Constrains on light elements in Earth's core via sound velocity measurements of liquid Fe alloys

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The Earth's core consists mainly of iron alloying with some lighter elements. The nature of the lighter elements is the key to understand the building blocks of the bulk Earth, the core formation process, and the chemical and thermal history of the core. Seismological observations give fundamental information of the physical properties of the core. The density and sound velocity of liquid outer core based on seismological observations are about 10 % less and about 4 % faster than pure Fe under the corresponding pressure and temperature conditions (Anderson and Ahrens, 1994 JGR). The effects of possible lighter elements on those properties of liquid iron are therefore important to constrain the core composition. We have measured the sound wave velocity of liquid Fe alloying with several candidates of the light elements such as carbon (C), silicon (Si), and sulfur (S) to 50–70 GPa, using the inelastic X-ray scattering method combined with a laser-heated diamond anvil cell technique. Based on obtained sound velocity data we constructed equations of state for liquid Fe-C (Nakajima et al., 2015 Nat.Commun.), Fe-Ni-S (Kawaguchi et al., submitted), and Fe-Si (Nakajima et al., in prep.). We found that both carbon and silicon increase significantly the P-wave velocity of liquid Fe, whereas sulfur has negligibly small effect. The abundances of C and Si in liquid Fe are only less than 1 wt.% and 2 wt.%, respectively, so as to explain the P-wave velocity of the outer core. However, such a small amount of C and Si cannot take into account for the 10 % core density deficit. On the other hands, the presence of 5.8–7.5 wt.% S can mutually explain seismological sound velocity and density of the outer core. Therefore, sulfur can be the most abundant among the light elements in the outer core.

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