Synthesis and Magnetic Characterization of "α"-$Fe_{16}N_2$ Interstitial Compound
- New Candidate for Permanent Magnetic Material with Rare Earth Element Free -

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To realize this more ideal social infrastructure in various IT and also power devices, necessity issue is to develop a new ecological system applying a highly potentialized material newly developed. Surprisingly, nearly half of total electric power, especially in Japan, has been wasted by the motor drive application, therefore, the construction of new motor system with low power consumption should be one of the key urgent issues. For current high performance motors, Nd-Fe-B permanent magnet is commonly used. In order for more powerful and torque full motor accompanying with down sizing in the future, not only high coercivity, H_c, but also higher saturation magnetic flux density, B_s, should be indispensable. From scientific view point, in currently used $Nd_2Fe_{14}B$ magnet, the magnetocrystalline anisotropy of this phase is still enough to show high H_c. However, we cannot expect the high magnetization, M_s, 168 emu/g. That means, we cannot expect higher increment of energy product, $(BH)_{max}$,~ 64 MGOe in this compound. That is the theoretical limit for $(BH)_{max}$ in $Nd_2Fe_{14}B$ magnet. While from a mineral resources view point, rare earth elements such as Nd, Dy, Sm and etc. commonly used for permanent magnet industry exist in highly deviated regions in the world, therefore, the mineral resources problem in the world wide scale become much more serious for the rare earth elements, especially for Dy.

In this study, we will focus on an α"-$Fe_{16}N_2$ iron nitride metastable phase with b.c.t structure as a new candidate for the futured permanent magnetic material with rare earth element free. This unique α"-$Fe_{16}N_2$ phase was firstly announced by M. Takahashi et al. in '72 as a thin film form with giant saturation magnetization about 290 emu/g[1]. After that, so many groups also including first reporter's group have been devoted to synthesize this phase for a couple of decade, resulting in from 240 emu/g to 315 emu/g[2-5]. Thus, poor reproducibility of the giant saturation magnetization had been so-called "magic moment". Concerning for this physical ambiguity, magnitude of M_s, one of the present authors, M. Takahashi (junior) has already pointed out in his review article[2] and also clarified the magnitude of magnetocrystalline anisotropy constant, K_u, of this phase was 1 x 10^7 erg/cm^3.[6] From this view, this compound is hopeful for futured magnetic material with rare earth free.

Gram scale of single phase α"-$Fe_{16}N_2$ nanoparticle powder from several tens to several hundreds nm in size could be successfully synthesized with extra high reproducibility via our uniquely developed multi-step procedures using home made iron oxide nanoparticle powder as a precursor. Thus synthesized α"-$Fe_{16}N_2$ nanoparticle powder shows 234 emu/g of saturation magnetization at 5 K and and 8.7 x 10^6 erg/cm^3 of magnetocrystalline anisotropy energy constant, whose values are superior to those of bulk pure iron and comparable to those of α''-$Fe_{16}N_2$ sputtered thin film reported by one of the present authors[2,6]. X-ray diffraction and Mossbauer spectra revealed the perfect formation of the single phase α''-$Fe_{16}N_2$. These results could open a new way of a bulk formation of non-equilibrium metastable interstitial iron nitride phase and will be utilized for the new permanent magnet material.