Toward Magneto-responsive Ultrafiltration Membranes

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Stimuli-responsive membranes can self-regulate their permeability and selectivity in response to a specific stimulus. Those smart membranes featuring dynamic properties have the potential to be utilized in advanced applications. However, to modify membrane's intrinsic barrier properties, it is common to induce a response by changing conditions of the feed stream; this can make the utilization of such membranes inflexible, inefficient or even impossible. To solve this issue, this project focuses on the development of advanced magneto-responsive ultrafiltration membranes featuring temporal and remote-controlled molecular sieving [1]. Our current approach is the design and fabrication of composite membranes with incorporated magnetic microgels (Fig. 1A). Triggered by high frequency alternating magnetic field (AMF), iron oxide nanoparticles (IONP) generate heat, which is sufficient to evoke a reversible phase transition in the thermo-responsive polymer poly(*N*-isopropyl acrylamide) (PNIPAAm). This transition is observed by deswelling of the microgel, which shall cause a shift of the molecular weight cut-off. We expect that a direct contact of the local heater with the target actuator by core-shell formation maximizes the synergistic effect.

IONP are synthesized by the well-known co-precipitation method and afterwards encapsulated with PNIPAAm by seeded precipitation polymerization [2]. By adjusting the ligand shell as well as the IONP and monomer concentrations, the optimum yield of IONP@PNIPAAm particles can be obtained. The core-shell particles are characterized regarding size and thermo-responsive swelling properties (Fig. 1B) and the heating efficiency of IONP is determined by calorimetric measurements.

The prepared IONP@PNIPAAm particles should be used in two different ways for membrane modification: *in-situ* modification and *post*-modification (cf. Fig. 1A). For *in-situ* modification the magnetic microgels should be blended into the dope solution to obtain anisotropic polyether sulfone (PES) mixed matrix membranes with incorporated magnetic hydrogels by non-solvent induced phase separation (NIPS). To achieve homogeneous mixed matrix membranes with high performance, the composition of the dope solution as well as the preparation conditions (mass ratio, temperature) are studied. So far, preliminary studies with mixed matrix membranes containing non-

magnetic microgels were carried out and demonstrate a large and reversible change of barrier properties (Fig. 1C).

Regarding *post*-modification, support membranes with defined pore sizes should be modified on the surface with a thin layer of magnetic microgels by particle filtration. For that isotropic PES support membranes with pore sizes around 100 nm are prepared by nonsolvent vapor induced phase separation [3]. The membranes are pre-functionalized with positively charged poly(ethyleneimine) to guarantee strong adsorption of the negatively charged magnetic microgels due to electrostatic attraction. By this means, IONP@PNIPAAm particles with hydrodynamic sizes around 400 nm in the swollen state are successfully coated on the PES surface. Currently, the composite membranes are studied regarding selectivity and permeability. Other parameters such as microgel particle size and concentration, pore size of the support membrane, the applied pressure for filtration and the number of microgel layers on the membrane surface are also investigated**.**

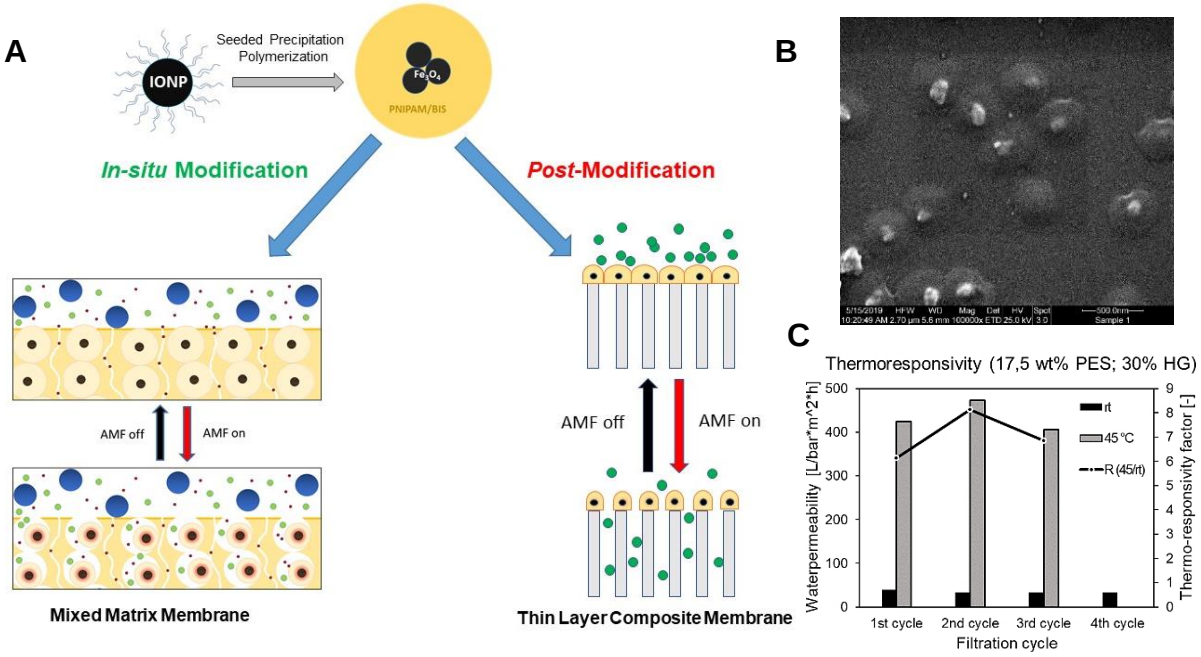

Fig. 1: A Concept of the project, **B** IONP@PNIPAAm microgel particles isolated by magnetic separation, **C** thermo-responsive water flux of a PES mixed matrix membrane with non-magnetic microgels.

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3. I. M. A. El-Sherbiny, R. Ghannam, A. S. G. Khalil, M. Ulbricht, *J. Membr. Sci.* **2015**, *493*, 782.