the materials annealed at different temperatures. The $Co_{23}Zr_6$ phases in the material annealed at 550 ℃ and 800 ℃ have Curie temperature at around 575 ℃ and 535 ℃, respectively. The different Curie temperature of the $Co_{23}Zr_6$ phase in the material annealed at different temperatures suggests that the precise chemical composition of the $Co_{23}Zr_6$ phase may be different in the materials annealed at 550 ℃ and 800 ℃. It is noted that the magnetization drop just below the Curie temperatures of $Co_{23}Zr_6$ phase is much greater in the material annealed at 800 ℃ compared to the material annealed at 550 ℃. It is also noted that a larger magnetization drop just before the Curie temperature of the Co_5Zr phase was observed in the material annealed at 550 ℃ compared to the material annealed at 800 ℃. This result indicates that the amount of the Co_5Zr phase is greater in the material annealed at 550 ℃ compared to the material annealed at 800 ℃ This TMA study also supports that the considerable coercivity in the material annealed at 550 ℃ may be due to the Co_5Zr phase and the coercivity deterioration in the material annealed at higher temperatures may be attributed to the increased amount of the $Co_{23}Zr_6$ phase.

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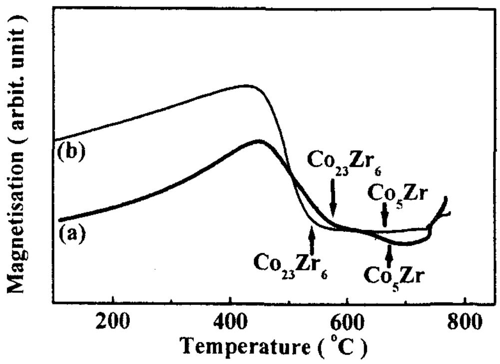

Fig. 1. Swift TMA tracings of the $Co_{82}Zr_{18}$ alloy annealed for 20 min at (a) 550 ℃, and (b) 800 ℃.