

Decoding the Mantle's Glue: Grain Boundary Networks and Deep Earth Processes

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Key words:	
Research theme(s):	• Geophysics and Geodynamics • Planetary Evolution and Materials
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP)

Overview

The geological evolution of our planet is tightly linked to deep geodynamic processes, which, themselves, are governed by the physical and chemical properties of the Earth's mantle. Earth's mantle is made up of minerals. Grain boundaries "glue" the mineral together to form rocks. Previous high-pressure experimental studies have shown that rocks exhibit physical properties that deviate from that predicted based on the properties of the minerals that make up the rock, possibly a consequence of the "glue" (Marquardt & Faul, 2018; Wang et al. 2023).

This project is guided by the question: **"What effect does the three-dimensional grain boundary network have on the properties of the mantle?"**

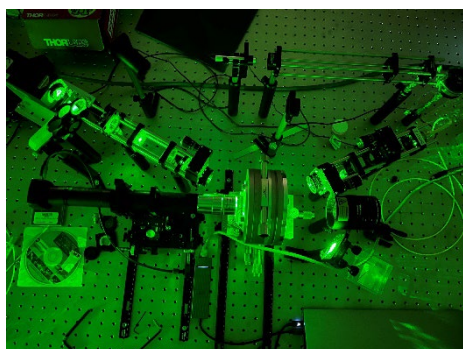


Fig.: (left) Optical laboratory spectroscopy to measure physical properties. (right) The group during Synchrotron experiments

You will study the physical properties of olivine samples, aiming to quantitatively link observed differences to the samples' grain boundary network. The results will facilitate the interpretation of geophysical observables in terms of the structure, dynamics and properties of Earth's deep interior. The results will also impact our understanding of the effects of grain boundaries on advanced ceramics with application for the design of novel materials to be used in a variety of industrial net zero applications, including solid oxide electrolysis cells or battery ceramics.

Methodology

Synthetic sintered olivine samples will be characterized by a variety of techniques available at the Department of Materials in Oxford, including Scanning Electron Microscopy, Transmission Electron Microscopy, Electron Backscatter Diffraction (EBSD). Physical properties at room conditions, as well as at high pressure and temperature, will be characterised by X-ray diffraction at Synchrotron facilities as well as optical Brillouin spectroscopy (e.g. Marquardt & Thomson, 2020). Complementary modelling will be conducted to quantitatively understand the measured material behavior and their dependence on the grain boundary network.

Timeline

Year 1: Literature review, planning of experimental campaigns, application for synchrotron beamtime, introduction to methodology.

Years 2 and 3: Sample synthesis, characterisation and preparation (polishing, FIB, electron microscopy), preparation of diamond-anvil cells, Brillouin spectroscopy, synchrotron experiments (DLS and DESY), data analysis and modelling, presentations at conferences.

Year 4: Data integration, thesis completion, papers for international journals.

Training & Skills

You will benefit from expertise in both Earth Sciences and Materials Sciences. You will be trained in a range of experimental high-pressure techniques (H. Marquardt) as well as grain boundary research and electron microscopy (K. Marquardt). As part of this project you will learn how to use electron microscopy techniques, prepare diamond-anvil cells and conduct high-pressure experiments using different techniques (XRD, optical spectroscopy). You will be trained in how to plan and carry out laboratory as well as synchrotron experiments, using world-leading research facilities. You will also receive learn how to model and interpret data, how to present scientific results, and how to write scientific papers for publication.

References & Further Reading

Marquardt, H. and A. R. Thomson, Experimental elasticity of Earth's deep mantle. *Nature Reviews Earth & Environment* 1(9), 2020: 455-469.

Marquardt, K. and U. H. Faul, The structure and composition of olivine grain boundaries: 40 years of studies, status and current developments. *Physics and Chemistry of Minerals* 45(2) (2018): 139-172.

Wang, B., J. Buchen, A. S. J. Méndez, A. Kurnosov, G. Criniti, H.-P. Liermann and H. Marquardt, Strong Effect of Stress on the Seismic Signature of the Post-Stishovite Phase Transition in the Earth's Lower Mantle. *Geophysical Research Letters* 50(10) (2023): e2023GL102740.

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