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# Coupling Numerical Modelling with Flow Experiment to Optimize Fabrication of Microfluidic Devices for Porous Media Applications

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Investigating the mechanisms that govern flow of fluids at the pore-scale are the cornerstone of understanding multiphase flow in porous media for a wide range of applications, including hydrocarbon recovery, CO2 sequestration and contaminant hydrology.
Microfluidic devices, coupled with visualization techniques allow us to study pore-scale processes [1, 2]. Glass substrates are often preferred over silicon and polymers for the manufacturing of microfluidic devices because of their high transparency, thermal stability, hardness and chemical resistance. However, conventional manufacturing of glass-based microfluidic devices is time consuming, expensive, complex and multistep [3]. We have recently developed a novel and relatively inexpensive laser-based process that can be used for the fabrication of microfluidic devices using glass substrates [4]. Features generated on the glass surface by using a picosecond laser beam enable more complex shapes than the surface features produced by more conventional photolithography and etching. Although laser-generated micro-channels have a limited aspect ratio (typically < 4:1), much higher surface roughness than etched micro-channels, and angled walls with a rounded bottom, rather than steep, vertical walls with a flat bottom, these characteristics do not limit the ability to closely simulate real porous materials relevant to CO2 sequestration, hydrology or hydrocarbon recovery.
To design and fabricate appropriate micromodels we have coupled micromodel flow experiments and pore-scale numerical simulations to investigate fluid flow behaviour in micro-structures under various experimental conditions. Simulations are particularly useful for guiding the prototyping of micro-models, since the geometry, physical dimensions, and surface properties of micro-channels and pores in the structure have a significant effect on fluid flow dynamics. In this research, we pinpoint critically important parameters that have an impact on the multi-phase flow at pore-scale, which should be considered in the fabrication of micromodels. We investigate the fluid displacement front, saturation distribution, and the influence of the micromodel imperfections on the bulk flow will be evaluated. We utilize the TETHYS computational fluid dynamics (CFD) code, developed by Pacific Northwest National Laboratory and previously used to perform simulations of microfluidics experiments and complex 3D porous media flows [5, 6, 7].
Additionally, a set of dynamic flow tests will be performed on the fabricated micromodels to obtain valuable qualitative (flow images) and quantitative (pressure, flow rate) data. This will allow the comparison between the measured experimental data after performing fluid flow tests on the fabricated micromodels with the results of pore-scale numerical simulations. We will report the impact of different parameters e.g., surface roughness and aspect ratio on fluid flow.

## References

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