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Fabrication of Responsive Photonic Microstructures using Cellulose Nanocrystal Composites

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Structural colour is a phenomenon commonly observed in the natural world, for example in the *Morpho* butterfly, scarab beetles and opals. This arises due to the development of periodic, nanoscale patterns that selectively interact with light. Many of these structures are stimuli-responsive, allowing them to change colour, e.g. the chameleon's iridophores. The development of biomimetic soft optical components using stimuli-responsive materials would offer unprecedented levels of functionality.

Self-assembly of chiral nematic liquid crystals, such as cellulose nanocrystals (CNCs), have been utilized in recent years to generate biomimetic, structurally coloured materials. [1, 2, 3] These rod-like molecules self-assemble into quasi-helical structures characterized by a repeat length known as the pitch. When the pitch is on the order of the wavelength of light, structural colour is observed.

In this work, monomer-CNC composites are prepared for use in direct laser writing (DLW). DLW is a 3D lithographic technique involving two-photon polymerisation (2PP) to selectively polymerise photoresists, allowing for fabrication of precise and complex (sub)-micrometer structures with high resolution. [4] The reflection band of the fabricated microstructures is controlled via concentration and composition of monomer composites. Stimuli-responsive behaviour is imparted by changing the monomer compositions. These fabricated CNC-based microstructures show rapid responsive behavior by expansion of polymer networks upon exposure to solvent or increased humidity, causing pitch (and thus reflected band) to change as shown in Figure 1. Use of DLW to produce diffraction-grating structures is also explored, opening possibilities for dual-structural colouration through intrinsic ordering of liquid crystals and extrinsic control of the fabricated microscale structures. The bio-inspired platforms developed here showcase the ability of cellulose-based materials to be utilised in chemical sensing, optical devices, anti-counterfeiting and encryption.

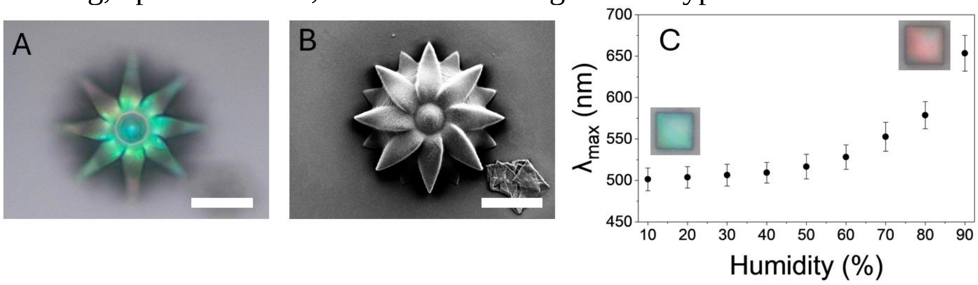

Figure 1. A) Brightfield image and B) SEM image of CNC-monomer microstructure with scale bar 20 μm, C) Dependence of λ_{max} of reflected wavelength on the humidity.

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