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Sound wave velocities of Fe_5Si at high-pressure and high-temperature conditions: Implications to lunar and planetary cores

LIWEI DENG[1,2,*], YOSHIO KONO[3,†], AND GUOYIN SHEN[3]

[1]Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[2]University of Chinese Academy of Sciences, Beijing, 100049, China
[3]HPCAT, Geophysical Laboratory, Carnegie Institution of Washington, Argonne, Illinois 60439, U.S.A.

ABSTRACT

Elastic properties of Fe alloys are critical in constraining the compositions of planetary bodies by comparing to the planetary observations. The sound wave velocities and density of an Fe_5Si (9 wt% Si) alloy in body-centered cubic (bcc) structure were measured by combining an ultrasonic technique with synchrotron X-ray radiography at pressure (P) and temperature (T) conditions of 2.6–7.5 GPa and 300–1173 K, respectively. At room temperature, it is observed that adding Si to bcc-Fe increases the compressional wave velocity (v_P) but decreases the shear wave velocity (v_S). At high temperatures, we observed a pronounced effect of pressure on the v_S-T relations in the Fe_5Si alloy. The v_P-density (ρ) relationship of the Fe_5Si alloy is found to follow the Birch's law in the P-T range of this study, whereas the v_S-ρ relation exhibits complex behavior. Implications of these results to the lunar core and the Mercurian core are discussed. Our results imply that adding Si to a pure Fe lunar core would be invisible in terms of v_P, but exhibit a decreased v_S. Including Si in a sulfur-rich lunar core would display an increased v_P and a decreased ρ. Our density and sound wave velocity model provide lower and upper limit for a Si-bearing lunar core if 1–3 wt% Si content of enstatite chondrite is taken as compositional analog. A Si-rich (>9 wt%) Mercurian core model is derived to satisfy newly observed moment of inertia values by Messenger spacecraft.

Keywords: Fe-Si alloy, elastic wave velocity, lunar and planetary cores, high pressure, high temperature