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Mapping the distribution of volatiles (NH_3, OH, H_2O, CO_3, SO_4) at nano-lengthscales: From cratonic to subduction zone settings

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Photo-Induced Force Microscopy (PiFM) is a nanoanalytical technique that combines atomic force microscopy (AFM) topographic imaging with infrared (IR) phase identification. Unlike conventional phase identification methods, which are constrained by the diffraction limit of light (250–300 nm), PiFM leverages attractive forces between a sample surface and a sharp AFM cantilever tip to achieve a spatial resolution of ~5 nm [1, 2]. In PiFM, a tunable IR laser is focused onto a metal-coated AFM tip. The interaction between the sample and the tip generates a photo-induced force (PiF), which directly correlates with the sample's absorption strength. By sweeping the laser across wavenumbers, a PiF-IR spectrum is obtained [2].

Here, we showcase the application of PiFM in petrology, a field that greatly benefits from nanoscale phase identification, particularly for investigating grain boundaries and identifying phases at the nanoscale. We analyzed both crystalline and amorphous phases from natural and experimental petrological samples across a wide range of compositions.

PiFM enables high-resolution investigation of chemical zonation in minerals as well as determination of volatile species (Fig. 1) [3–5]. In addition, in high-pressure experiments, volatile-bearing melts rarely quench to glasses; instead, they form mats of nanoscale crystals during cooling, making conventional analysis challenging. With its unparalleled spatial resolution, PiFM allows precise identification of these quench phases, which are otherwise obscured by the larger spot sizes of traditional spectroscopic techniques [6].

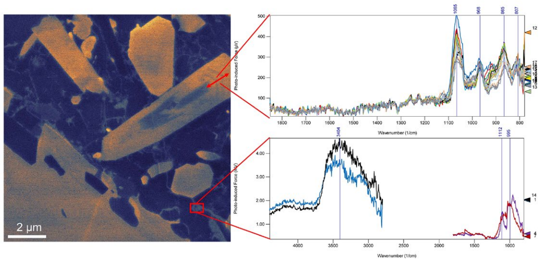

Figure 1: A PiFM map reveals clinopyroxene (yellow) embedded in volcanic glass (dark blue). Spectra collected along a transect across the clinopyroxene highlight growth zonation, with variations in the four absorption bands corresponding to the observed zonation. Additionally, spectra from the glass region were analyzed for water content, showing a strong OH absorption band at 3400 cm^{-1}.

References

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