Novel Evaluation of Oil Recovery in Rock-Like Mixed-Wet Microfluidic Systems

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Abstract. Oil-brine-rock wettability is an important petrophysical feature that affects fluid distribution and multiphase flow in hydrocarbon reservoirs. The industry is highly interested in assessing the recovery mechanisms in mixed-wet systems like carbonate and shale reservoirs. Microfluidics is a technology that can directly visualize and assess flow dynamics at the pore scale. However, when it comes to simulating mixed-wet environments, this approach has several drawbacks. For the first time, we use microfluidic devices to study the impact of wettability on oil recovery in formations with single and mixed wettabilities. The microfluidic system is designed to mimic the true pore network of an oil-bearing reservoir rock, as determined by thin-section photographs of a core. The microdevices were made of silicon for its compatibility with oil. The microfluidic substrates with regulated wettability, including water- and mixed-wet systems, were built using a unique approach that mimicked pore-network formations with varied pore-throats. We performed several sets of comparative experiments to investigate the wettability effect on oil recovery at the pore scale. Fluid flow was conducted in silicon-based microfluidic devices holding the same pore-network structure but differed in the wetting state. One microdevice did not undergo any surface modification processes and had a hydrophilic surface, mimicking a water-wet system. A second microdevice underwent selective wettability alteration and had hydrophilic and hydrophobic surface regions, mimicking a mixed-wet system. The flow experiments conducted shared identical conditions: water injection in oil-saturated microdevices. Results showed a reduction in the oil recovery and thus a higher remaining oil saturation in the mixed-wet compared to the water-wet microdevice with distinct phase distributions. The results highlight the importance of using accurately designed microdevices to mimic mixed-wet formations when evaluating oil recovery, as single-wetting state microdevices may under-, or over-estimate the recovery process.