Thin nanocellulose coatings as tunable selective layers for membrane separation

Tuukka Levä [a], Himal Ghimire [a], Christian Pflieger [b], Joona Nieminen [c], Mikko Mäkelä [a], Tekla Tammelin [a], Alexey Khakalo [a]

[a] *Biomaterial processing and products, VTT Technical Research Centre of Finland Ltd, PO Box 1000, FI-02044 Espoo, Finland*
[b] *Applied Membrane Technology Fraunhofer Institute for Ceramic Technologies and Systems IKTS, D-98574 Schmalkalden, Germany*
[c] *Department of Separation Science, LUT School of Engineering Science, LUT University, PO Box 20, FI-53851 Lappeenranta, Finland*

tuukka.leva@vtt.fi

Nanocellulose coatings offer hydrophilic, hygroscopic and chemically modifiable surfaces that can be applied as the selective layers in porous membranes.[1, 2, 3] However, they have inherent trade-off between permeance and rejection that depends on the nanocellulose dimensions and chemistry, coating thickness and nanocellulose-water interactions.[4] We investigated this trade-off by controlling the coatings' nanocellulose composition, applied coating thickness and membrane pre-wetting before filtration. Specifically, we used a pilot-demonstrated method[1] to fabricate nanocellulose-enabled ultrafiltration membranes by cast-coating dilute suspensions of chemically unmodified cellulose nanofibers (CNFs) and negatively charged TEMPO-oxidized CNFs (TCNFs) onto commercial polyethersulfone support (Figure 1). We identified with least-squares regression modelling that the permeance increased with decreasing coating thickness and that the dry-installation of the membranes without pre-wetting enhanced their size exclusion rejection capacity. Further characterization supported these trends and guided the selection of membranes for roll-to-roll pilot production that could be industrially implemented in the future. The pilot scale membranes had molecular weight cut-offs of 4-9 kDa and pore size distributions around 5 nm, which reflected the nanocellulose fiber width. The piloted membranes' specific permeances ranged from 100 to >300 L m^{-2} h^{-1} MPa^{-1}. While thicker coatings decreased the permeance, they also increased the membranes' negative surface charge, enabling electrostatic salt rejection in addition to steric sieving. Overall, thin coatings provided higher permeance and steric rejection performance (~90% for polyethylene glycol with theoretical particle sizes ≤5 nm), whereas thicker coatings resulted in lower permeance but improved electrostatic rejection (~50% of Na_2SO_4). The nanocellulose-enabled membranes matched or exceeded the performance of commercial ultrafiltration references and tolerated at least 2 MPa pressures and pH 2-12.

Keywords:
nanocellulose, water purification, ultrafiltration, pilot scale, coating

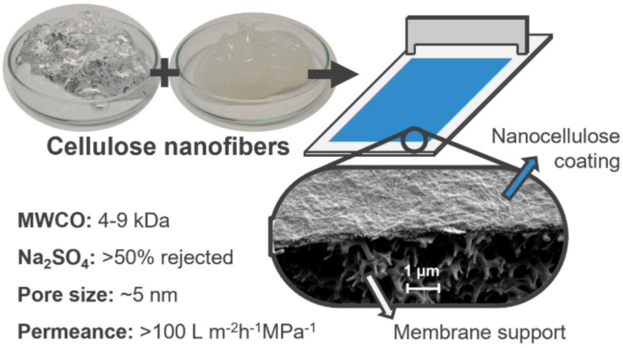

Figure 1. Nanocellulose-enabled membranes were manufactured by cast-coating CNFs on a porous support.

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