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Synthesis of modified polyvinyl alcohol and carbon nanotube composite membrane for the purification of water

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ABSTRACT

Water is one of the most important resources we have on earth and finding ways to maintain it is important. It has been found that the main pollutant discharge to water sources is oily wastewater which is produced by a lot of different industries. The aim of this thesis was to produce a membrane that can remove synthetic oil from water at reasonable flow rates. Since membranes are generally fragile, the mechanical properties of the membrane are enhanced by the addition of carbon nanotubes (CNTs). Carbon nanotubes are cylindrical graphite sheets that are produced from a carbon source (such as acetylene) and, depending on the method of production, a metallic catalyst. One of the most commonly used catalysts is ferrocene which is relatively cheap and easy to produce. Thus in this study an attempt was made to produce carbon nanotube by using ferrocene as both the carbon source and the catalyst. This was done in a chemical vapour deposition reactor (CVD) at temperatures between 800°C and 950°C. The product was analysed using transmission electron microscopy and Raman spectroscopy. It was found that CNTs are produced at all the tested temperatures and that at higher reaction temperatures, there was less adherence of the product to the walls of the reactor. Raman spectroscopy of the samples showed that MWCNTs were produced. Membrane filtration has been established as a widely used method for water purification and various filtration techniques are capable of removing synthetic oil from water. There are 2 major problems with membranes, which are fouling and concentration polarization. The fouling was addressed by using polyvinyl alcohol, which is highly hydrophilic in nature, as the top layer in a thin film composite membrane and

thus by using it as the layer that comes into contact with the solution fouling can be decreased. The bottom layer of the thin film composite membrane was a polysulfone membrane. Concentration polarization was looked at by conducting a study which determined whether concentration polarization can be decreased by increasing turbulence over the membrane. A representation of a singular tube in a tubular module, a polysulfone membrane (ultrafiltration membrane) and twisted tape were used for the tests. The twisted tape was used to induce turbulence in the tube. The addition of a twisted tape to the tube increased the stable flux by 72% and it reduced the rate at which the flux decreased from -14.99 to -5.51 L/(hm^2)/min. Carbon nanotubes were added to the polysulfone layer in order to increase the mechanical strength of the bottom support layer of membrane. The membrane structure was characterised by scanning electron microscopy and BET analysis. Increasing the CNT concentration in the membrane increased the pore sizes and the number of pores. The BET analyses showed that there is a 46% increase in the pore size between 0% CNT and 5% CNT concentrations and a 68% increase in pore size from 0% to 10% CNT concentration increase. The addition of CNTs to the polymer matrix also had an effect on the mechanical strength of the membranes with a peak mechanical strength increase obtained at a CNT concentration of 7.5%. At the concentration of 7.5% CNT in the polymer composite, a 119% increase in the ultimate tensile strength, 77% increase in the Young's modulus and 258% increase in the membrane toughness were seen indicating the suitability of the membrane in practical applications. Increasing the trans-membrane pressure decreased the membrane rejection of oil but increased flux. There is a trade-off between achieving high flux by increasing the trans membrane pressure

and running the risk of filtrate breakthrough in any membrane system, especially if the filtrate can change shape, as is the case in this system where oil is used. In the same way, increasing the CNT concentration in the membrane decreased rejection but increased membrane flux. Because an increase in the CNT concentration led to an increase in the pore sizes of the membrane it was inevitable that the rejection decreased as the oil made it through the membrane. An artificial neural network was then generated in order to model the filtration of oil from water. Encog is a framework for java and .Net and it contains classes that can be used to create an artificial neural network (ANN) and this was used to create the network. The network generated was a 3 layer feedfoward network with 1 output, 13 hidden neurons and 3 input neurons. The training error of the network was found to be 0.99% and the evaluation error was 0.92% which means this network can approximate the system quite closely. The network was transferred to Matlab where it was trained using the Levenberg-Marquardt method and the results obtained showed that the network describes the data well. A grid search method was then implemented to determine the best combination of CNT concentration and pressure. It was found that the best range to operate is at CNT concentrations between 5 and 8% and pressures between 1 and 4 bar.