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High Pressure Far Infrared Spectra of Talc

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Beamline(s): U2A

Introduction: It is well accepted that substantially more water is currently subducted into the Earth's mantle than is released volcanically. Accordingly, it is thought that over time the mantle's water content is increasing, and a very active area of research in the Earth sciences is concerned with the transport and storage of this water. Indeed, on a mass basis, many times the current hydrosphere is likely stored in the solid Earth. Hydrous minerals with stoichiometric water are common constituents of metamorphosed basalt, and are the phases that transport water into the mantle as part of the process of subduction. These minerals intrinsically incorporate hydroxyl groups (OH⁻) or distinct water molecules (H₂O) in their structure. The mantle solidus is depressed by the dehydration of some subduction zone minerals, most notably amphibole at depths between 80 and 100 km, and produces volcanic arcs. However, this does not lead to the complete dehydration of the subducting slab, and it is not known to what depth the remaining hydrous phases are able to transport water.

An extensive experimental literature has been generated to address the high pressure and temperature phase equilibria in metabasalt; however, to fully understand the mantle's water budget it is critical to know the thermodynamic properties of subduction zone minerals. These data include the heat capacity, thermal expansion, bulk modulus and Grüneisen parameters. As part of our ongoing effort to determine these thermodynamic parameters for common minerals in metabasalt we have recently used the U2A infrared beamline at NSLS to collect *in situ* far infrared (FIR) measurements of Mg₆[Si₈O₂₀](OH)₄-talc.

Methods and Materials: For our high-pressure measurements we utilized a diamond anvil cell (DAC), and the synchrotron infrared radiation source to obtain high-quality spectra in a time frame that allowed data collection at many pressure points. The NSLS synchrotron source is coupled to a Bruker FTIR with a custom-built Ar-purged sample chamber. We used a natural talc sample for these measurements. Samples were prepared as a thin film by pressing a powdered sample between the diamond anvils; the thickness of the film was chosen by trial and error so that spectral features could be clearly resolved. Petroleum jelly, which does not absorb in the FIR, was used as a pressure-transmitting medium, and the ruby fluorescence technique was used to measure pressure in all experiments.

Results: Ambient pressure FIR and MIR measurements of this sample agree very well with previous studies (e.g. Farmer 1964). Our FIR spectra at selected pressures on compression and decompression are shown in Figure 1. At ambient pressure we observe four modes in the FIR: 393, 426, 451 and 467 cm⁻¹; these have been previously assigned as predominantly S-O stretching vibrations of the silicate framework (Farmer and Russell 1964). By 2 GPa the mode at an initial frequency of 393 cm⁻¹ (with what appears to be a shoulder on the low frequency side) clearly splits into two modes. At about 4 GPa an additional mode appears at 450 cm⁻¹. All modes increase monotonically with pressure; however between 10 and 20 GPa the intensity of the vibrations near 400 cm⁻¹ diminish and become unresolvable. Substantial peak broadening occurs above 7 GPa, and by 20 GPa the spectrum is dominated by two intense absorption features near 480 and 520 cm⁻¹. At 30 GPa, the highest pressure of this study, an additional weak vibration is observed at 375 cm⁻¹. This peak disappears rapidly upon decompression; indeed, the decompression cycle closely approximates the frequencies upon compression, and the post-compression spectrum is indistinguishable from the pre-compression spectrum.

Conclusions: We reached a maximum pressure of greater than 30 GPa, which corresponds to a depth of approximately 900 km; previous phase equilibria experiments determined high pressure and temperature stability as ~5 GPa and 700°C (Yamamoto and Akimoto 1977). There are gradual, but substantial, changes in intensity and peak broadness. These changes may be largely an artifact of pressure-induced preferred orientation, and the basic silicate framework appears to persist metastably well beyond the known thermodynamic stability limits for this phase.

References:

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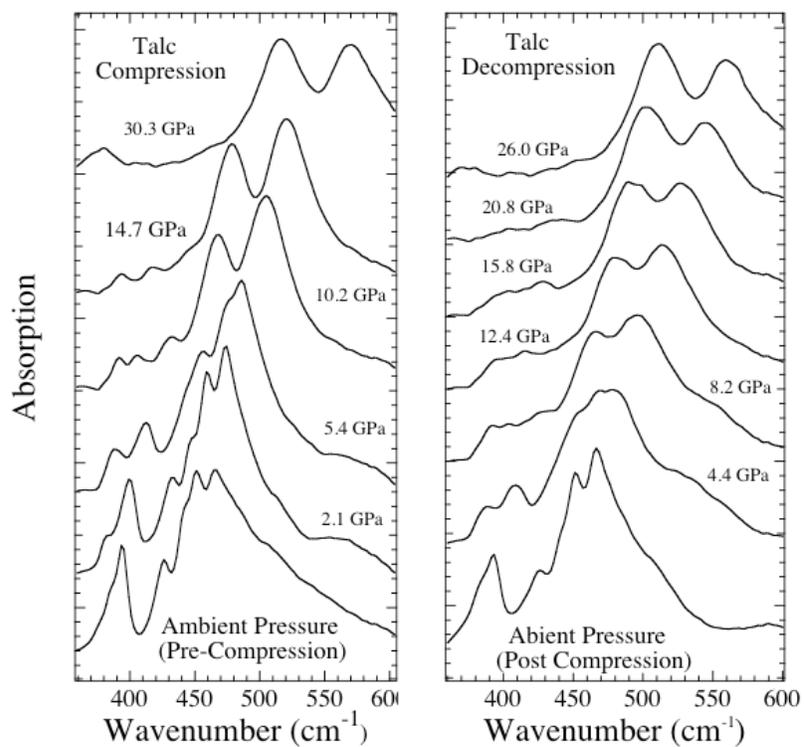


Figure 1. FIR compression and decompression spectra of talc as a function of pressure to 30 GPa. Significant changes in intensity and broadness are observed above 5 GPa, and the spectra are dominated by two intense spectral features above 15 GPa. However, the ambient pressure spectrum is fully reproduced upon decompression.