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Micro-FTIR imaging using a focal plane array detector: An advanced method for the investigation of H_2O and CO_2 diffusion processes in silicate melts

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The detection of concentration gradients of volatiles like H_2O and CO_2 in volcanic glasses is essential for the quantification of diffusion processes in corresponding silicate melts. Micro-FTIR imaging with a focal plane array (FPA) detector can provide detailed information on the spatial distribution of H_2O and CO_2 in the sample. The FPA detector consists of 64x64 detector elements (pixels) and allows the simultaneous recording of 4096 individual spectra in the range of 3900-950 cm^{-1} within one measurement (frame) at a spatial resolution of a few microns per detector element. Multiple frames can be stitched together (FPA mapping) to cover large sample areas. The spectral range includes the fundamental OH-stretching vibration and the H_2O-bending vibration as well as the vibrations of molecular CO_2 and of CO_3^{2-}.

First FPA measurements were performed on glasses of CO_2 diffusion couple experiments for the determination of total CO_2 concentration distance profiles and compared to measurements with a common single element (SE) detector. The profiles were obtained with an infrared microscope with a 15x objective in transmittance mode, covering a maximum sample area of 170x170 μm. A digitally controlled, motorized stage facilitated mapping across the sample.

In SE mode, spectra were recorded using a knife-edge aperture of 15x170 μm with the short side length parallel to the diffusion direction. The measurements were performed in steps of 10 μm in the direction of CO_2 diffusion. In the resulting spectra the areas of the CO_2 or CO_3^{2-} absorption bands were used as a measure of total dissolved CO_2 content in the glass. The diffusion coefficients $D_{CO_2,total}$ were determined by a Boltzmann-Matano analysis of each concentration distance profile. In comparison to the SE method, FPA mapping (if limited to the direction of CO_2 diffusion) results in 64 parallel, gapless concentration profiles. Sample characteristics like cracks and bubbles can be imaged sharply and resulting profiles can be corrected in length.

For both methods the calculated diffusion coefficients are within the error, though FPA measurements reveal a trend towards slightly lower D-values. This might be due to the higher resolution, because more data points are available for profile length corrections and analysis. Compared to the SE method, the measurements with the FPA detector are not only faster, but also more accurate. This method is therefore suitable to study diffusion processes over a relatively short distance and has e.g. also the potential to elucidate the process of diffusive bubble growth of sufficiently sized bubbles or early fractionation processes of CO_2 and H_2O in degassing silicate melts.