Abstract

As climate change becomes more apparent, growing concern over anthropogenic greenhouse gas emissions motivates researchers to develop more effective and efficient technologies for CO_2 capture. In particular, carbon capture in ambient air, known as direct air capture, can be used to reduce CO_2 emissions from nonlocalized sources. Although there is a significant amount of research on materials for CO_2 capture, many of these materials are expensive or difficult to prepare. One class of materials recently applied for CO_2 adsorption are ion exchange resins (IERs) that are advantageous due to their high surface area, low cost and ability to be easily regenerated by moisture swing. The IER reacts with water to release captured CO_2, potentially performing a lower cost alternative to the standard temperature swing regeneration.

In this work, we investigated an electrospun scaffold of polystyrene, polyethylene oxide and polycaprolactone as a support for a commercial IER to determine whether it can improve its CO_2 adsorption behavior. Undoped scaffolds were characterized by infrared spectroscopy (IR), neutron magnetic resonance spectroscopy (NMR), and scanning electron microscopy (SEM) imaging to determine fiber spinnability and diameters. Scaffolds were doped with a commercial A500 IER provided by Purolite and imaged with light microscopy. CO_2 adsorption and desorption experiments were performed to verify the improvement from electrospinning at IER weight loadings of 16, 23, 28 and 32% wt using thermogravimetric analysis (TGA) at temperatures ranging from 40 to 70°C. Electrospun IERs (ES-IERs) had higher CO_2 adsorption than the A500 IER at all conditions tested, with adsorption capacities up to 80% higher and adsorption rates up to 126% higher than the baseline IER. Increasing IER loadings resulted in improved CO_2 adsorption capacities, with diminishing improvement above weight loadings of 28%.

Data was fit to several kinetic models and by minimizing least squares it was found that the Avrami's fractional kinetic model, with n_A = 1.24-1.30 for the A500 IER and n_A = 1.41-1.82 for the ES-IER, was the best fit. This indicates that the A500 IER and ES-IER have similar adsorption growth and mechanisms, with n_A values between 1 and 2. Activation energies were determined to be -1.06 kJ/mol for the IER and -7.87 kJ/mol for the ES-IER. The improved performance of ES-IERs present a promising material for carbon capture, that offers opportunities for energy and cost savings as the rates and capacities for carbon capture are improved with electrospinning.