【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Engineering)

Title of Project : Research and development on artificial production of next generation of Rare-Earth Free Magnets with $L1_0$ phase similar to Cosmic magnet

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Research Project Number : 17H06154 Researcher Number : 30315642
Research Area : Engineering
Keyword : Energy Materials

【Purpose and Background of the Research】

High performance rare earth based magnet (Nd-Fe-B) developed domestically about 30 years ago resulted in the production of small sized and high efficiency motors for next generation of automobiles (HV, PHV, EV, FCV), home appliances, and industrial machineries. These magnets contribute significantly in saving energy, and led the world to grow in a sustainable manner. Further improvements in the performance of rare earth based magnets have reached the limit. Additionally, economic advantages are disappearing due to expiration of basic patents. Above all, the major obstacle is in the sustainable supply of rare earth elements, and it is predicted to be serious in future. Shortage in supply can hamper the growth of economy, industries and energy saving technologies in our country. Therefore, demand for a new low cost and high performance magnetic material, that can replace rare earth magnets is intense. In the current scenario, a trace amount of hard magnetic $L1_0$ FeNi phase discovered in meteorites (which were formed over billions of years) is of huge interest. This is because of magnetic performance similar to rare earth, but the artificial production of this phase is extremely difficult.

This project dares to create a chemically ordered $L1_0$ FeNi phase artificially. The aim is to develop a next generation of completely rare earth free magnet.

【Research Methods】

Our focus is on achieving a fast atomic diffusion at lower temperatures that is observed during nanocrystallization of amorphous phase. By nanocrystallizing an FeNi-based amorphous alloy, we have obtained $L1_0$ FeNi phase with ordering parameter ~ 0.8 and volume fraction ~ 10%. In this project, first of all, we will grasp the fundamental physical properties of this artificially prepared $L1_0$ FeNi phase, and clarify its potential as a hard magnetic material for next generation of magnets. Therefore, we aim at grasping the optimum alloy composition by exploring different FeNi-based amorphous systems and optimizing the nanocrystallization process. This is to increase the volume fraction of ordered phase in the currently obtained sample, and measure the intrinsic physical properties of $L1_0$ ordered phase alone. Subsequently, we will grasp the basic physical properties in detail by thermal analysis using differential scanning calorimeter (DSC), magnetic properties by vibrating sample magnetometer (VSM), structural properties by high resolution electron microscopy observation, micromagnetics simulation, etc.. After it, we will extract and resolve the issues related to production and industrialization of FeNi based magnets.

Figure 1 Representative phases in Fe-Ni binary system and their atomic arrangements

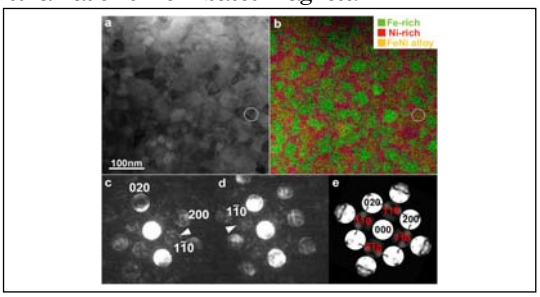

Figure 2 TEM observations on artificially produced $L1_0$ FeNi phase.

【Expected Research Achievements and Scientific Significance】

We resolve the risks of rare earth supply, secure Japan's future technological superiority based on energy saving technologies and contribute to the maintenance of international competitiveness in our country. It revives the stagnating field of hard magnetic materials, and it is expected to open the door to new "super equilibrium" in material science through non-equilibrium.

【Publications Relevant to the Project】

・An Artificially Produced Rare-Earth Free Cosmic Magnet. [Scientific Reports,5,(2015),16627-1-16627-7]
Makino A., Sharma P., Sato K., Takeuchi A., Zhang Y., Takenaka K.

・Crystallization induced ordering of hard magnetic $L1_0$ phase in melt-spun FeNi-based ribbons. [AIP Advances,6(5),(2016),055218-1-055218-9]
Sato K., Sharma P., Zhang Y., Takenaka K., Makino A.

【Term of Project】 FY2017-2021

【Budget Allocation】 156,600Thousand Yen

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