Environmental Engineering & Sciences

Department of Civil and Environmental Engineering

Xiao Su

University of Illinois at Urbana-Champaign

Assistant Professor

Chemical and Biomolecular Engineering

Molecular Engineering of Redox-Active Electrochemical Interfaces for Chemical Separations and Environmental Remediation

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12 – 1 pm

Newmark Civil Engineering Lab 2312

Molecular level design is crucial for the development of new, more efficient electrochemical interfaces in a wide range of chemical and environmental applications. In particular, selective separations remain one of the most important steps in chemical and biochemical processing, and are crucial for water treatment and purification. Thermal and pressure-based systems incur high energetic costs - up to 40% of the North American industrial energy consumption, while adsorption technologies often require harmful solvents and excess regenerants. Despite great interest in energy storage and electrocatalysis, electrochemical systems have seen limited applications in separation processes, due to an inherent lack of molecular selectivity and the narrow range of materials chemistry available.

Redox-functionalized electrodes offer an attractive platform for performing selective electrochemical separations based on their remarkable ion binding capabilities.[1] Here, we present the advances in the development of advanced redox-electrodes for novel water and environmental remediation processes, both in terms of fundamental chemistry and in the electrochemical engineering. First, we present the development of a range of Faradaic electrodes with specific interactions towards charged compounds. We investigate the selective sorption and release of anions, cations, and even proteins, based solely on electrochemical control.[2, 3] Furthermore, we unravel the underlying intermolecular mechanisms by a combination of electronic structure calculations and spectroscopy, to further tune our systems for fine chemical separations. Second, we have focused on asymmetric cell design, in which the cathode works in tandem with the anode; thus reducing energy costs, suppressing parasitic reactions, and as a result, enhancing ion-selective performance for micropollutant removal.[4]

Finally, we show that redox-active platforms can be explored for their electrocatalytic properties, especially for capture and remediation of water pollutants ranging from nitrosamines[5] to heavy metals such as arsenic and chromium. From a fundamental perspective, our concepts point towards an emerging direction in electrochemical interface design – by superimposing properly tuned chemical interactions, we can reach beyond double-layer effects and achieve highly selective ion separations. From a practical perspective, these findings are expected to demonstrate redox-based methods as a sustainable technology for water purification, environmental remediation and green chemical processing.

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