Explosion Sintered $Sm_2Fe_{17}N_y$ Permanent Magnet

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Since the discovery of $R_2Fe_{17}N_y$ by Coey and Sun Hong[1, 2], the intrinsic[3—7] and extrinsic[8—11] magnetic properties of these nitrides have been extensively investigated. Having very good intrinsic magnetic properties with Curie temperature of 749 K and room temperature anisotropy field of 14 T superior to $Nd_2Fe_{14}B$, and room temperature saturation magnetization of 1.5 T, the $Sm_2Fe_{17}N_y$ nitride is expected to become new permanent magnet for application. The $Sm_2Fe_{17}N_y$ nitride with intrinsic coercivity of 3 T has been obtained by mechanical alloying. The $Sm_2Fe_{17}N_y$ magnets bonded by metal zinc have intrinsic coercivity $\mu_{0i}H_c$ over 0.5 T and magnetic product $(BH)_{max}$ about 80 $kJ \cdot m^{-3}$ (10 MGOe)[9, 10]. The $Sm_2Fe_{17}N_y$ magnet bonded with epoxy resin has $\mu_{0i}H_c$ of 1.08 T and $(BH)_{max}$ of 72 $kJ \cdot m^{-3}$ (9 MGOe)[11]. Since $Sm_2Fe_{17}N_y$ nitride disproportions at high temperature, the conventional powder metallurgy technique cannot be used for making the sintered $Sm_2Fe_{17}N_y$ permanent magnet. In order to overcome this difficulty, we prepared the $Sm_2Fe_{17}N_y$ magnet by explosion technique. Although the explosion technique has been used for sintering metals[12] and ferrites[13], no reports can be found so far in literature for sintering rare-earth permanent magnets. In this note, we report some results by using the explosion technique in sintering the $Sm_2Fe_{17}N_y$ nitride permanent magnet.

The Sm_2Fe_{17} alloy was prepared by arc-melting with all the elements having purities better than 99.5%. Due to the loss in melting, the quantity of Sm has 15—40% excess. The alloy ingot was annealed in Ar atmosphere at temperature 950—1050°C for 5—10 h. X-ray diffraction patterns showed the alloy has single phase with Th_2Zn_{17} structure (Fig.1 (a)). The detailed nitrogenation of Sm_2Fe_{17} has been reported in our early work[11]. The intrinsic magnetic properties are in agreement with those in earlier literature[2, 5, 11].

The $Sm_2Fe_{17}N_y$ fine powder with size less than 3 μm was prepared by ball milling, and then pressed to be a cylinder in an applied field of about 1.5 T. The cylinder was sintered by explosion technique. The sintered magnet has a density of $6.0—7.4\times10^3$ kg/m^3, which is above 85% of the theoretical value. The sample discussed below has a density of 6.5×10^3 kg/m^3.

Fig.1 shows some X-ray diffraction patterns. It is clear that the explosion sintering does not change the crystalline structure of $Sm_2Fe_{17}N_y$ nitride (Fig. 1 (c) and (d)), and neither the alignment of the magnet (Fig.1(e)). After nitrogenation, there is a little α-Fe impurity in $Sm_2Fe_{17}N_y$ nitride (Fig.1(b)), comparing with pure 2:17 phase of the Sm_2Fe_{17} alloy. The α-Fe impurity increases in the $Sm_2Fe_{17}N_y$ nitride powder prepared by ball milling for 6 h (Fig.1(d)) and in the $Sm_2Fe_{17}N_y$ magnet made by explosion sintering (Fig.1(e)).

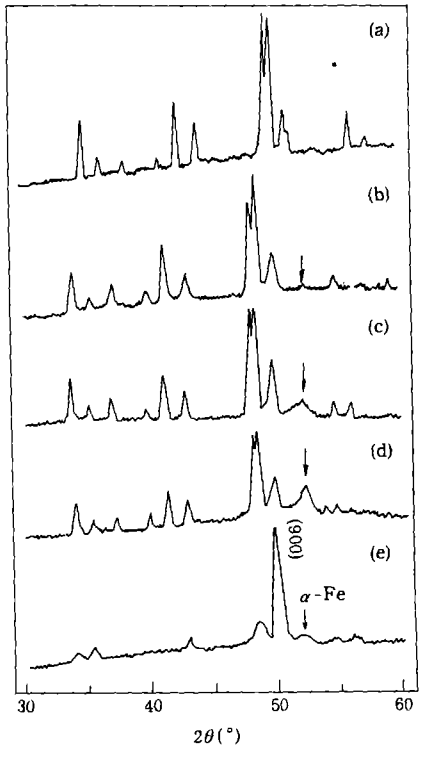

Fig.1. X-ray diffraction patterns (Co Kα). (a) Sm_2Fe_{17} alloy; (b) $Sm_2Fe_{17}N_y$ nitride; (c) $Sm_2Fe_{17}N_y$ nitride powder ball milled for 6 h; (d) powder of explosion sintered $Sm_2Fe_{17}N_y$ magnet; (e) on the orientation surface of the explosion sintered $Sm_2Fe_{17}N_y$ magnet.

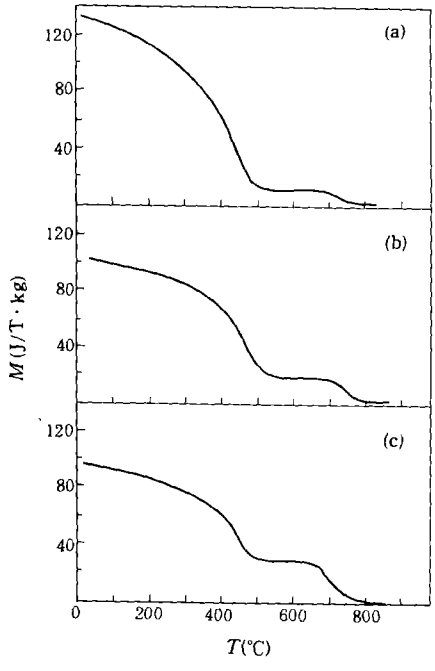

Fig.2. Temperature dependence of magnetization in an applied field of 1.2 T. (a) $Sm_2Fe_{17}N_y$ nitride; (b) $Sm_2Fe_{17}N_y$ powder ball milled for 6 h; (c) explosion sintered $Sm_2Fe_{17}N_y$ magnet.

Magnetization as a function of temperature measured by extraction magnetometer in an applied field of 1.2 T is shown in Fig.2. It can be seen that the $Sm_2Fe_{17}N_y$ main phase has a Curie temperature about 475°C in all cases. This means that the explosion sintering does

not affect the intrinsic magnetic properties. The second stage in the curves represents the α-Fe phase, of which the height indicates its quantity in the samples.

The demagnetization curve of the explosion sintering $Sm_2Fe_{17}N_y$ magnet is shown in Fig.3(a). The remanence Br = 0.83 T, the intrinsic coercivity $\mu_{0i}H_c = 0.57$ T and the energy product $(BH)_{max} = 88\ kJ \cdot m^{-3}$ (11 MGOe). Comparing to the orientation sample made by fixing the ball milled $Sm_2Fe_{17}N_y$ powders with wax (Fig.3(b)), the explosion sintering improved the rectangularity of the demagnetization curve, but decreased the intrinsic coercivity (from 0.86 T to 0.57 T). This may be attributed to the change of the domain structures from the powder to compact magnet by explosion sintering. However, the increase of α-Fe impurity in the sintered magnet might affect the coercivity.

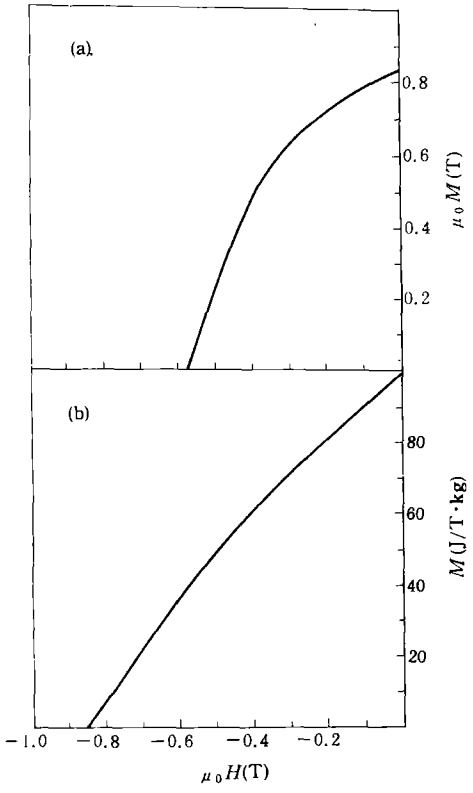

Fig.3. Demagnetization curves. a) Explosion sintered $Sm_2Fe_{17}N_y$ magnet; (b) wax bonded magnet of $Sm_2Fe_{17}N_x$ ball milled for 6 h.

As a new technique, the explosion sintering makes the $Sm_2Fe_{17}N_y$ powder forming a compact magnet by the high pressure shock wave ($\sim 10^3$ MPa) at a very short time ($\sim 10^{-6}$s), which maintains the crystalline structure and the magnetic properties of $Sm_2Fe_{17}N_y$ nitride. Comparing to epoxy resin bonded $Sm_2Fe_{17}N_y$ magnet[11], the explosion sintered $Sm_2Fe_{17}N_y$ magnet has better rectangularity of demagnetization curve to get higher energy product. If the magnet density is raised (the Br will be raised), the rectangularity is further improved plus enough coercivity ($\mu_{0i}H_c > 0.5$ T), and then the energy product of explosion sintered $Sm_2Fe_{17}N_y$ magnet will be further increased. For instance, taking Br as 1 T, the theoretical energy product can be $200\ kJ \cdot m^{-3}$ (25 MGOe). Having higher Curie temperature than $Nd_2Fe_{14}B$ and corrosion resistance, the sintered $Sm_2Fe_{17}N_y$ magnet is expected to occupy an area in the application field.

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