Sm-Fe-N powders and bulk magnets by ultra-low oxygen processes

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Many researchers have tried an anisotropic $Sm_2Fe_{17}N_3$ sintered magnet so far in order to obtain a heat-resistant permanent magnet with high coercivity and remanence. However, it had been stagnating for a long time because of two obstacles: one is thermal decomposition which limits the sintering temperature, and the other is significant deterioration of coercivity during sintering. For the latter problem, we have so far clarified the involvement of surface oxide film on the raw powder, and then demonstrated that powders with less surface oxide can suppress the coercivity deterioration [1). Based on these facts, we built up our own low-oxide powder metallurgy system to produce a sintered magnet without air-exposure from pulverization to sintering. Using this process, the present study examined the possibility of creating a high-performance $Sm_2Fe_{17}N_3$ sintered magnet [2). Our system consists of some glove boxes connected in series, and these glove boxes are equipped with functions such as pulverization, magnetic alignment, sintering, and so on.
First, the $Sm_2Fe_{17}N_3$ fine powders with less surface oxidation were produced by using a high-pressure jet-mill under the low oxygen environment. By varying milling conditions, fine powders of various mean sizes down to 1 micrometer could be prepared. Among these, the finest powders had the largest coercivity more than 14 kOe but their $(BH)_{max}$ was very low due to kink and powder agglomeration. The powders prepared with appropriate conditions exhibited the large $(BH)_{max}$ of 43 MGOe as well as low oxide less than one third of conventional.
The prepared powders were then subjected to magnetic-aligned compaction and rapid sintering under the low oxygen atmosphere. As expected, the powders with less oxide film showed only slight decrease in coercivity of less than 15% by sintering, whereas the conventional techniques suffered the reduction more than 70% [3). Sintered density was reached to a relatively high value of 91% by even sintering temperature of 500 ºC. On the other hand, the achievement of suppression of coercivity deterioration has revealed a new problem of decrease in saturation magnetization. Specifically, the saturation magnetization of powder was reduced by about 5% during sintering. This reduction would be derived from low crystallinity of the jet-milled powder. Due to this reduction in saturation magnetization, $(BH)_{max}$ of sintered magnets was 24 MGOe regardless of the high $(BH)_{max}$ of raw powder. Nevertheless, this value was achieved for the first time by the accessible sintering technique.
We are also conducting the research to improve the coercivity of sintered magnets by direct metal coating on $Sm_2Fe_{17}N_3$ particles without surface oxide film. In the neodymium magnets, it is known that the coercivity is greatly improved by adding a specific other element into the grain boundaries. Hence, there is a possibility that the same effect can be obtained in $Sm_2Fe_{17}N_3$. Currently, we discovered that several elements such as Al, Ce, Ru, Mn, Ti and so on, are effective for improving the coercivity of $Sm_2Fe_{17}N_3$.sintered magnet besides Zn which has been ever known to increase the coercivity [4). In addition to the low oxygen powder metallurgy technique, we are trying to prepare $Sm_2Fe_{17}N_3$ nanoparticles by a low-oxygen thermal plasma synthesis. Nanoparticles are expected to improve not only coercivity but also sinterability. We have so far confirmed that this synthesis method is able to synthesize Sm-Co nanoparticles.

Reference
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2) R. Soda *et al*., AIP Adv. **6** (2016) 115108.
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