

Carbon dioxide diffusion in cordierite and beryl: SR-FTIR imaging

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FTIR micro-spectroscopy is an extremely sensitive technique for detecting and analyzing H and C species. Water molecules, hydroxide ions and CO₂ occur frequently in natural materials as major/minor constituents or fluid inclusions, and may have significant role on the physical properties of synthetic minerals or technological materials. The distribution of volatile species may be extremely heterogeneous across the sample, hence the use of focal-plane-array (FPA) of detectors in FTIR experiments has recently proved to be mandatory for the study of light elements. In particular the higher spatial resolution guaranteed by synchrotron light sources has greatly improved the quality of the obtained data, especially in HT/HP experiments ^[1].

In this work we investigate the diffusion of CO₂ in cordierite and beryl using up to date FTIR micro-spectroscopy and imaging techniques. Cordierite and beryls are two isostructural microporous minerals of great geological and technological relevance because their structural channels may contain significant amounts of H₂O and CO₂ ^[2]. The diffusion of CO₂ in cordierite was studied by several authors ^[3, 4], who pointed out the extreme difficulty to reach sample saturation and homogenization. Hence, knowledge of the actual distribution of the volatile molecules across the matrix is crucial to evaluate the diffusion within the minerals.

Experiments were done on CO₂-free cordierite and beryl as starting materials. Single-crystals were treated in CO₂-saturated environment at different pressure, temperature and time conditions using a non end-load piston-cylinder press at INGV (Rome). The run products were previously analyzed via micro-FTIR spectroscopy at INFN-LNF (Frascati) in order to quantify the CO₂ content and its distribution across the sample. Preliminary data showed that pressure plays a major role in diffusing gaseous CO₂ across both cordierite and beryl, whereas the effect of temperature is less pronounced. High-resolution FPA (focal-plane-array of detectors) SR-FTIR imaging was done at beamline B22, Diamond laboratory (Oxford, UK). The data showed that the diffusion of CO₂ occurs exclusively along the structural channels, parallel the crystallographic c-axis direction. Notably, sample cracks formed during the experiments enhanced the gas diffusion; measured CO₂ contents along these cracks are even 4 times higher.

Several CO₂-rich natural cordierite samples were heat-treated up to 1200 °C using a 1400XY Linkam heating stage to investigate the rate of CO₂ loss as a function of temperature. Step-heating experiments on oriented cordierite slabs showed that the process of CO₂ loss starts at around 800 °C and is strongly dependent on the grain size and sample thickness. Modeling of quantitative data using the classical diffusion equations ^[5] revealed that the CO₂ loss at ambient pressure is a slow process with activation energy of about 200 kJ/mol.

References

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