Counterion condensation and new porous ionic materials for electrochemical separations

Ion-conducting polymer electrolyte membranes and binders are central components to many types of electrochemical processes (e.g., fuel cells, batteries, and electrodialysis). Ionic conductivity is an important property of these materials as it controls the thermodynamic efficiency of electrochemical systems operated at high current density. Many studies correlate micro-structure attributes in polymer electrolytes to ionic conductivity. However, the impact of counterion condensation, a proxy for the extent and strength of ion-pairing interactions in polymer electrolytes, on ionic conductivity has received less attention and is not clearly known. This talk highlights our effort to study counterion condensation in thin film block copolymer electrolytes with precisely defined microstructures that are defect free and have long-range order. These molecular engineered nanostructures were attained through the principles of directed self-assembly. 2D force mapping combined with all-atomistic molecular simulations substantiate that microphase separated block copolymer electrolytes are less prone to counterion condensation resulting in lower resistances to ionic charge transport. The second part of the talk focuses on new resin-wafer materials, porous but ion conducting packed beds, for ionic separations via electrodeionization and membrane capacitive deionization. These new materials include ionomer binders to replace conventional polyethylene in the resin-wafer and ion-exchange resins that consist of silica particles grafted with polycation and/or polyanion brushes. These new materials have lowered the area-specific resistances for resin-wafers resulting in far more effective ionic separations under the most challenging dilute concentration range.

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