Studies on Ionic Liquids and Ionic Liquid-Derived Tunable NanoGUMBOS as Influencers of Protein Folding, Performers as Biosensors, and Materials for FRET-Based Energy Transfer

Abstract and Keywords

This dissertation explores the design, synthesis, and functional properties of ionic liquids (ILs) and ionic liquid-derived nanoGUMBOS (Group of Uniform Materials Based on Organic Salts) with some applications in protein folding, biosensing, and energy-transfer processes. A central focus of this work is to understand how these tunable organic salt systems interact with biomolecules and how their aggregation behavior governs their optical and functional characteristics. First, ionic liquids were investigated as agents for protein refolding. Detailed studies confirmed that selected ILs facilitate efficient protein refolding without disrupting native structural integrity. The refolding process was found to proceed through a mixed-micelle formation, providing a new insight into how ILs can stabilize partially folded intermediates and can promote recovery of its biological function. Building on this foundation, a series of pyrene derivative-based nanoGUMBOS was synthesized to examine aggregation patterns within nanoparticulate environments. Spectroscopic analyses revealed a unique phenomenon in the presence of heparin, the exciaggremer-like emission of these nanoparticles gets decreased. In contrast, monomer emission has increased, an effect opposite to trends typically observed in excimer-forming systems. This study highlights their potential as sensitive biosensing materials. Additionally, warfarin-based nanoGUMBOS were synthesized and characterized to further probe structure-property relationships within organic salt nanoparticles. These systems showed strong photonic behavior and effectively acted as fluorescence resonance energy transfer (FRET) donors for hydrophobic dyes, emphasizing their relevance in ion-mediated drug-delivery applications. Finally, GUMBOS and ionic liquids derived from polycyclic aromatic hydrocarbons were employed to study exciton dynamics and were further explored for white-light generation. Their broad emission profiles and tunable optical characteristics position them as attractive candidates for next-generation photonic materials. Collectively, this research advances the understanding of how molecular architecture within ionic liquids and nanoGUMBOS dictates protein interactions, optical response, and energy-transfer behavior. The findings establish these materials as versatile platforms for applications in biophysics, sensing, and photonic technologies.

Keywords: Ionic liquids, GUMBOS, Protein folding, Refolding, Mixed micelle, Exciaggremer, Biosensing, FRET, White light generation