Self-diffusion in iron alloys at extreme conditions

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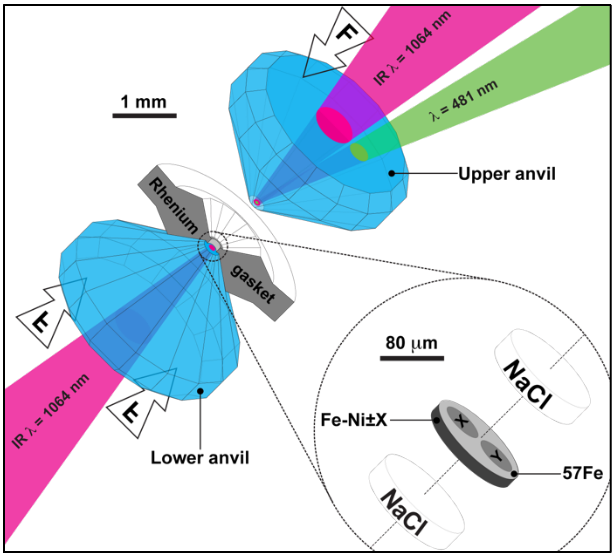

Fig. 1: Cross-section through a self-diffusion experiment on pure iron in a laser heated diamond anvil cell.

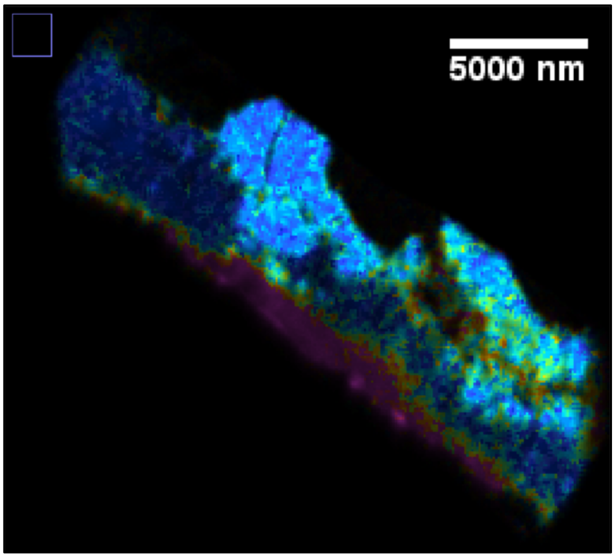

Fig. 2: Secondary-Ion Mass Spectrometry map showing the ratio of $^{57}Fe/^{56}Fe$ ratio in a pure iron sample recovered from 44 GPa and 2200 K.

Project Background

A complete understanding of the rotational dynamics and anisotropic structure of the inner cores of planets and their role in the initiation and maintenance of planetary magnetic fields depends on accurate estimates of the viscosity of iron-rich core alloys at extreme pressures (e.g. 360 GPa for Earth, 40 GPa for Mercury) and temperatures (up to 6000 K). These conditions are only accessible experimentally using laser heating of samples in the diamond anvil cell (Figs. 1 & 2). Current estimates for the viscosity of Earth's inner core, based on *ab initio* computations, the interpretation of seismic data, and measurements extrapolated from the results of experiments performed below 25 GPa range over 10 orders of magnitude and are incapable of being used to choose between competing rheological models for planetary inner cores.

Project Aims and Methods

This project aims to use micro-fabrication to create diffusion couples that are small enough to fit into diamond anvil cells with sample chambers on the order of 100 μm in diameter (Figs. 1 & 2). Discs of pure iron will be laser machined and then coated with isotopically enriched iron using magnetron sputter coating in the School of Earth Sciences, University of Bristol. Samples will be laser heated at pressures up to 100 GPa at precisely controlled temperatures using the cutting-edge laser heating system also available at Bristol. Cross-sections through recovered samples will be extracted using Focussed Ion Beam milling (both at Bristol and in collaboration with Prof. Clark at Macquarie) and diffusion profiles will be measured using a combination of nano-scale Secondary Ion Mass Spectrometry (nano-SIMS) at the NERC Ion Microprobe facility in Edinburgh and in collaboration with Prof. Clark at Macquarie (Fig. 2). The project will also explore Atom Probe Tomography (APT) as an alternative analytical technique (at the University of Oxford). APT is capable of reconstructing the precise 3-D location and isotopic identity of every atom within a micron scale sample and has the potential to yield very precise diffusion measurements. These techniques also provide opportunities for measuring chemical interdiffusion between iron and minor and trace elements in planetary cores, including e.g. Ni, S, Si and C.

Candidate

We are looking for a highly motivated candidate from the UK or the EU. The candidate should have a background in either Earth Science, Physics, or Chemistry, preferably to MSc/MSci level. A strong interest in Earth or planetary sciences and a desire to perform precise experimental and analytical work is essential.

Training & Logistics

The successful candidate will spend years 1 & 3 of the PhD in Bristol running and analyzing experiments and years 2 & 4 at Macquarie University, Sydney, Australia, performing additional analyses, constructing models of inner core dynamics based on the experimental results and writing up the findings for publication. The necessary skills for building and performing laser heated diamond anvil cell experiments will be built up through independent study and one-to-one supervision in the lab. Training on the FIB, nano-SIMS and APT equipment will be performed by the experts at those facilities. Attendance of specific lecture courses and workshops will also be encouraged (as required). The student will be expected to present results at national and international conferences and to publish findings in international journals. This will require excellent communication and written skills. In addition, the project will require the development of the skills necessary to analyze, fit and model diffusion data. A working knowledge of geophysics and geodynamics of planetary cores will also be necessary. This will leave the candidate in an excellent position for a career in earth or planetary science, or any field requiring strong analytical and experimental skills.

References / Reading List

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Links
http://www.bristol.ac.uk/earthsciences/courses/postgraduate/
http://www.bristol.ac.uk/earthsciences/people/oliver-t-lord/overview.html

Application deadline: April 2020

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Details of the Bristol Macquarie Cotutelle Programme: https://www.bristol.ac.uk/doctoral-college/partnerships/cotutelle/

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