

Shock-induced transportation of light elements into iron: Implication for the Earth's core composition

Mineyuki Nishio[1]; Toshimori Sekine[2]; Eiichi Takahashi[3]

[1] Earth & Planetary Sci., TITECH; [2] AML/NIMS; [3] Earth and Planetary Sci., Tokyo Inst. of Tech.

<http://www.geo.titech.ac.jp/lab/takahashi/takahashilab.html>

In order to explain the density deficit of the Earth's core, many investigations on multi-component systems between iron and light element have been carried out. The following three processes have been frequently discussed as acquiring mechanisms of the light elements into the Earth's core: 1) the convective mixing of both iron alloy and the organic matter that had condensed from solar nebula and accreted in the primitive Earth, 2) the chemical diffusion of light elements between the sinking iron droplets and the molten surroundings in the magma ocean and 3) the chemical reaction at the core mantle boundary (CMB) through the whole history of the Earth.

In the Earth-building theories, the roles of both impact and static processes have been taken into account. In discussing the composition of the planetary core, only the static transportations such as the normal chemical diffusion and the thermal convection have been considered. On the other hand, the existence of the impact-induced processes has been neglected. Because all the primitive materials for the Earth must have experienced shock events during the planetary accretion stage, the effect of the shock-induced transportations (if any) on their composition have to be studied.

Although the mechanisms of those shock-induced transportations are still not completely apparent, some studies on shock compressions have reported the shock-induced peculiar reactions; the mixing by Rayleigh-Taylor instability at the boundary of two phases, the migration of dislocation defect with higher rate than at static conditions, the activation of reactions by pulverization, the accelerated mixing by the high velocity jettings and so on.

Carbon, nitrogen, oxygen and sulphur as the reasonable candidates of the light elements in the core are volatile and have been thought to get scattered and lost to the outer space in the accretion stage of the Earth. In order to investigate the tendency which element is easier to be incorporated into the iron under shock compression, we carried out shock recovery experiments using a propellant gun at NIMS in this study. Layered samples of iron metal and amorphous material with a composition of $C_{32}N_{51}O_{16}S_{2.72}$ as source of carbon, nitrogen, oxygen and sulphur were used and encapsulated in steel containers. The concentrations of these light elements in iron were measured by Electron Probe Micro Analyser.

As a result, the amounts of the light elements in iron were dependent on whether iron had melted or not. They were almost below the detection limit within analytical errors, but only carbon in sample without melted iron showed a significant concentration gradient from ca. 6 to 2 wt% for a distance of 30 μm . The solid-state diffusion distances of C under static condition are estimated to be more than 30 μm according to calculations based on available data. Therefore, the present results can be explained by solid-state chemical diffusion of C as impurity.

Consequently, we conclude that the influence of shock-induced transportation is little on the acquisition of light elements into melted iron, although we should address the fact that only carbon was incorporated in solid iron. The stable phases for S, O, and N at ambient pressure are gas or easy to be vaporized, but carbon is stable as solid state. In the present experiments only carbon could have diffused into iron in the shock process, but the other would have been vaporized and escaped out from reaction system. This was confirmed recovered sample structure indicating large volume of voids.