Chitosan-impregnated sod-Metal Organic Frameworks (sod-ZMOF) for CO₂ capture: synthesis and performance evaluation

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Abstract

South Africa is amongst top countries emitting large amount of carbon dioxide (CO₂) gas in the atmosphere. This is explained in that its energy resources mostly rely on coal. Several investigations have revealed that CO₂ is a major greenhouse gas and, as such it contributes to about two-thirds in aggravating the greenhouse effect. Due to the aforementioned problems, much effort is being devoted to reduce CO₂ emissions through the development and evaluation of cost effective methods for capturing and storing CO₂. The amine-based absorption using monoethanolamine (MEA) is the most common and mature technique for CO₂ capture. However, problems associated with this process are huge energy required for solvent regeneration and corrosiveness of the piping. This calls for efficient alternative adsorption process for CO₂ removal.

Adsorptive CO₂ removal by solid adsorbents is a promising way. Besides being less energy intensive, this process has the ability of operating in moderate temperature and pressure [1]. Adsorptive CO₂ removal using solid adsorbents has shown to be very effective. There are a number of solid adsorbents used for CO₂ capture but metal organic frameworks (MOFs) have drawn much attention over the past decade [2]. This is explained in that MOFs have large surface area, adjustable pore sizes, open metal sites and less energy for regeneration. A recent study reported in the literature is application of zeolite-like metal organic framework (ZMOF) developed by Chen et al. [2] for CO₂ capture. The material displayed a relatively high CO₂ adsorption capacity as compared to other types of MOFs. In addition, properties of MOFs can be enhanced by incorporating them with other materials through grafting, impregnation and ion exchange. Against this background, this research aimed at optimizing ZMOFs (sod-ZMOF in particular) through structural modification or formation of composite material for enhanced CO₂ adsorption. Sod-ZMOF was impregnated with chitosan after which is characterized and evaluated for CO₂ adsorption.

Sod-ZMOF was synthesized by mixing 4.5-imidazoledicarboxylic acid, indium nitrate hydrate, DMF, Acetonitrile, imidazole, nitric acid respectively and heated. The sod-ZMOF crystals produced were impregnated with chitosan. Chitosan was extracted from chitin. Chitin from crabs was first sieved and then
demineralization, depronization and deacetylation were done in order to extract chitosan. Chitosan was impregnated onto sod-ZMOF by first dissolving it into acetic acid and stirred to obtain chitosan solution. Then sod-ZMOF was added to the aforementioned chitosan solution and stirred. The suspension mixture was then filtered and allowed to dry. The synthesized sod-ZMOF was characterized using X-ray powder diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and Thermo gravimetric analysis (TGA). XRD patterns showed that sod-ZMOF is crystalline. TGA analysis showed that sod-ZMOF is thermally stable till temperature of 250°C. From FTIR analysis; functional groups that are present in the organic linker (4,5-imidazoledicarboxylic acid) are also present in sod-ZMOF. Chitosan was also extracted from chitin and impregnated onto sod-ZMOF. The sod-ZMOF was characterized using TGA for thermal stability and FTIR for surface chemistry. Performance evaluation of the material was carried out with an adsorption set-up using CO₂/N₂ gas mixture with 10% CO₂. The evaluation was conducted on the sod-ZMOF without chitosan and sod-ZMOF impregnated with chitosan for comparison. For the adsorption experiments, temperature of 41°C, pressure of 200 kPa and flow rate of gas 126 ml/min was used. The highest adsorption capacity obtained at these conditions was 48.72 mlCO₂/g adsorbent and 41.58 mlCO₂/g adsorbent for sod-ZMOF and sod-ZMOF chitosan, respectively. The impregnation of chitosan on sod-ZMOF resulted in a decrease in adsorption capacity of the material. It is expected for sod-ZMOF-chitosan to have a higher adsorption capacity than sod-ZMOF as chitosan has amine groups with high affinity for CO₂. The decrease in adsorption of sod-ZMOF-chitosan could be attributed to the occupation of the pore volume of the sod-ZMOF by some impurities which were not completely rid of during the drying. However, the adsorption kinetics of the sod-ZMOF-chitosan was faster than that of the sod-ZMOF. The faster kinetic of the chitosan impregnated sod-ZMOF could be attributed to the presence of the chitosan in the ZMOF.

References
