

研 究 主 論 文 抄 録

論文題目

Synthesis of novel materials under strong gravitational field

(強い重力場を用いた新規物質の合成)

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主論文要旨

Gravity is physical valuable of field, while pressure and temperature are thermodynamic state valuables. Under a strong gravitational field ($\sim 10^6$ G level), heavy atoms are displaced in the gravitational direction, and light atoms are done in the opposite direction by the different body forces relative to respective atomic weigh. If the gravity potential due to relative body force overcomes the chemical potential, gravity-induced diffusion (sedimentation of atoms) would appear. On the other side, under such conditions, a nonequilibrium crystalline state would appear by the one-dimensional displacement of atoms, and a structure change might occur. Even a small change in the crystal structure should induce subtle change in electronic properties of compound. Also, the gravity condition has reasonable potential to synthesise novel compounds. In this study, we focused on the synthesis of novel materials using strong gravitational field.

In the Chapter 1, we introduced a strong gravitational field, expected effect on materials, some previous work and purpose of this study.

In the Chapter 2, we introduced a high temperature ultracentrifuge apparatus at Kumamoto University and experimental setup.

In the Chapter 3, to investigate diffusion phenomenon at the interface between Cu and brass under a strong gravitational field generated by ultracentrifuge apparatus, we performed gravity experiments on samples prepared by electroplating with interfaces normal and parallel to the direction of gravity. For the parallel-mode sample, for which sedimentation cannot occur thorough the interface, the concentration change was significant within the lower gravity region; many pores were observed in this region. Many vacancies arising from crystal strain due to the strong gravitational field moved into the lower gravity region, and enhanced the atoms mobilities. For the two normal-mode samples, which have interface normal to the direction of gravity, the composition gradient of the brass-on-Cu sample was steeper than that for Cu-on-brass. This showed that the denser Cu atoms diffuse in the direction of gravity, whereas Zn atoms diffuse in the opposite

direction by sedimentation. Results from the simulation of sedimentation indicated that the value of the coefficient of diffusion for Cu rose above that under normal conditions. This rise may be related to the behavior of the vacancies.

In the Chapter 4, we focused on the change of the crystal structure of a material in a strong gravitational field. Inducing structural changes in crystals using a strong gravitational field can be advantageous compared with using high temperature or pressure but is little understood. We performed a strong gravity experiment on a single crystal of Fe_3O_4 with an a-axis crystal direction using an ultracentrifuge ($0.4 \times 10^6\text{G}$, 673K), and quenched a structure of Fe_3O_4 single crystal with a new structure ($I4_1/amd$; tetragonal) that was stable under ambient conditions and had the same form as Hausmannite (Mn_3O_4). Raman spectra of the crystal subjected to high gravity confirmed the phase transition. The permeability and remanence of the crystal exposed to high gravity increased when the direction of the magnetic field was parallel to that of gravity.

In the Chapter 5, we report the synthesis of some carbon compounds from mixture of buckminsterfullerene (C_{60}) and yttrium metal under a strong gravitational field. The initial sample were prepared by mixing powder of C_{60} and Y 1: 1 ratio (at %). The initial sample was centrifuged at $100,000\text{rpm}$, $0.40 \times 10^6\text{G}$ at maximum, 500°C and for 60 hours. Magnetic hysteresis loops of initial sample shows the diamagnetic properties depending on the fullerene. On the other hand, that of gravity sample shows the ferromagnetic properties. The XRD pattern of the magnetic material separated from the gravity sample by a magnet did not show the Y and C_{60} peaks. The elemental analysis using EDX revealed that the magnetic material did not have the ferromagnetic impurity. The Y K-edge spectrum of magnetic material shows the chemical shift to the electronic structure of carbide; however, the electronic structure of Y metal remained.