Grain size refinement of Nd-Fe-B sintered magnets

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High remanence and large coercivity are required for Nd-Fe-B magnets in high-efficiency motors such as traction motors for EV or HEV. The addition of Dy is the most common way to increase the coercivity of Nd-Fe-B magnets. The problem of the Dy addition is the reduction of the remanence or the rise of material cost. Accordingly, efforts to reduce Dy use have been undertaken all over the world. One of the important idea to reduce the Dy use is a grain size refinement of $Nd_2Fe_{14}B$ crystal. Also, optimizing the grain boundary structure is necessary to achieve the large coercivity. We have been challenging the grain size refinement of Nd-Fe-B sintered magnets since 2007.

From 2007 to 2012, we had developed under “Rare Metal Substitute Materials Development Project” commissioned by the New Energy and Industrial Technology Development Organization (NEDO). In this project, we obtained fine powder with average particle size of around 1 μm using a helium jet-milling[1]. We fabricated the fine grained Dy-free Nd-Fe-B magnets using this powder with coercivity of around 20 kOe; about 40% of Dy can be saved by this technique.

Then, from 2012 to now, we have been challenging to develop the new production process for the further grain size refined Dy-free Nd-Fe-B sintered magnets under "Future Pioneering Projects / Development of magnetic material technology for high-efficiency motors" commissioned by NEDO.

The sub-micron grained sintered magnet was developed using both HDDR process and helium gas jet-milling[2]. This magnet (HDDR sintered magnet) had a better temperature coefficient of coercivity than the conventional sintered magnet. However, the coercivity at room temperature is around 13 kOe which is rather lower than we expected[3]. It can be seen that the HDDR sintered magnet has thinner Nd-rich grain boundary phase with around 1 nm than that of conventional magnet (thickness: 2 nm). We have been trying to expand the grain boundary phase of the HDDR sintered magnets by various methods such as the grain boundary diffusion (GBD) technique. One of the results is shown in Fig.1.

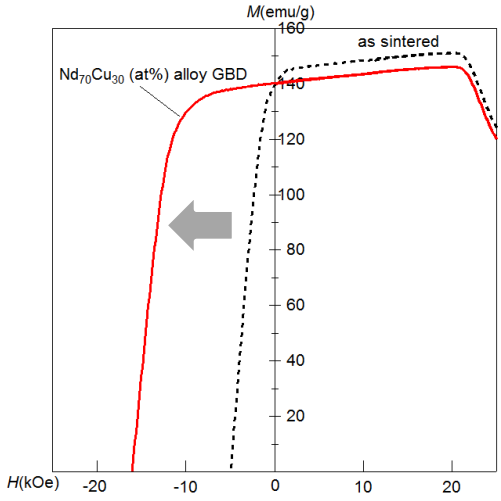

Fig.1 GBD for the HDDR sintered magnets

References

1) Y. Une and M. Sagawa, J. Jpn. Inst. Met. **76**, 12 (2012) (in Japanese)
2) M. Nakamura, M. Matsuura, N. Tezuka, S. Sugimoto, Y. Une, H. Kubo, and M. Sagawa, Appl. Phys. Lett. 103 (2013) 022404.
3) Y. Une, H. Kubo, T. Mizoguchi, T. Iriyama, M. Sagawa, M. Nakamura, M. Matsuura, and S. Sugimoto, The 38th Annual Conference on MAGNETICS in Japan (2014), 2pB-2