Melting in the Fe-Si System at High Pressures and Temperatures

MR13A-0991

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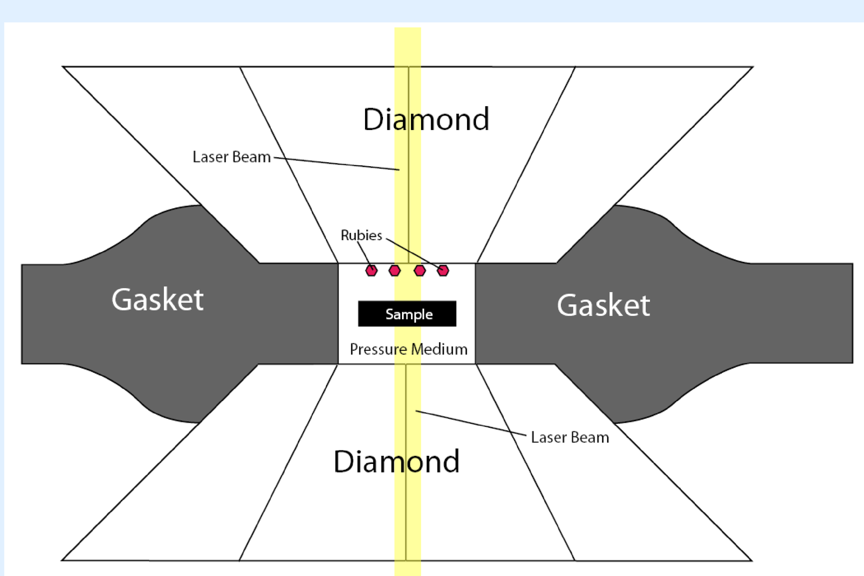
Introduction

The Earth's core consists mainly of iron and nickel with several weight percent of a light element. Geochemical and cosmochemical constraints suggest Si as a strong candidate for this light element contribution. Therefore it is important to understand the phase diagram, including melting relations, in the Fe-Si binary at high pressures and temperatures. We have conducted melting experiments in the Fe-Si system using double-sided laser heating with a new method for temperature measurement in diamond anvil cells.

Diamond Anvil Cell Methods

Fe-Si alloys with compositions of 9 wt% Si and 16 wt% Si were flattened to ~10 µm. A flake of the material was then loaded into the sample chamber between two layers of either NaCl or KBr. These salts acted both as a pressure medium and as an insulator. The sample chamber inside the steel gasket was ~100 µm in diameter. Grains of ruby were added to the sample chamber to measure pressure by ruby fluorescence. Laser heating was performed from both sides to minimize the axial temperature gradient. A cross-section of the loaded cell is shown below.



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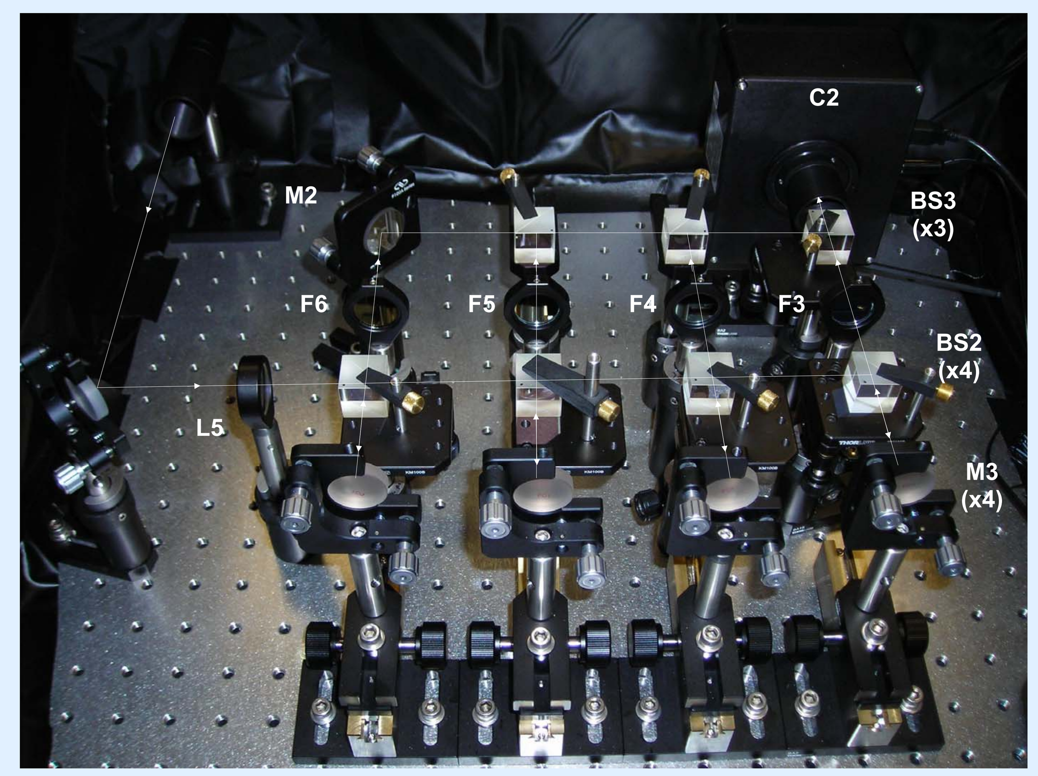
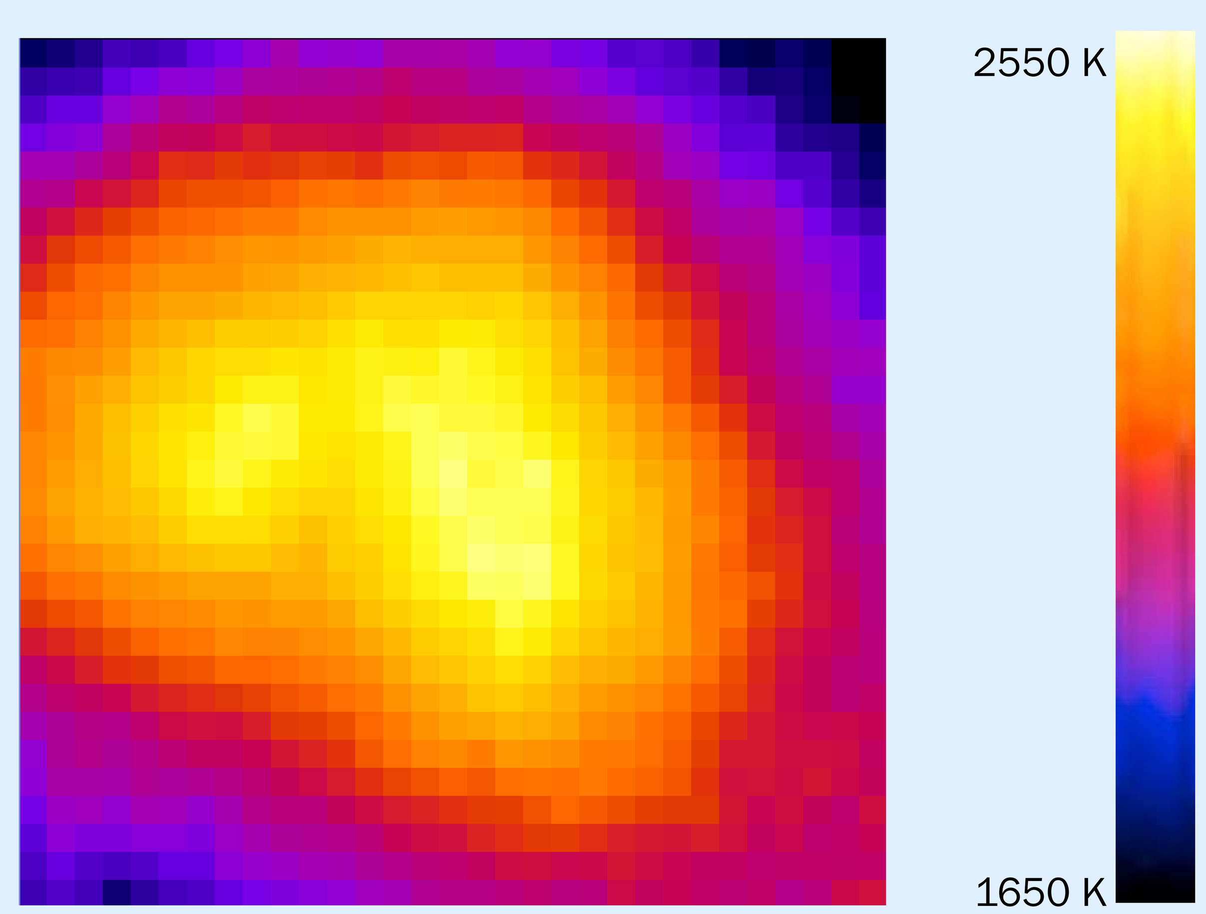
Temperature Measurement

Two dimensional temperature measurements were obtained using the method described by Campbell (2007). Thermal emission images of the sample were split four ways, and each was filtered to a different spectral band, centered at 670 nm, 750 nm, 800 nm and 900 nm. Each monochromatic image was focussed independently onto a CCD camera that captured all four images simultaneously. The optical path is shown in the photograph below.



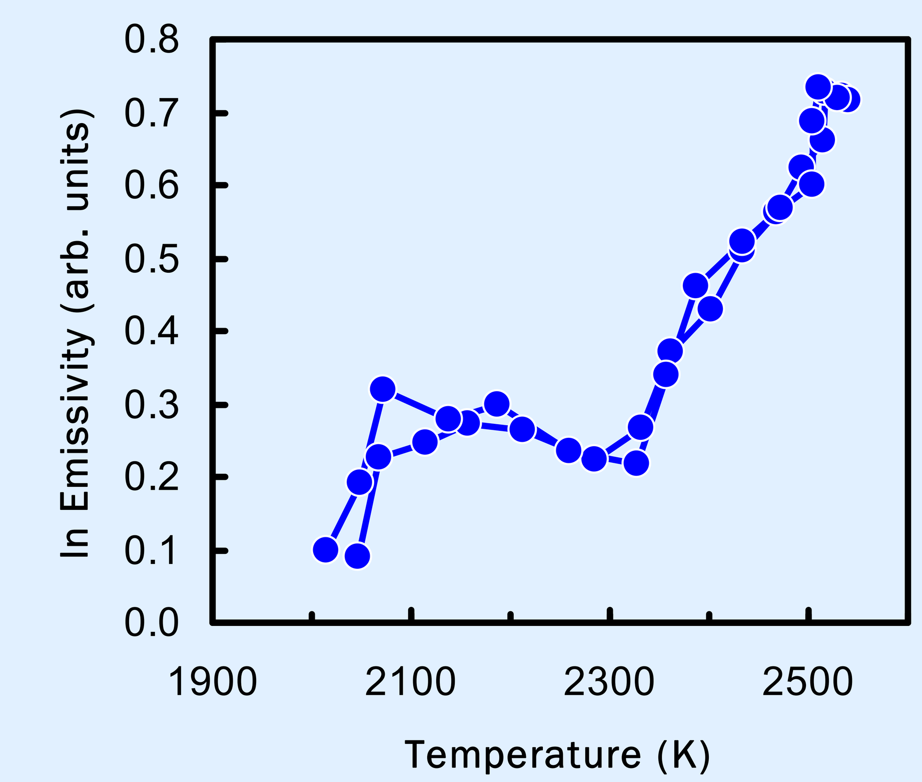
The four images were intensity-calibrated and correlated spatially, interpolating between adjacent pixels for highest spatial precision. The images from sample N38-4 are shown below.

Four-color temperatures were then calculated from each set of spatially correlated pixels by fitting the intensities to the Planck function (Heinz and Jeanloz, 1987). In this way, a two-dimensional temperature map of the laser-heated sample was constructed. Additionally, the relative emissivity of the sample was obtained from the fitted function. The temperature map for a sample N38-4 at 21.8 GPa is shown below. The image is 24 µm square.



Results

Phase transitions can produce changes in the optical properties of the sample. Below is a vertical transect showing emissivity vs. temperature across the same laser-heated spot shown at left. The kink in the graph at 2325 K is interpreted as a phase change, in this case melting.



Melting data for Fe-Si alloys obtained using these methods are shown below. Also shown is one melting temperature (highlighted) obtained through standard spectroradiometry over the central 5 µm of the sample. The data compare closely to the 21 GPa melting data of Kuwayama and Hirose (2004), obtained by MAP. For a starting composition of 16 wt% Si, there is approximately a 100 K depression in the melting temperature at 21 GPa relative to the Fe melting curve described by Shen et al. (1998). This is considerably smaller than the measured eutectic depressions of ~200 K in the Fe-O system (Seagle et al., 2007) and ~800 K in the Fe-S system (Campbell et al., 2007).

Melting Temperatures of $FeSi_{9\%}$ and $FeSi_{16\%}$