

Photo-induced Force Microscopy: a novel AFM-based nano-IR method for phase identification on the nano-scale

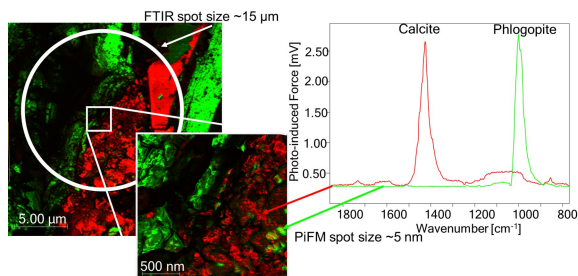
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Infrared Photo-Induced Force Microscopy (IR PiFM) is a novel nanoanalytical technique that enables the simultaneous acquisition of AFM topographic information with IR phase identification. While the resolution of other phase identification techniques is limited to 250-300 nm by the diffraction limit of light, PiFM utilises the attractive forces between the sample surface and a sharp cantilever tip mounted to a highly sensitive AFM to increase the spatial resolution to ~5 nm. In IR PiFM, a tunable IR laser (spectral range of 770 to 1900 cm⁻¹) is focused onto a metal-coated AFM tip to create a tip-enhanced field at the apex of the tip. The sample interacts with the tip-enhanced field and generates a photo-induced force (PiF) that correlates with the sample's absorption strength. By recording the strength of the PiF signal as the laser is swept over a range of wavenumber, PiF-IR spectra are generated that agree well with FTIR spectra, thus allowing the use of FTIR database for phase identification [1]. In addition to the acquisition of individual phase spectra, PiFM also enables mapping with ~5 nanometre spatial resolution, well beyond the capabilities of FTIR microscopy.

Here we present applications of PiFM to samples from experimental petrology, a research field that hugely benefits from nano-scale phase identification due to small samples sizes. We studied various crystalline and amorphous phases from high-pressure experimental run products with mafic to silicic and carbonatitic compositions. Volatile-bearing melts in high-pressure experiments rarely quench to glasses, commonly consisting of mats of extremely small crystals formed during cooling at the end of the experiments, making analysis of melts difficult. Due to its unmatched spatial resolution, PiFM finally opens a window for the identification of these micron- to nanoscale quench phases that are obscured by the larger spot sizes of conventional spectroscopic methods (see figure).

In addition to phase identification, we present data on the speciation of light volatile elements in minerals and glass [2], which have also become more accessible in small samples with PiFM.

References

- [1] Nowak et al., (2016). *Science Advances*, 2(3), e1501571.
- [2] Otter et al., (2021). *Geostandards and Geoanalytical Research*. 45(1), 5-27.