



Thermoresponsive Microgels as Functional Draw Agents for Forward Osmosis Desalination

by

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**“If I have seen further, it is by standing upon the shoulders of
giants”**

Isaac Newton

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To my family,

Tan Ka Hing, Tjong Lisa Mariana & Tan Andreas Arifin

Abstract

Forward osmosis (FO) process has recently been viewed as a low energy membrane separation technology for desalination process due to the absence of high hydraulic pressure. Typical FO desalination is a two-step process: water separation and water recovery, where the water recovery stage currently consumes more energy than the reverse osmosis (RO) process. There has been surge of interest to lower the energy requirement during water recovery process by finding suitable draw materials. One of the potential draw agents proposed for FO desalination is the thermoresponsive polymer hydrogel, which is able to absorb and release water reversibly by a slight change in the operational temperature. Unfortunately, the performance of these hydrogels as FO draw agents was very poor compared to other types of draw agents such as thermolytic solutes and linear polymers. As a result, further work in developing thermoresponsive polymer hydrogels as practical FO draw agent is necessary.

In this thesis, thermoresponsive copolymer microgels were proposed and applied as FO draw agent for the first time. A series of copolymer microgels of N-isopropylacrylamide and acrylic acid was synthesized and evaluated as FO draw agent. The microgels show significantly improved performance than the previously synthesized bulk hydrogels due to their large surface areas. The microgels could generate high water flux up to 23.8 LMH and water recovery up to 55% depending on the concentration of acrylic acid in the microgels. The subsequent study investigated the effect of different acidic comonomers in the copolymer microgels on the FO water flux and water recovery performance. The results show that microgel

with itaconic acid had the best overall performance among other acidic microgels due to the strong ionization of this comonomer as indicated by its pK_a . The water flux and water recovery for this microgel are 44.8 LMH and 47.2 %, respectively. The apparent water flux of this microgel is 3.1 LMH. Thermoresponsive cationic copolymer microgels with different chemical structures of cationic comonomers were then synthesized and applied as FO draw agent to overcome long equilibrium swelling times of the acidic copolymer microgels. It was shown that microgel with 2-(diethylamino) ethyl methacrylate as a comonomer had the best performance among other cationic copolymer microgels. Furthermore, the shortest equilibrium swelling time, 30 minutes, among other microgels was achieved when this microgel was applied as FO draw agent. The water flux and water recovery for this microgel are 45.6 LMH and 44.8 %, respectively. The apparent water flux of this microgel is 5.5 LMH which is higher than the previously synthesized acidic microgels. In this study, Hansen solubility parameter was also proposed as a tool to predict the performance of the microgels as FO draw agents. The solubility parameters of the comonomers and the dissociation constants of the comonomers correlated well with the experimental results. Finally, different non-ionic copolymer microgels were synthesized and applied as FO draw agent. The microgel with acrylamide as a comonomer shows enhanced water recovery performance while maintaining relatively high water flux when used as FO draw agent. The water flux and water recovery for this microgel are 24.7 LMH and 78.7 %, respectively. The apparent water flux of this microgel is 6.1 LMH. This work will pave the way to design functional polymer materials as draw agent for FO desalination application.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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