

Research Interests

Electrochemical Surface Science of Molecular Transformation for Energy Conversion, Environment Sustainability, and Biomedicine

Electrochemical surface science is a field of study that recognizes the role of surfaces as the critical region of many electron-transfer events. The ultimate goal of my research program is to understand, control, and consequently predict the potential-dependent oxidation-reduction reactions of natural-product-inspired small molecules and their derivatives. A fundamental atomic-level understanding of the interfaces between conductive solids (electrodes) and liquid solutions is pivotal to the advancement of the interconnected fields of **analytical chemistry, environmental science, and biomedicine**.

Thrust 1. Electron transfer processes are key to many **analytical techniques** used in electrochemical detection, such as cyclic voltammetry and chronoamperometry. The Department of Chemistry and Physics at LSUS is home to a **BioLogic SP-200 potentiostat-galvanostat** that can examine how a substance of interest interacts with an electrode by monitoring electron flow, which allows chemists to analyze trace amounts of substances in a sample. Equipped with an understanding of electron transfer at solid-liquid interfaces, analysts can improve the sensitivity, selectivity, and speed of detection for various analytes such as drugs, toxins, and biomolecules. Analytical chemists often study redox-active molecules (e.g., metabolites, pharmaceuticals) by investigating their electron-transfer properties at electrode interfaces. Model molecules under investigation are **polyphenolic and quinonoid compounds** of botanical origin, specifically hydroquinones and anthraquinones. This knowledge is critical in pharmaceutical development, where the oxidation and reduction behavior of drug candidates is explored to understand their metabolic pathways and interactions. **By controlling electron transfer reactions, chemists can help develop more effective and safer drugs through improved analyses.**

Thrust 2. Electron transfer between strategic surfaces and pollutants is a cornerstone of the **science of environmental monitoring**. At the LSUS laboratories, surfaces are atomically modified and leveraged to reduce toxic metals or break down xenobiotics such as pharmaceuticals and food additives. Electrochemical methods are supplemented by elemental analyses via a **Perkin Elmer PinAAcle 500 atomic absorption spectrophotometer** and separation techniques using an **Agilent high-pressure liquid chromatograph**. Efforts along this research thrust are three-pronged: (1) the surface chemistry of *Salvinia molesta*, an invasive species in Louisiana's waterways, and the utilization of the fern biomass as a sorbent for environmentally persistent dyes like methylene blue and malachite green; (2) adsorption isotherm studies of arsenic, lead, cadmium and low molecular-weight soil metabolites in the root system of sweetpotatoes, in collaboration with the LSU AgCenter; (3) development of analytical protocols for the detection of perchlorate ions in soil, as residual signatures for detonation and munition use.

Thrust 3. **Chemical upcycling** represents a transformative approach in converting waste materials into valuable products to promote sustainability. Urea, a waste product of mammalian metabolism and intensive agricultural practices, holds significant promise as a resource for chemical upcycling. The electrochemical oxidation of urea, first demonstrated almost half a century ago as a conceptual "artificial kidney", has drawn **renewed interest as a chemical fuel** because the energy density of

urea (16.9 MJ dm^{-3}) closely outrivals that of methanol (15.9 MJ dm^{-3}). The bulk solution-based chemistry of urea is enriched by recognizing that **new reaction pathways are unlocked through electrochemical treatments**, especially when urea and its intermediates are chemically bound at electrode surfaces. Atoms directly attached to the electrified surface become most susceptible to chemical change. For instance, N-N bonded urea is hypothesized to favor N_2 release, while O-bonded tilted urea facilitates the formation of cyanate (CNO)-like species by bringing O, C, and N atoms closer to the electrode surface. Other target molecules in the research pipeline include recalcitrant lignin residues, a component of biomass that is difficult to depolymerize, and per- and polyfluoroalkyl substances (PFAS), persistent pollutants that pose environmental and health concerns.