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Microfluidic visualization of asphaltene deposition under high temperature

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The goal of this study lay in the evaluation of the asphaltene deposition on the artificial 2D porous structure of the carbonate rock using high-pressure and high-temperature (HPHT) microfluidic technology. Such technology was utilized to evaluate the behavior of heavy oil quickly and effectively under reservoir conditions, on par with traditional tests. Our workflow started with the designing of microfluidic chip structure. Based on computed tomography data, a unified geometry of the porous space was developed, with pores and pore throats close to the target formation. The resulting design was realized as a silicon-glass microchip that can withstand high temperatures (up to 350℃) close to the formation during steam injection. In the first step, the dead heavy oil was injected into the whole microfluidic system at the ramped temperature. Later, high-viscous oil was displaced by the solvent, and then the precipitated heavy fractions were analyzed with microscopy. The microfluidic experiments were conducted under four different temperature conditions. At stages of 50 and 110℃, during displacement of heavy oil with n-heptane, there was no attenuation of filtration or precipitation of heavy fractions. The permeability of the microfluidic chip was found to decrease as deposits formed in the filtration channels during the third stage of the experiment at 170℃. The deposition of heavy fractions was confirmed by visual inspection of the microfluidic channels and analysis of the deposited material using scanning electron microscopy (SEM). The nature of a deposition was established by comparing the image in white and fluorescent light. Precipitation of an organic nature (asphaltenes) fluoresced, while deposits that did not fluoresce were mechanical impurities. For the last test, a new clean microchip was utilized, where displacement at 300 ℃ resulted in a similar blockage of the channels by asphaltenes and fine mechanical impurities (particle size less than 3 microns). Overall, the results suggest that temperature plays a crucial role in asphaltene deposition for heavy oil. These findings have valuable implications, since asphaltene deposition is a significant problem during oil production and transportation. The conducted experiment has demonstrated its effectiveness for studying the behavior of high-viscous oil at elevated temperatures using HPHT microfluidic technology. Further studies are needed to investigate the underlying mechanisms of asphaltene deposition, develop effective strategies to mitigate this problem, and conduct the sensitivity analysis to bring new insights to the effective heavy oil reservoir development.

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