Microfluidic study of salt crystallization in porous media

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Introduction

Salt crystallization is one of major sources of damage in building materials [1]. To effectively prevent this problem, it is crucial to comprehend the underlying salt crystallization mechanisms in porous media [2].The evolution and growth of salt crystals can significantly control the hydraulic properties of the porous media. To investigate the underlying mechanisms, we use microfluidics to directly observe how salt crystal grows and affects the morphology of pore space. The use of micromodel allows one to directly observe the formation, growth, and morphology of salt crystals [3].

Materials & method

Microfluidic: A homogeneous microfluidic, as shown in **Fig. 1** is chosen for the experiments. The initial porosity of the micromodel is 0.41 .

Salt solution: Fresh NaCl brine solution with a concentration of 26.9 wt% (75% below the saturation concentration of 36 wt%) was prepared as required for this study. The 8-Hydroxypyrene-1,3,6-trisulfonic acid trisodium salt (HPTS) dye (H1529-1G, Sigma-Aldrich) was added to the brine solution for easier phase differentiation.

Experimental procedure: The micromodel was initially vacuum saturated with the fluorescent brine solution (Fig. 1). A partially dry air (Fig. 2) with a flow rate of 100 standard cubic centimetre per minute (sccm) was injected through a channel in the right side of the micromodel matrix (Fig. 1) using a humid air generator (GenRH-T, Surface Measurement Systems, UK). , Fig. 3 shows a photograph of the experimental setup. The raw images were captured by a Zeiss microscope and recorded by a computer. The experiment was terminated after about 90 minutes of air injection. The final state of the micromodel was studied using a KENENCE digital and a Nikon confocal microscopes.

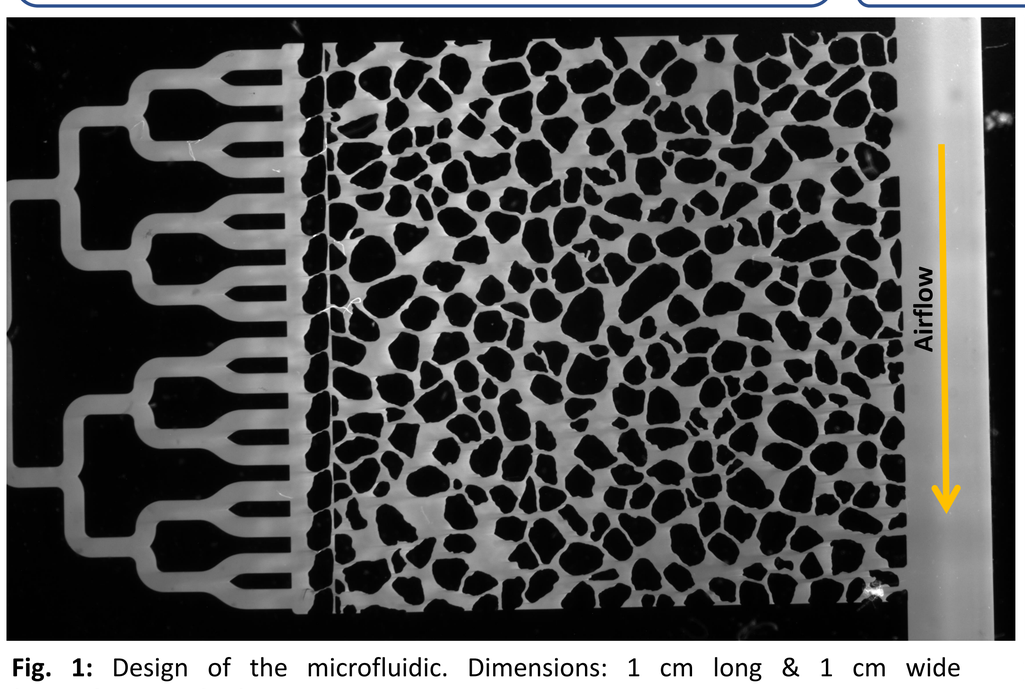


Fig. 1: Design of the microfluidic. Dimensions: 1 cm long & 1 cm wide (magnification of 7x).

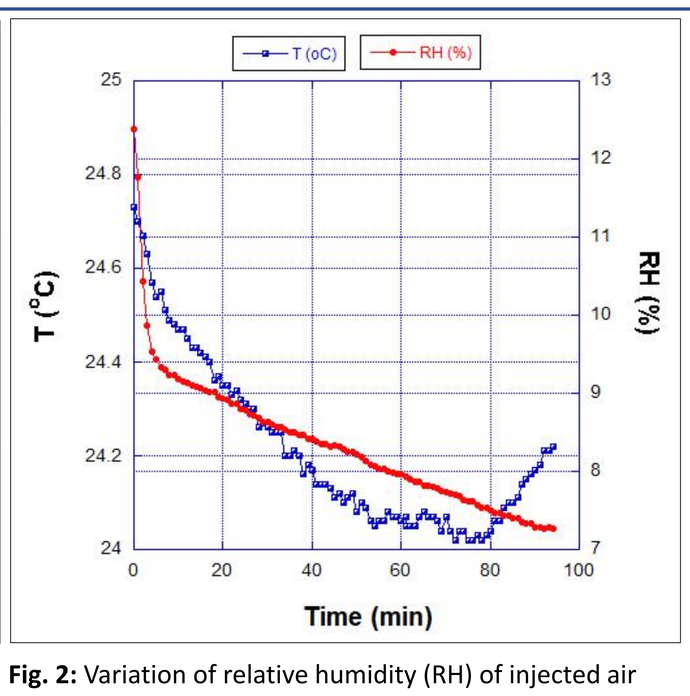


Fig. 2: Variation of relative humidity (RH) of injected air and temperature (T) over time.

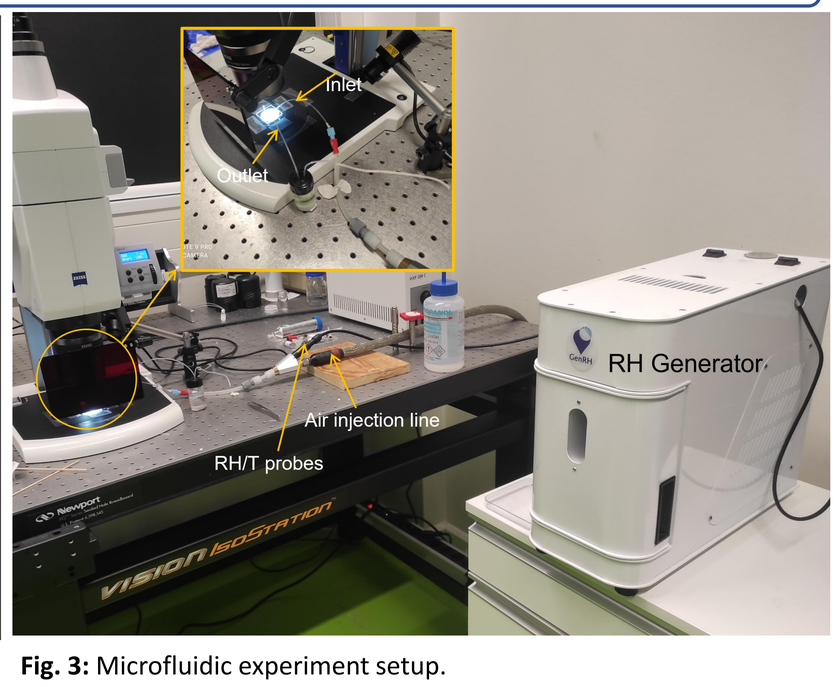
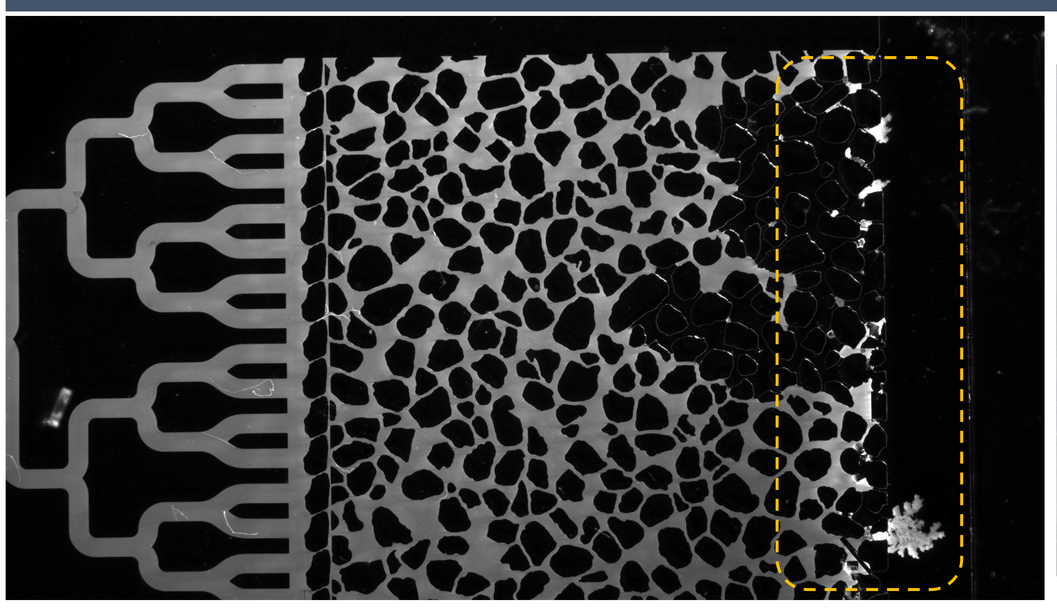
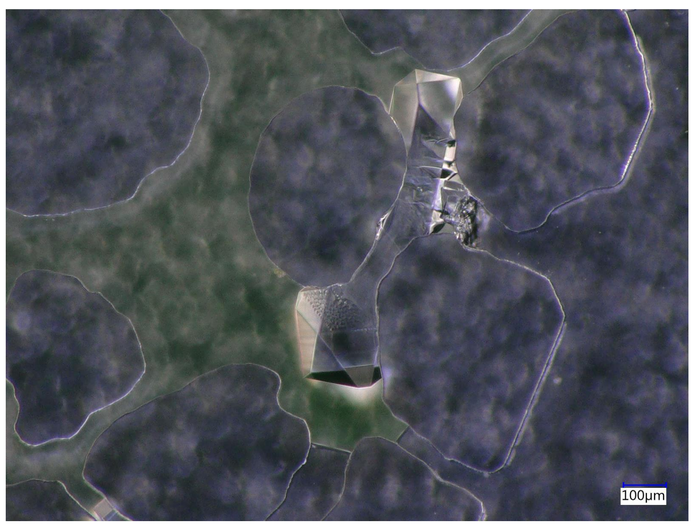
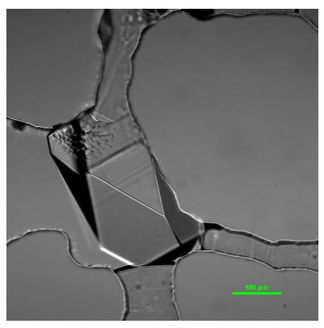


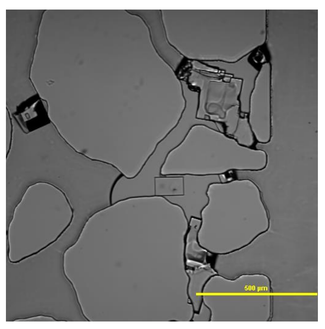
Fig. 3: Microfluidic experiment setup.

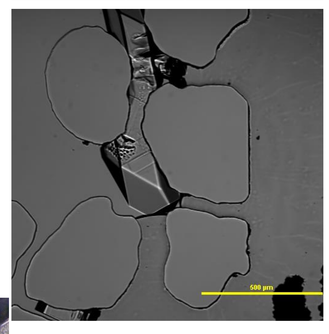
Results

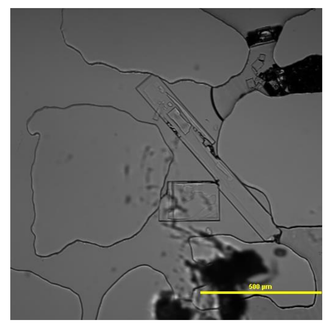


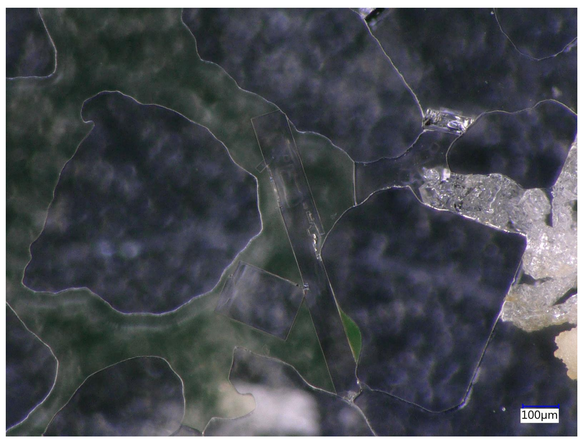


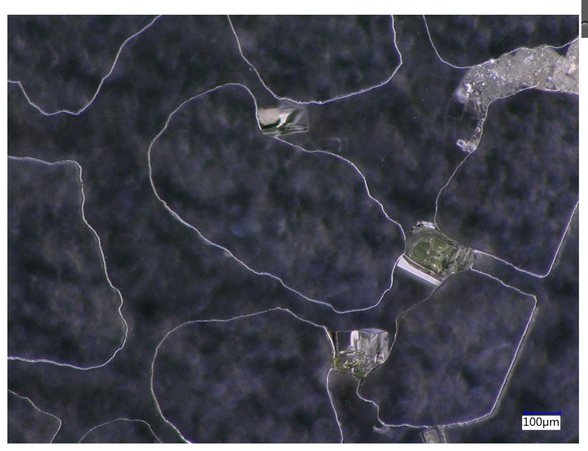




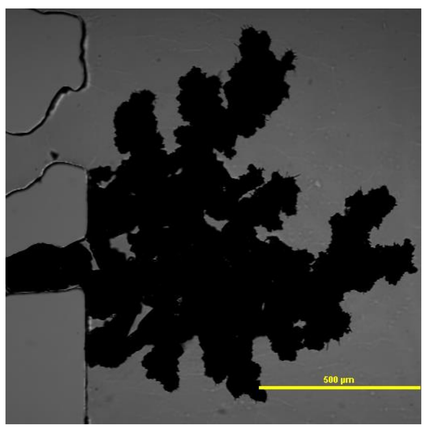








KEYENCE digital microscope (100x/200x)



Confocal microscope (10x/20x)

Conclusions

- Single crystals (monocrystals) growth → transparent crystals
- Polycrystalline aggregates → opaque masses
- Evolution of efflorescence and subflorescence
- Complete pore throat blockage → crystal growth are restricted by throat size and topology
- Partial pore and through blockage
- Very large crystal formed along the pore body
- Crystal sizes: 20-1000 µm
- Trapping of saline solution due to crystal formation
- Observation of liquid (brine) films on the surfaces of PDMS grain and solid crystal (4-phase system: Air-Brine-Crystal-Grain)
- Tiny transparent crystals inside dried pore space only visible in confocal
- Observing dried and moistened salt crystalline aggregates at the time of test termination

References

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