Effect of Light Elements to Heterogeneity of Attenuation in the Earth’ s Inner Core

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Seismic observations have provided strong evidence of hemisphere variations, showing less attenuation, and lower seismic P-wave velocity in the western hemisphere than in the eastern hemisphere in the uppermost 100 km of the inner core (Deuss, 2014; Poupinet, Pillet, & Souriau, 1983; Souriau, 2015; Tanaka & Hamaguchi, 1997). Two major hypotheses have been proposed to explain these features: (a) inner core translation, wherein eastern hemisphere is melting at the surface of the inner core and the other side is solidifying (Monnereau, Calvet, Margerin, & Souriau, 2010), partial melting may play a key role to produce such attenuation heterogeneity at the inner core boundary; (b) thermochemical convection occurs (Alboussière et al.,2010; Deuss, 2014), which may cause the distribution of light elements. Therefore, knowledge of alloy with partial molten texture and anelastic behavior of light elements-bearing alloy is necessary to constrain the heterogeneity in the Earth’ s inner core. As sulfur and silicon have been considered to be more probable candidates of light elements in the inner core (Miller, 2009; Poirier, 1994; Sakamaki et al., 2016; Tsuchiya & Fujibuchi, 2009), we investigated the attenuation behavior of iron alloy containing these elements.

Three different alloys (iron, S-bearing, Si-bearing alloy) were studied. Starting materials, for S- and Si-bearing alloys were synthesized at 1 GPa in a piston cylinder apparatus. The S-bearing alloy was used to investigate anelastic behavior of the partial molten state. The measurement of seismic attenuation was conducted by in situ X-ray radiographic observation at 1.6 GPa and up to 1473 K using the deformation-DIA press at the bending magnet beam line BL04B1 at SPring-8 (Yoshino et al., 2016). The alumina aggregate, sapphire single crystal and forsterite single crystal were used as a reference material in a series of experiments. The periods of oscillation were from 0.5 to 100 s.

Pure iron with average gran size, 10 μm, showed no frequency dependence of seismic attenuation factor Q^{-1} in bcc phase, and week temperature dependence. For S-bearing samples with initially partial molten texture, melt separation occurred during experiment. The attenuation information of partial molten state could not be obtained. Attenuation of Si-bearing samples (average grain size larger than 1 mm) became larger with increasing Si-concentration, and showed no frequency and temperature dependences.

The experimental results showed that the seismic attenuation of Fe alloy is not frequency (0.01-2 Hz) dependent, which is consistent with the observed seismic data that there is no frequency dependence in some range of frequency due to different relaxation time in the uppermost inner core (Li & Cormier, 2002; Souriau & Roudil, 1995). The silicon can influence the heterogeneity of attenuation in the Earth’ s inner core. If silicon is one of the dominant light elements in the core, which means the concentration of silicon in west hemisphere is higher than it in east hemisphere in the uppermost 100 km of the inner core combined with the sound velocity data of Si-bearing alloy (Lin, 2003). So it can support the opinion that the core freezes in western hemisphere in uppermost of the inner core, growing the solid inner core and releasing silicon (Gubbins et al., 2011; Monnereau et al., 2010). It is needed to constrain the relationship between seismic attenuation and molten state.

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