Disclination creation and stabilization to create a new generation of functional materials

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Composites for creating electronic inks, glues, organic solar cells and energy storage materials require the dispersion of colloids in polymers. Phase separation limits the efficiency since a high loading of the conductive particles is required. Aggregates of colloids do not contribute to the materials' performance since they remain separated from the substrate. The University of Edinburgh filed a patent for a new approach in 2020 to optimise the structure and efficiency of such materials with the principal investigator Dr Tiffany Wood.

A nematic liquid crystal can be formed by anisotropic molecules or nanocolloids that prefer to adopt uniform alignment in a particular direction, known as the 'director'. Discontinuities between surface alignment and the bulk orientation of a nematic liquid crystal can give rise to defect lines, otherwise known as 'disclinations'. The flow behaviour of nematic liquid crystals can be dramatically changed by nucleating disclinations. These can be nucleated by the dispersion of colloids or by discontinuities in surface topology or chemistry and have been shown to extend between surfaces up to 200 microns apart. Disclinations attract impurities within a liquid crystal, such as molecules or nanocolloids. Dispersed material moves into the disclinations to reduce the free energy of the system.

Early stage experiments have shown that disclinations can be used to form strings of colloids (or other dispersed material) spanning opposing substrates. This technology could be used to optimize the surface area of colloidal networks to improve the efficiency of e.g. organic solar cells (often made from liquid crystal polymers), energy storage materials and to create conductive networks in water soluble liquid crystals (e.g. using a nematic phase made from cellulose nanocrystals). This experimental project will enable the student to explore the fundamental physics underpinning a new area of science and to improve our understanding of the limitations of practical application of this technology. The student will use imaging techniques to examine structure, conductivity measurements, rheology and will be able to access facilities at the Scottish Microelectronics Centre based at the University of Edinburgh.

The student will join the Soft Matter and Biological Physics Research Group in the School of Physics and Astronomy at the University of Edinburgh and will be supported by a 3rd year PhD student working with Dr Wood. A 3 month placement at the Centre for Process Innovation will enable the student to understand current approaches and run experiments to demonstrate learnings through the PhD project to real application.