2D Material Liquid Crystal Nanocomposites for Optoelectronic and Photonic Devices

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Abstract: We synthesise, characterise and move toward application of 2D material liquid crystalline nanocomposites for optoelectronic and photonic devices, focussing on those produced using graphene oxide, tungsten disulfide and boron nitride.

In the modern age, electronic systems are the predominant and most ubiquitous technology in existence. In particular, silicon structures at the nanoscale are the driving force behind almost all computing globally. However, as we approach the achievable limits of silicon-based devices, new technological paradigms are required to keep pace with Moore's law. One nascent technology of huge potential is optoelectronic devices capable of interacting with and controlling the propagation of light. Current limitations to the efficacy and uptake of optoelectronic and photonic devices cover a broad range, including: cost, scalability, achievability and reproducibility of desired results and compatibility with existing technologies.

The development and characterisation of new materials, therefore, is a key requirement towards overcoming these hindrances. 2D material liquid crystals (2DLC) hold great promise as drivers of a revolution in the development of optoelectronic and photonic devices. By combining the exotic and varied properties, within the few-layer limit, of the ever-expanding body of exfoliatable layered materials (graphene, transition metal dichalcogenides, MXenes, *etc.*), with the inherent reconfigurability of liquid crystals under applied fields, novel nanocomposites with huge potential can be produced. Such 2DLCs can be synthesised in a number of ways; firstly, exfoliated particles of a 2D material can be dispersed in a liquid crystalline host matrix. Alternatively, the 2D material particles themselves can act as the liquid crystal mesogens, through micro- or nano-scale self-assembly when dispersed at suitable concentrations within an organic solvent host fluid. These materials inherently possess several properties that make them of significant interest, such as: fluidity, hence they can be readily integrated into microfluidic systems; reconfigurability under applied electric field, magnetic field and thermal gradients; and scalability of the synthetic routes for these materials.

Here, we present characterisation results for a number of different 2DLC nanocomposites. Optical microscopy can be used to understand the optical birefringence of the 2DLC materials, which can then be further understood through direct measurements of the linear dichroism of the materials. With optical microscopy, monitoring of the birefringence can then be used as a method for the *in-situ* monitoring of material reconfigurations under applied fields. Circular dichroism measurements also give an insight into chirality of the 2DLC nanocomposites. Scanning electron microscopy (SEM) can be used to investigate self-assembly and the ordering of materials, particularly through looking at structures that can be deposited using 2DLC materials. Finally, Raman spectroscopy is a powerful tool for the *in-situ* monitoring of self-assembly and reconfiguration processes, enabling precise three-dimensional visualisation of the positions of dispersed nanoparticles and their change with time.