Toward Optimized Nanofiltration for Tertiary Desalination

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In the next decades water scarcity will be a global challenge and thus purification of wastewater will become more relevant. Membrane separation processes are already well established in the water industry, but for some water sources (e.g. wastewater) the selectivity still needs to be improved. Nowadays standard treatment for wastewater is secondary treatment, which cannot remove salinity and some organic micropollutants. An attractive solution to this problem is nanofiltration (NF). These types of membranes have a pore size of ~1 nm which corresponds to a molecular weight cut-off of 300-500 g/mol. For charged species the Donnan effect can have the biggest influence on selectivity and is mainly dependent on the surface charge. For example, a negatively charged membrane surface results in a low rejection of divalent cations such as Ca^{2+} and Mg^{2+}, which can be beneficial when treated saline wastewater shall be used for irrigation.[1] In contrast, most currently available NF membranes are strongly rejecting multivalent ions. In this project, we aim to develop currently unavailable NF membranes that would reject NaCl by about 50 %, yet with lower rejection of desired calcium, magnesium, sulfate and phosphate ions. There are two investigated approaches. First, the potential of a rather easy approach toward such NF membranes via grafting of strong cation-exchange polymer layers with high charge density on suited ultrafiltration (UF) membranes is investigated (**Figure 1**).[2] The formation and composition of these cation-exchange membranes as well as resulting membrane performance are studied for different preparation parameters to improve the membrane performance (**Figure 2 (A)**). Further work will be testing of mixed salt solutions to evaluate these types of membrane for tertiary water treatment.

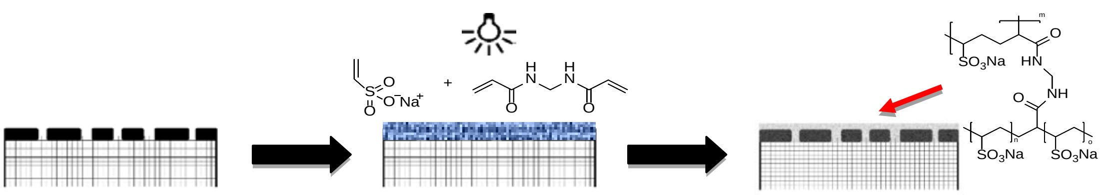

Figure 1: *Schematic overview on the preparation of n-NF membranes by UV-initiated "grafting-from" based on direct activation of the membrane polymer polyethersulfone (PES) and radical cross-linking graft copolymerization.*

More promising, but also more challenging is the second approach, the preparation of charge mosaic (CM) membranes, which consist of positively and negatively charged domains in the membrane's barrier layer. To obtain such CM membranes, polymeric nanogels with a high charge density are prepared via emulsion-polymerization.[3] The nanogel size is adjusted by using different surfactant concentrations (**Figure 2 (B)** and **(C)**). These building blocks are subsequently embedded in a layer of a polyelectrolyte with opposite charge on a suited porous support membrane. The feasibility for obtaining NF membranes with the new building blocks is demonstrated by "laminating" the negatively charged nanogels on a PES UF membrane with help of a polycationic interlayer (**Figure 2 (D)**). Ongoing work is devoted to the improvement of the fabrication of such novel CM composite membranes via different modification procedures (dip-coating, layer-by-layer) and by using different base membranes.

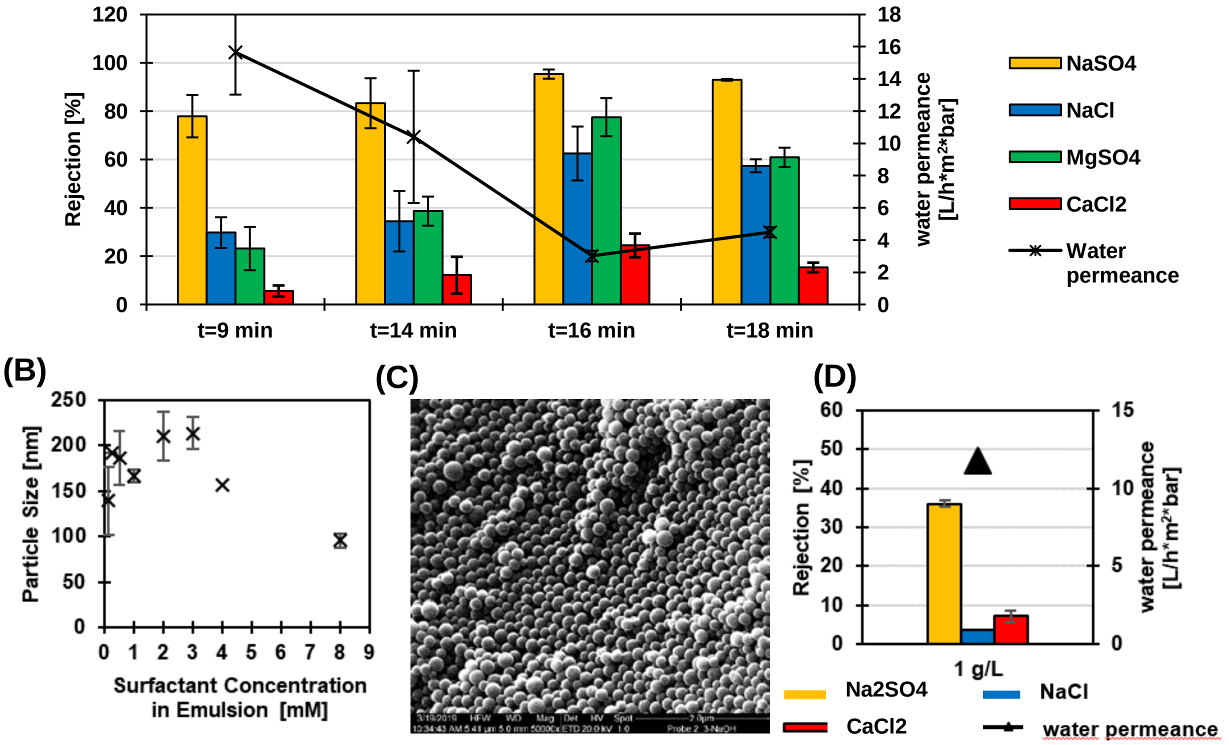

*Figure 2: **(A)** Membrane performance of n-NF membranes obtained by varied grafting parameters (measured at @ 8 bar and using single salts at 1 g/L). **(B)** Size of PSSA particles as function of surfactant concentration. **(C)** Scanning electron micrographs of poly(styrene sulfonic acid) (PSSA) nanogel particles, obtained by emulsion polymerization **(D)** Membrane performance of a composite membrane obtained by step-wise coating a PES UF membrane first with polyethyleneimine and second with PSSA nanogels (@ 3 bar; using single salts @ 1 g/L).*

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References:

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[2] R. Bernstein, E. Antón, M. Ulbricht, *ACS Applied Materials & Interfaces* **2012**, *4*, 3438-3446.
[3] R. Tiwari, A. Walther, *Polymer Chemistry* **2015**, *6*, 5550-5554.