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Microfluidics-based analysis of dynamic contact angles relevant for underground hydrogen storage

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The contribution of renewable energy, specially wind and solar, is expected to increase significantly in the future global energy mix [1]. However, due to the intermittent nature of these energy resources, development of large-scale (TWh) energy storage systems is essential [2]. Underground hydrogen storage (UHS) in porous media, such as depleted oil and gas reservoirs and aquifers offer feasible solutions [3, 4, 5, 2].

A good understanding of H_2/water transport properties such as relative permeability and capillary pressure is needed to ensure the safety of UHS, as well as to optimize injection and withdrawal cycles [6, 7, 8, 9, 10, 2]. Relative permeability and capillary pressure functions are highly dependent on the wetting properties of the system [11,12,10]. The wettability in H_2/brine/rock systems can be characterized by the contact angle between the rock-brine and the brine-H_2 interfaces.

Recently, several different techniques, including the captive-bubble cell and the tilted plate technique, have been applied to measure or derive contact angles relevant for UHS [13, 14, 6]. Although, water-wet conditions were reported in all these studies, inconsistencies exist between the reported data. This could possibly be explained by differences in the measurement techniques and types of rocks and fluids used in the experiments.

To help shedding new lights on characterisation of this crucial interface property, we have measured contact angles in microfluidic systems. Microfluidic chips resemble actual subsurface systems much closer compared to tilted plate techniques or captive bubble cells, because of the dynamic and micro-channel-based nature of the flow conditions. The experiments were carried out at P = 10 bar and T = 20 ℃ using a microfluidic chip with channel widths ranging between 50 - 130 µm. Advancing and receding contact angles of H_2/water, N_2/water and CO_2/water systems were measured. The results indicate strong water-wet conditions with H_2/water advancing and receding contact angles of respectively 13 - 39°, and 6 - 23°. It was found that the contact angles decrease with increasing channel widths. Little hysteresis was measured, and consequently, the results are not in line with Morrow's curve. The receding contact angle measured in the smallest channel width (50 µm) agrees well with the literature coreflood tests on the Vosges Sandstone [13], suggesting that this channel width is representative of actual subsurface systems. The N_2/water and CO_2/water systems showed similar behaviour to the H_2/water system and no significant differences in contact angle were observed for the three different gases.

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Time Block Preference

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

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