The grain boundary diffusion process with Nd-Cu-Zn alloy on Nd-Fe-B magnets hot deformed by Spark Plasma Sintering

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NdFeB permanent magnets are well known as the highest energy product magnets, so widely adopted to the motors of electric or hybrid vehicles and wind turbines. Hot-deformed Nd-Fe-B magnets can be produced relatively less complicated process and smaller grain size and smaller temperature coefficient value of coercivity compared with sintered Nd-Fe-B magnet. Hot-deformed Nd-Fe-B magnets can be produced from pulverized melt spun ribbons by hot pressing and die upsetting process. After hot pressing process, the isotropic full density compact is obtained and which is used as a precursor for die upsetting process. The anisotropic ultrafine platelet shaped grains can be aligned to c-axis along the press direction by mass transport and grain boundary sliding during die upsetting process. However, the magnetic properties are much lower than the desired value in despite of the nearly single domain grain size. The relatively low coercivity is attributed to excessive grain growth and insufficient magnetic isolation among the hard phases.

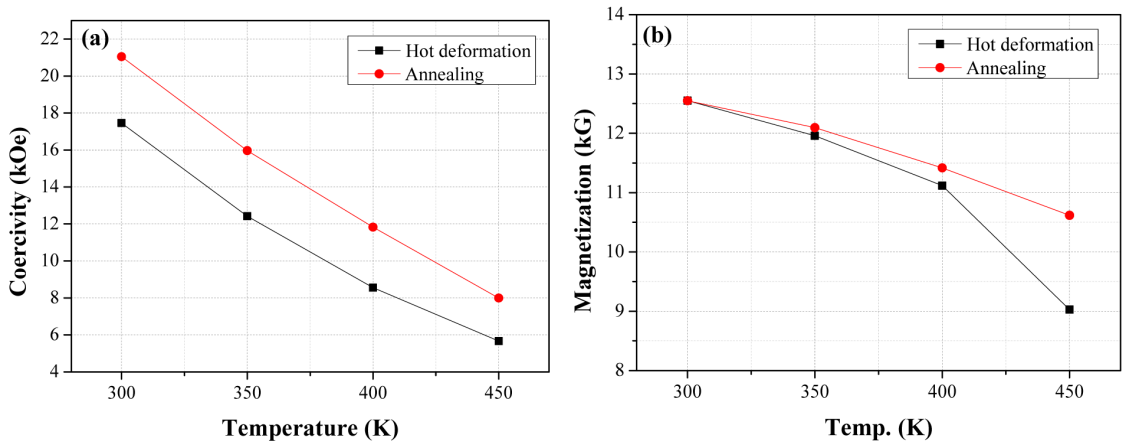

Fig.1 (a) coercivity and (b) remanence vs. temperature plot of the hot deformed and annealing processed magnets with Nd-Cu-Zn alloy diffusion.

Low melting point eutectic alloy (Nd-Cu alloy, Pr-Cu alloy) or Dy compounds (Dy, DyF_3 and DyH_x) has been selected as effective additive applied to grain boundary diffusion process, through isolating the $Nd_2Fe_{14}B$ grains with non-magnetic intergranular phase or substitute parts of Nd to $Dy_2Fe_{14}B$ with high anisotropy field to improve

coercivity. However, the non-magnetic phase and the antiferromagnetic effect of Dy and Fe lead to the decrease of remanence after grain boundary diffusion process. Moreover, as the heavy rare earth element, the cost of Dy source is staying at a high level. Therefore, enormous efforts have been focused to develop high coercivity Dy-free Nd-Fe-B. Zn with low melting point (420 ^{o}C) has been found to increase the wettability of grain boundary and enhances the texture formation during die upsetting process, further lead the increase of remanence and coercivity.

In this work, Nd-Cu-Zn alloy was mixed with the initial MQU-F ribbons. Hot deformed Nd-Fe-B magnets were produced by SPS through the optimized method, followed by annealing process. The effects and microstructure evolution with addition on the magnetic properties of hot deformed and annealed magnets were discussed in our work.

Keywords : Nd-Fe-B magnets; Hot deformation; Nd-Cu-Zn; Mechanism; SPS