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研究者育成
成果報告

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希土類フリー磁性ナノ粒子複合材料の合成と評価

Synthesis and Evaluation of Rare-Earth-Free Magnetic Nanoparticles Composite Materials

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成 果 の 概 要

Magnetic materials play a key role in modern life as they facilitate the conversion of electrical to mechanical energy, transmission and distribution of electric power, microwave communications, and data storage systems. Nowadays, magnetic materials are used in various advanced devices, such as motor, recorder data devices, biomedical, sensor, spintronic devices, ferrofluid-related devices, etc. These broad applications require a magnetic material with high energy product.

Rare-earth-free magnetic materials such as α′′-$Fe_{16}N_2$ NPs have the highest magnetic moment among the ferromagnetic materials. However, this NPs have high magnetic interaction among NPs and small magnetic coercivity. Therefore, the nanostructuration of α′′-$Fe_{16}N_2$ NPs for enhancing its magnetic performance, which is important and inevitable condition for producing high performance rare-earth-free magnetic materials, is important to be investigated. In this study, preparation and evaluation of α′′-$Fe_{16}N_2$ NPs composite fibers via electrospinning and films via spin coating are systematically investigated.

The synthesis of α′′-$Fe_{16}N_2$ composite fibers via electrospinning was investigated by studying the effect of applied magnetic field on diameter of α′′-$Fe_{16}N_2$/PVP composite fiber and its magnetic performance. An external magnetic field of 0.1 T was applied during process of electrospinning. The experimental results showed that the applied magnetic field gave the fiber of smaller diameter and more uniform distribution. The higher loading of α′′-$Fe_{16}N_2$ NPs in the fiber resulted in smaller diameters than the lower loading. It was found from the TEM observation that the α′′-$Fe_{16}N_2$ NPs were aligned stably in one dimension along the longer direction of the fiber as shown in Fig. 1 (a) and (b). No change in the crystal structure of α′′-$Fe_{16}N_2$ due to

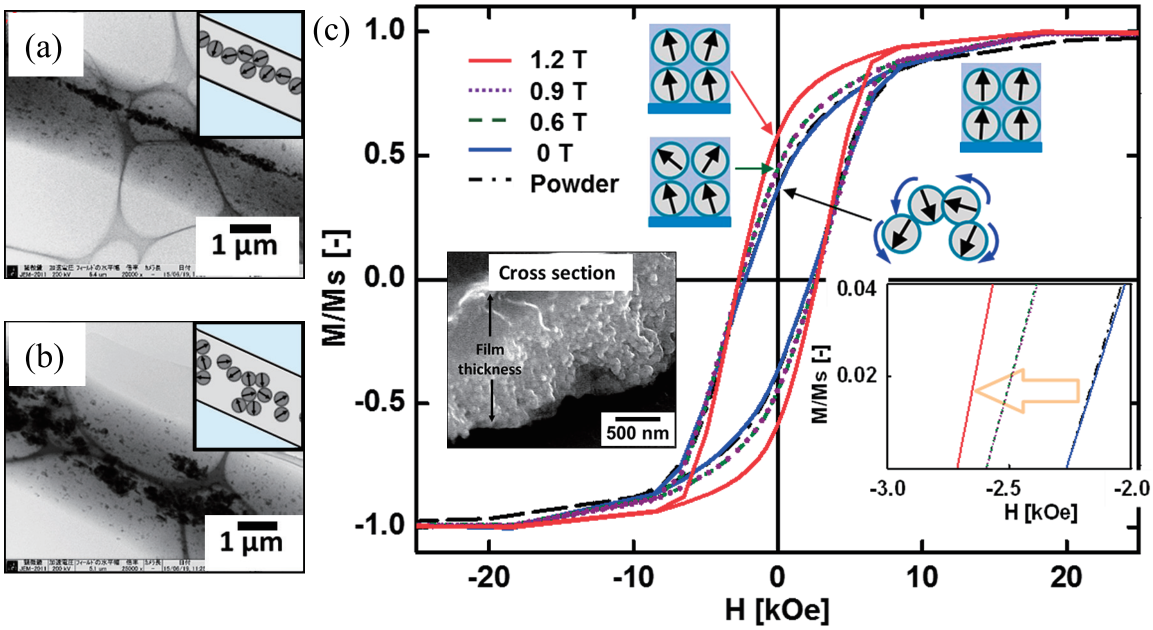

Fig. 1 SEM images of α″-$Fe_{16}N_2$/PVP composite fibers prepared (a) with, (b) without magnetic field and (c) hysteresis loops of α″-$Fe_{16}N_2$ composite film under various strength of magnetic field. Inset Figure is SEM images of α″-$Fe_{16}N_2$ composite film.

the electrospinning was observed. Further, the SQUID measurements for the 28.4 wt% loading of α″-$Fe_{16}N_2$ NPs revealed an extremely high saturation magnetization of 49 emu/g with a coercivity of 1 kOe.

The synthesis of α″-$Fe_{16}N_2$ NPs composite film via spin-coating under magnetic field was also investigated. In this method, core–shell single-domain α″-$Fe_{16}N_2$/Al_2O_3 NPs were used as a basic material. α″-$Fe_{16}N_2$ NPs were prepared by nitridation process followed by beads-mill dispersion process to break-up the agglomerated as-prepared NPs. The well dispersed NPs slurry mixed with epoxy resin is then spin coated. During the drying process, magnetic field was applied to align the magnetic moment of the NPs. The effect of magnetic field strength and direction on the magnetic performances were studied in detail. The α″-$Fe_{16}N_2$ composite film prepared under magnetic field has higher performances than that of without magnetic field. Magnetic coercivity, remanence, and maximum energy product enhanced by 24%, 66%, and 160%, respectively, with increase in magnetic orientation of 35% by applying 1.2 T of magnetic field. The shape of hysteresis loops of the films approached to rectangular by increasing the vertically applied magnetic field as shown if Fig. 1 (c). These results were further verified by applying the magnetic field horizontally.

These results suggest the potential of constructing bulk magnetic materials using α″-$Fe_{16}N_2$ NPs with tunable magnetic performances by applying a magnetic field, which furthermore reveals promising features for many other magnetic applications, such as magnetic sensors. The results of this research also showed that the magnetic properties of magnetic materials can be tuned by tuning their magnetic moment. This magnetic property tuning process is also possible to be applied to others magnetic materials.

外部発表成果

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