Membranes with ordered, self-aligned pores for valorization of aqueous streams

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Motivation

Currently, many waste streams in the dairy industry are discarded and valuable resources, such as lactose, minerals, and proteins, are lost because separation at the molecular level is not yet possible. Liquid crystalline (LC) polymer membranes are promising materials for molecular separation of these resources. The advantages of LCs as nano-porous materials are: 1) formation of isoporous and straight-through pores due to their self-assembling nature 2) high porosity 3) ability to tune the pore size and functionality by post-modification [1]. Thanks to these properties, LC membranes can potentially contribute to next-generation membranes for water purification, desalination and selective recovery of valuable compounds from wastewater streams.

Technological challenge

Conventional membrane materials and their fabrication methods mostly lack design at a molecular level. There is limited control over the molecular organization and structure in the selective layer thus true molecular selectivity is hard to achieve [2]. Nanostructured LC membranes are promising candidates for molecular separation. Using the self-assembly of LC molecules ensures control at a molecular level and gives rise to narrow pore size distributions and control of pore size and functionality. However, to exceed the performances of current state-of-the-art membranes, nanoporous LC membranes should overcome the following two challenges: 1) The formation of thin, defect-free selective layers supported by a microporous support; 2) Large-scale production combined with alignment control over longer length scales [2].

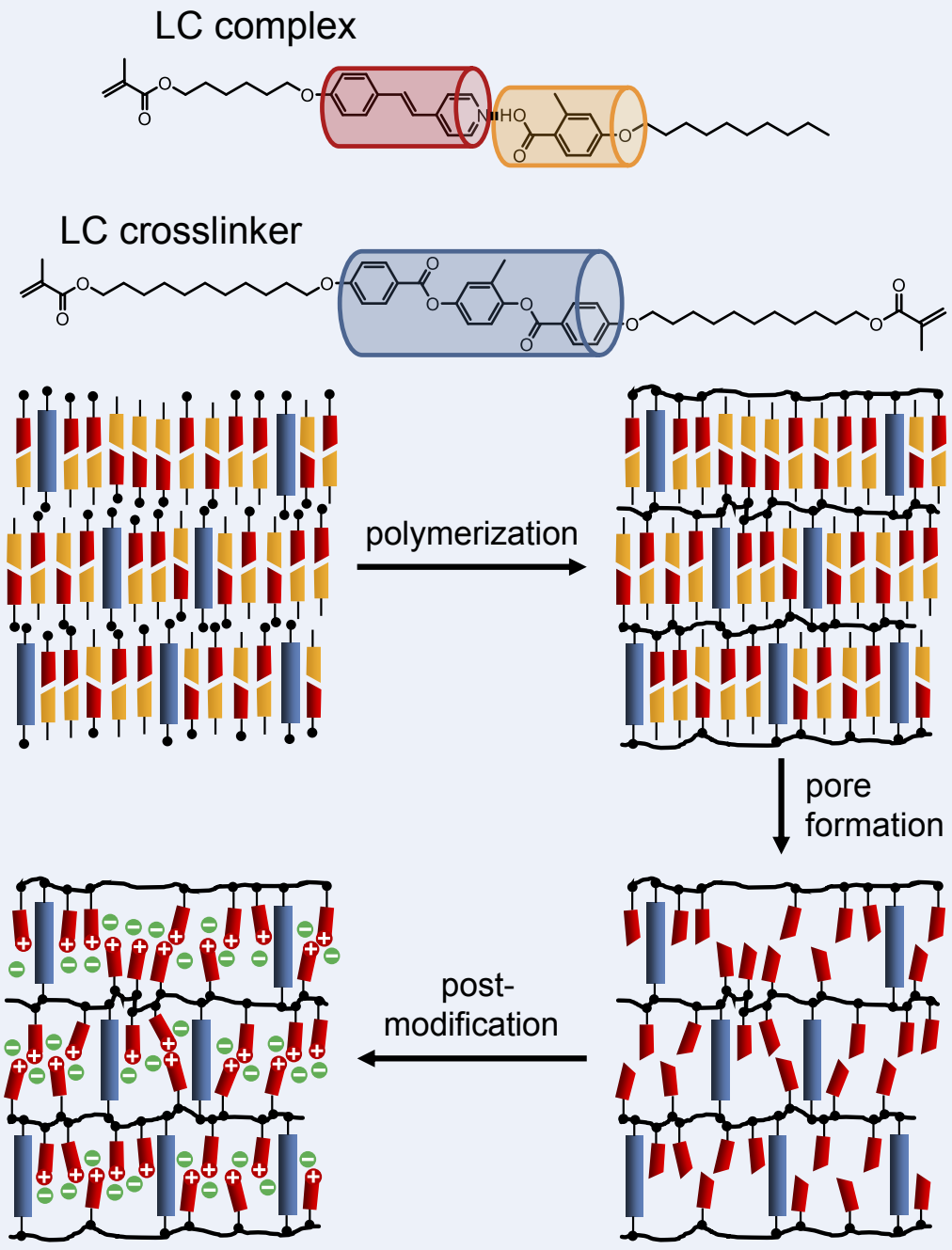

Fig 1. Molecular structure of the LC monomers and schematic overview of the fabrication steps for nanoporous self-aligned LC networks [3].

Fabrication of LC membrane

LC membranes are fabricated by the following steps: (1) The LCs are aligned by temperature control and alignment layers; (2) The LCs are crosslinked by photo-polymerization to maintain structure at room temperature; (3) Pores are created by either breaking non-covalent bonds in the LC network (which results in voids) or by removal of a template molecule; (4) Pore-functionality of the membranes can be tuned by post-modification to obtain the desired selectivity (Fig 1).

Research goals

This research project aims to:

- Develop an LC membrane with isoporous and straight-through pores.
- Determine the selectivity of the membrane for small molecules and ions.
- Tune the selectivity by changing the pore size or pore-functionality through post-modification.
- Fabricate a thin-film composite LC membrane with aligned pores that can withstand higher pressure filtration.

References
[1] T. Kato et al., Angew. Chem. Int. Ed. 57 (2018) 4355-4371
[2] J. Kloos et al., J. Membr. Sci. 620 (2020) 118849
[3] D.J. Mulder et al., J. Mater. Chem. C 18 (2018) 5018-5024

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