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Research Article

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Rocking-Chair Capacitive Deionization for Continuous Brackish Water Desalination

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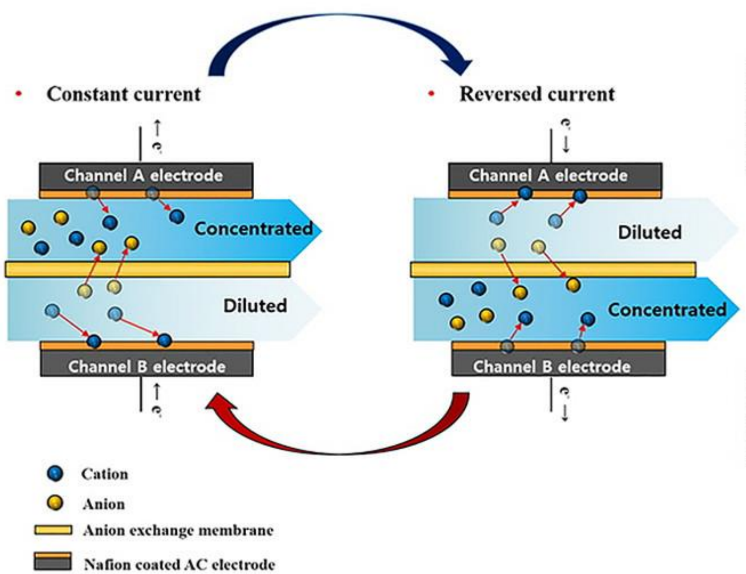
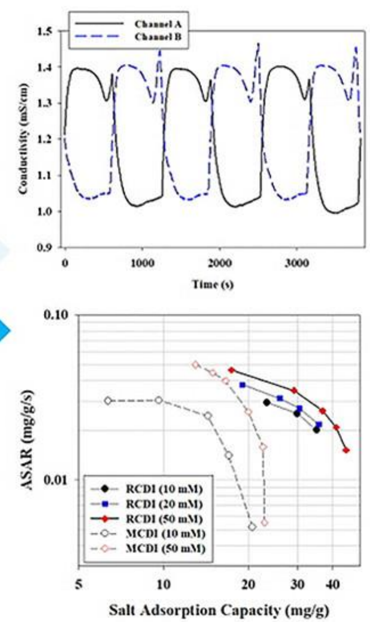
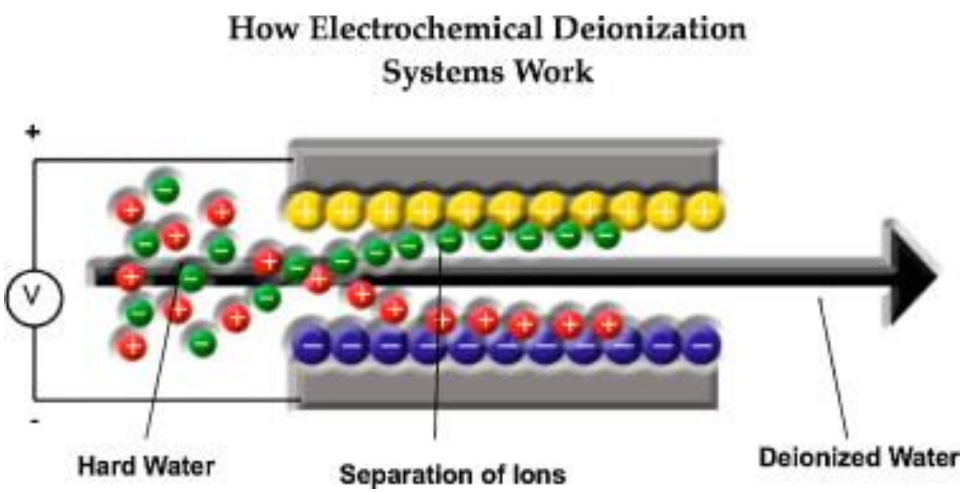
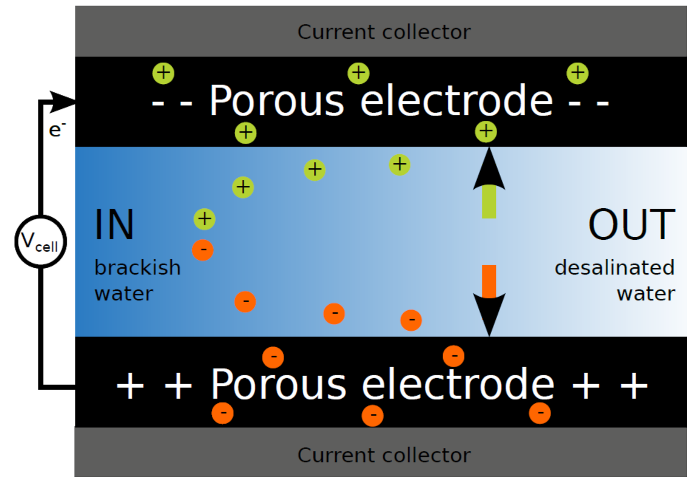




Md Rabiul Islam
15-09-2018

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 *55 (2010) 3845–3856* and Wikipedia.

Why this paper I have chosen or what is the reasons to discuss this work in the group?

- 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.
- 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.
- In this paper desalination was done using brackish water under rapid operation conditions (up to ±30.0 A m−2) which is a **constant-current operation condition** that is several times higher than that of previously reported desalination technologies using battery materials.

Background

Desalination 400 (2016) 18–24

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

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DESALINATION

Energy consumption analysis of constant voltage and constant current operations in capacitive deionization

CrossMark

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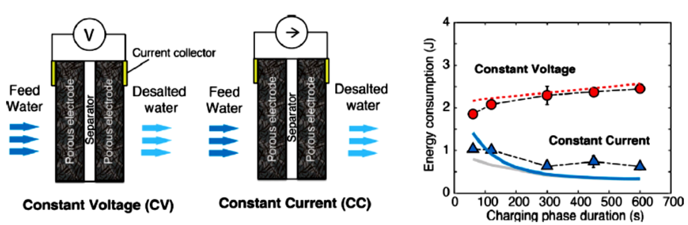
HIGHLIGHTS

- Two circuit models useful in elucidating constant current (CC) versus constant voltage (CV) CDI energy consumption dynamics.
- CC mode consumes significantly less energy than CV mode for equal amounts of input charge and identical charging duration.
- CC mode has approximately same salt removal as CV and avoids initial high-power resistive dissipation of CV mode.

GRAPHICAL ABSTRACT



$$\frac{E_{CC}}{E_{CV}}(t) = \frac{2RC}{t}\,\frac{1-e^{-\frac{t}{RC}}}{1+e^{-\frac{t}{RC}}}.$$

Perhaps surprisingly, this ratio is always smaller than unity regardless of the values of resistance R and capacitance C (Fig. S-1b). This simple model therefore suggests CC operation always consumes less energy than CV for the same amounts of input charge and for identical timespans. In addition, energy consumption for either CV or CC mode strongly depends on the equivalent total resistance R.

Water Research 143 (2018) 367–375

Contents lists available at ScienceDirect

Water Research

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WATER RESEARCH

Energy consumption in capacitive deionization – Constant current versus constant voltage operation

Check for updates

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What is this work about

In this paper they have discussed about water purification using RCDI (constant current) using anion exchange resin coating and the Nafion-coated activated carbon can selectively adsorb and desorb anion and cation respectively.

Relevance to the group or my work

In this paper they have prepared the Nafion-coated activated carbon which can be used as +ve particle for dust, also charge measurement of this particle can be done.

In this paper….

- 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.
- CDI requires a separate regeneration step to release the absorbed ions on the electrodes, resulting in an inefficient, time-intensive process.
- 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.
- In this paper proposes a continuous CDI system based on the rocking-chair ion movement using Nafion-coated activated carbon electrodes referred to as rocking-chair capacitive deionization (RCDI), which has a superior desalination rate and stability compared to previous continuous desalination systems using battery materials with constant-current operation.

Results and discussion

Preparation of the Nafion-Coated Activated Carbon Electrodes.

Activated carbon + acetylene black as a conducting agent + poly(tetrafluoroethylene) (PTFE) as a binder

Mixed in ethanol

Activated carbon(AC) electrode

0.2 ml of Nafion was drop casting on AC electrode

Nafion-coated AC electrodes

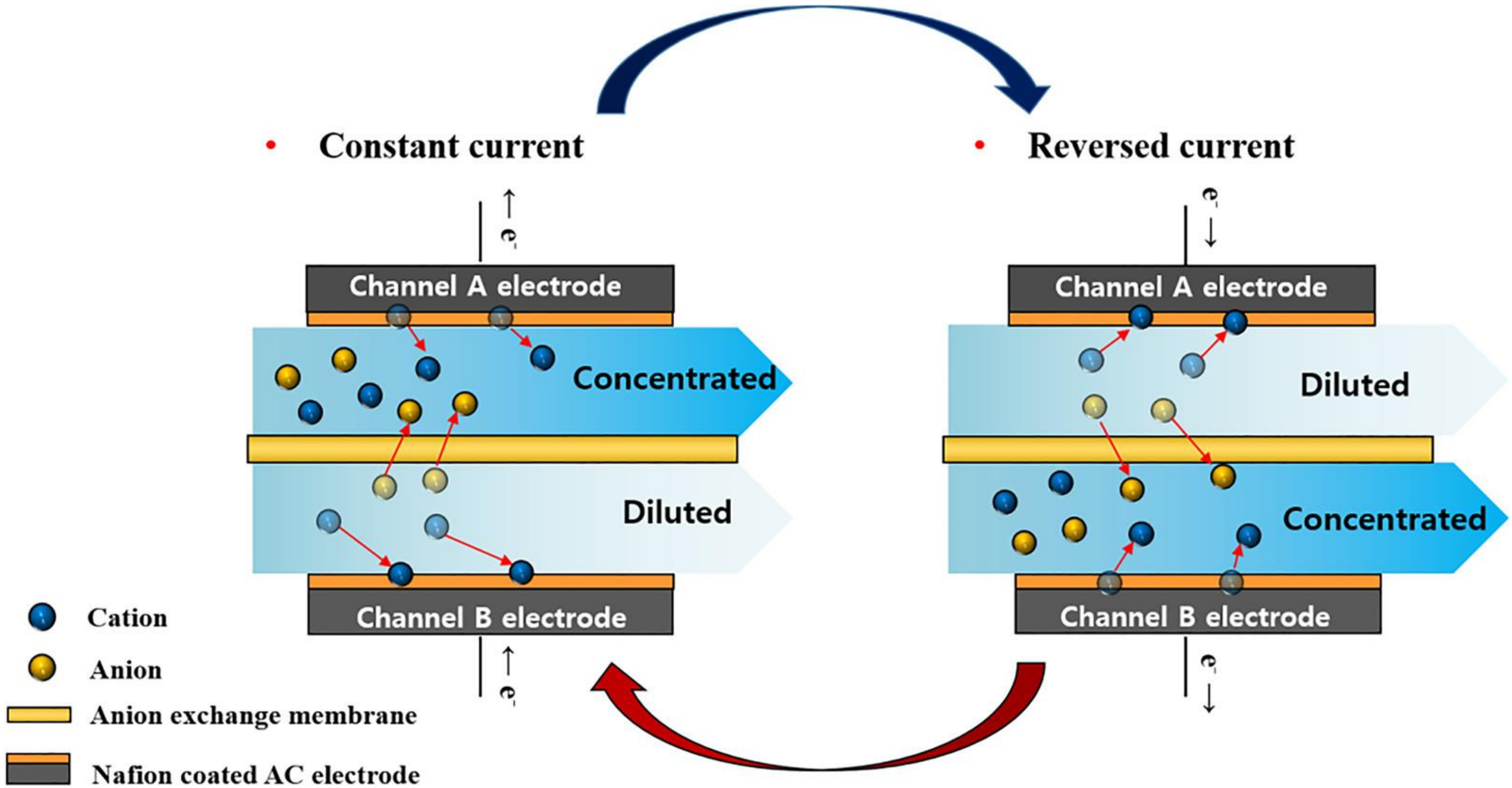

Figure 1.Schematic diagram of the rocking-chair capacitive deionization (RCDI). RCDI system consists of a pretreated Nafion-coated activated carbon electrode in channel A, Nafion-coated activated carbon electrode in channel B, and anion-exchange membrane. During the constant-current operation in the RCDI, the positive compartment solution is concentrated by the released cations from the carbon electrode in channel A and by the anions from the channel B solution driven by diffusion whereas the channel B solution is diluted. Channel A solution is diluted by the reverse movement of cations and anions during the reverse current operation.

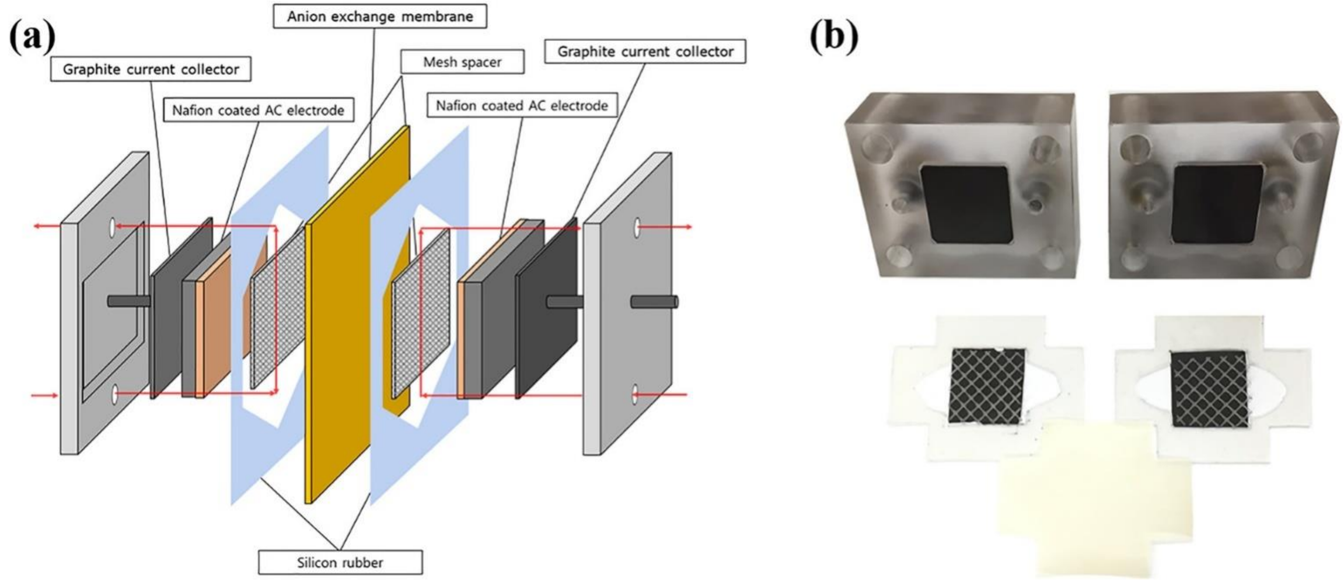

Figure 2. (a) Illustration of the RCDI module for the desalination tests, and (b) RCDI cell.

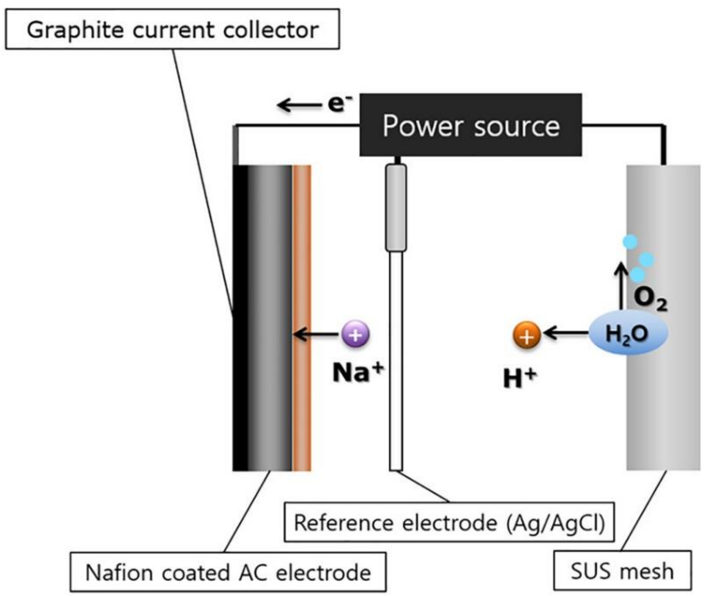

Figure 3. Schematic of the cell geometry for the pretreatment electrode (Na-ion-adsorbed electrode)

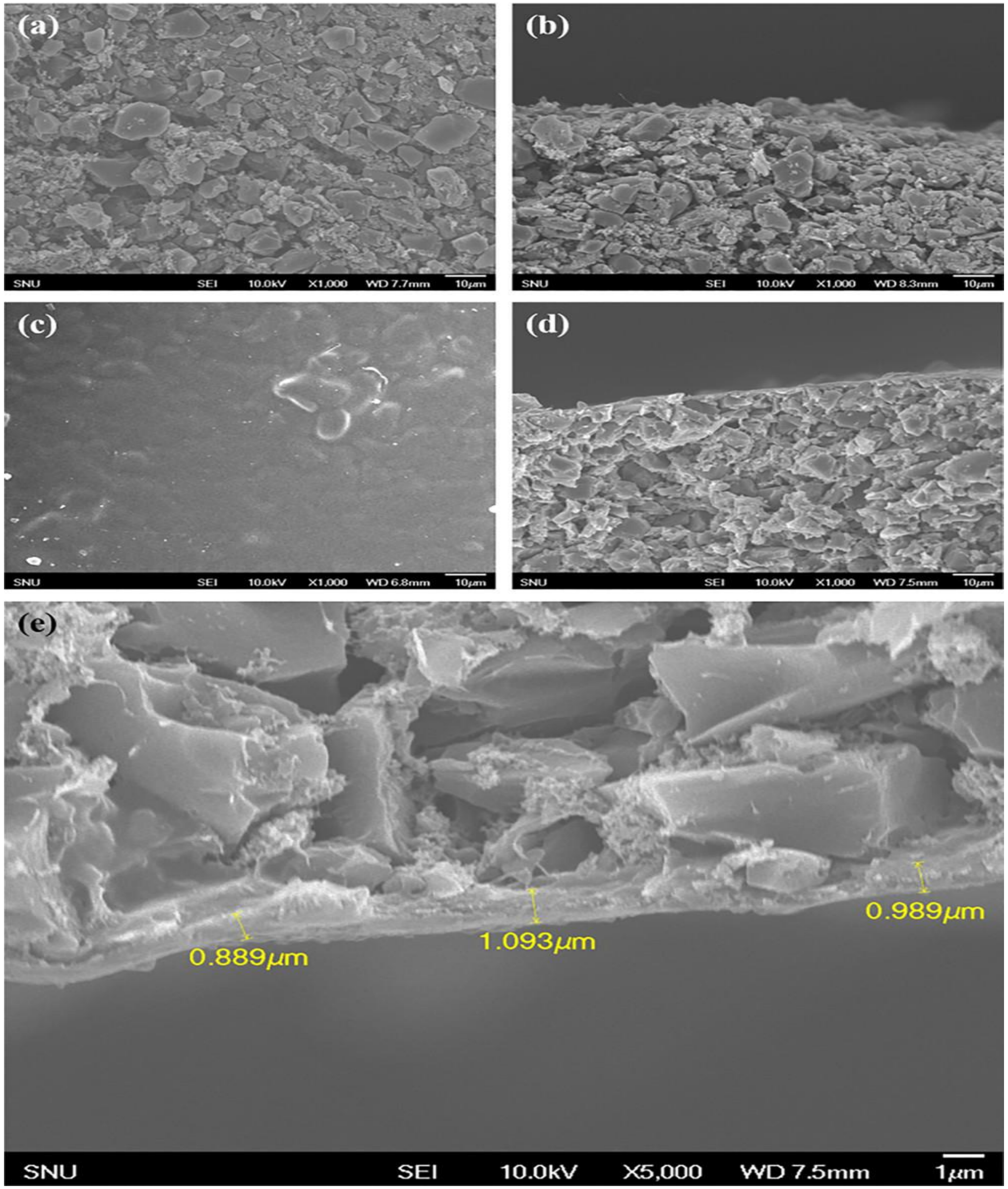

Figure 4. Scanning electron microscopy (SEM) images of the pristine activated carbon (a and b) and Nafion-coated activated carbon electrodes (c–e).

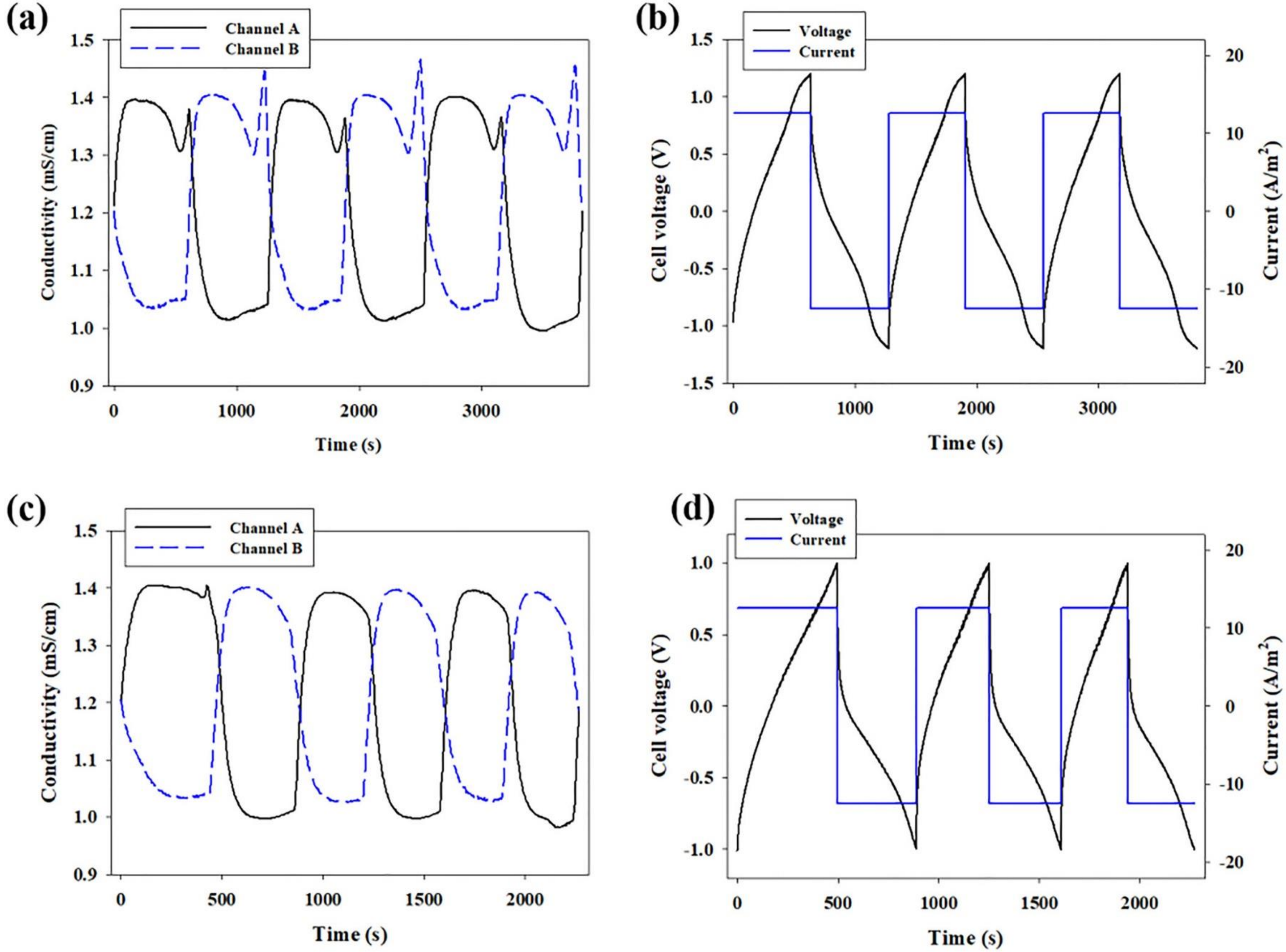

Figure 5. Effluent conductivity changes of channel A (black solid line) and channel B (blue dashed line), and curve of the voltage and current vs time during the constant-current desalination tests (i = ±12.5 A m–2) in a voltage range from −1.2 to 1.2 V (a and b) and from −1.0 to 1.0 V (c and d). Initial concentration of the NaCl solution was 10 mM.

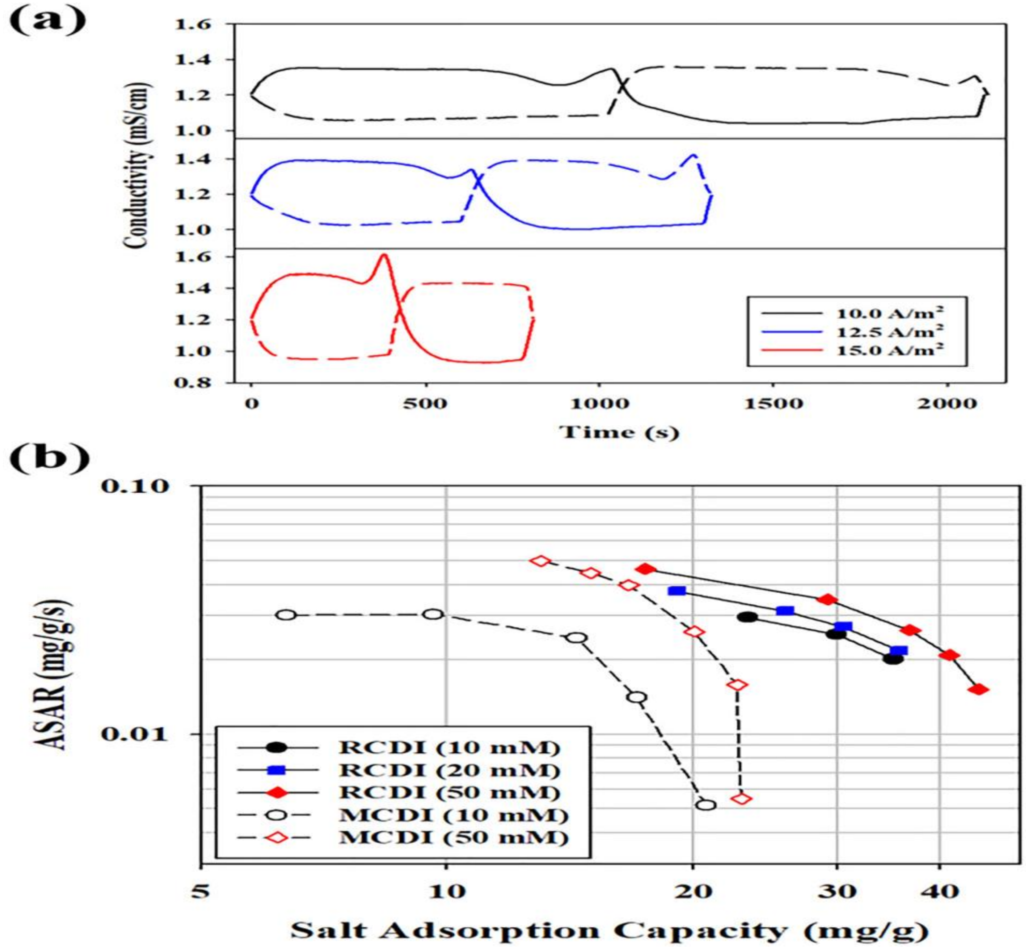

Figure 6.(a) Conductivity profiles at different current densities (solid line, channel A; dashed line, channel B). (b) CDI Ragone plot of the RCDI system with respect to the source water concentration (10, 20, and 50 mM NaCl) under constant-current adsorption/desorption operations with a cell voltage range from −1.2 to 1.2 V. CDI Ragone plot is representative of the salt adsorption capacity (SAC) and average salt adsorption capacity (ASAR). MCDI data at 10 and 50 mM were constructed from ref (32).

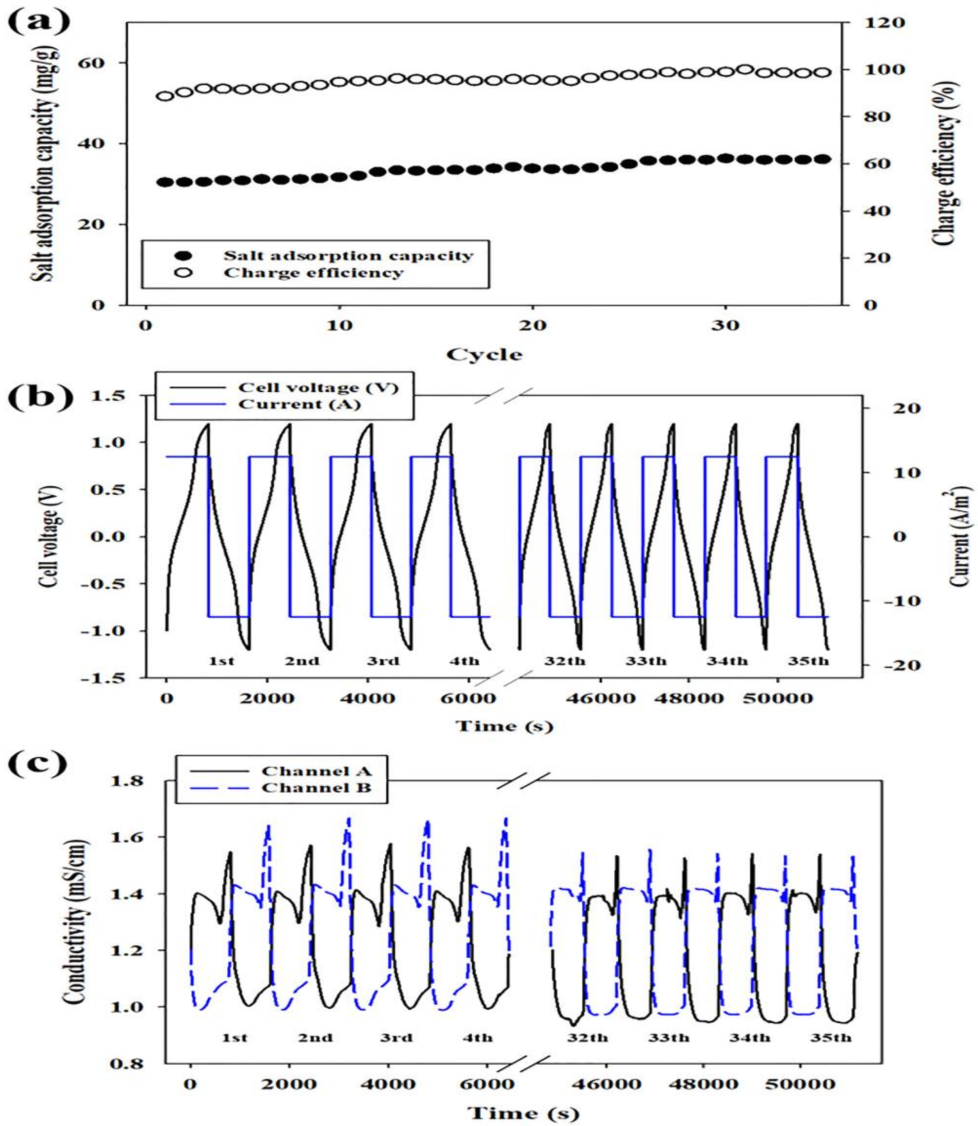

Figure 7. Representative stability performance of the RCDI system. Test was conducted for 35 cycles under constant-current adsorption/desorption operations in 10 mM NaCl solution (current ±12.5 A m–2, voltage range from −1.2 to 1.2 V). (a) Changes in the salt adsorption capacity and charge efficiency during the cycling process. (b) Cell voltage and current vs time plot. (c) Conductivity changes of the effluent from channel A and channel B.

Conclusion:

- It is simple and easy to operate using a Nafion-coated activated carbon electrode. With the cationexchange resin coating, the Nafion-coated activated carbon can selectively adsorb and desorb cations.
- Continuous operation is possible in the RCDI system with the spontaneous diffusion of anions.
- This system had a high maximum SAC (**44.6 mg g−1**) compared to the conventional CDI system.
- It is possible for the system to operate in a rapid current operation (maximum ± 30.0 A m−2) with excellent cycling stability.
- The RCDI can be easily scaled up by increasing the size of the electrodes; moreover, it is possible to reduce the installation expense by replacing the Nafion with an inexpensive cation-exchange resin.
- RCDI in this study can be used in a variety of applications such as desalination and water softening as well as an analysis tool in CDI technologies.


Thank You