INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Ion transport across biological membranes plays a fundamental role in maintaining cellular homeostasis and regulating numerous physiological processes, including signal transduction, osmotic balance, pH regulation, and cellular metabolism. Disruption of ion transport is associated with several pathological conditions, making synthetic ion transporters attractive candidates for therapeutic and biomimetic applications. This dissertation focuses on the design, synthesis, and functional investigation of synthetic ion transport systems with applications in therapeutics, molecular communication, and artificial transmembrane signaling. Chapter 1 provides an overview of the biological significance of ion transport and discusses the therapeutic and non-therapeutic applications of natural and synthetic ionophores. The chapter further highlights recent advances in stimuli-responsive ion transport systems and summarizes commonly employed methods for studying ion transport across membranes. Chapter 2 describes the development of a multi-stimuli-responsive ion transporter obtained by conjugating bis-thiourea ion-binding units with an RGD peptide through a carbonate linker for targeted delivery. Mechanistic investigations reveal its ion transport behavior, while in vitro studies demonstrate its ability to induce apoptosis through disruption of cellular ion homeostasis. Chapter 3 presents a salicylaldehyde-based imine system capable of self-assembly in lipophilic environments to selectively transport Zn^{2+} ions across membranes. The transported Zn^{2+} ions subsequently coordinate with tyrosine to catalyze the conversion of non-fluorescent precursors into fluorescent products, thereby generating a transmembrane signal amplification system. The system further operates as a three-input AND molecular logic gate, demonstrating ion transport-assisted molecular communication across membranes. Chapter 4 reports a self-assembled tripodal molecular system that forms ion channel-like assemblies in hydrophobic environments and facilitates Zn^{2+} transport into lipid vesicles. Inside the vesicles, Zn^{2+} ions interact with a photosensitizer that produces reactive oxygen species upon light irradiation. These reactive species subsequently promote enzyme-mimetic oxidation reactions, including the oxidation of tryptophan to N-formyl kynurenine. The studies presented in this dissertation collectively explore the integration of ion transport with targeted delivery, signal amplification, logic gate operations, and photoactivated catalytic transformations in biomimetic membrane systems.