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The Control of Wettability for a Micror-Fluidic Channel using electrokinetic Technique and its Effect on Externally Measured Pressures

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The hysteretic relationship between capillary pressure (Pc) on saturation (S) has been shown to be a projection of a higher-dimensional surface that depends on interfacial area per volume (IAV) as the additional state variable. Most studies that validate the capillary-pressure–saturation-IAV relationship are performed on 2D micro-models or cores where scanning is performed in pressure and not in saturation. We have developed an EWOD technique (electro-wetting on dieletric) to internally manipulate fluid saturation to determine the effect on externally measured pressures.

Applying electric fields to electrolytic fluids changes the contact angle among the fluids and the soild. For a parallel-plate electro-wetting set-up, the pressure difference is given by gsl (cosq'EW - cosqEW)/d', where d' is the aperture, qEQ and q'EW are the contact angles before and after the application of voltage, V, and gsl is the interfacial tension between the solid and liquid phases. This pressure difference enables direct control over internal fluid distributions. The contact angle reverts to the original value when V = 0.

A sealed micro-model with Electro-Wetting on Dielectric (EWOD) electrodes was fabricated using a PDMS wedge-shaped channel with an entrance width of 0.5 mm and an exit width of 2 mm. The channel length was 4 mm, and had a depth of 0.9 mm. The PDMS channel was attached to an aluminum plate that served as the ground electrode. An ITO slide coated with PDMS formed the high voltage electrode and was used to seal the micro-model. X-ray Micro-CT scans showed that the contact angle between electrodes changes from from ~110˚ (non-wetting) to ~70˚ (wetting) for an applied voltage of 318 V AC.

By applying voltage to the wedge-shaped micromodel, with the inlet and the outlet opened to the atmosphere, the externally measured capillary pressure remained constant even though the fluid-air interface moved and the saturation increased. A comparison of hysteresis loop with/without voltage exhibits a difference of ~20 Pa in the drainage scan while almost the same in the imbibition scan. For a closed system, the externally measured change in capillary pressure was ~30 Pa and the saturation in the channel increased. To explore the effect of roughness, micro-model with different roughness steps were fabricated. With rough channels, pinning was observed. EWOD provides method to assess the contributions of wettability to the fundamental physics of immiscsible fluids in analog porous media.

References

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Primary author: ZHOU, Xuhui (Purdue University)

Co-authors: NOLTE, David; PYRAK-NOLTE, Laura

Presenter: ZHOU, Xuhui (Purdue University)

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