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Review

A comprehensive review on the application of aerogels in CO_2-adsorption: Materials and characterisation

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ABSTRACT

Recently, greenhouse gases - especially CO_2 – have been released into the atmosphere in ever-increasing quantities through activities such as industrial emission and combustion. Owing to their high absorption capacities, they appear to be implicated causatively in observed increases in surface temperature and global climate changes. Between porous solid sorbents, aerogels have recently been considered as promising adsorbents for CO_2 capture due to their tunable surface chemistry and proper textural properties. Currently, a variety of different aerogels are being developed at laboratory scale, and some of them have been taken to pilot production. In order to explore the commercialisation-feasibility of aerogels as CO_2 capture adsorbents, more research needs to be done on low-cost materials and production processes, with low or controlled sorption of water as well as a good thermal regeneration capacity. In this review paper, different aspects of scientific investigations on CO_2-sorption applications of aerogels have been studied. The review contains seven main sections: preparation, characterisation, modification of aerogels, literature studies on CO_2-sorption performances, kinetic and thermodynamic models on CO_2 adsorption, important factors on CO_2 capture and outlook for future perspectives.

1. Introduction

A promising approach to tackle climate and environmental changes, especially with the possibility of apparent increasing atmospheric temperatures in recent decades and predictions of this continuing trend in the future, is to minimise the net emission of CO_2 as a main and primary greenhouse gas into the atmosphere. In view of this pressing societal and environmental need, CO_2-capture technology must be able to be implemented economically and at large scale. Three main methods for the capture of CO_2 are pre-combustion, post-combustion and oxy-combustion [1]. Various processes can be envisaged for separation of CO_2 contained in a gas mixture. They are based on absorption [2] physical/chemical adsorption [3] membranes [4] and cryogenic separation [5]. However, there are multiple problems associated with these technologies, such as their energy-intensive nature, high levels of corrosion of process equipment, oxidative degradation of the aqueous amines employed during liquid phase absorption, the possibility of generation of toxic by-products during the CO_2 capture, and excessive solvent consumption through evaporative losses [6–8].

Solid physical and chemical adsorbents [9] such as zeolites [10] metal organic frameworks (MOFs) [11] activated carbon [12] mesoporous silica [13] aerogel [14] mesoporous alumina [15] metal oxides [16] covalent organic polymers [17,18] and amine-based materials, are considered as the latest technologies for atmospheric CO_2 capture that are able to battle problems related the technologies mentioned above.

Fig. 1a reveals the potential of these sorbents and compare them over the flue gas operating range. Between these sorbents, amine species can be incorporated into the porous support by either physical impregnation, chemical grafting or direct (one–pot) synthesis to improve the CO_2 adsorption capacity [10]. However, many materials have been developed for this purpose, and the interest in aerogels among these materials is increasing all the time [21].

Aerogels are the three-dimensional and the highly porous materials (see Fig. 1b) that are derived from organic, inorganic or hybrid molecular precursors that are generally prepared by a sol–gel process and an appropriate drying technology [22]. Evolution of the aerogels is illustrated in Fig. 2. In 1932, Kistler developed an aerogel for the first time by sol–gel and supercritical drying [23]. Aerogels can now be made of many different compositions and enhanced properties. Aerogels can be classified based on their appearance (as monoliths, powders, and films), their structure (as microporous, mesoporous and mixed porous) or by

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