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Use of Ceramic Materials for the Adsorptive Storage of Natural Gas – a Review, Part 2

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ABSTRACT

Natural gas currently is gaining a worldwide acceptance as an economical fuel for vehicles and other applications. Even from the environmental point of view, natural gas performs better than gasoline and diesel. However, the storage of natural gas is considered one of the major bottlenecks toward its widespread application. The adsorptive storage of natural gas (ANG) is a promising alternative to the traditional, expensive storage by compression [i.e., compressed natural gas (CNG)]. However, ANG suffers from many techno-economic problems. In many countries (e.g., USA, China), a large effort has been made toward the replacement of high-pressure compression by an alternative method of storage suitable for working at pressures up to 500 psi (3.4 MPa). This upper limit of pressure easily can be achieved with a single-stage compressor. Alternatively, the vehicle can be refueled directly from a high-pressure natural gas pipeline. In this way, a significant decrease in the capital and operating costs of compression stations can be achieved. Due to its relatively low pressure, ANG obviously has some advantages according to weight, shape, safety, and costs of the storage vessel. In the future, ceramic adsorbent materials such as silica gel, activated alumina, zeolite, or silicon carbide may play an important role in ANG technology. In this review, a comparison of activated carbon as a traditional adsorbent as well as new ceramic adsorbents is discussed for the storage of natural gas.

KEYWORDS

adsorbed natural gas, ANG, compressed natural gas, CNG, nanoporous activated carbon
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2.4 Zeolite adsorbent

There have been a number of experimental studies on the feasibility of using existing materials for the storage of methane. Zeolites are such materials [70–71]. Zeolites are crystalline hydrated aluminosilicates of alkali and alkaline earth metals. Their crystalline framework is arranged in an interconnecting lattice structure. The arrangement of these elements in a zeolite crystal creates a porous framework structure with interconnecting channels of various sizes. The zeolites structures contain (-Si-O-Al-) linkages that form surface pores of uniform diameter and enclose regular internal cavities and channels of discrete sizes and shapes depending on the chemical composition and crystal structure of the specific zeolite involved. Its significance as commercial adsorbent depends on the fact that each of the

crystals contains interconnecting cavities of uniform size separated by narrower openings or pores of equal uniformity [72]. Pore sizes range from about 2 to 4.3 Å. This structure enables the gas adsorption by zeolites, which selectively adsorb specific gas molecules consistently within a broad range of chemical and physical environments.

The adsorption functions of zeolites are accomplished when gas molecules of different sizes are allowed to pass through the channels. Depending upon the size of the channel, molecules are separated. The process is known as molecular sieving. The ability of activated zeolites to adsorb gases selectively partly is determined by the diameter of the channels ranging from 2.5 to 4.3 Å (0.25–0.43 nm) according to the type of zeolite [72]. The specific size of the channels enables zeolites to act as molecular gas sieves and to selectively adsorb gases such as ammonia, hydrogen sulfide, carbon dioxide, sulfur dioxide, water vapor, oxygen, nitrogen, and others. Zeolites predictably are potential materials for the adsorption of natural gas due to the availability and ability of

the microporous interconnecting channels of discrete sizes and shapes within their structure. Zeolites have micropores with dimensions that are comparable to the dimensions of methane molecules [73], as the size of methane molecules amounts to 0.32 nm [72, 74]. This fact shows that zeolites are capable of methane adsorption in which methane molecules could penetrate through the surface and fill the microporous channels within the zeolite substrates.

Cracknell [70] has established comparisons for both zeolite (assumed to have cylindrical pores) and carbon (assumed to have slit pores) related to the advantage of storing methane from grand canonical Monte Carlo (GCMC) simulation for different pore sizes at a temperature of -60 and +1 °C. These results suggest that an optimized pore of porous carbon is a more suitable material for the adsorptive storage of methane than an optimized zeolitic pore. The best pore size for this purpose depends on the operating conditions of the system. It was found that for a storage pressure of 3.4 MPa (500 psi) at a temperature of +1 °C, the model slit car-

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