Thirty Years Exploring Organic Electrochromism: Building the Color Palette from the PEDOT Foundation

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Organic molecules and polymers exhibit distinct anodic and cathodic electrochromic (EC) coloration as the electronic transitions of their neutral and charged states can be localized to specific regions of the electromagnetic spectrum. This allows, in essence, any color to be attained, along with highly transmissive states. This presentation starts with dimethylviologen and poly(3,4-ethylenedioxythiophene) (PEDOT),[1] molecular and polymeric cathodically coloring electrochromes, which serve as the respective "fruit flies" in this class of materials. Electropolymerization of EDOT, and many derivatives such as the Bis-EDOT-arylenes, led to a first family of multi-color electrochromic films, easily switched between colored states. Moving to solution polymerization and processing/printing, derivatives of poly(3,4-propylenedioxythiophenes) (PProDOTs) yielded materials with especially high EC contrast. This is exemplified in Figure 1a where the magenta PProDOT film absorbs broadly through the visible in the neutral form, and subsequently strongly bleaches between 400 – 800 nm in the oxidized form. By systematically adjusting the electron-rich character and steric interactions along the polymer backbone, a full set of EC polymers was developed that completed the color palette.[2] While these polymers do exhibit high EC contrast, the remnant visible light absorption in the oxidized state leaves a light gray/blue tint. As illustrated in Figure 1b, to overcome this we have developed a means to "flip the spectrum" in a family of anodically coloring electrochromes, which absorb exclusively in the ultraviolet in the neutral state, and the visible to near infrared in the charged states.[3] In addition to providing a full suite of colors, the neutral states are fully clear. While we have succeeded in completing a full color palette of EC polymers and molecules, electrochromic switching and environmental stability hurdles must still be overcome. This talk will end by looking to the future as we explore the limits of organic electrochromic materials.

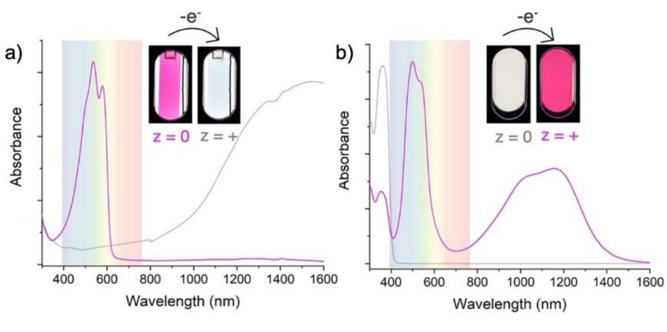

Figure 1. Spectral extremes for neutral and charged states showing transition between colorless/transmissive and colored states of a) cathodically coloring and b) anodically coloring electrochromes.

References

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[2] Österholm, A. M., Shen, E., Reynolds, J. R. *Handbook of Conducting Polymers* - Conjugated Polymers: Properties, Processing, and Application, 4rd Ed., Chapter 6, pgs 201-248 (2019). ISBN: 9780429190520 "Electrochromism in Conjugated Polymers – Strategies for Complete and Straightforward Color Control"

[3] Österholm, A., Nhon, L., Shen, E., Dejneka, A., Tomlinson, A.L., Reynolds, J.R *Mater. Horiz.*, 9, 252-260 (2022). "Conquering Residual Light Absorption in the Transmissive States of Organic Electrochromic Materials"