Invited 1

Novel Electrochemical Systems for Energy Storage and Water Desalination Leveraging Flow-through Porous Media

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The development of inexpensive and robust renewable energy and water desalination systems are two of the major technological challenges faced today. Electrochemical systems leverage ion transport and electrochemical reactions to store and deliver energy or desalinate salt water streams. This talk will focus on the novel electrochemical systems which implement flow-through porous materials with micron-scale flow dimensions to enhance device performance. Example devices will include hydrogen-bromine laminar flow batteries for large-scale energy storage, flow-through electrode capacitive water desalination, and shock electrodialysis desalination. I will further describe work on novel experimental techniques for improved characterization of porous electrodes.

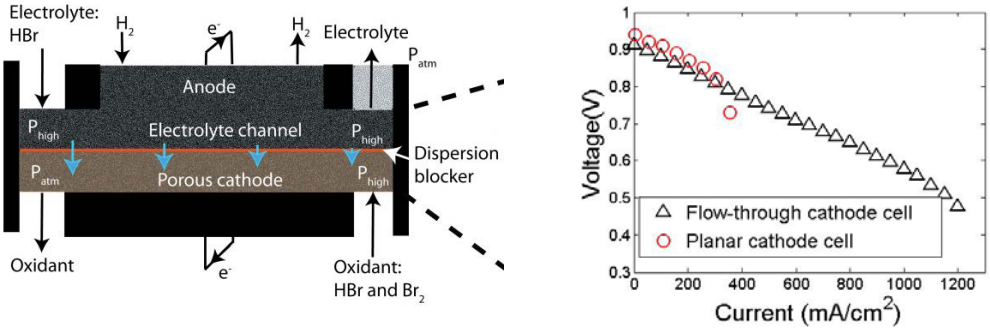

Figure 1: a) Schematic of the architecture of a membraneless hydrogen bromine flow battery with porous flow-through electrodes. b) Polarization curve data demonstrating that use of porous flow-through electrodes enable over 3 X improvement in limiting current density.

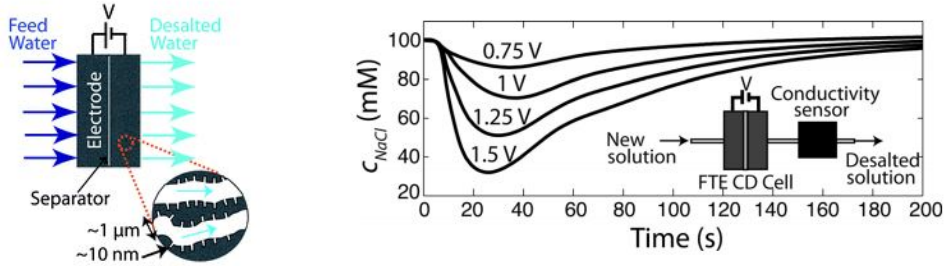

Figure 2: a) Schematic of the architecture of a flow-through electrode capacitive desalination cell. b) Performance of the capacitive desalination cell, demonstrating concentration reductions of the NaCl feed stream of up to 70 mM as well as up to roughly 1 mg/g*min mean sorption rate.

1. ME Suss, WA Braff, CR Buie, MZ Bazant. *A Cyclable Laminar Flow Battery for Large Scale Energy Storage*. Presented at the 225th ECS Meeting, May 11-15, 2014.

2. ME Suss, et al. *Capacitive desalination with flow-through electrodes*. Energy & Environmental Science 5.11 (2012): 9511-9519.

Invited 2

Electrically Wired Photosynthetic Reaction Center Electrodes for Photo-Bioelectrochemical Cells

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During the last several years, substantial research efforts have been directed towards the application of the photosynthetic reaction centers photosystem I (PSI) and photosystem II (PSI) as active components for the light-induced generation of electrical power or fuel products. As a part of this effort, we have developed several photo-bioelectrochemical cells, employing different nano-architectures, and consisting of PSI, PSII, or coupled PSI/PSII assemblies:

(1) A layered poly(N,N′-dibenzyl-4,4′-bipyridinium), (PBV^{2+})/PSI composite on a carboxylate-modified ITO electrode.[1]
(2) A bis aniline-crosslinked Pt nanoparticles/PSI-modified Au surface.[2]
(3) A water-driven photo-bioelectrochemical cell, consisting of an anode based on PSII immobilized on a poly(mercapto benzoquinone) layer.[3]
(4) A layered PBV^{2+}/PSI/poly(lysine benzoquinone) (PBQ)/PSII composite-modified electrode.[1]
(5) A photoactive PSI/Cytochrome c/PSII composite on an ITO electrode.[4]

The coupled PSI/PSII systems (4) and (5), demonstrate a Z-Scheme-like mechanism, mimicking nature's photoinduced electronic transitions.

The different systems will be described, and their photo-bioelectrochemical features will be further discussed.

1. *Small* **2013**, *9*, 2970-2978.
2. *J. Phys. Chem. B* **2010**, *114*, 14383-14388.
3. *Nat. Commun.* **2012**, *3*:742.
4. *Energy Environ. Sci.* **2013**, *6*, 2950-2956.

Invited 3

Highly efficient Hole conductor free perovskite based solar cells

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Perovskite is a promising light harvester for use in photovoltaic solar cells. In recent years, the power conversion efficiency of perovskite solar cells has been dramatically increased, making them a competitive source of renewable energy.

This work will discuss several topics related to perovskite based solar cells:

- An in-depth study on two-step deposition, separating the perovskite deposition into two precursors. The effects of spin velocity, annealing temperature, dipping time and methylammonium iodide concentration on the photovoltaic performance are studied.
- Various concentrations of methylammonium iodide and methylammonium bromide are studied in hole conductor free perovskite solar cells, which reveal that any composition of the hybrid $CH_3NH_3PbI_nBr_{3-n}$ can conduct holes.
- Kelvin probe force microscopy is used to measure cross-sections of hole conductor free $CH_3NH_3PbI_3$ perovskite solar cells. The work function change are measured at the interfaces between the $CH_3NH_3PbI_3$ perovskites and a metal oxide, nanocrystalline TiO_2 and Al_2O_3, respectively. The findings from this research are critical for the understanding and further improvement of perovskite based solar cells, and are valid for cells with a hole transport material.

Invited 4

Non-Precious Metal-Based Catalysts for Oxygen Reduction in PEM Fuel Cells – Is this Just a Dream?

Lior Elbaz, Department of Chemistry, Bar-Ilan University, Israel

The major hurdle in proton-exchange-membrane fuel cells (PEMFCs) is still the cost of the catalysts which constitutes approximately 30% of the overall cost of the cell at current prices. Platinum, still the best commercial catalysts for oxygen reduction and hydrogen oxidation, is to blame.

Although this technology has the potential to become a game changer in the energy market, with prices expected to soar as demand rises, the future of PEMFCs and their derivatives is at risk. There are only two possible solutions for this problem: (1) lowering the Pt loading significantly without losing overall performance and (2) development of other catalysts that will compare to Pt in performance but will consist of abundant, cheaper materials also known as non-precious metal based catalysts (NPMCs).

In this talk the latter solution will be discussed with a thorough review of the various catalysts developed in the past, those that are currently under development and a view to the future. The question that will be presented will be: Is PEMFCs based on NPMCs is just a legend?

Invited 5

Modeling of materials and processes for Li-Air and Na-Air batteries

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Li-Air and Na-Air batteries involve complicated physical and chemical processes at different scales. For a device modeling one has to model both quantum and classical processes at different size and time scales. With quantum simulations it is possible to get properties such as chemical reaction potentials, catalytic effects of surfaces, electronic conductivity and the stability and thermodynamics of reaction products. With classical methods it is possible to calculate properties such as ionic and molecular conductivity, diffusion, solubility and others. Classical methods include tools such as molecular dynamics and also macroscopic transport equations that go to the mesoscopic and continuum scales. In this lecture I will present some of the key questions that we want to solve and the work done in my group, using Density Functional Theory (DFT), Molecular Dynamics (MD) and Poisson-Boltzmann modeling to address those questions. In particular, I will discuss some mixing problems of different electrolytes and the diffusion of Ions and Oxygen in those electrolytes.