Abstract

Recently, Conducting Polymer (CP) membrane based drug delivery system shows capability of delivering controlled release of ionic molecules for several therapeutic applications. Some experimental studies have been reported in recent past, which can be considered as 'proofs of the concept'. But such devices are far from commercialization as prolonged use is not yet possible because of several factors like polymer degradation, leaking of drug molecules etc. CPs have conjugated pi-bonds, which shows redox reversibility under applied cyclic voltage.

Controlled delivery through CP membrane is considered to have two subsequent steps under applied cyclic voltage; namely inclusion of ionic molecules to oxidized CP film from source solution and molecular release from reduced CP film to recipient fluid. A comprehensive theoretical framework is proposed to depict the underlying physicochemical phenomenon for such systems. Dynamics of electrochemical transport process is modeled and simulated using Poisson-Nernst-Planck (PNP) framework with proper boundary conditions. Probable redox reactions are included along with the electro-migration and diffusion terms in PNP framework. Butler-Volmer theory is used to describe voltage dependent kinetics. For slow ionic diffusion through CP films, ad-hoc algebraic electroneutrality constraint is replaced to have more accurate model predictions.

The proposed framework is validated with related experimental data generated by different groups of researchers, available in literature. Some of the important variables affecting the molecular release are diffusivity, voltage scan rate, charge generation rate and CP film thickness. Process bottlenecks like leaking and retention of ions in the CP film are identified. Process performance (i.e. higher molecular flux, lower leak and retention of the ions) and operating variable domains are evaluated through sensitivity analysis.

Experimental studies are performed on modification of properties for CP film, which affects molecular release. Formation of nanostructures is one of the potential ways to alter the surface to volume ratio (which affects diffusivity) and other intrinsic parameters

like electrical conductivity of the CP film. Three different methods viz. pH, dopant and electrical field induced nanostructure formation and property variation have been explored. Main aim of this study is to establish better understanding of CP membrane based molecular release.

Keywords

Controlled molecular release; Conducting polymer; Diffusion; Electromigration; Redox reaction; Mathematical modeling; Cyclic voltammetry; Nanostructure.