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Interactions of Ionic Impurities with Semiconducting Alignment Layers in Liquid-Crystal Spatial Light Modulators

Thomas Ducatel*, Yaochen Lin and Thomas Heiser
ICUBE Laboratory (UMR 7357), University of Strasbourg, France.
**Corresponding author e-mail: thomas.ducatel@etu.unistra.fr*

Ionic impurities in thermotropic liquid-crystal (LC) materials remain a major source of instability for spatial light modulators. Under an applied electric field, ions drift toward the alignment layers (AL), creating interfacial voltage drops that generate optical artefacts such as image sticking or flickering [1]. To mitigate these effects, LC devices typically require high-frequency (> kHz) AC driving and LCs with extremely low ionic conductivity ($\sigma < 10^{-12}\ \Omega^{-1}\cdot m^{-1}$), which can be restrictive for low-power or low-voltage applications.

These constraints are particularly relevant for Photovoltaic Spatial Light Modulators (PSLMs), a new class of self-powered, optically addressed modulators relying on a photovoltaic effect to control LC birefringence [2]. Because the photovoltaic component generates a DC voltage under illumination, PSLMs should be highly sensitive to ionic impurities. Surprisingly, their impact is strongly attenuated: the optically induced change in birefringence of a high-dielectric-anisotropy LC with significant ionic content can be maintained for up to 5 hours under continuous illumination [2]. This stability may arise from the specific electrical properties of the alignment layers used in a PSLM, which fundamentally alter ion dynamics.

In this work, we investigate interfacial ionic interactions in liquid-crystal devices employing poly(3-hexylthiophene) (P3HT) as alignment-layer (AL), similar to that used in a PSLM. We have recently demonstrated that, in such devices, sustained modulation of birefringence is possible even when using liquid-crystal materials with significant levels of ionic impurities [3].

To probe the underlying mechanisms, we employ impedance spectroscopy and organic electrochemical transistor–type measurements to monitor ion dynamics at the LC/AL interface. Our results show that ionic impurities increase the electrical conductivity of the AL, indicating bulk ion diffusion within the polymer rather than surface accumulation at the interface. Consequently, electric double layer formation is significantly reduced, thereby enhancing the operational stability of the device.

References

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