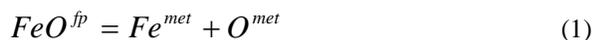


**EFFECT OF SILICON ON THE PARTITIONING OF OXYGEN BETWEEN LIQUID IRON METAL AND SILICATE LIQUID.** K. Tsuno<sup>1,2</sup>, D. J. Frost<sup>1</sup> and D. C. Rubie<sup>1</sup>, <sup>1</sup>Bayerisches Geoinstitut, Universität Bayreuth, Universitätsstrasse, Bayreuth, 95440, Germany, <sup>2</sup>Department of Earth Science, Rice University, 6100 Main Street, MS-126, Houston, TX, 77005, USA (Kyusei.Tsuno@rice.edu).

**Introduction:** Planetary cores potentially contain significant concentrations of light elements. For example, the Earth's core is known to contain up to ~10 wt% of one or more light elements [1, 2], with O and Si being potential candidates. It is likely that light-element concentrations were fixed through equilibrium between liquid silicate and Fe alloy during core formation. In addition, in order to understand reactions at the core-mantle boundary (CMB), it is necessary to estimate the proportions of oxygen and silicon in the Earth's core. Here we present new experimental results and thermodynamic models that enable the partitioning of oxygen and silicon between liquid metal and liquid silicate during core formation to be quantified.

**Experiments:** High-pressure experiments were performed in order to determine experimentally the partitioning of oxygen and silicon between liquid Fe-alloy, ferropicriolite, and liquid silicate as a function of pressure, temperature and composition. The experiments were performed in a multianvil apparatus at 25 GPa and 2773-3300 K. The sample assembly used in this study is shown in Fig. 1. For generating temperatures up to 3300 K, a ZrO<sub>2</sub> sleeve usually used for thermal insulation was removed because reaction between ZrO<sub>2</sub> and the LaCrO<sub>3</sub> heater causes temperature instabilities [3]. Temperature was measured using a W97Re3-W75Re25 thermocouple, and high temperature was further calibrated by melting MgSiO<sub>3</sub> enclosed in a Pt capsule at 25 GPa. Starting compositions were mixtures of Fe powder and (Mg,Fe<sub>0.18</sub>)SiO<sub>3</sub>, enclosed in single crystal MgO capsules. Run products were imaged using scanning electron microscopy, and were analyzed for Mg, Fe, Si, and O using an electron microprobe.

**Results and discussion:** The resulting phase assemblage was composed of liquid metal alloy, ferropicriolite, and silicate melt (Fig. 2). The partitioning of oxygen between liquid metal alloy (*met*) and ferropicriolite (*fp*), is described by the reaction:



for which the distribution coefficient  $K_d$  is defined as

$$K_d = \frac{X_{Fe}^{met} X_O^{met}}{X_{FeO}^{fp}} \quad (2)$$

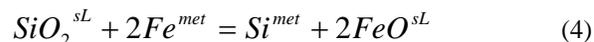
where  $X$  is molar concentration.

Our results show that the presence of Si dissolved in liquid Fe has a very large effect in reducing the concentration of oxygen in this phase (Fig. 3), compared with the results of earlier studies of oxygen partitioning in Si-free systems using both multianvil and diamond-anvil cell techniques [3, 4]. We can describe the results using a thermodynamic model in which the activity coefficient for O in liquid metal alloy is expressed by

$$\begin{aligned} RT \ln \gamma_O^{Met} = & x_{Si}^2 [W_{FeO-Si} + 2x_{FeO} (W_{Si-FeO} - W_{FeO-Si})] \\ & + x_{Fe}^2 [W_{FeO-Fe} + 2x_{FeO} (W_{Fe-FeO} - W_{FeO-Fe})] \\ & + 2x_{FeO} x_{Si} x_{Fe} (W_{Si-FeO} + W_{Fe-FeO}) \\ & + x_{Si} x_{Fe} [0.5(W_{Fe-FeO} + W_{FeO-Fe} + W_{FeO-Si} \\ & + W_{Si-FeO})](1 - 2x_{FeO}) \end{aligned} \quad (3)$$

where the interaction parameters are  $W_{FeO-Si} = W_{Si-FeO} = 4.23 * 10^5 (J / mol)$ . Other interaction parameters are described in Frost et al. [4].

The partitioning of Si between liquid metal alloy and silicate liquid (*sL*) is described by the reaction:



for which the distribution coefficient is defined as

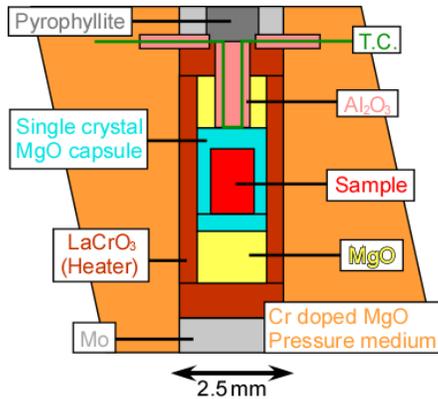
$$K_d = \frac{[X_{Si}^{met}][X_{FeO}^{sL}]^2}{[X_{SiO_2}^{sL}][X_{Fe}^{met}]^2} \quad (5)$$

Our results, combined with published diamond-anvil cell data obtained up to 140 GPa [5, 6, 7], show that the partitioning of Si into liquid Fe-alloy increases strongly with temperature and decreases weakly with pressure (Fig. 4).

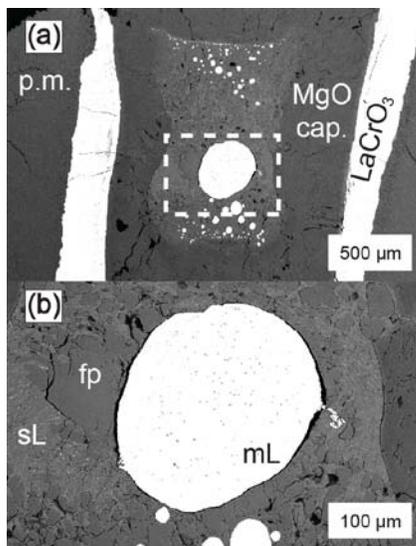
By combining thermodynamic models for the partitioning of oxygen and silicon between liquid Fe and silicate, we conclude that Si is most likely the dominant light element in the Earth's core, with the concentration of oxygen being very low. By modeling metal-silicate reaction at the core-mantle boundary, we show that the Earth's core is undersaturated in both oxygen and silicon with respect to the bulk composition of the mantle.

Consequently, the very base of the mantle could be strongly depleted in both SiO<sub>2</sub> and FeO.

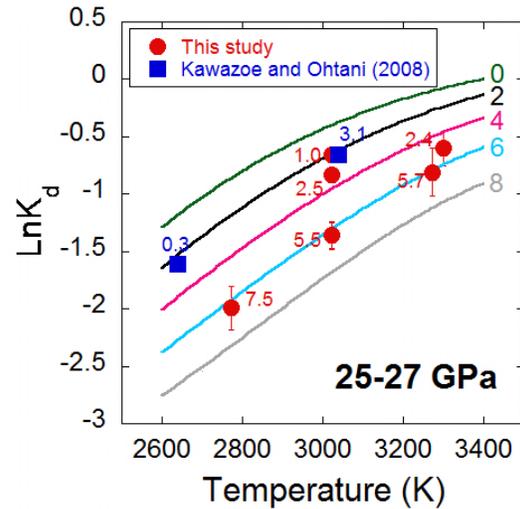
**References:** [1] Birch F. (1952) *JGR*, 57, 227–286. [2] Anderson O.L. and Isaak D.G. (2002) *PEPI*, 131, 19–27. [3] Asahara Y. et al. (2007) *EPSL*, 257, 435–449. [4] Frost D.J. et al. (2009) *JGR*, in press. [5] Takafuji N et al. (2005) *GRL*, 32, L06313, doi:10.1029/2005GL022773. [6] Kawazoe T. and Ohtani E. (2006) *PCM*, 33, 227–234. [7] Mann U. et al. (2009) *GCA*, 73, 7360–7386.



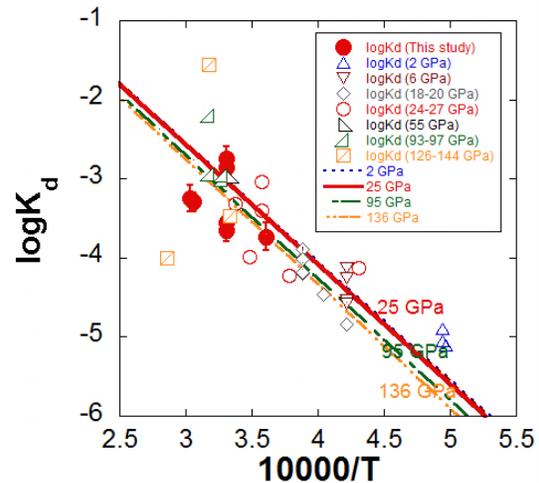
**Fig. 1.** Cross section of the multi-anvil cell assembly.



**Fig. 2.** (a) BSE image of a run product quenched from 25 GPa and 3023 K. “MgO cap.” and “p.m.” indicate the single crystal MgO capsule and Cr-doped MgO pressure medium, respectively. (b) A magnified image of the region surrounded by the dashed line in (a). mL, fp and sL indicate liquid metal alloy, ferropericlasite, and silicate liquid, respectively.



**Fig. 3.** The distribution coefficient for the partitioning of oxygen between ferropericlasite and liquid Fe metal. Numerals indicate the concentration of Si in mole per cent. The experimental data are from this study and [6], and fitted thermodynamic models are from this study



(Eq. 3) and Frost et al. [4].

**Fig. 4.** The Si distribution coefficient showing partitioning between liquid Fe metal and silicate liquid as a function of temperature. Data are from this study, and [5, 6, 7].