**Statement of Research Interests**

**Background**

**My main interests lie in the development of innovative technologies to explore new renewable energy resources.** As we all aware that world’s population is increasing, along with the rapid growth of many developing economies, the demand for energy will soon be enormous. Exploring new forms of renewable energy would lessen the human population’s dependence on fossil fuels. Consequently, I have spent several years on developing two technologies that can harvest the salinity gradient energy (i.e., the Gibbs free energy released from mixing two solutions of different salinity). One technology I developed during my Ph.D. study is capacitive mixing (CapMix). CapMix employs a porous electrode pair (i.e., electrical double layer capacitor) that is alternately charged in concentrated solution and discharged in dilute solution. The energy required to charge the electrodes is less than the energy extracted during the discharge; therefore, it is possible to extract part of the energy associated with the mixing of the system. Another technology I have been working on during my postdoc research is reverse electro-dialysis (RED). RED consists of an alternating series of cation and anion exchange membranes. The salinity difference on either side of the membranes drives ion transport towards the electrodes where it is converted into electron flow. I believe my effort benefits society by addressing a need to capture energy from renewable, carbon-neutral sources.

**Current research**

As a postdoc, I have been applying my research skills in the following three projects: 1) invention of a novel electrode system that uses continuously recirculated flow electrodes (FEs) in RED; 2) investigation of the effect of natural organic matters and ionic composition on the performance of RED; and 3) development of a novel capacitive neutralisation dialysis process for energy recovery. Each topic is expanded in the following sections.

**Continuously recirculated FEs in RED**. RED is a promising technology that generates electricity from the mixing of salinity gradients. One important component in RED is the electrode system that converts ionic current into electrical current. However, conventional electrode system options face environmental, economic, and operational limitations. For example, the chemical-based iron hexacyanoferrate system can irreversibly damage membranes and contaminate the produced drinking water and/or the environment with toxic cyanide compounds. The challenge is therefore to find an electrode system that reduces environmental/human health concerns and can be easily scaled for commercial-scale applications. To solve the abovementioned problems, we invented a novel electrode system that uses continuously recirculated flow electrodes (FEs) in combination with large surface area brush current collectors (CCs). These FEs are made of environmentally friendly carbon particles that can be produced from virtually any organic resource, including wood, sawdust, or waste products. Our initial proof-of-concept study showed that continuously recirculating FEs between anode and cathode compartments in RED can generate uninterrupted power from mixing fresh and salty water. This proof-of-principle study has led to one publication (under review for the Journal of Power Sources) and one patent (under provisional filing).

**Effect of natural organic matters (NOM) and ionic composition on the performance of RED.** Another RED study investigates the performance of this technology under real-world conditions and evaluates the feasibility of implementing it along the coast of North Carolina. Our knowledge of RED is largely based on synthetic sodium chloride solutions that simulate natural waters. Therefore, we measured the RED performance of five real water pairs, including seawater, river water, desalination brine, saline wastewater from a pickling plant and treated wastewater collected in coastal area, waste from a local pickle company, and a municipal wastewater treatment facility. The finding suggested that the presence of NOM has a larger impact on power density than ionic composition. An improved understanding of the organic matter is necessary for assessing the suitability of real waters for use in RED, and we have prepared one publication that is currently under review for the Journal of Power Sources.

**Energy recovery using capacitive neutralisation dialysis.** Together with Dr. Zhao (associate professor at East China Normal University), we developed a neutralization dialysis cell that produces electrical energy from treating industrial waste acidic and basic effluents. During the ion exchange process, not only is electrical energy produced, but also a salt stream is desalinated. Our joint research led to one publication that is under reviewed for the Environmental Science & Technology.

**Future research**

I am planning to focus on applications of environmental technology at the nexus of energy and water, especially regarding energy conversion systems based on salinity gradients. More specific topics involve the following:

**Effect of carbon properties on the performance in FE-RED.** Although we showed a proof-of-concept design that integrates FE in RED, the power output was still lower than that of the widely-used redox electrode system. Consequently, further system optimization is needed. My goal is to reduce the electric resistance of the FE electrode system and improve the efficiency by applying modified carbon particles in the system. To reach this goal, we first need to understand the effect of carbon properties (e.g. pore size, surface area, and point of zero charge) on the FE-RED performance. Based on this knowledge, activated carbon materials can be tuned to meet our need, and I will pursue three research questions: Which carbon properties have the largest impact on the FE performance in RED? How to modify carbon to achieve a better performance? What kind of materials can be used instead of or in addition to activated carbon?

**Effect of faradic reactions on the performance of FEs.** FE has been applied in many electrochemical systems in cooperation with aqueous electrolyte. Once the operational voltage is higher than the thermodynamic limit of faradic reactions, energy can be used to power these reactions (e.g., water splitting) and produce unwanted ions. These faradic reactions lead to the formation of chemical products and pH fluctuation that decrease the system performance. In this research, I would like to investigate the following questions: what kind of faradic reactions are present in FE cells? How are these reactions different from using solid film electrodes? Can continuously recirculating FE between anode and cathode mitigate the pH change and reduce the negative impact of faradic reactions?

**Investigate new cell design and electrode materials in CapMix technology.** I have developed CapMix technology during my Ph.D. study, and I have a vision to further advance this technology in terms of cell design and material selection. I had proposed a new wire electrode design using membrane coated carbon nanotubes (CNTs) yarn. My study highlights the potential of CNT yarns in capacitive electrode processes with a lower environmental footprint and higher energy efficiency compared to the traditional solid planar electrodes. However, more robust and uniform membrane coating layer is still needed to scale up multiple electrodes in either parallel or series connections. Moreover, new electrode materials (especially nano-materials) have been deployed in CapMix system. Recent follow-up research by Dr. Bruce Logan at Penn State showed that an enhanced performance was achieved by using manganese oxide electrode. However, some questions still remain unknown. My goal is to determine the mechanisms of manganese oxide charging and discharging cycles in relation to aqueous solution conditions, manganese oxide structure, and particle size; to increase the power output; and to eventually make this technology more cost competitive.

**Other interests and possible collaborations**

In addition to my energy related work, I am interested in performing collaborations in a wide range of application using electrochemical systems such as bioelectrical cell for water treatment and capacitive deionization (CDI) for salt and contaminant removal.

**Capacitive deionization (CDI) for perfluorinated compounds removal.** The presence of perfluorinated compounds (PFCs) in source waters and drinking water is of growing concern to water professionals. This group of organic compounds, used for industrial and consumer applications such as nonstick coatings and firefighting foams, has potential health implications for humans and wildlife. PFCs are persistent in the environment and highly soluble in water. Although activated carbon have proven to remove up to 90% of PFCs in finished water, recent studies have shown that perfluorobutanesulfonic acid (PFBS), one of PFCs, has low affinity to carbon surface. Therefore, my idea is to use electrical assistance, such as CDI, to enhance carbon adsorption. CDI cells have employed porous carbon electrodes that remove salt ions from feedwaters by storing them in nanopore electric double layers. In this case, polymer ions are adsorbed instead of salt ions, which I am currently working on the proof-of-concept.

**Microbial fuel cell (MFC) for copper recovery.** For my M.Sc. thesis, I worked on MFC that recovers copper metal at the cathode. My research resulted in one publication on ES&T and led to a European Union funded project at Wetsus (Dutch water technology institute). To date, some research questions are still left un-solved. For example, how to selectively recover metals from a stream containing multiple metal ions must be determined. I would prefer to collaborate with Wetsus for some funding opportunities.

**Teaching statement**

**Teaching philosophy**

My goal is to foster students’ passions and curiosity not only to science and technology, but also to life and our society. I am an advocate of the passionate and curious mind and feel that everyone is innately equipped to be endlessly exploratory, to ask questions, and to be fascinated by the world and other minds around them.

During my previous role as a teaching assistant, I have found that the best way to encourage curiosity and enthusiasm is to root my class in inquiry-based learning. Students tend to learn fundamental concepts better when they know they will be asked soon to apply them to problems they find important and relevant. I intend to structure my courses with challenging and interesting questions from the beginning of the semester and try to infuse my students with a desire to know more, with the realization that an answered question leads to many others, and with the analytical tools to satisfy their curiosity. My role is being a facilitator and guide in a challenging adventure designed to foster collaboration, discourse, and discovery.

Achieving these objectives requires making the students actively participate as much as possible. On a simple level, this involves developing inquire-based activities to stimulate their curiosity while guiding them through the scientific process. For example, my students gained first-hand experience by designing an energy-efficient house powered by renewable energy. With given parameters, they have to compare different heating/cooling devices, investigate technologies that utilize many renewable energy sources, and evaluate the economic feasibility in small groups. When students can explain and debate their ideas in addition to perform literature reviews, they retain the information longer and can conceptualize the material for use in new contexts.

I believe that teaching through inquiry and active participation enables my students to be independent thinkers and pioneers when they graduate. By emphasizing both the importance and the pleasure of asking and solving scientific questions, I hope I can foster a thirst for knowledge that extends beyond the classroom.

**Teaching Interest**

Environmental science and engineering is a uniquely diverse field with classes ranging from the fundamentals of chemistry and physics to complex technologies and processes and to applied materials courses such as fuel cells and polymer processing. As a faculty member, I would be interested in applying my teaching principles to a wide range of undergraduate and graduate courses in the general areas of Environmental Engineering, Renewable Energy, Physical Chemistry, and Electrochemistry. I also would love to collaborate with other faculties to create more interdisciplinary courses.