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Study on the formation and magnetic properties of $Sm_2Fe_{17}N_x$-type interstitial material

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Introduction

The Sm_2Fe_{17} alloy, from which the $Sm_2Fe_{17}N_x$-type interstitial compound is produced, has considerable amount of α-iron in cast condition, and this will reduce the intrinsic coercivity of the produced $Sm_2Fe_{17}N_x$-type interstitial compound unless removed prior to the nitrogenation. Addition of small amount of refractory element, such as Nb and Ta, to the Sm_2Fe_{17} alloy has been known to suppress the formation of primary α-iron during solidification, instead, lead to primary crystallisation of Sm_2Fe_{17} phase. In the present study, the $Sm_2Fe_{17}N_x$ interstitial compound has been prepared by reaction between the Sm_2Fe_{17}-type alloy with or without Nb and N_2 gas. One aim of the present work is to investigate the effects of Nb-substitution for Fe in Sm_2Fe_{17}-type alloy on the formation and disproportionation characteristics of the $Sm_2Fe_{17}N_x$-type interstitial material. This article has also discussed some of the results of investigating magnetic properties of the $Sm_2Fe_{17}N_x$ interstitial material prepared from the Nb-free or Nb-containing alloy and the epoxy-bonded or Zn-bonded magnets produced from it.

Experimental Work

Sm_2Fe_{17}-type and Nb-substituted Sm_2Fe_{17}-type alloys were prepared using an induction melting. $Sm_2Fe_{17}N_x$-type interstitial material was prepared by nitrogenating the pulverised material under N_2 gas (nitrogen pressure : ~ 1 kg/cm^2) at 430 ° or 475 °C. Nitrogenation behaviour of the Sm_2Fe_{17}-type alloys and the disproportionation characteristics of the nitrogenated materials were studied by means of differential thermal analysis (DTA) and thermopiezic analysis (TPA). Heating rate in DTA or TPA is 5 °C/min, and isotherm at certain temperature was also carried out. The magnetic properties of the produced $Sm_2Fe_{17}N_x$ interstitial material were characterised by means of vibrating sample magnetometer (VSM) or thermomagnetic analyser (TMA). Prior to VSM measurement, the nitrogenated materials were milled finely using a ball mill for 24 hours, and the milled powder (average particle size : around 3 μm) was bonded using candle wax. Epoxy-bonded magnets were prepared by well mixing the milled powder with 3 wt% fluid epoxy resin and then compressing the mixture into pellets using a metal die (compressing pressure : 500 kg/cm^2). The pellets were cured at room temperature for 24 hrs. Zinc-bonded magnets were prepared by well mixing the milled powder and zinc metal powder (particle size less than 45 μm) and then pressing the mixture into pellets using a metal die (compressing pressure : 1500 kg/cm^2). The prepared pellets were annealed at 430 °C for 1 - 4 hrs under nitrogen gas (N_2 pressure : 1 kg/cm^2).

Results and discussion

The nitrogenation characteristics of pulverised powder were determined by means of TPA. Nitrogen TPA traces for the powder showed a broad region of nitrogen absorption from around 430 ° to around 730 °C. These wide ranges of temperature cover both the nitrogenation stage and the disproportionation stage. DTA tracing under nitrogen was also undergone in an attempt to investigate disproportionation characteristics of the interstitial material. The DTA results has shown that the disproportionation temperature of $Sm_2Fe_{17}N_x$-type interstitial material my be enhanced slightly by the Nb-substitution for Fe in Sm_2Fe_{17}-type alloy. We have investigated the effect of Nb-substitution on the nitrogenation kinetics using TPA. This investigation clearly indicated that the Nb-substitution could improve substantially the nitrogenation kinetics. The powder material of Nb-free or Nb-containing alloys was nitrogenated, and we measured the quantity of absorbed nitrogen. It was quite surprising for the Nb-containing alloy to have a high nitrogen content, x value around 4.8. The magnetic properties of nitrogenated Nb-free or Nb-containing alloys were characterised in VSM. Remanence and intrinsic coercivity of the nitrogenated material produced from Nb-containing appears to be slightly lower than those of the material from Nb-free alloy. The lower remanence of the material produced from Nb-containing alloy may be attributed to the presence of nonmagnetic $NbFe_2$ phase. The degradation of remanence and intrinsic coercivity due to Nb-substitution is negligible in practical point of view.