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Systematic study of wettability alteration of glass surfaces by dichlorooctamethyltetrasiloxane silanization; a guide for contact angle modification

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Wettability plays an important role in many natural and industrial processes, like mineral processing, hydrocarbon production and ground water remediation. For multiphase fluid flow in porous media, extensive research has been performed on the influence of the wettability on the phase distribution and morphology in both, static and dynamic conditions (1,2,3,4,5). Wettability is also crucial for the topics of increasing interest - hydrogen and carbon dioxide storage, for example for the description of injection dynamics and assessment of caprock stability (6).
In order to investigate wettability effects on multiphase flow in a controlled and standardized manner, researchers utilize model systems like bead-packs or micromodels. Glass is one of the materials used for the creation of such models, being transparent, chemically inert and easily formable. Additionally, the wettability of the glass surfaces can be altered from its original hydrophilic to more hydrophobic state by reaction of silane/siloxane groups with the hydroxyl groups of glass known as silanization (10).
The degree of wettability alteration by silanization reaction depends on numerous variables (7,8,9) such as the reaction time, temperature, concentration, the nature of the solvent and the prior glass cleaning procedure. Although silanization is widely used for glass wettability modification, comparable detailed systematic approaches over a large range of geometries, treatment conditions and measurement systems are scarce in the literature (7,8,9).
In this work, dichlorooctamethyltetrasiloxane (Surfasil) treatment was investigated with the purpose of systematically obtaining and providing a guide for achieving a wide range of contact angles. Secondly it was investigated whether different geometries display comparable contact angles under similar treating conditions using independent methods of contact angle determination.
Wettability was quantified through contact angle measurements on glass plates, beads and 2D micromodels. Initially, the influence of the solvent, treatment time and Surfasil to solvent ratio on plates was investigated using the sessile drop method. After establishing a clear relationship between the parameters and contact angles, the same treatment parameters were applied to single bead, microchip and multiple glass beads, the latter to form a bead pack. Contact angles from single beads and micromodels were obtained using image analysis of projections, while contact angles within the bead-pack were extracted from segmented 3D micro-CT images using algorithms (11).
By varying treatment times and the Surfasil to heptane ratio, it was possible to achieve a wide range of comparable and repeatable contact angles; from the initial 20 to 100 degrees as ultimate non-wetting state measured for air-water systems; for plates and individual beads, see figure attached. The flooding treatment in the micromodel was so far limited to the ultimate non-wetting state, showing comparable results to the plate and individual beads within limitations of the measurement.
Contact angle derivations from the bead pack using the 3D micro-CT images showed higher contact angles in comparison to the single bead, but it confirms a larger spread of the contact angle as observed in the literature (12).

Figure caption: The dependency of the contact angle on the volume ratio. The contact angle increases until it reaches a plateau value.

Participation

In-Person

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