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A Laboratory Study of Foam Coarsening in Model Fractures

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Foam is composed of gas bubbles separated by continuous liquid films. The films, called lamellae, are stabilized by surfactants. Foam has many applications in underground resources, such as acid stimulation (Thompson and Gdanski 1993), aquifer remediation (Hirasaki et al. 1997) and enhanced oil recovery (Kovscek and Radke 1994; Rossen 1996). In enhanced oil recovery, foam injection can improve sweep efficiency by reducing the mobility of gas. To achieve an optimized mobility control, the stability of foam must be maintained while it propagates deep into the reservoir. At the pore scale, the coalescence of foam can take place due to different mechanisms including capillary coalescence and diffusive coarsening. Coarsening behavior has been well studied in bulk foam (Weaire and Glazier, 1993; Weaire and Hutzler, 1999). However, it is less understood in porous media.

In this study, we have built two 1-meter-long model fractures analogous to microfluidic porous media, and investigate the effects of coarsening on static foams in the models. The model fractures are made of glass plates. Direct observation and analysis of the foam structure inside the fractures are facilitated using a high-speed camera. Each model fracture has one flat wall and one rough wall. The gap between the two walls represents the aperture of the fracture. The distribution of aperture can be represented as a 2D map of pores and throats. We use two model fractures with different roughness distributions. One model has a roughness in a regular pattern with a hydraulic aperture of 46 μm . The other one has an irregular pattern with a hydraulic aperture of 80 μm .

Prior to coarsening, foam is pre-generated, and then injected into the fractures. After foam flow reaches steady-state, the injection and production valves are closed. Once foam stops flowing, as the residual pressure gradient dissipates, the coarsening process commences.

In this study, we have observed that the foam coarsens due to gas diffusion in both model fractures. Due to coarsening, bubble numbers decrease and bubble size increases. The time scale of coarsening in our models is much larger than what has been reported elsewhere (Marchalot et al., 2008; Jones et al., 2018). In the regular model, coarsening stops after 2 hours. At the end of coarsening, all lamellae have zero curvature and rest at pore throats. Bubbles attain the same size as pores and almost all the liquid accumulates in plateau borders at throats. Compared to the regular model, the coarsening process is slower in the irregular model. Bubbles coarsening slows down to a barely-measurable diffusion rate after 7 hours. However, small bubbles exist and the average bubble size increases even after 24 hours of coarsening. A possible explanation is that, for these small bubbles, the lamella area available through which gas can diffuse to a neighbouring larger bubble is greatly reduced. In both models, the capillary pressure increases to 1.3 kPa, which is too low to cause lamellae to break.

Time Block Preference

Time Block A (09:00-12:00 CET)

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