Fabrication of Perforated Isoporous Membranes: Enabling High-Resolution and High-Flux Separation of Cells

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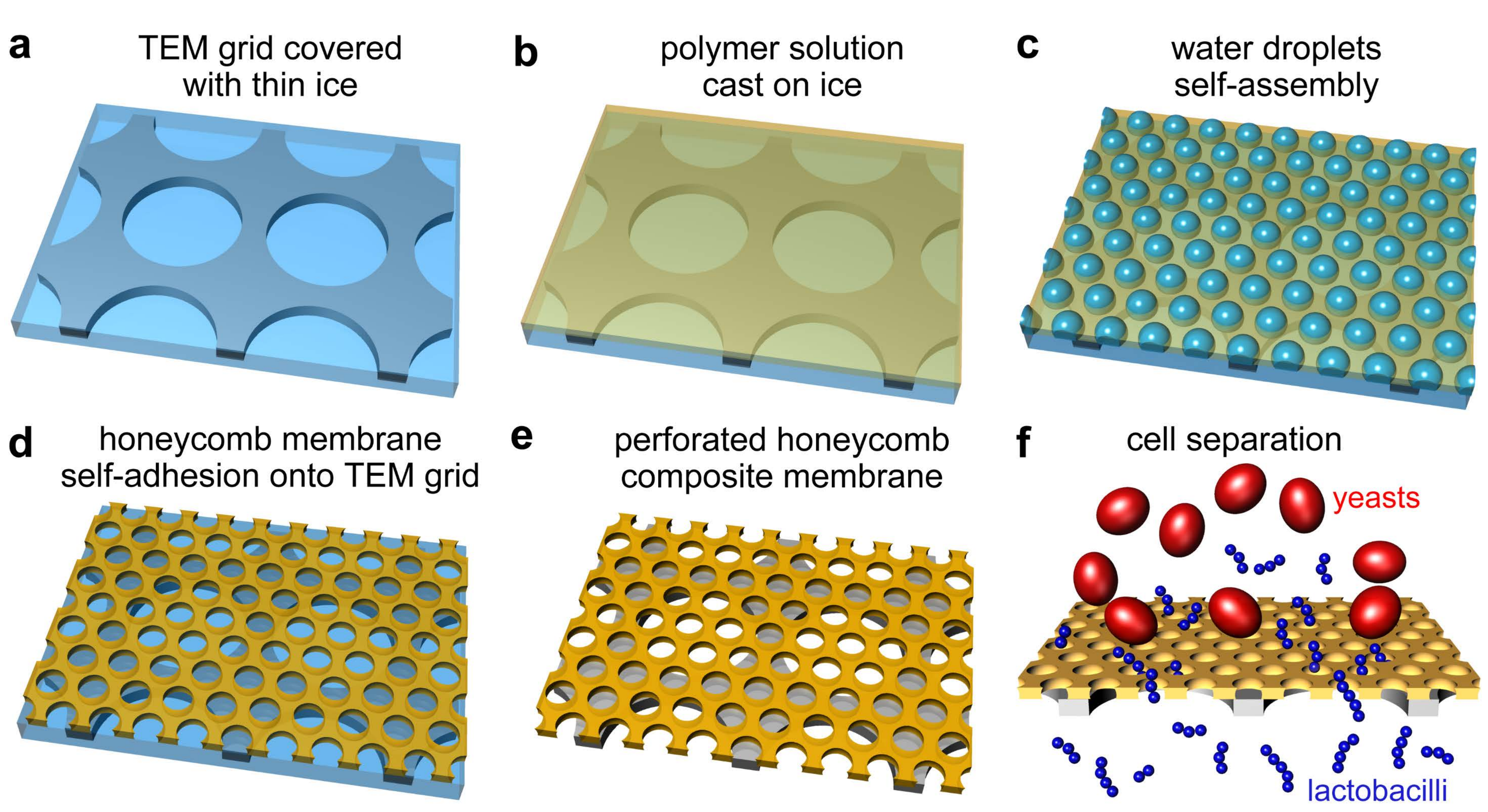
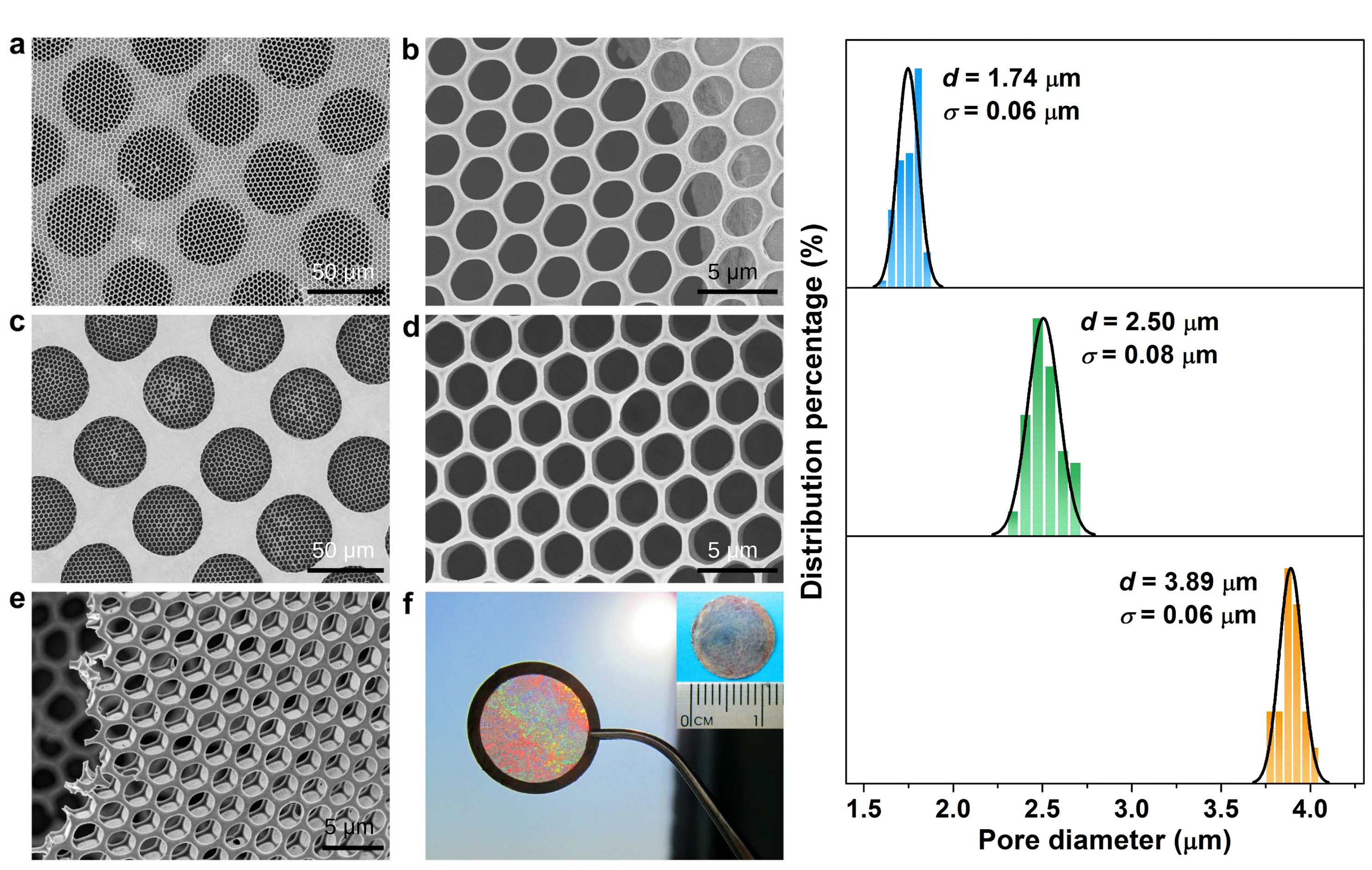
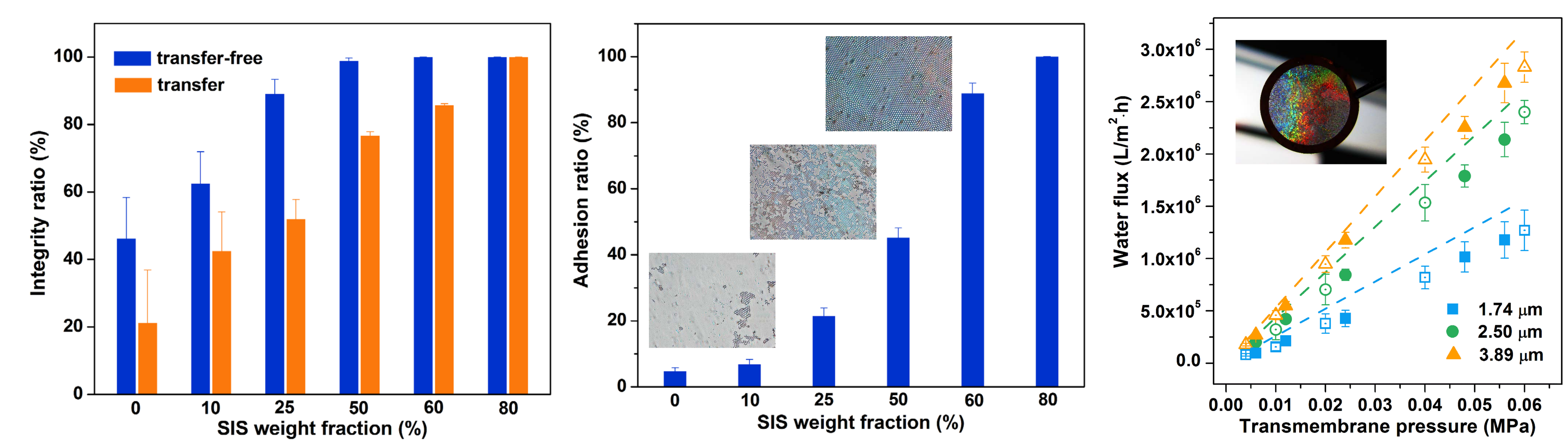
Thin perforated membranes with ordered pores are ideal barriers for high-resolution and high-efficiency selective separation of biological species. However, for self-assembled membranes with a thickness less than several micrometers, an additional step of transferring the membranes onto porous supports is generally required, which may cause severe pore cracks, and thus attenuate the membrane separation selectivity and mechanical durability. Here, we present a facile transfer-free strategy for fabrication of robust perforated composite membranes via the breath figure process, and for the first time, demonstrate the application of the membranes in high-resolution and high-flux cell separation of yeasts and lactobacilli at an ultralow operation pressure, achieving almost 100% rejection of yeasts and more than 70% recovery of lactobacilli with excellent viability. The separation flux could reach up to 2.0×10^4 L m^{-2} h^{-1} under a pressure as low as 0.004 MPa. Such perforated ordered membranes can also be applied in other size-based separation systems, enabling new opportunities in bioseparation and biosensors.



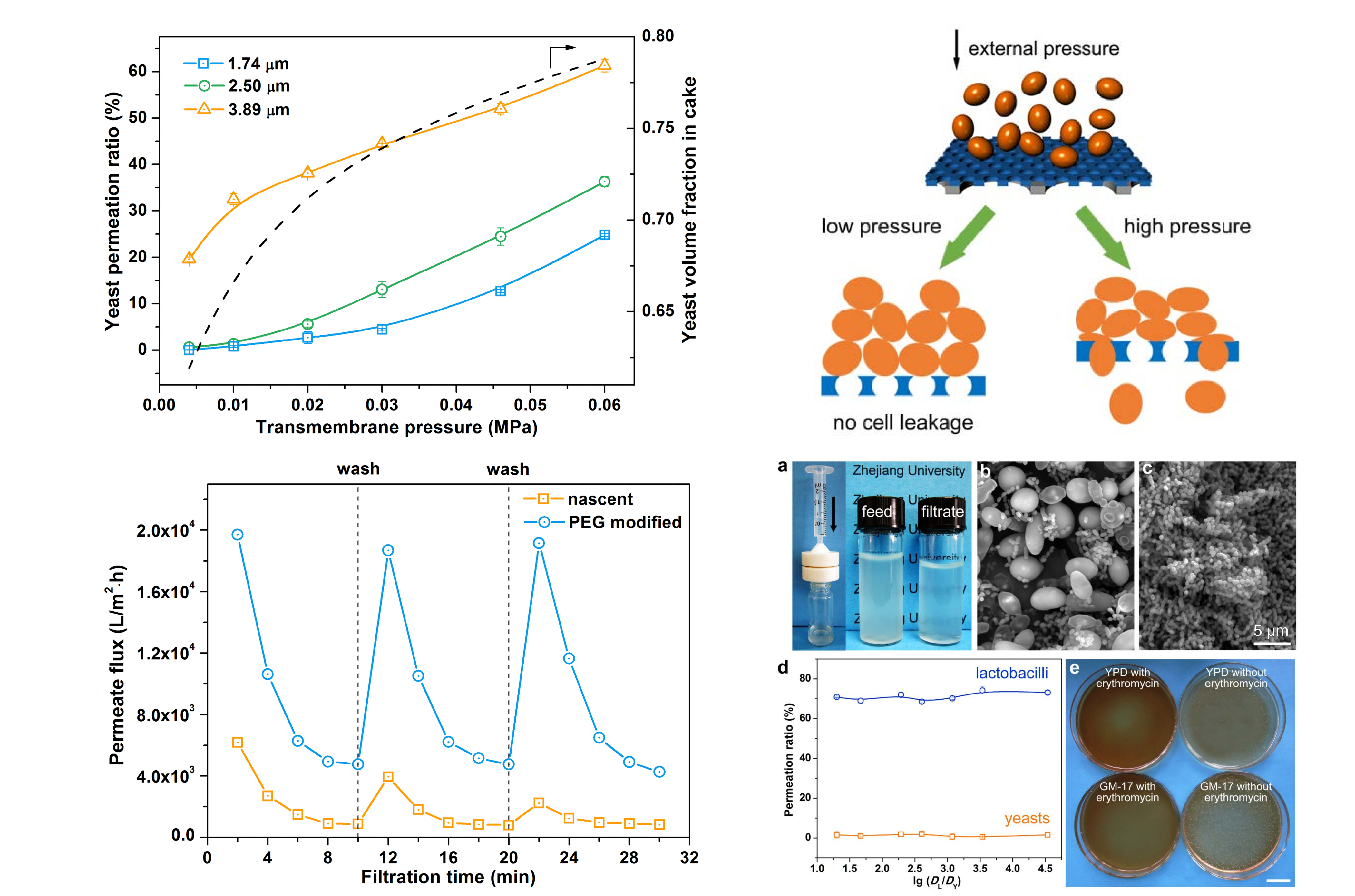
Transfer-free membrane fabrication. A thin ice layer above the porous support gradually melted into water and infiltrated down through the wide openings of the substrate, leading to self-adhesion of the membrane onto the underlying support structure.



Composite membranes. Perforated honeycomb-like composite membranes were obtained without pore cracks in a large area using PS-*b*-PDMAEMA/SIS blend as the membrane-forming material. The pore size of the membranes can be facilely modulated in the range of 1.5-4 μm via an appropriate dynamic control over the airflow speed and relative humidity in the breath figure process.



Enhancement of membrane mechanical properties and water flux. The membrane integrity and interfacial adhesion strength were both significantly improved due to the transfer-free method and introduction of SIS. The relationship between the pure water flux and operation pressure through the membranes fitted perfectly well with the hydrodynamic model of Hagen-Poiseuille equation, which indicated the formation of ideal straight through pore channels inside the membranes.



Cell separation. The pressure-driven permeation behavior of yeasts and lactobacilli through the membranes demonstrated an almost 100% rejection of yeasts and more than 70% recovery of lactobacilli in the filtrate under low pressure. High-flux cell separation with excellent reusability was performed at an operation pressure of 4 kPa by PEG decoration of the membrane surface via dopamine chemistry.

Conclusions

- Robust perforated composite membranes with ordered and uniform pores were fabricated via a facile transfer-free strategy, which greatly improves the homogeneity and interfacial adhesion strength of the membranes.
- The thin perforated membranes were applied in high-resolution, high-flux and energy-saving size-selective cell separation, resulting in an almost 100% rejection of yeasts and more than 70% recovery of lactobacilli.

References

Ou, Y.; Lv, C. J.; Yu, W.; Mao, Z. W.; Wan, L. S.; Xu, Z. K. *ACS Appl. Mater. Interfaces* 2014, *6*, 22400-22407.

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