Materials Science & Engineering Doctoral Defense

Flexible nanocomposite electrodes: Synthesis, characterization, and electrochemical applications

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Abstract

Electrochemical technologies emerge as a feasible solution to monitor and treat pollutants. Although electrochemical technologies have garnered widespread attention, their commercial applications are still constrained by the use of expensive electrocatalysts, and the bulky and rigid plate design of electrodes that restricts electrochemical reactor design to systems with poor electrode surface/ volume treated ratios. By making electrodes flexible, more compact designs that maximize electrode surface per volume treated might become a reality. This dissertation encompasses the successful fabrication of flexible nanocomposite electrodes for electrocatalysis and electroanalysis applications.

First, nano boron-doped diamond electrodes (BDD) were prepared as an inexpensive alternative to commercial boron-doped diamond electrodes. Comparative detailed surface and electrochemical characterization was conducted. Empirical study showed that replacing commercial BDD electrodes with nano-BDD electrodes can result in a cost reduction of roughly 1000x while maintaining the same electrochemical performance.

Next, self-standing electrodes were fabricated through the electropolymerization of conducing polymer, polypyrrole. Surface characterizations, such as SEM, FTIR and XPS proved the successful fabrication of these self-standing electrodes. High mechanical stability and bending flexibility demonstrated the ability to use these electrodes in different designs, such as roll-to-roll membranes. Electrochemical nitrite reduction was employed to demonstrate the viability of using self-standing nanocomposite electrodes for electrocatalytic applications reducing hazardous nitrogen oxyanions (i.e., nitrite) towards innocuous species such as nitrogen gas. A high faradaic efficiency of 78% was achieved, with high selectivity of 91% towards nitrogen gas.

To further enhance the conductivity and charge transfer properties of self-standing polypyrrole electrodes, three different nanoparticles, including copper (Cu), gold (Au), and platinum (Pt), were incorporated in the polypyrrole matrix. Effect of nanoparticle wt% and interaction between metal nanoparticles and polypyrrole matrix was investigated for electroanalytical applications, specifically dopamine sensing. Flexible nanocomposite electrodes showed outstanding performance as electrochemical sensors with PPy-Cu 120s exhibiting a low limit of detection of 1.19 µM and PPy-Au 120s exhibiting a high linear range of 5 µM - 300 µM.

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