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Supplementary Material

UNDERSTANDING FRACTURE APERTURE AND PERMEABILITY EVOLUTION DUE TO CARBONATE MINERALIZATION UTILIZING 3D PRINTING

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1. METHODOLOGY FOR CALCULATING SURFACE ROUGHNESS PARAMETER

For quantitative comparison, the following surface roughness parameters were utilized which are in accordance with ISO 25718-6 (2) and ASME B46.1 (1).

S_a, *Areal average surface roughness:* The arithmetic average of the absolute values of the profile height deviations recorded within the evaluation length or evaluation area and measured from the mean line. Analytically S_a can be calculated using the following equation (**Eq. S1**) where N and M represent the number of array sizes in the evaluation direction.

$$S_a = \frac{1}{MN}\sum_{k=1}^{M}\sum_{j=1}^{N}|Z_{jk}| \tag{S1}$$

S_{sk}, *Skewness:* Skewness is the quotient of the mean cube value of $Z(x)$ and the cube of the root means square roughness or ($S_q = \sqrt{\frac{1}{MN}\sum_{k=1}^{M}\sum_{j=1}^{N}|Z^2{}_{jk}|}$) within a sampling length. If $S_{sk} = 0$, symmetric against the mean line (e.g. normal distribution). If $S_{sk} > 0$, the deviation is beneath the mean line, or else if $S_{sk} < 0$, the deviation is above the mean line. A negative skewness means the surface has more valley depths than peak heights (**Eq. S2**).

$$S_{sk} = \frac{1}{(S_q)^3}\frac{1}{MN}\sum_{k=1}^{M}\sum_{j=1}^{N}|Z^3{}_{jk}| \tag{S2}$$

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S_{ku}, *Kurtosis:* The quotient of the mean quartic value of $Z(x)$ and the fourth power of S_q within a sampling length. In other words, if $S_{ku} = 3$, it is similar to a normal distribution, if $S_{ku} > 3$ the height distribution is sharp, and if $S_{ku} < 3$ the height distribution is flatter (**Eq. S3**).

$$S_{ku} = \frac{1}{(S_q)^4}\frac{1}{MN}\sum_{k=1}^{M}\sum_{j=1}^{N}|Z^4{}_{jk}| \quad \text{(S3)}$$

S_{dr}, *Developed interfacial area ratio:* The developed interfacial area ratio is categorized as surface texture parameters. It quantifies how much surface area in a particular region of interest contributes to the texture compared to a nominally flat surface. Basically, it is the percentage of surface area that the surface texture adds to an ideal smooth and flat surface of the same cross-sectional area as the measurement region (**Eq. S4**).

$$S_{dr} = \frac{(Surface\ area\ with\ texture) - (Ideally\ smooth\ surface\ area)}{(Ideally\ smooth\ surface\ area)} \quad \text{(S4)}$$

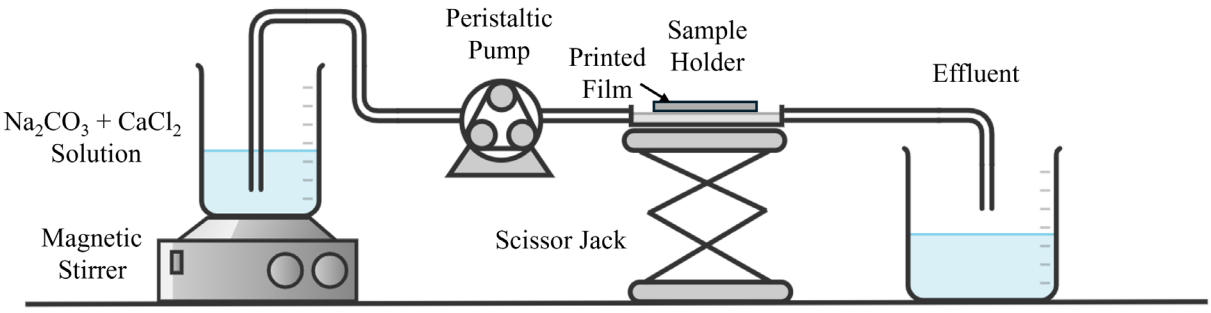

Figure S1: Experimental setup for 2D film calcite precipitation.

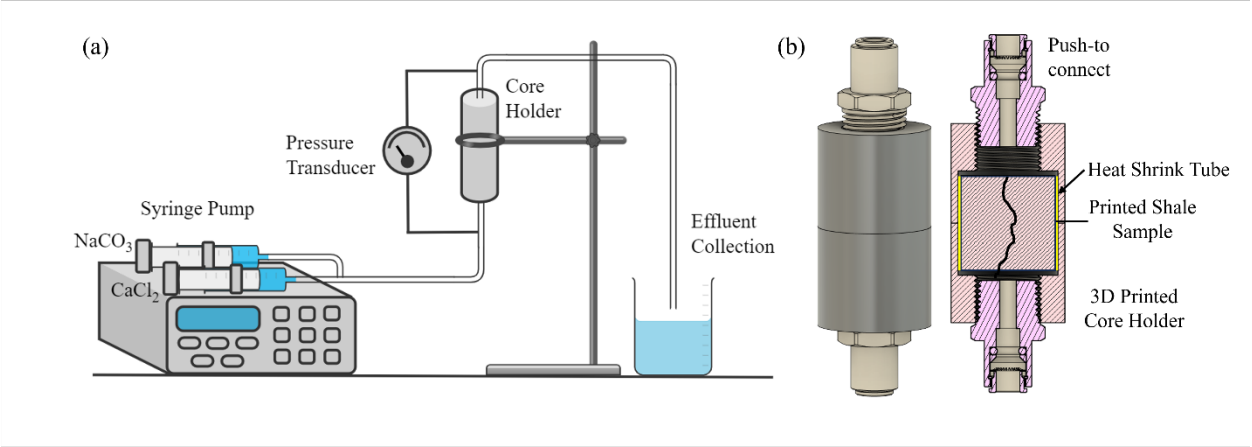

Figure S2: (a) Experimental setup for plug flow column calcite precipitation experiment, **(b)** 3D printed core holder and the cross-section.

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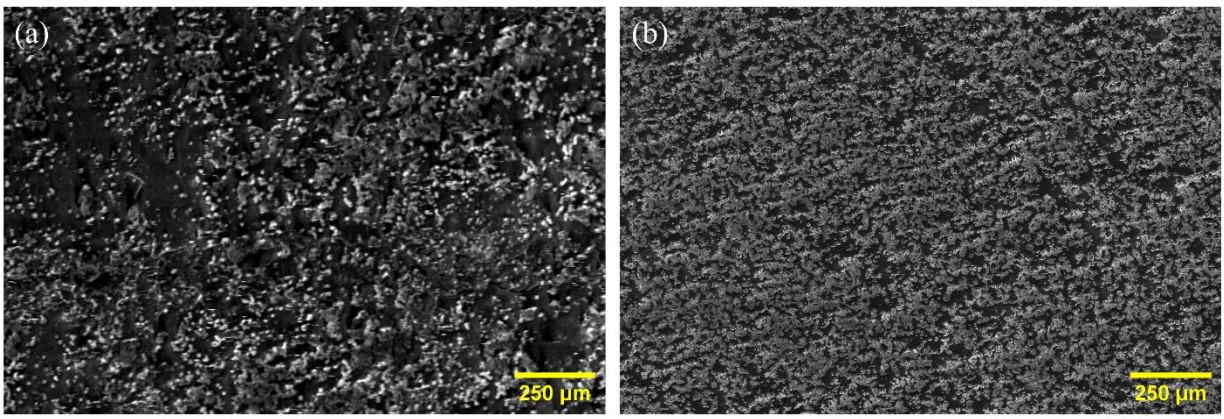

Figure S3: SEM image of calcite precipitation on DLP fabricated 2D films after **(a)** 4-hour flow experiment and **(b)** 24-hour flow experiment.

References

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