Chemical Engineering Doctoral Defense

Designing Sorbent-Containing Electrospun Fibers For Dilute Chemical Separations

School for Engineering of Matter, Transport and Energy

Mitchell Armstrong

Advisor: Dr. Bin Mu

abstract

An urgent need for developing new chemical separations that address the capture of dilute impurities from fluid streams are needed. These separations include the capture of carbon dioxide from the atmosphere, impurities from drinking water, and toxins from blood streams. A challenge is presented when capturing these impurities because the energy cost for processing the bulk fluid stream to capture trace contaminants is too great using traditional thermal separations. The development of sorbents that may capture these contaminants passively has been emphasized in academic research for some time, producing many designer materials including metal-organic frameworks (MOFs) and polymeric resins. Scaffolds must be developed to effectively anchor these materials in a passing fluid stream. In this work, two design techniques are presented for anchoring these sorbents in electrospun fiber scaffolds.The first technique involves imbedding sorbent particles inside the fibers: forming particle-embedded fibers. It is demonstrated that particles will spontaneously coat themselves in the fibers at dilute loadings, but at higher loadings some get trapped on the fiber surface. A mathematical model is used to show that when these particles are embedded, the polymeric coating provided by the fibers may be designed to increase the kinetic selectivity and/or stability of the embedded sorbents. Two proof-of-concept studies are performed to validate this model including the increased selectivity of carbon dioxide over nitrogen when the MOF ZIF-8 is embedded in a poly(ethylene oxide) and Matrimid polymer blend; and that increased hydrothermal stability is realized when the water-sensitive MOF HKUST-1 is embedded in polystyrene fibers relative to pure HKUST-1 powder.The second technique involves the creation of a pore network throughout the fiber to increase accessibility of embedded sorbent particles. It is demonstrated that the removal of a blended highly soluble polymer additive from the spun particle-containing fibers leaves a pore network behind without removing the embedded sorbent. The increased accessibility of embedded sorbents is validated by embedding a known direct air capture sorbent in porous electrospun fibers, and demonstrating that they have the fastest kinetic uptake of any direct air capture sorbent reported in literature to date, along with over 90% sorbent accessibility.

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