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Sound velocities of liquid Fe-Si alloys at Earth's core pressures by laser-shock compression

SAKAIYA, Tatsuhiro[1*] ; HOSOGI, Ryota[1] ; KONDO, Tadashi[1] ; TERASAKI, Hidenori[1] ; SHIGEMORI, Keisuke[2] ; HIRONAKA, Yoichiro[2]

[1]Graduate School of Science, Osaka University, [2]Institute of Laser Engineering, Osaka University

Sound velocity at Earth's core conditions are one of the most important physical properties in Earth science because it can be directly compared with the seismological Earth model (PREM: Preliminary Reference Earth Model) [1]. The composition of solid inner core is estimated from the comparison of the model [1] and the extrapolation of sound velocities as a function of density of iron and iron alloys obtained by the static compression experiment [2, 3]. Birch's law, a linear sound velocity-density relation [4], is used to extrapolate sound velocities to densities in the core condition. On the other hand, the composition of liquid outer core is estimated from the partitioning and solubility data in the inner core boundary condition for the composition of solid core. There has been some works for the sound velocity of iron on the Earth's core condition by dynamic techniques using explosive [5], gas gun [5, 6], and laser [7]. However, the previous dynamic compression experiments are not enough to reveal the core of Earth, giant planets [8], and super-Earth which is at core pressures over 800 GPa [9]. In this study, we measure the sound velocity and density of liquid iron alloys by shock-compression method using high-power laser at pressures corresponding to super-Earth core pressures.

We conducted shock-compression experiments using a High Intensity Plasma Experimental Research (HIPER) system at the GEKKO-XII laser irradiation facility [10] at the Institute of Laser Engineering, Osaka University. The samples are Fe-Si alloys ($Fe_{95}Si_5$, $Fe_{90}Si_{10}$, $Fe_{80}Si_{20}$ and $Fe_{66}Si_{34}$ in weight percent). The sound velocities and densities of shock-compressed Fe-Si alloys using the high-power laser were measured by x-ray radiography [7, 11, 12] at pressures up to 960 GPa. The linear relation between the sound velocity and the density for FeSi alloy well follows Birch's law [4] up to 960 GPa along the Hugoniot. The extrapolated sound velocity of FeSi alloy was about 40% faster than that of PREM at inner core boundary pressure. The outer core is composed of Fe-Si alloy with 5-13 wt.% Si assuming Si is only light element at the core. This Si content is consistent with the results of previous work by sound velocity measurement [13] and shock-compression experiment [14].

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