Final Report

Self-Sustained Portable Capacitive Deionization Device for Water Purification

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Focus Area: Water purification, urban sustainability, solar energy harvesting

1. Background

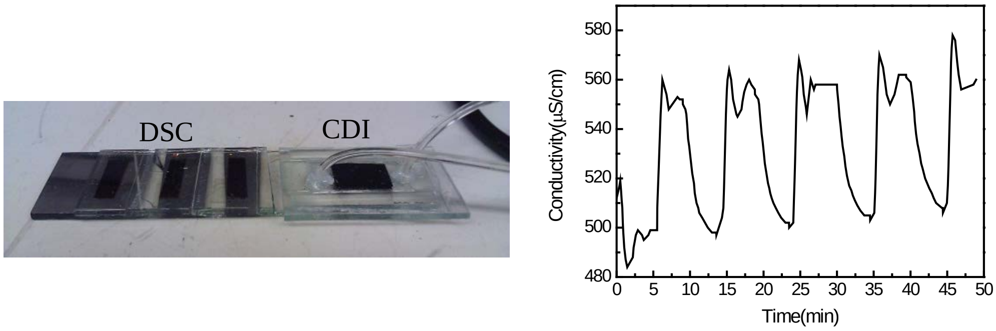
The project aims at developing a self-sustained portable capacitive deionization device, which in specifically in our case, a dye-sensitized solar cell (DSC)- capacitive deionization (CDI) integrated device. This final report broadly contains the novel materials developed for the device electrodes and the performance of a DSC-CDI device which demonstrates our initial idea.

2. Project Objective

Objective and Approach: The overall objective of this research is to create a self-sustained portable water purification system integrating energy efficient capacitive deionization (CDI) with low cost dye sensitized solar cells (DSCs). We will develop innovative nano-carbon materials for high efficiency and versatile CDI electrodes, and integrate the high efficiency CDI with low-cost DSCs. The off-grid operation and small foot-print of the proposed portable system have minimum impact on the oftentimes overloaded aging urban energy and water infrastructures. It also has great potentials in military and domestic applications where more energy intensive water purification technologies are not viable.

3. Summary of Main Results

Fabrication of CDI electrode, DSC module and DSC-CDI device were the focus of the first half of this project. The first CDI electrode material tested was activated carbon powder (Sigma). A 2V DSC module made of three unit cells was connected to the CDI device. The DSC-CDI (figure 1(a)) integration followed a monolithic design. Namely, one of DSC and CDI electrodes were printed on one substrate. Due to the different thickness of the spacers for DSC and CDI, the other electrodes were sealed individually. During the test, the solar module was continuously illuminated by a solar simulator with light intensity of AM1.5G. The conductivity versus time curve is shown in figure 1(b). In the figure one peak represents one desalination-regeneration cycle. In less than one hour, the DSC-CDI integration device showed good repeatability in 5 desalination-regeneration cycles. The total conductivity was slowly rising possibly because of slight amount of water electrolyzed. The bumps on the peaks are due to the conductivity meter sensing fluctuation caused by water flow.



(a) (b)

Figure 1. Desalination curve of a CDI driven by 2V solar module for 5 cycles.

The three-unit-cells module generates an output voltage of 2V. DC voltage source of 2V was also tested as energy supply as comparison (Figure 2). The two curves showed very similar trends. They CDI device shows slightly reduced ions loading capacity comparing to the one driven by DV voltage source in identical time. This reduction is caused by a smaller current generated by solar module than DC voltage source.

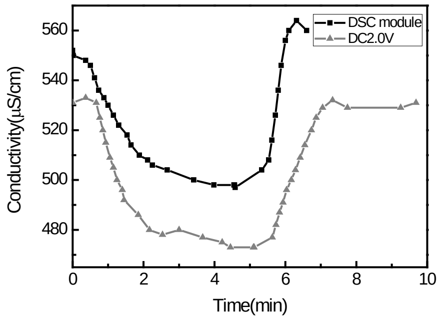


Figure 2. Comparison of desalination curve for the same CDI device driven by DSC module and DC 2V source separately.

In the second half of this project, a number of advanced electrodes materials have been successfully synthesized and integrated into the system. 3D graphene-carbon nanotube structure, which aims at better electrical contact between the carbon structures and the substrate, has been realized by growing single-wall carbon nanotube on top of graphene. Ultra-long multi-walled carbon nanotube forests have been grown and transferred onto transparent conductive glass to make electrodes for CDI (figure 3). Large area molybdenum disulfide atomic layers have been synthesized and used as counter electrode alternative to platinum in DSC. The MoS_2 based DSC shows comparable performance to platinum based one. All the novel materials we developed for the electrodes are highly promising and expected to exhibit outstanding performance comparing to conventional materials. Currently we are working on integrating them into the DSC-CDI device.

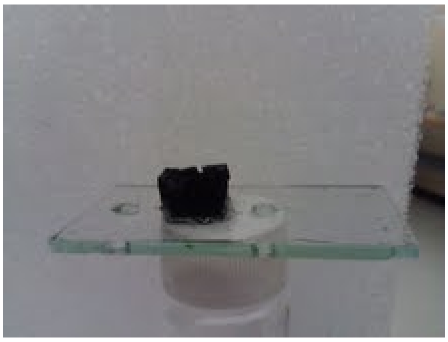


Figure 3. 1 centimeter long multi-walled carbon nanotube forest transferred to a transparent conductive glass. PDMS has been used as binder and the adhesion is strong. This technique gives much larger carbon loading amount comparing to other carbon nanotubes based electrode preparation methods do.

4. Metrics

- 1 graduate student (Mr. Jing Zhang-MEMS) lead the project team consisting of 2 other graduate students (Ms. Pei Dong-MEMS and Mr. Sina Najmaei-MEMS) and 3 undergraduate students at different stages of this project
- 2 undergraduate students worked on the related projects
  o Mark Vander Schaaf , Materials Science, Spring and Fall Semesters, 2012
  o Trinh Nguyen, UH-Downtown campus, Summer and Fall semester, 2012
- 1 undergraduate Rice University student undertook an independent study about literature survey of the state-of-the-art solar-CDI system under the PI
  o Jin Qian, Materials Science, Fall Semesters, 2012
- 1 Journal publication
  o J. Zhang, S. Najmaei, H. Lin and J. Lou “Molybdenum Disulfide Atomic Layers for Efficient Dye-Sensitized Solar Cells”, in submission.
- Discussions and lab demonstrations (with Prof. Q. Li) to representatives from major oil companies including BP, Shell, China Petro (CNPC) in the past several months. There are ongoing discussions to leverage on current developments for larger scale demos and possible field testing with the key players in shale gas developments.