COMMUNICATION

Capacitive Deionization

ADVANCED MATERIALS

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Exceptional Water Desalination Performance with Anion-Selective Electrodes

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Why I have chosen this paper?

- Currently, more than 300 million people around the world rely on desalinated water for part or all of their daily needs. That demand will only grow with larger populations and improved standards of living around the world.
- However, well-developed desalination processes such as reverse osmosis (RO), electrodialysis (ED), and distillation not only require large-scale infrastructure but also have a high cost for controlling fouling during operations. Therefore, it is desirable to develop a novel desalination technology with simple equipment, easy operation, and high energy efficiency.
- Among the various desalination technologies, capacitive deionization (CDI) is considered as one of the promising desalination technologies because of its energy-efficient, ecofriendly, facile operation.

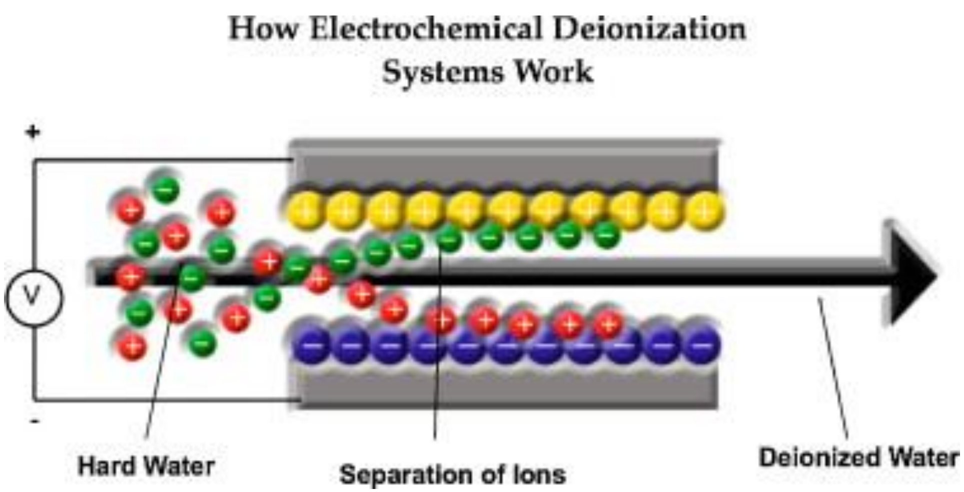
What is this work about

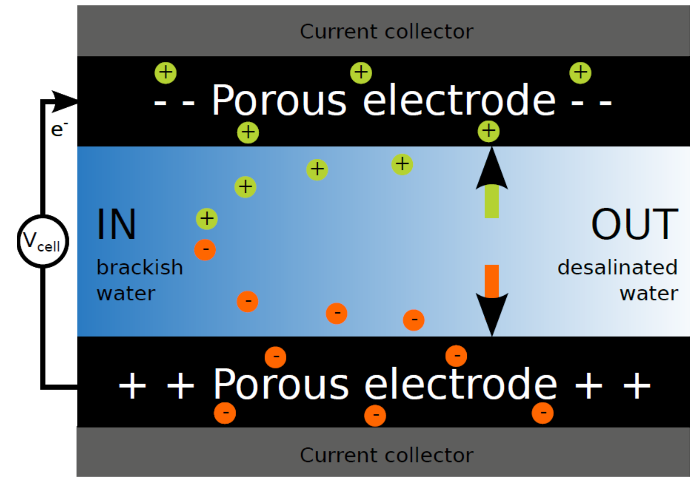
- In this paper, anion-selective electrodes are obtained by chemical modification of the carbon electrode with (3-aminopropyl)triethoxysilane and it used as a CDI electrode.

Relevance to the group or my work

- This paper shows how covalently anion-selective electrodes has prepared by chemical modification of carbon. So covalently cation and anion ion-exchange resin can be prepared and it can be used for different applications (sensor, CDI).

What is CDI?





- **Capacitive deionization (CDI)** is a technology to deionize water by applying an electrical potential difference over two porous carbon electrodes.
- Liquid is flowing between the high surface area electrode pairs having a potential difference of 1.0-2.0 V DC.

Image courtesy: M.A. Anderson *et al*., Electrochimica Acta 2010, *55, 3845–3856*

In this paper….

- Water scarcity is becoming a serious issue across the world.
- However, well-developed desalination processes such as reverse osmosis (RO), electrodialysis (ED), and distillation not only require large-scale infrastructure but also have a high cost for controlling fouling during operations. Therefore, it is desirable to develop a novel desalination technology with simple equipment, easy operation, and high energy efficiency.
- Further applications of conventional CDI are limited due to its low salt adsorption capacity (0.1−15 mg g^{-1}), low charge efficiency (30−70%), and poor cycling stability.
- An innovative MCDI cell design based on two cation-selective electrodes and a single anion-selective membrane, and thereafter this design was experimentally validated by various authors.
- But MCDI electrode has issues due to decrease the conductivity of electrode surface.
- To overcome the limitations of these disadvantages, various attempts have been reported including using novel cell architectures, such as water desalination with a wire electrode, flow-electrode CDI (FCDI), and multichannel flow stream membrane CDI.
- Anion-selective electrodes are obtained by chemical modification of the carbon electrode with (3-aminopropyl)triethoxysilane.

Results and discussion

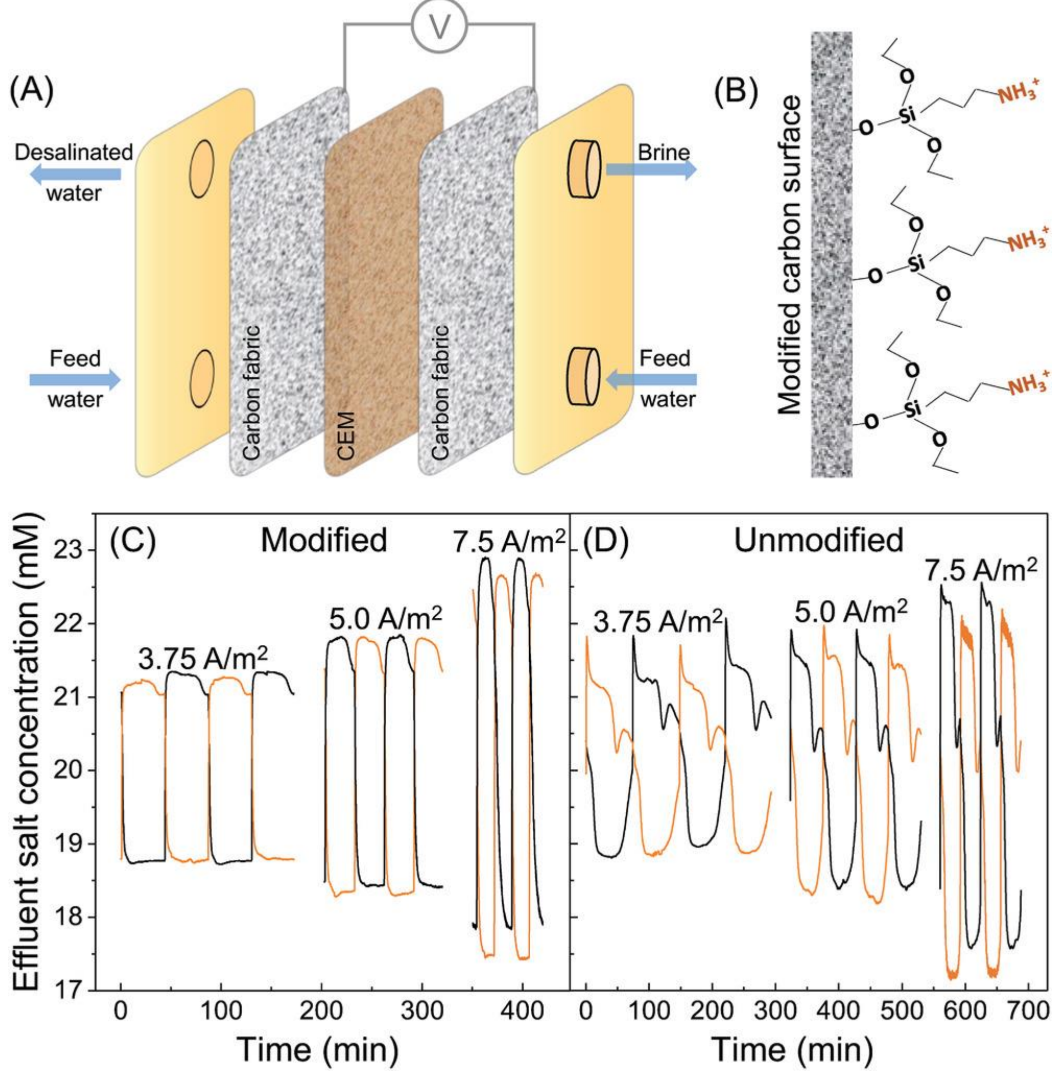


Figure 1. A) Schematic overview of desalination with anion-selective electrodes with a single cation-exchange membrane (CEM) and two identical activated carbon fabric electrodes, either both modified or both unmodified. In this cell, water flows through the porous electrodes. When current runs in one direction, one channel produces desalinated water (freshwater), while the other produces concentrated (brine). When a certain voltage is reached, the direction of the current is reversed until a lower endpoint for voltage is reached, and now freshwater is produced in the channel that previously was producing concentrate, and vice versa. B) Schematic view of modified carbon surface with silanes bearing terminal amines. C) Effluent salt concentration of both channels for desalination cycles with modified and D) unmodified activated carbon electrodes at a constant current of 3.75 A m^{-2}, 5.0 A m^{-2}, and 7.5 A m^{-2} in 20 *10^{-3} M NaCl.

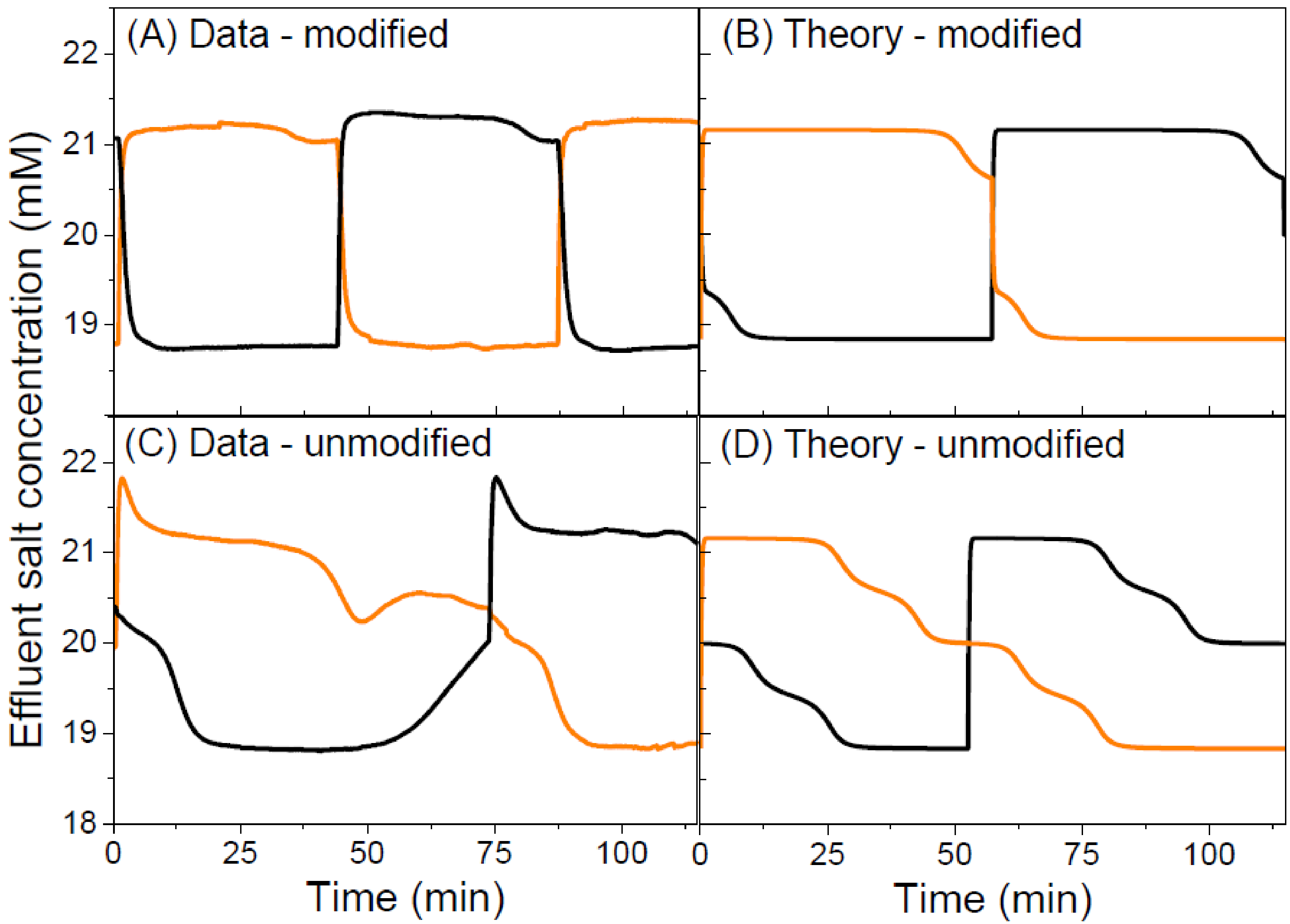


Figure 2. Effluent concentration of both channels (**Figure 1**) as function of time for the modified (A, B) and unmodified electrodes (C, D). Experimental (A,C) and theoretical (B,D) data are shown. During charging, the current density, *I*, was 3.75 A/m^2 and the pre-set upper cell voltage during charging V_{max}= 0.9 V. During discharge, both *I* and V_{max} have the same pre-set value but with opposite sign.

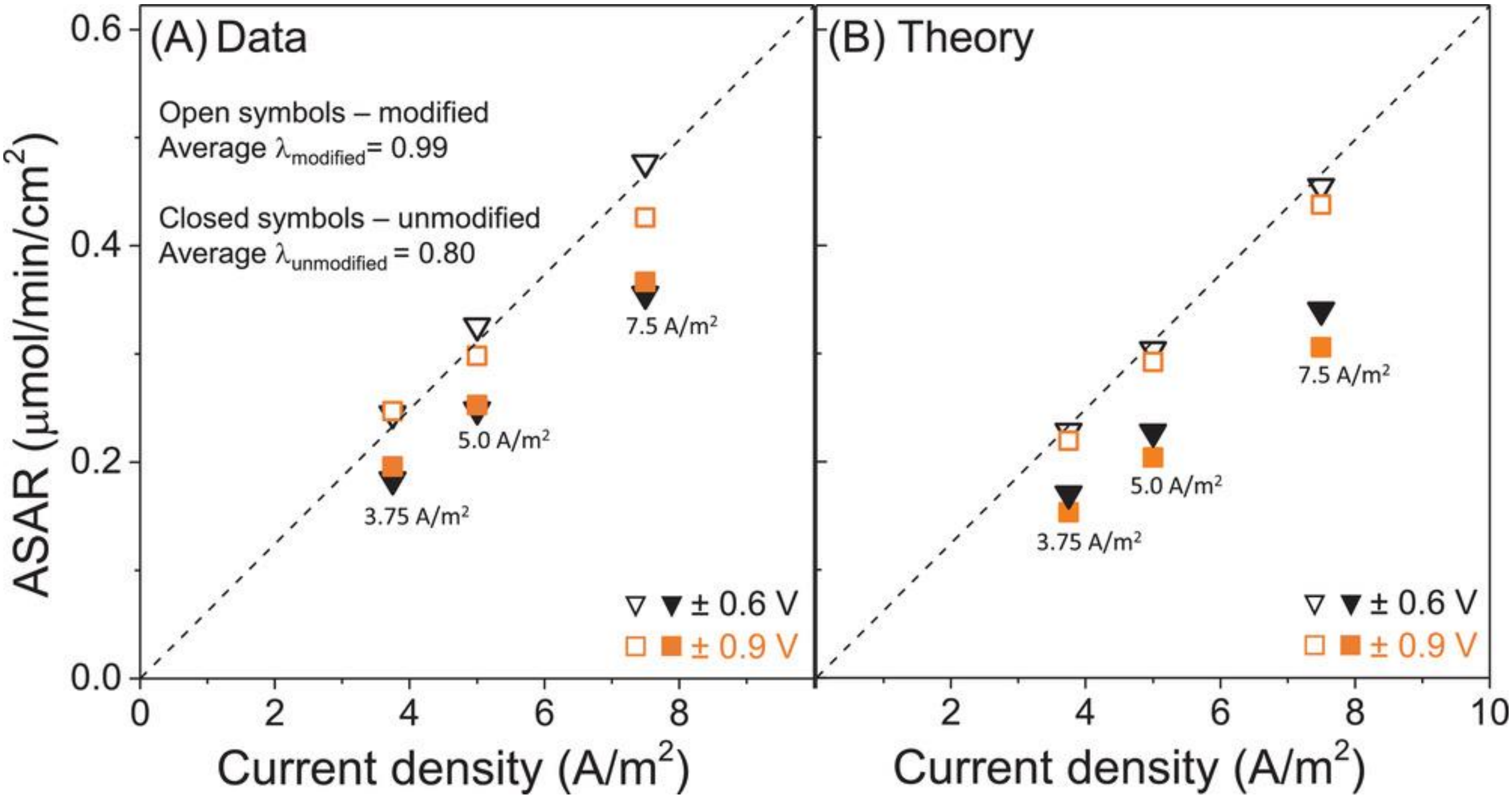


Figure 3. Average salt removal rate, ASAR, as function of current density for chemically unmodified and modified activated carbon electrodes and for different values of V_{max}: A) experimental and B) theoretical results. Current efficiency λ, of unity is represented by the dashed line. Theoretical results are calculated using the amphoteric Donnan model.

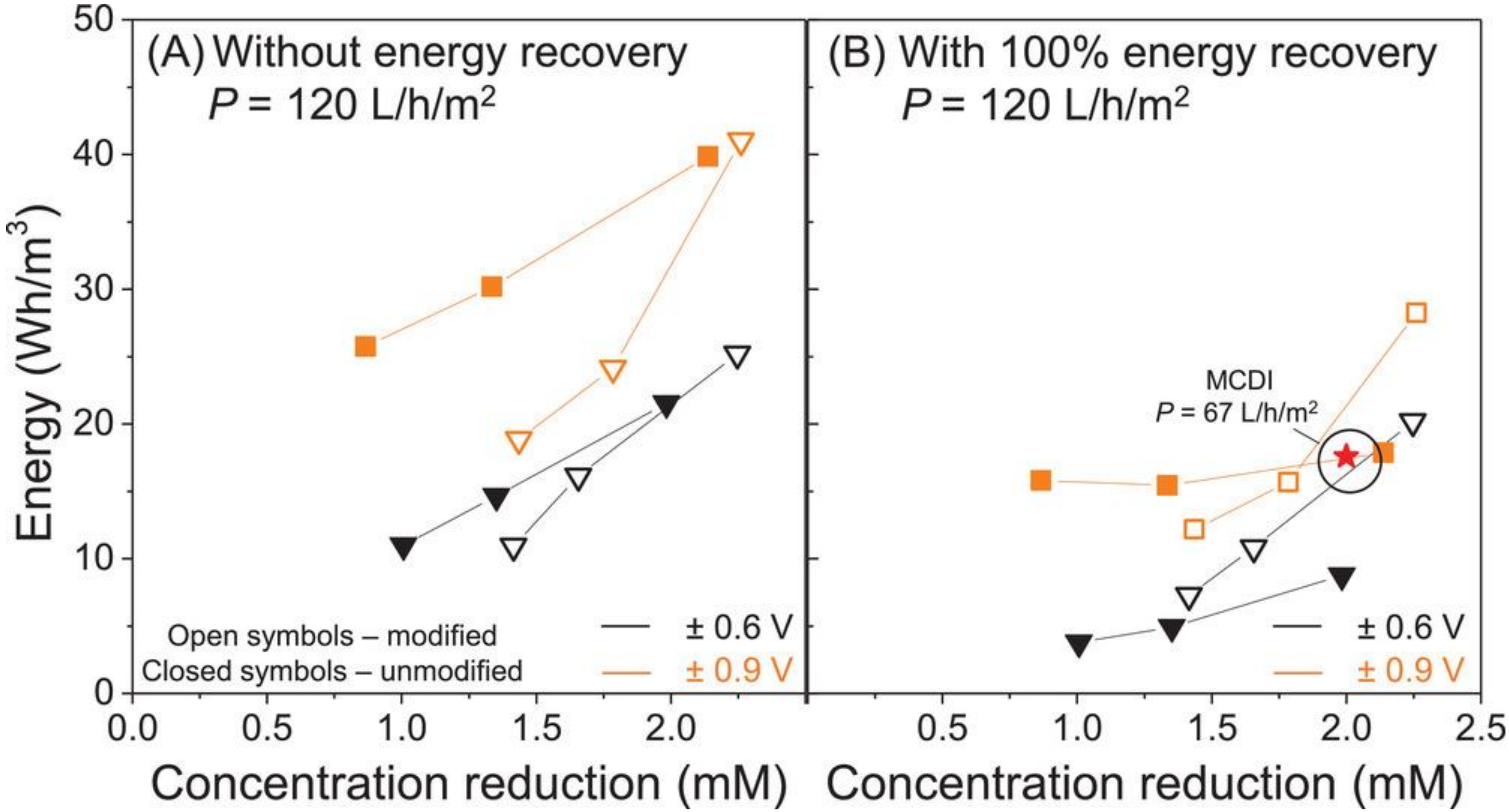


Figure 4. Energy consumption (EC) per m^3 of desalinated water produced of CDI with modified (open symbols) and unmodified electrodes (closed symbols): A) without energy recovery (ER) and B) with 100% ER. Values of EC for 100% ER are benchmarked against a standard MCDI system,operated with a salt concentration reduction of c = 2 * 10^{-3} M and a lower water productivity of PMCDI = 67 L $h^{-1}m^{-2}$.

Conclusion

- In this paper, they have demonstrated that a choice for anion-selective electrodes, in combination with a cation-selective membrane, leads to a functional cell design that continuously desalinates water..
- They have shown that theory describes the experimental data well, and we find that with 100% energy recovery, energy consumption of the new cell design is much lower than a standard MCDI system.
- It was shown that, after chemical modification, the porosity is reduced from 0.55 mL g^{-1} to 7.0 μL g^{-1}, and the BET-area of our electrodes is reduced from ≈1100 to ≈18 m^2 g^{-1}, while the desalination performance of the electrodes is increased.
- This is the first time that a low-porosity carbon electrode has shown such excellent performance for desalination in CDI.


Thank You