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Photocurable Liquid Crystal Elastomer Nanocomposites for Monolithic, Self-Sensing Electro-thermo-mechanical Metamaterials

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Liquid crystal elastomers (LCEs) enable large, reversible shape change by coupling nematic director alignment to macroscopic deformation, making them a key materials class for soft robotics [1,2]. A major bottleneck, however, is that most LCE actuators operate as open-loop systems: they require external power and rely on discrete, separately mounted sensors, which limits scalability and functional integration.

Here we outline a single-step, multimaterial manufacturing strategy for self-sensing LCE architectures that combine programmable LCE actuation with intrinsic electromechanical readout. We envision integrating a photocurable, shear-alignable LCE resin (optionally reinforced with alignment-promoting nanofillers) with β-phase-rich P(VDF-TrFE) layers to form printed bilayer/trilayer laminates [3]. This hybrid design will permit deformation-induced electrical signal generation without externally enforced sensing components.

We will establish quantitative structure-processing-function relationships by linking processing parameters, including (i) print-path-induced shear and curing dose, (ii) thermal history, and (iii) interfacial modulus matching to director order, phase transition behavior, network anisotropy, and piezoelectric signal generation [4]. We propose to engineer bilayer and trilayer architectures, allow neutral-axis tuning and controlled strain transfer, yielding curvature-dependent electrical outputs during thermal and electro-thermal actuation. Furthermore, we envision in building architected bending beams and lattice metamaterials to demonstrate coupled motion and real-time sensing within a monolithic printed body.

By establishing rigorous structure-processing-function relationships linking liquid-crystal (LC) alignment physics to hybrid electroactive performance, we plan to advance LCEs toward intrinsically integrated actuation, sensing, and energy transduction. The resulting framework can provide a scalable pathway for self-sensing soft robotic systems, wearable haptics, and bio-integrated devices requiring mechanical compliance, low mass, and embedded intelligence.

References

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