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Evaluating Si as a Candidate Light Element

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The identity of the light element(s) in the core is key to evaluating whether the D" layer at the core-mantle boundary is generated by a chemical reaction between the core and mantle. In addition, the identity of the light element is important for determining the bulk composition of the Earth which in turn has implications for accretion scenarios. Si has long been a favorite light element of cosmochemists because the upper mantle is depleted in Si relative to primitive meteorites, the presumed building blocks of the Earth. Thus adding Si to the core can reconcile the bulk composition of the Earth with that of primitive meteorites as well as provide a source of the observed density deficit of the core, and recent models arrive at estimates varying from 7.3 to 14 wt.% Si in the core (for example Allègre et al., 1995 and Wänke and Dreibus, 1997). We use the results of our high-pressure diamond anvil experiments to evaluate whether a Si-rich core is geochemically reasonable.

We use the laser-heated diamond anvil cell to study the high pressure and temperature interactions of mantle minerals with Fe-metal and Si-enriched Fe-metal. Our basic sample consisted of a metallic plate in contact with San Carlos Olivine. In the experiments reported here, the metal was either pure Fe, Fe with 17 wt.% Si or Fe with 9 wt.% Si. We insulated the sample assemblage from the highly conductive diamond anvil with a plate of Al_2O_3, $MgSiO_3$ glass, or CaF_2. After loading the sample into the diamond cell and prior to pressurizing, the samples are dried overnight in a vacuum oven and then sealed under Ar. This procedure ensures that there is no water or O from the atmosphere present so that the oxygen fugacity prevailing during the experiment is set by the sample assemblage. The interface between the metal and silicate was heated with an YLF laser with a hot spot size ranging from 10 to 40 microns. The metallic portion of the sample was melted during heating, and the initially clear San Carlos olivine darkened due to the transformation to the high pressure phases perovskite and magnesiowüstite. The samples were recovered after the runs and polished down to the heated surface, and analyzed by electron microprobe.

In experiments with San Carlos olivine and Fe-metal as starting materials, we find less than 0.2 wt.% Si in the metal--even at conditions as extreme as 1 Mbar and 3300 K. Experiments with Si-enriched Fe-metal as a starting material show a reduction in the amount of Si in the metal and the amount of Fe in the silicate (i.e. Si is oxidized out of the metal into the silicate while FeO in the silicate is reduced to Fe metal). Model calculations based on these experimental results suggest that if the core and mantle are in equilibrium, then the core can contain no more than 3 wt.% Si, which is not enough to account for the density deficit in the core.

The results of the experiments with Si-enriched Fe-metal (i.e., the reduction of the amount of Si in the metal and Fe in the silicate) indicate that if a Si-rich core did form, then it would react with the present day mantle and form a zone of chemical reaction at the core-mantle boundary. However, we must examine whether the results of that interaction are compatible with the seismological observation of a increase in seismic velocities at D" often interpreted as an increase in density. The reduction of Fe out of the silicates would decrease their density. The addition of SiO_2 to the silicates from the oxidation of Si in the metal would increase the perovskite portion of the silicate, and at the pressure of the core-mantle boundary perovskite is less dense than magnesiowüstite (Chopelas and Boehler, 1992). Thus, a reaction between a Si-rich core and the mantle would decrease the density of the silicate in comparison to the overlying mantle in contrast to what is seismologically observed.

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