" *Advancing Electrochromism and Photonics for Intelligent Windows and Smart Labels* "

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Since Deb's groundbreaking work in 1967,[1] the manipulation of different redox states to govern color has proven indispensable for advancing intelligent windows in the realms of energy and light management for buildings and transportation applications (e.g., rearview mirrors). Notably, metal oxides like WO_3 and organic molecules such as methyl viologens have been pivotal in the commercialization of this technology.

In 1979, the discovery of semiconductor polymers sparked a wave of research into their optical properties. Heeger and his colleagues extensively explored this, placing particular emphasis on polythiophenes due to their relatively low toxicity and straightforward synthesis.[2] However, it wasn't until 1994 that the first electrochromic effect was reported for PEDOT, which remains the most widely utilized polymer in electrochromic devices to this day. Subsequently, there was a concerted synthetic effort to fine-tune the optical properties and solubility of polythiophenes.[3]

While metal oxides could be deposited in various ways, including nanopatterning to enhance kinetics and efficiencies for smart window applications, only the combination of PEDOT and PSS emerges as a genuine commercial alternative to inorganic materials. This is attributed to the water dispersibility of PEDOT/PSS and the high electrical conductivity of their thin films.

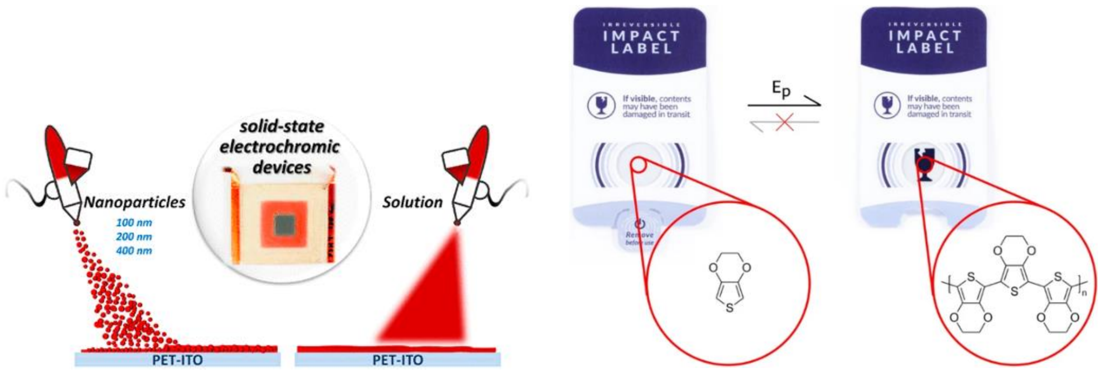

Figure 1 – Use of nanoparticles to make electrochromic films (taken from [4]) and in situ electropolymerization of 3,4-ethylenedioxythiophene and application in irreversible electrochemical indicators.[5]

In this communication, we will demonstrate the efficacy of utilizing metal oxide nanoparticles[6][7] and polythiophenes[4][8] as a sustainable solution for the development of eco-friendly electrochromic inks, paving the way for advanced electrochromic devices.[9] This innovative approach not only expands the color palette but also enhances device performance, resulting in quicker switching times and prolonged lifespans. Furthermore, we explore the application of this methodology to create conductive layers[10][11] and employ electrodeposition techniques for polythiophenes,[5][12] introducing a novel concept for irreversible electrochromics with potential applications in safety labels.[13] We will also delve into the applications of photonic materials, with a particular focus on Luminescent Solar Concentrators.[14]

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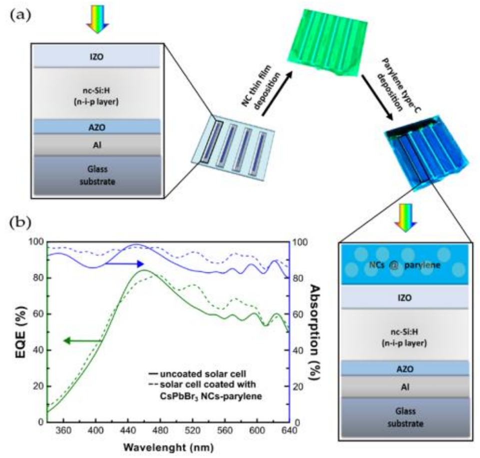

Figure 2 - Photovoltaic cell integration: (a) layers that make up the uncoated nc-Si:H PV cells and the process of incorporation of the CsPbBr3 NCs-parylene type C thin film leading to the coated PV cell; (b) EQE (green lines) and absorption (blue lines) of the solar cell of replica ii before (solid line) and after (dashed line) the incorporation of the CsPbBr3 NCs-parylene type C thin film.[14]

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