Control over H^+/OH^- recombination in bipolar ion-exchange membranes enables extremely low overpotential reactivity for water dissociation or efficient light-driven ion pumping

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Abstract

Ion-exchange membranes are critical components of nearly every electrochemical technology and serve the purpose of keeping reactive chemical species separate while affording rapid ionic conduction as well as local chemical environments that are benign to electrocatalytic materials. Recently, bipolar ion-exchange membranes, consisting of cation-exchange membranes laminated to anion-exchange membranes, have been recognized by several electrochemical communities as being of interest, even though their first report was by Prof. John Bockris in 1959. Prof. Bockris showed that bipolar membranes form ionic diodes, which meant that the pH of the selective acidic and alkaline contacts differed and were reasonably stable. For carefully engineered high-quality bipolar membranes, this ionic diode behavior can be leveraged – in conjunction with photoacid sensitizers – for light-to-ionic energy conversion, which is useful for technologies that drive solar water electrolysis or solar desalination of salt water. For ionic diodes with intentionally placed rapid H+/OH– recombination centers, ionic charge transport occurs rapidly at any pH value, therefore enabling membranes, electrocatalysts, and reactions to operate at their preferred pH values. In my presentation, I will describe how John Bockris' observation over a half-century ago, plus basic knowledge of semiconductor physics, provides clear clues to the design of materials with few H^+/OH^- recombination centers, which enable for the first time direct sunlight-driven ion-transfer (non-redox) chemistries, or the design of materials with many H^+/OH^- recombination centers, which enable for the first time rapid water dissociation catalysis at extremely low overpotentials that are of use to CO_2 electrolyzers and fuel cells. For each design strategy I will share recent results obtained using model materials systems. While neither model material contains inorganic species, the design rules presented are agonistic to the class of functional materials that are utilized.

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