Graphene oxide membranes for milk industry

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Significance of R & D
① Our research group develops graphene oxide membranes for milk filtration.
② This research is working on removal of lactose from milk. We realize by graphene oxide membrane filtration
③ By removing lactose from milk with and antifouling membrane, we contribute to membrane technologies for the food industry.

Abstract

With the increase in population the demand for food keeps increasing. In particular, the milk industry keeps developing to meet the consumer demands. Milk intolerance affects a large population (90%) in east Asia, whereas in other regions at least 30% of the population has this condition.[1] Therefore, new technologies could help address this demand. Graphene oxide membranes have been widely studied for water desalination, pigment filtration and solvent separation,[2] however its application in the food industry remains to be explored.

In this work, we used a spray-coated graphene oxide membrane [2] that can effectively remove lactose and some salts from a commercial milk product without losing protein and fat, confirmed by infrared spectroscopy. During the studies the permeate flux did not suffer decline, due to the excellent anti-organic fouling properties. This membrane could be easily washed with a high water flux. The antifouling properties were also confirmed against proteins such as lysozyme and bovine serum albumin in static experiments and during cross-flow operation. In addition, molecular dynamics simulations also demonstrated the anti-organic fouling capability of graphene oxide against lysozyme and bovine serum albumin. This membrane could help create lactose free dairy products with similar taste as the original products, with expected long operation lifetime and lower maintenance cost due to its anti-organic fouling properties.

Membrane preparation

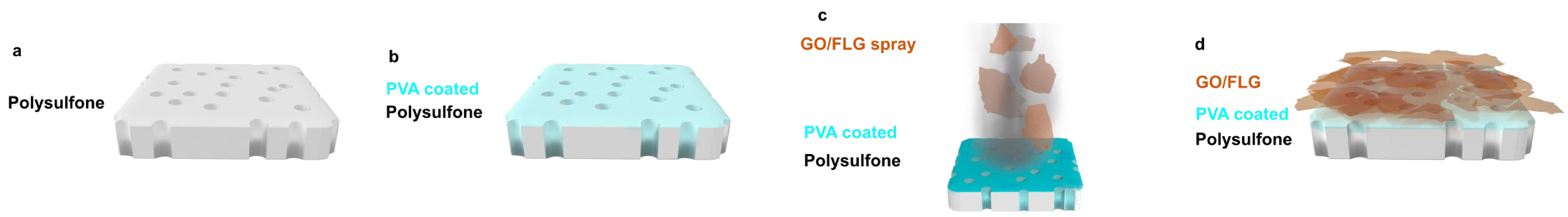

Figure 1. Graphene oxide/few-layered graphene membrane preparation. (a) Porous polysulfone substrate. (b) Functionalization on the substrate surface and (c) then GO solution is deposited by spray coating. (d) The GO sheets are aligned parallel to the flat surface.

Results

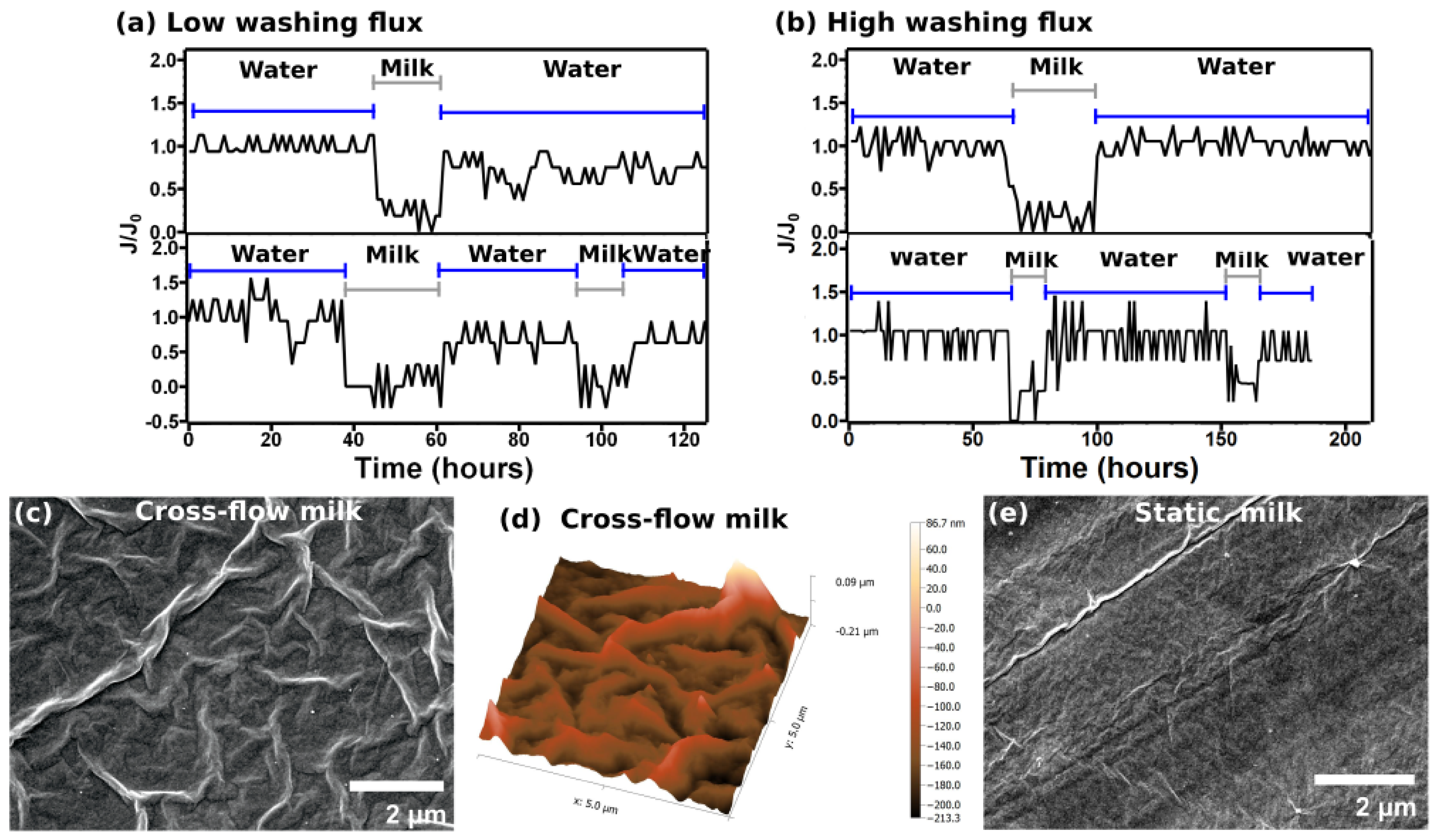

Figure 1. Normalized permeate flux when using (a) low-flux (300 ml/min) washing, (b) high-flux (1000 ml/min) washing after exposing the GO membrane to milk feed for filtration. (c) SEM and (d) AFM topography images of the GO membrane after cross-flow milk filtration with high washing flux. (e) SEM image after static exposure to milk for 3 days.

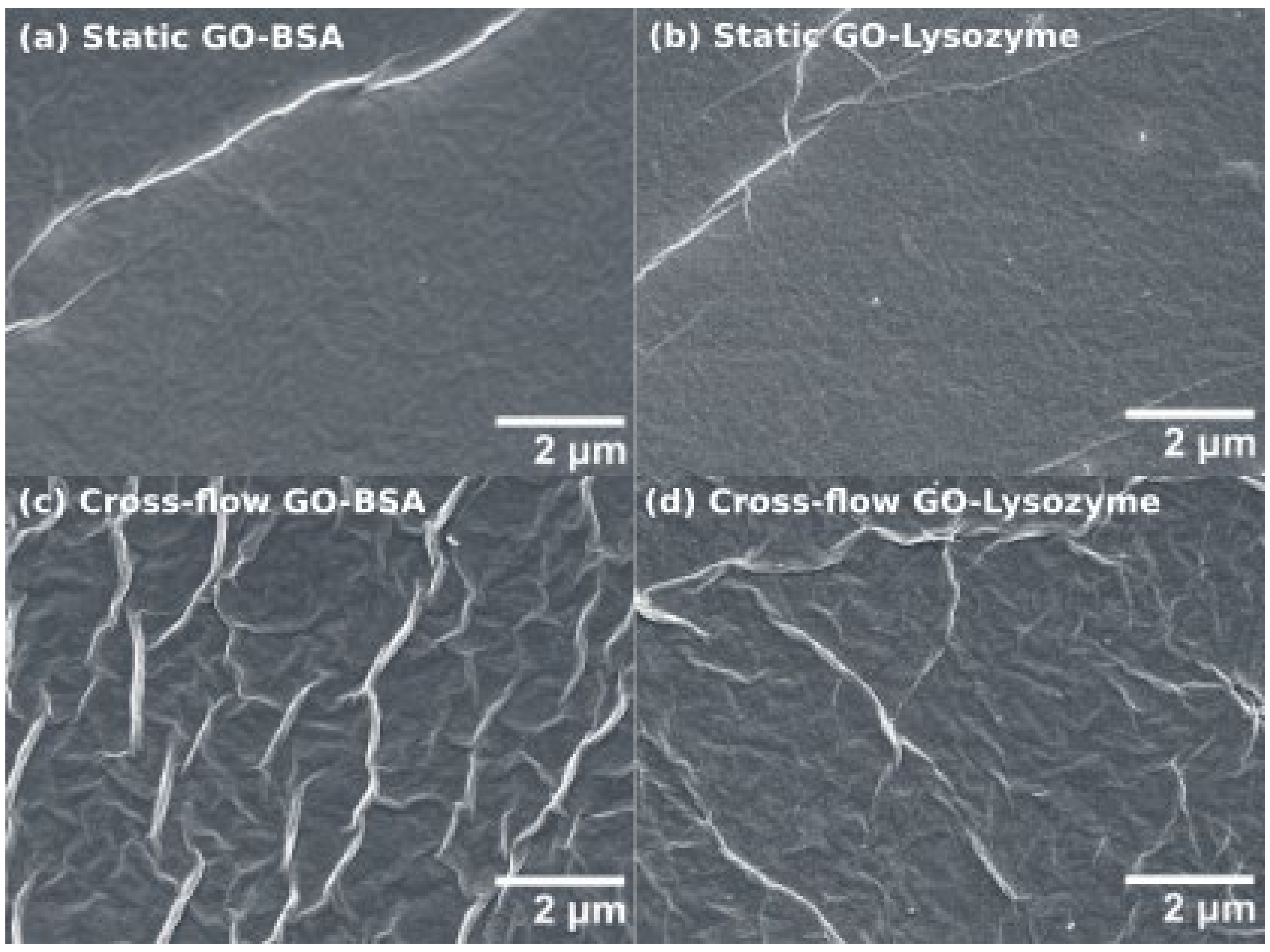

Figure 2. Microscopy images of GO membranes after static and cross-flow fouling. SEM images of GO after fabrications, static fouling with (a) BSA and (b) lysozyme and with cross-flow operation with (c) BSA and (d) lysozyme. All feed solutions had 200 ppm of protein and were exposed for 3 days (0.5 MPa) to the fouling solutions.

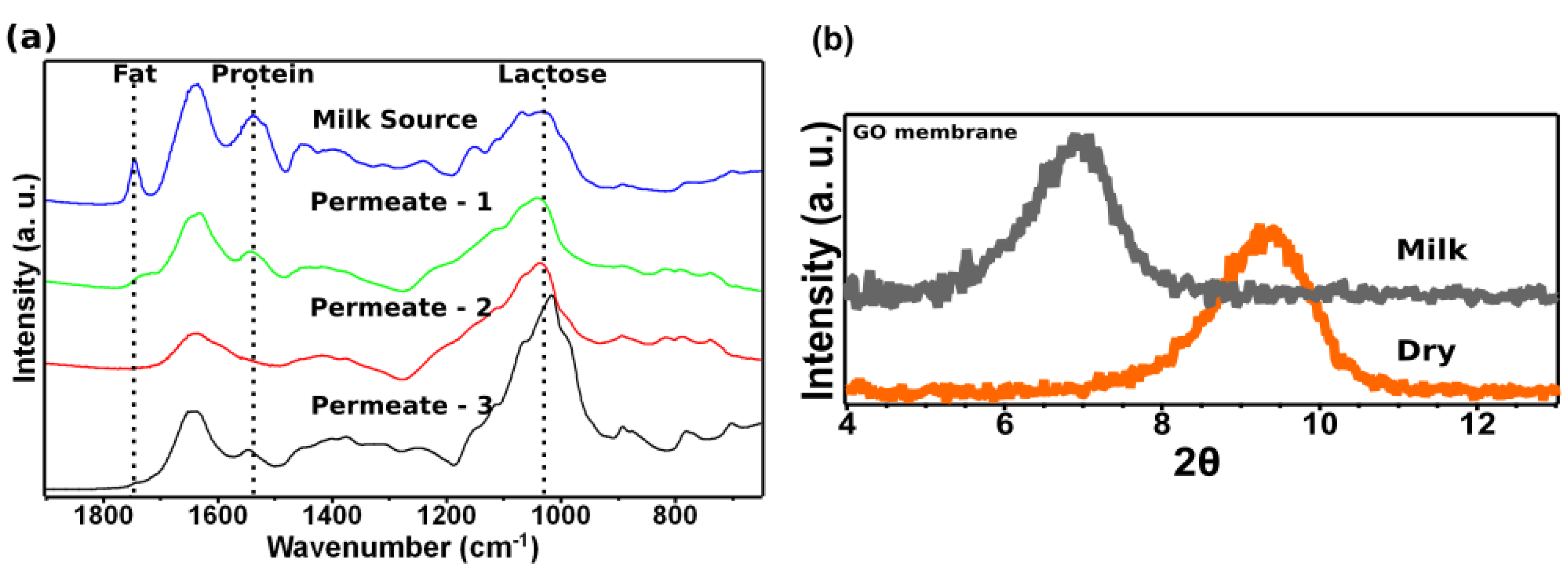

Figure 3. (a) ATR-FTIR spectra of milk source and permeate. Permeate was taken from three independent filtrations. (b) X-ray diffraction of GO membrane measured dry and hydrated in milk.

References
1. J. L. Turnbull, et al., Aliment. Pharmacol. Ther. 41, 3 (2015).
2. A. Morelos-Gomez et al., Nature Nanotech. 12, 1083 (2017).

【 Future developments 】
Computation optimization methods can be applied to improve filtration performance and scale up conditions. With these two key aspects solved it could be closer for social implementation.

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