Lab on a Chip

Supplementary Information

A microfluidic chip equipped for geoelectrical monitoring of the critical zone processes

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1 Quality assessment of the chip for SIP acquisition

To examine the compatibility of the microfluidic chip with SIP acquisition, we perform measurements on the channel saturated with sodium chloride (NaCl) solution, a non-polarizable medium, for which one expects a flat in-phase conductivity spectrum at a value corresponding to the brine conductivity σ_w and a quadrature conductivity spectrum at zero for all the frequency range. We used two different NaCl concentrations: 10^{-3} and 10^{-1} mol L^{-1}, displayed in black and red on Fig. 1, respectively. From plots of the in-phase conductivities σ' (Fig. 1a), there is a good agreement between the SIP values and the measured σ_w of the corresponding saturating brine. The plots of the quadrature conductivities (Fig. 1b) show values close to zero, except for 10^{-1} mol L^{-1} NaCl at the highest frequencies. These high-frequency non-zero quadrature conductivities are low compared to the in-phase conductivity values and originate from small dielectric effects at the electrode-electrolyte interface (Abdulsamad *et al.*, 2016). These results show that the microscale electrode array enables SIP acquisition with accurate measurements of the in-phase conductivity and low polarization effects.

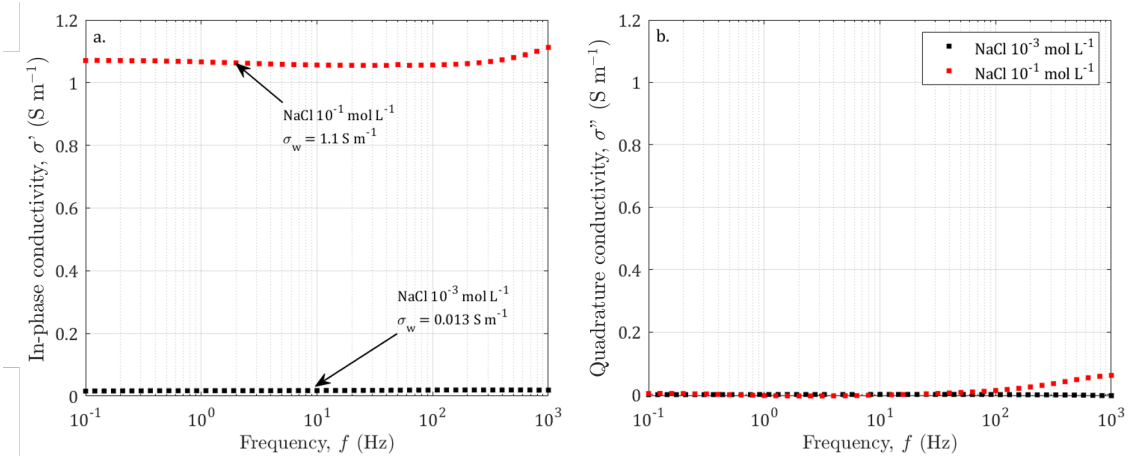

Figure 1: Complex electrical conductivity spectra of the microfluidic chip saturated with brine. (a) the in-phase conductivity and (b) the quadrature conductivity.

To fully evaluate these values quantitatively the results of the phase angle are also plotted on a log scale in Fig. 2. The phase angle shows acceptable results (Kremer *et al.*, 2016). Even if there is some dispersion below 100 Hz, the values are much smaller than the phase angles measured during the dissolution of the calcite crystal.

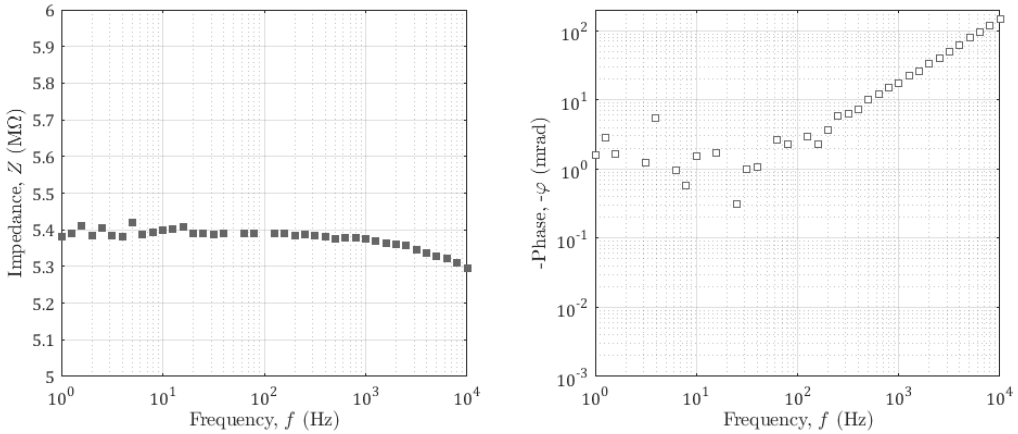

Figure 2: Complex electrical conductivity spectra of the microfluidic chip saturated with brine. (left) the impedance and (right) the phase angle.

2 Video of the calcite dissolution

The video is available online. The video is set with 21 images per second. The microscope magnification is set to ×5. The channel is oriented vertically in the video and the acid solution flows from the bottom to the top of the image. The width between the left and right borders has a length of 1.5 mm.

3 The SIP data

To offer a complete visualization of the SIP dataset, we represent all the values on in-phase and quadrature components on spectrograms. This representation is not classical for SIP data but is inspired by passive seismic monitoring. It has the advantage to present each in-phase and quadrature conductivity value with its unique frequency and time coordinates without superimposing with others. Compared to the selected spectra displayed in the main text, the time discretization is more accurate with a noticeable time shift from high frequencies toward low frequencies because of the required time of acquisition. The vertical black lines correspond to the reported times of interest presented in the main text. This representation enables to show the direct impact of the running processes on the electrical acquisition. The impact on the SIP signal is even remarkable within a spectrum acquired over a time period covering the events at times t_0, t_6, and t_f, corresponding to the HCl arrival between the electrodes, the brutal detachment of the large bubbles, and the end of the dissolution, respectively.

References

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T. Kremer, M. Schmutz, A. Maineult and P. Agrinier, *Geophysical Journal International*, 2016, **207**, 1258–1272.

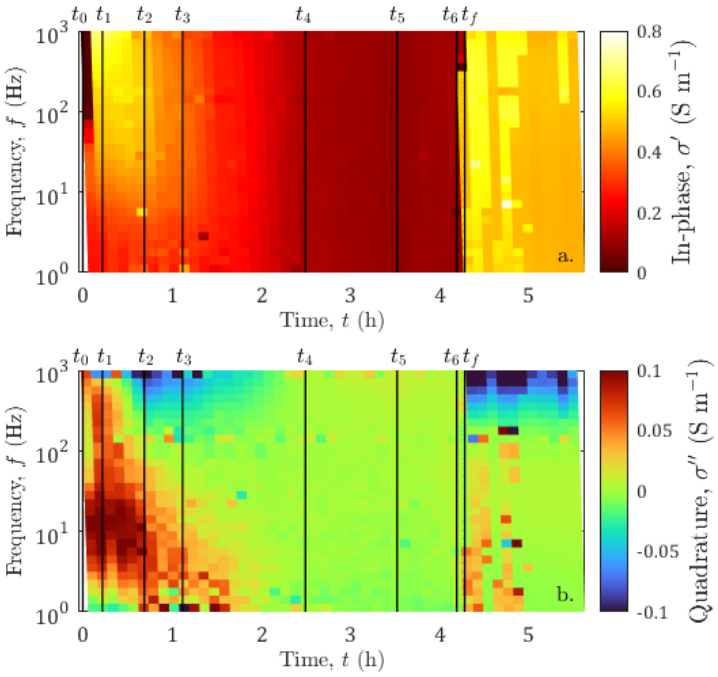

Figure 3: Complex electrical conductivity spectrograms of (a) the in-phase conductivity and (b) the quadrature conductivity for the entire dissolution experiment. Times of interest are labeled as vertical black lines.