Electrospinning bipolar membranes for water electrolysis

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Motivation

Bipolar membranes (BPMs) consist of a cation-exchange layer (CEL) and an anion-exchange layer (AEL) separated by a thin interfacial layer (IL)[1]. They are currently used in acid-base production, electrodialysis, or resource recovery. Recently, BPM water electrolysis (BPMWE) has enabled hydrogen evolution in acidic media and oxygen evolution in alkaline media[2], but this process requires high current densities that exceed the capabilities of commercial BPMs. Using electrospinning, we can produce the BPM out of nanofibers, which are randomly deposited and allowed to entangle. This results in increased interfacial area and better membrane durability[3]. Membranes optimized for BPMWE can also be applied to other electrochemical systems.

Technological challenge

BPMs currently suffer from low mechanical stability when operated at high current densities, which are necessary in electrolyser operation. When the rate of water dissociation is high, the interfacial area can be torn apart by the fluxes of protons and hydroxide ions migrating out of the membrane, leading to delamination and blistering. BPMs also have low chemical stability, namely at high pH, leading to the decomposition of the AEL. Additionally, the lack of long-term continuous operation studies prevents accurate lifetime estimation. Lastly, the introduction of a catalyst in the interfacial layer in an electrospinning setup is still challenging. However, using a three-needle electrospinning setup (Fig. 1) opens doors to new approaches in membrane development.

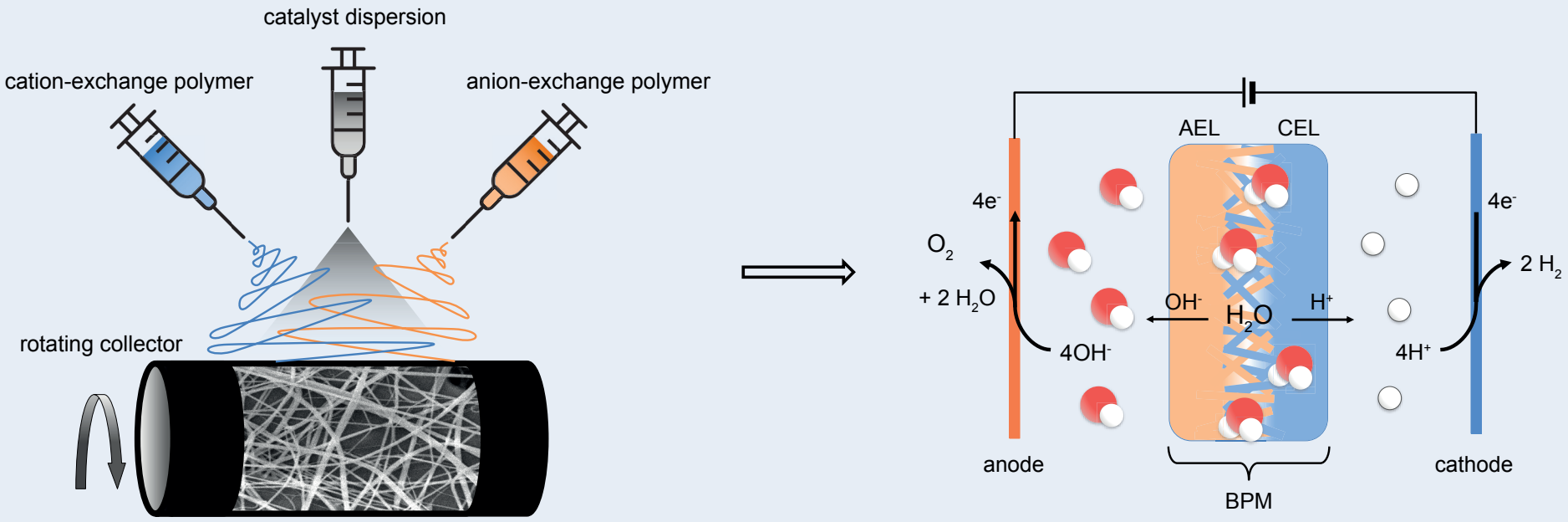

Fig 1. Schematic of BPM fabrication using electrospinning (left) and membrane-electrode assembly (right). Fibrous mat collected on a rotating drum is hot-pressed into a dense membrane. When put under electric potential, the BPM is able to dissociate water molecules into protons and hydroxide ions.

Research goals

- This research aims to:
- Fabricate a BPM able to perform the water dissociation reaction at high current density;
- Further the understanding of the water dissociation reaction inside a BPM;
- Understand which factors contribute to BPM durability & lifetime;
- Develop a suitable method of introducing water splitting catalyst into the membrane junction using the electrospinning system.

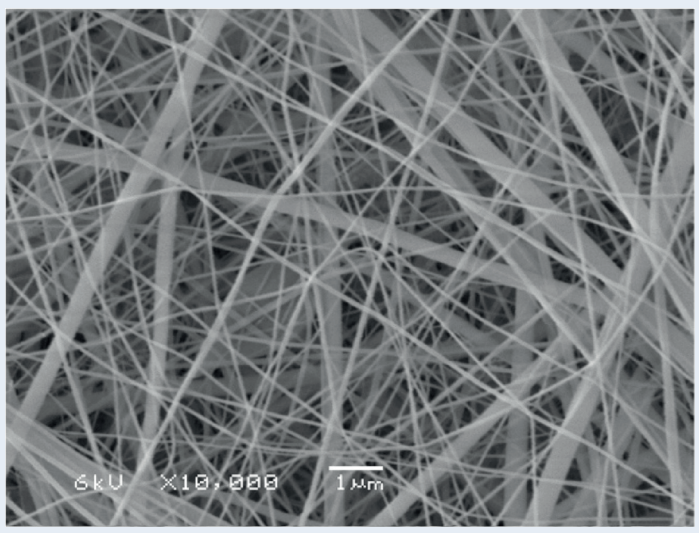

Fig 2. SEM image (10,000x magnification) of an electrospun interfacial layer, comprising fibers from 2 different polymers.

References

[1] Pärnamäe et al. (2021). J. Membr. Sci. 617, 118538.
[2] Oener et al. (2020). Science, 369 (6507), 1099–1103.
[3] Al-Dhubhani et al. (2021). ACS Appl. Energy Mater., 4 (4), 3724–3736.

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