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A microfluidic flow-through reactor for combined chemical and optical analysis of mineral dissolution under conditions relevant to enhanced weathering.

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Enhanced weathering by mineral carbonation is a promising approach for large-scale carbon sequestration. However, secondary layer formation (passivation) during carbonation significantly reduces reaction rates, limiting the method's efficiency [1-3]. The mechanisms and kinetics that control passivation layer formation remain poorly understood, in part due to the lack of experimental tools capable of simultaneously measuring reaction kinetics and performing optical surface analysis. This challenge is particularly relevant to subsurface- and ex-situ carbonation, where temperature and pressure influence fluid composition and consequently, reaction rates.

To address this gap, we present **a microfluidic flow-through reactor** made from silicon and glass designed to: (i) withstand **high-pressure** and **high-temperature** conditions of at least 225°C and 185 bar, simulating subsurface and ex-situ conditions; (ii) enable measurement of dissolution rates via elemental analysis of the effluent with **one-minute time resolution**; and (iii) provide **optical access** for live observation of mineral surfaces and potentially, the onset of passivation, using common microscopy techniques like fluorescence, dark-field and polarization microscopy.

These combined features ensure that our system meets the key requirements outlined in the first paragraph: the simultaneous measurement of reaction kinetics and optical surface analysis under carbonation conditions. Additionally, prior studies using an unusually high sampling rate of once per five minutes revealed oscillatory fluxes of dissolving ions, suggested to be driven by a dissolution-reprecipitation process [4]. By improving the time-resolution to once per minute, our system may more precisely identify the onset and progression of this process, resulting in a better understanding of its kinetics and its relation to surface passivation.

With this approach, we aim to generate higher time resolution dissolution data coupled with optical imaging of the dissolution process to capture transient processes like secondary layer formation more accurately. Ultimately, a better understanding of these short-timescale processes could help bridge the gap between laboratory experiments and large-scale field applications, bringing enhanced weathering closer to practical implementation.

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