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Methods for Hydrogen Storage Characterization in Porous Substrates

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Hydrogen energy has been a subject of increasing interest over the past decade. The use of hydrogen for energy storage allows for a clean energy carrier that produces only water and heat after oxidation. Focus has been hydrogen storage, which demands abundant and safe storage volumes. Similar to the carbon dioxide storage campaign, subsurface formations offer large pore volumes for gas storage, but characterizing porous substrates for this purpose is still in development. Depleted oil reservoirs, salt dome caverns, and aquifers are prime subsurface candidates for this purpose. There are associated issues with the injection of large volumes of the gas into these formations such as unfavorable chemical reactions, leakage through the cap rock, and large capital expenses associated with suitable surface injection equipment. This research aims at testing our ability to estimate adsorption capacity in synthetic or natural porous systems. To this end, materials were first characterized via low-pressure adsorption isotherm analysis. Secondly, low-pressure nitrogen adsorption results were compared to nitrogen and hydrogen high-pressure adsorption isotherms to determine if surface area analysis suffices to estimate storage potential for hydrogen. Additionally, nuclear magnetic resonance (NMR), first in its non-spectroscopic mode, namely Time Domain NMR (TD-NMR), and subsequently in its spectroscopic mode, using a high-field NMR spectrometer, was used to analyze hydrogen adsorbed in porous media. In this sense, we developed TD-NMR protocols that enabled capturing data at relatively high pressure (up to 3000 psi) using a custom-designed NMR tube in which the gas pressured was controlled with a pump. A similar setup was used on a Bruker Biospin NMR spectrometer. Results show that low-pressure nitrogen adsorption isotherms provide insufficient guidance to understand the hydrogen adsorption response at high pressure, which likely reflect the fact that surface area is at best an incomplete characterization method for this purpose. TD-NMR transverse relaxation time (T2) distribution shows some sensitivity to hydrogen adsorption in porous media at high pressure, which indicates the potential of this technique to characterize hydrogen storage. High-field NMR, while being a more complex method, sheds light on hydrogen behavior in porous media that complements the other two sources of information.

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