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Direct Laser Writing of Liquid Crystalline Actuators and Sensors

Aoife Donohoe, [1,2] Aoife M. Morris, [1,2] Jing Qian [1,2] and Colm Delaney* [1,2]
[1] School of Chemistry, Trinity College Dublin (IRL)
[2] AMBER, Research Ireland Centre for Advanced Materials and BioEngineering Research (IRL)
Corresponding author e-mail: cdelane5@tcd.ie

Direct Laser Writing (DLW) via multi-photon polymerisation enables the fabrication of microstructures with sub-micron precision. A broad array of materials, including stimuli-responsive polymers, hydrogels, and composites have been adapted for DLW, facilitating the creation of 3D and 4D microstructures that can expand, contract, bend, or even reconfigure in response to environmental cues such as temperature, light, or pH.[1-2]

This work will showcase the development of liquid crystal photoresists for DLW, to achieve micro-actuators and sensors. It will encompass versatile platforms for next generation responsive microsystems. This will include demonstration of shape-changing thermoresponsive microstructures fabricated from nematic phase LC monomers, and photonic microstructures displaying chiral nematic order.

Using the first approach we show 3D micro-structures designed to undergo directional contraction upon stimulation by factors such as temperature or light. In the second approach, we exploit functionalised hydroxypropylcelluose (HPC) to generate soft responsive liquid crystal hydrogel microstructures (Figure 1 a-b). Combining DLW with chiral nematic ordering yields microstructures with a tunable reflection band in a single material composition (Figure 1c). In the hydrated state, the lower critical solution temperature (LCST) of the HPC chains can be leveraged to produce rapid-response thermo-actuators that display measurable and highly repeatable color changes across the entire visible range (figure 1d). Increasing ion concentration decreases hydration of the HPC chains, resulting in a collapse of the helical pitch and a blue shift of the reflected wavelength, providing a pathway for real-time ion sensing. We extend these principles to micro-actuators with built-in structural colour that offer straightforward, real-time readout of actuator state.

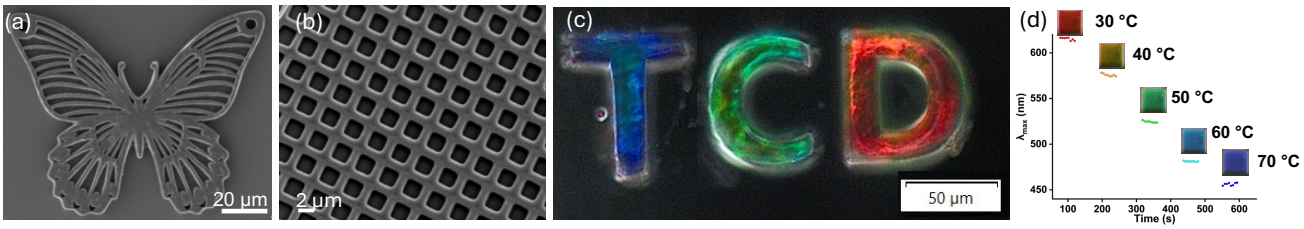

Figure 1. DLW of functionalised hydroxypropylcellulose; a, b) SEM images of DLW-fabricated microstructures; c) darkfield microscope images highlighting the effect of fabrication parameters on HPC microstructure colour; d) effect of heating on reflection band of microstructure.

[1] J Qian *et al*. *Advanced Functional Materials*, *33*(39), 2211735 (2023).
[2] T. Faraone *et al.* Advanced Materials 37 (43) 2504116 (2025).

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