Wettability alteration of microfluidic devices using plasma and its influence on trapping mechanisms in geological reservoirs

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Abstract

Geological storage of carbon dioxide (CO2) in saline aquifers is one of the prominent approaches within the carbon capture utilization and storage (CCUS) framework. CO2 storage in geological reservoirs is a multi-fluid flow problem where properties of the rock matrix, the fluids, and the injection define the efficiency of the storage. Wettability, as an influential parameter, seems to be left out from macro-scale models of CO2 trapping mechanisms. In order to assess the impact of porous media wettability on capillary and solubility trapping, we decided to approach the topic by downscaling to pore scale (order of micrometers to nanometers). Therefore, an experimental approach using microfluidics, plasma jet and Raman spectroscopy has been deployed. We designed microfluidic chips to mimic simple porous rock structures and enable direct visualization and tracking of the physical trapping and solubilization process. Properties of plasma are utilized to change the wettability of micromodels by injecting plasma jet inside the microchannels. On top of that, we utilized the μ-Raman setup to track the evolution of CO2 dissolution in water during microfluidic experiments. Overcoming technical challenges, we discovered the positive impact of plasma on the hydrophilic properties of microchannels, however, the wettability aging of micromodels still portrays a challenge. Increased hydrophilicity of micromodel surfaces after plasma treatment acts favorably on the dissolution of CO2 in water due to the increased interfacial area, however, negatively affects physical trapping of CO2 bubbles. Preliminary Raman spectrometry results indicate possible analysis of dissolved CO2 even at close to atmospheric pressure despite the large fluorescence coming from the micromodel material (borosilicate glass). More work is needed for quantitative analysis of the CO2 signal, however, it has been confirmed that gaseous CO2 signal intensity (Fermi diad) scales with increasing pressure.

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