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ABSTRACT:

From Dye Photophysics to Responsive Structures: Functional Materials and Electron-Beam Opportunities

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Responsive hybrid materials often appear simple in their final form, such as a colored spot, a luminescent coating, or a patterned microfeature. Their function, however, is defined by the way dyes are immobilized, how local polarity and sol–gel chemistry evolve over time, and how structure develops during processing. This talk presents a research route spanning dye chemistry, sol–gel design, and ionogel engineering toward functional materials with application-relevant and eye-readable optical outputs, with an outlook on the use of electron beams as tools for local structuring and control.

The first part focuses on silica-based hosts doped with xanthene dyes and shows how molecular photophysics can be translated into stable optical response under practical conditions. This includes dye impregnation strategies for luminescent food-spoilage sensing . The discussion then moves to silica ionogels, where the ionic liquid is not merely a solvent or additive, but an active design parameter . By controlling ionic-liquid composition together with sol–gel kinetics, both the response rate and the thermal sensitivity of the material can be programmed, enabling visual time indicators that record cumulative thermal exposure through a reproducible color evolution.

The current stage of this work shifts toward functional microstructures, including disk-like features that combine thermal stability with reversible stimulus-responsive behavior in dye-based and dye-doped ionogels. In parallel, electron-beam-induced structuring of ionic liquids has already been demonstrated , suggesting that the beam can serve as a practical tool for introducing spatial organization into such systems. In this context, electron-beam processing offers a route toward direct writing, localization, and local tuning of functionality, enabling patterned responsive elements, gradients, and multistate optical response maps. The next step is therefore to explore electron beams not only as a fabrication method, but as a practical strategy for programming functionality directly within responsive materials.

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