The management and conversion of light: Photocatalysis and electrochromics for solar energy conversion and light management

Electrochromic conjugated polymers have during the last two decades shown promise as switchable components in displays, windows, signs and other optical applications. Properties such as response time, solubility, electrochemical stability, and color have been fine-tuned, but contrary to their inorganic counterparts there are currently no commercial applications comprising electrochromic polymers. This dissertation addresses several aspects concerning the development of electrochromic devices using polymers coated onto flexible substrates using spray-coating, spin-coating and slot-die coating methods. A key challenge in device fabrication is the development of a suitable electrolyte system, and two electrolyte systems are compared in fully printable and laminated devices on flexible substrates. Devices of various sizes are presented and the transmission contrast, when switched between the fully bleached and fully colored state, are found to be 43 % at Absmax with a response time of less than 10 seconds. To show possible applications, an electrochromic display powered by a printed organic photovoltaic device are demonstrated, that can switch between the two redox states during solar exposure.

In order to reduce production cost, indium-doped tin oxide (ITO) is substituted for two different thin silver grids as electrode material. These grids coated with a commercially available conductive poly(3,4-ethylenedioxythiophene):poly(4-styrenesulfonate acid) formulation (PEDOT:PSS) show sub-second response times for a 30% optical contrast. PEDOT:PSS is found to be superior to the polypyrrole previously employed in electrochromic devices, and in addition the PEDOT:PSS layer increase the conductivity in the hexagonal grid structure. To explore direct photopatterning and multi-film processing a methacrylate substituted poly(ProDOT) is synthesized. Thin films of this polymer crosslink upon UV irradiation and become insoluble in common organic solvents. Electrochemical, spectroelectrochemical, and colorimetric analyses of the crosslinked polymer films are presented, which show that crosslinking does not affect the electrochromic properties.

Electrochromic polymers show appreciable electrochemical stability, but the photochemically stability has never been thoroughly addressed. The stability of thin flexible organic electrochromic films are shown to depend on polymer composition and a hypothesis is presented that shows good correspondence between the experimental results and a simple mathematical model, although there are questions that remain unanswered. The majority of the polymers degrade within 4-5 hours when exposed to solar radiation (AM 1.5 G), and to extend the lifetime of electrochromic devices, oxygen and UV barrier foils are found to drastically slow the photochemical decomposition of the polymer films. When properly protected, the polymer films are sufficiently stable for several years indoors and for a few years under outdoor conditions.

Two photocatalytic reactions are explored; carbon dioxide reduction and water splitting. Practical solutions are presented, and the use of flexible substrates as carrier foils is explored. A key challenge in these conversion systems is the necessary precautions that must be taken when evaluating conversion and this is most convincingly done by using isotopically labelled carbon dioxide. In this regard infrared spectroscopy is found to be a useful analytical tool. The successful photo reduction of isotopically marked carbon dioxide results in a product composition of both 13C and 12C species, and based on similar findings presented in the literature, it is believed that carbonaceous residues that reside on the chamber or catalyst surface contribute to the product composition.

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