

Abstract

Carbon dioxide capture is essential to reducing CO₂ emissions in an attempt to mitigate climate change. Absorption via amine based solvents is currently the mature technology that is applied for the capture of CO₂. However, amines can pose health and environmental risks when emitted into the air from CO₂ capture plants. Furthermore, the efficiency penalty caused by CO₂ capture via absorption and the huge costs associated with the regeneration of the spent amine based solvent poses a threat to the economic viability of CO₂ capture by the absorption process. Adsorption technology is an alternative to absorption technology. Adsorption technology seems promising due to its moderate energy consumption (which stems from the ability to operate at moderate temperatures and pressures) as well as being health and environmentally benign. Recently, extensive research has been conducted on designing adsorbents that have the ability to adsorb large quantities of CO₂ with a low energy consumption. The challenge in CO₂ adsorption technology is to design an adsorbent that is not only non-toxic, biodegradable and cost effective but also has the ability to selectively and efficiently remove CO₂ gas from a mixed gas stream. This study proposes chitosan, a biodegradable, non-toxic polymer, as one such adsorbent. Chitosan has the potential to be a suitable adsorbent for CO₂ capture because it contains the desired amine groups which act as CO₂ adsorption sites.

In this study, chitosan was studied as an adsorbent in order to confirm that it is suitable for CO₂ capture. Chitosan and chitosan impregnated carbon nanotubes (CNTs) (chitosan/MWCNTs) composite adsorbents were synthesized. Chitosan was impregnated onto MWCNTs in order to enhance the physical properties (surface area, pore size and pore volume), CO₂ adsorption capacity and CO₂ affinity of the composite adsorbent. The synthesized materials (chitosan and chitosan/MWCNTs) were characterized and evaluated for CO₂ adsorption.

Chitosan was successfully synthesised from chitin. This was confirmed using FTIR spectroscopy. The synthesised chitosan had desirable properties for CO₂ capture. This was confirmed using TGA and custom built CO₂ adsorption equipment. The synthesised chitosan samples were inexpensive, had the desired amine groups and were thermally suitable at industrial CO₂ capture operational temperatures. The CO₂ adsorption capacity of the synthesised chitosan was generally low when compared with literature. The highest CO₂ adsorption capacity achieved by the synthesised chitosan in this study was 11 gCO₂/kg adsorbent. However, it is important to consider that the polymer is derived from a waste material and as such it is possible to cost effectively utilize a large amount. The amount of CO₂ adsorbed by the synthesised chitosan is dependent on the number of amine groups present.

Against this background this study aimed to increase the number of amine groups present. This was done using response surface methodology (RSM) to develop a polynomial regression model. The

developed polynomial regression model is able to predict the DDA of the synthesised chitosan based on the synthesis variables used. The polynomial model was validated using chitosan from literature and found to be statistically significant. The polynomial model showed the optimum synthesis conditions to yield the highest DDA.

Chitosan was successfully impregnated onto MWCNTs. This was confirmed using FTIR spectroscopy. The synthesised chitosan/MWCNT adsorbent was not suitable for CO₂ capture. This was confirmed using Raman spectroscopy, N₂ physisorption, SEM TGA and custom built CO₂ adsorption equipment. The CO₂ adsorption capacity of the synthesised chitosan/MWCNTs was low when compared to literature. This is attributed to the fact that the MWCNTs used in this study are not suitable as adsorbents for CO₂ capture as they showed a low CO₂ adsorption capacity before chitosan impregnation. However, the CO₂ adsorption capacity of the MWCNTs was improved by 650 % after chitosan impregnation. Reports from literature, where CNTs were impregnated with other amines did not show such a significant increase in CO₂ adsorption capacity. It is hypothesized that if chitosan were impregnated onto more suitable CNTs for CO₂ capture it would improve the CO₂ adsorption capacity of that CNT by 650 %. Thus, yielding a suitable non-toxic, biodegradable adsorbent for CO₂ capture. It is concluded that chitosan possesses properties that make the polymer suitable for use as an adsorbent for CO₂ capture.