Experimental and Scanning Electron Microscope Characterization of Hydrogen Storage in Coal

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The global push toward net-zero CO_2 emissions has elevated hydrogen's role as a clean energy source, especially in Alaska. However, a significant challenge lies in ensuring a stable year-round energy supply. Large-scale hydrogen storage, crucial for this transition, is most cost-effectively achieved in underground geological formations. While surface storage in compressed tanks is costly ($400–$700/kg of H_2), underground storage in formations like aquifers, salt caverns, coal seams, and depleted oil/gas reservoirs could reduce costs significantly to $35–$38/ kg of H_2. Research on utilizing depleted oil and gas reservoirs, salt caverns, and aquifers has been extensively discussed in the literature, but studies on coal seams are still in their early stage. Prior studies have shown that coal seams can store substantial amounts of hydrogen, and the storage potential depends on the rank of coal. However, the factors accounting for the differences in adsorption capacity are unclear and debatable. This work underscores the importance of understanding the mechanism of sorption capacity, flow behavior during hydrogen storage in coal ranks, and factors accounting for the adsorption capacities. The experimental setup included a reference cell to control gas flow to two sample cells containing coal samples. A syringe pump delivered gases and monitored pressure using three transducers (0–35 MPa range, 10 Pa accuracy). Temperature was maintained with a water bath, and data were collected with a data acquisition system. Tests were conducted on 50g of Anthracite and Bituminous coals, pulverized to 250–177 microns and oven-dried for 24 hours at 105°C. Before testing hydrogen adsorption, helium was introduced to determine the sample cell matrix volume exposed to hydrogen. The adsorption capacity of the coal samples was tested at a constant temperature of 30 ºC with a pressure range from 0.76 MPa to 15.17 MPa. The manometric method was adopted, whereby the adsorption or desorption of gas is determined by simply monitoring the pressure drop. Regarding the Ideal Gas Law, the difference in moles was used to determine the amount of gas adsorbed at each pressure increment. The isotherms for the different coal ranks were acquired and fitted with the Langmuir models. For the coal ranks tested, the hydrogen adsorption capacity for Bituminous Coal is higher, with an adsorption capacity of 1.33 mmol/g, than that of Anthracite Coal, which is 0.20 mmol/g.

The coal samples were analyzed under an SEM to understand the difference better. The SEM revealed more visible striations or lamellae in the Bituminous coal than in the Anthracite Coal. The surface of Bituminous coal looks rougher with visible pores, which may provide more pathways for hydrogen to interact. A High Percentage of Si and Al in Anthracite from the XRF data shows a higher possibility of quartz inclusion.