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Pressure dependence of Si diffusion in γ-Fe

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Abstract

The pressure dependence of Si diffusion in γ-Fe was investigated at pressures of 5–15 GPa and temperatures of 1473–1673 K using the Kawai-type multi-anvil apparatus to estimate the rate of mass transportation for the chemical homogenization of the Earth's inner core and those of small terrestrial planets and large satellites. The obtained diffusion coefficients D were fitted to the equation $D = D_0 \exp[-(E^* + PV^*)/(RT)]$, where D_0 is a constant, E^* is the activation energy, P is the pressure, V^* is the activation volume, R is the gas constant, and T is the absolute temperature. The least-squares analysis yielded $D_0 = 10^{-1.17\pm0.54}$ m^2/s, $E^* = 336 \pm 16$ kJ/mol, and $V^* = 4.3 \pm 0.2$ cm^3/mol. Moreover, the pressure and temperature dependences of diffusion coefficients of Si in γ-Fe can also be expressed well using homologous temperature scaling, which is expressed as $D = D_0 \exp\{-g[T_m(P)]/T\}$, where g is a constant, $T_m(P)$ is the melting temperature at pressure P, and D_0 and g are $10^{-1.0\pm0.3}$ m^2/s and 22.0 ± 0.7, respectively. The present study indicates that even for 1 billion years, the maximum diffusion length of Si under conditions in planetary and satellite cores is less than ~1.2 km. Additionally, the estimated strain of plastic deformation in the Earth's inner core, caused by the Harper–Dorn creep, reaches more than 10^3 at a stress level of 10^3–10^4 Pa, although the inner core might be slightly deformed by other mechanisms. The chemical heterogeneity of the inner core can be reduced only via plastic deformation by the Harper–Dorn creep.

Keywords: γ-Fe, silicon diffusion, high pressure, planetary core; Physics and Chemistry of Earth's Deep Mantle and Core