Iron-rich orthopyroxene (Opx, nominal composition (Mg,Fe)SiO$_3$) plays a particularly important role in current models of the thermal and magmatic evolution of the Moon. Its crystallization during the solidification of a global lunar magma ocean resulted in a gravitationally unstable mineral stratification in the lunar mantle, eventually prompting a large-scale mantle overturn [1]. The thermal effects associated with this overturn are thought to have led to the formation and eruption of the lunar mare basalts that cover a significant part of the lunar near-side surface. Thermo-chemical models of the Moon’s interior evolution thus require accurate knowledge of the volume ($V$) of Opx as a function of pressure ($P$), temperature ($T$) and composition.

Although many studies have focused on the behaviour of enstatite (MgSiO$_3$) at high pressure, surprisingly, the $P$-$V$-$T$ equations of state of end-member ferrosillite (FeSiO$_3$) have not been determined to date. The topology of the ferrosillite phase diagram equals that of enstatite (MgSiO$_3$), with ortho-ferrosillite stable at high temperature, high-clinoferrosillite stable at high pressure, and low-clinoferrosillite stable near ambient conditions (Fig 1). Physical property determinations of these three polymorphs are very scarce. As a result, both density calculations for Fe-rich orthopyroxene in the lunar interior, and thermodynamic assessments of orthopyroxene phase stability in Earth’s upper mantle are at present poorly constrained.

We have started using synchrotron X-ray diffraction measurements to determine the thermal equation of state of synthetic end member ferrosillite as a function of $P$ and $T$ in the MAX80 multi-anvil press at station F2.1, covering in great detail the $P$-$T$ range under which orthopyroxene is present in the Moon and a significant portion of the conditions relevant to Earth’s mantle. In our first session we successfully collected spectra of both synthetic orthoferrosillite FeSiO$_3$ (pre-synthesised at 2 GPa and 1273 K at VU University Amsterdam) and of natural Fe-rich orthopyroxene, at pressures from ~0.6 to ~4.3 GPa and temperatures from 298 K up to the melting temperature of FeSiO$_3$ (approximately 1623 K at ~4 GPa). Data processing is currently underway, as is detailed sample characterisation to assess the extent of sample alteration (e.g., Fe$^{2+}$ to Fe$^{3+}$ conversion) during the measurements.

Figure 1: FeSiO$_3$ phase diagram, after [2].

References