[Nonlinear and Liquid Crystal Physics](http://www.physics.manchester.ac.uk/ndlc)

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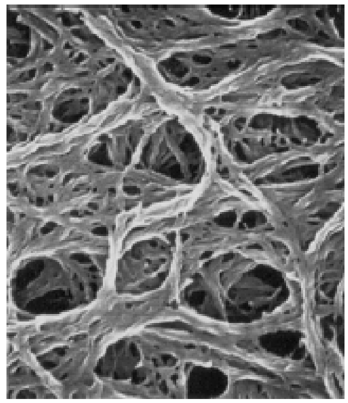
Title: Polymer Modified Ferroelectric Liquid Crystals

Supervisor: Dr Ingo Dierking



Polymer network formed by photo-polymerisation in a liquid crystal host material.

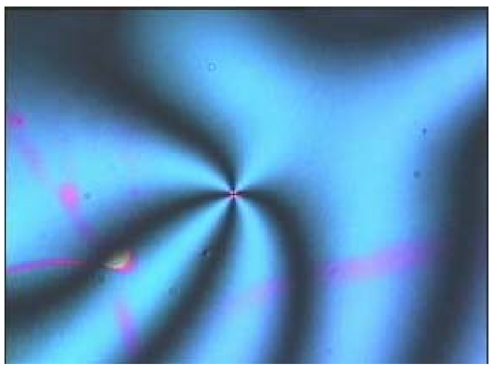
Ferroelectric liquid crystals (FLC) are materials at the forefront of applied liquid crystal research for display and light modulator applications. Despite of their great advantages, such as micro-second switching and excellent viewing angle, they also have certain intrinsic drawbacks, namely mechanical stability and smectic layer motion. These may be overcome by photo-polymerisation of a small amount of monomers to form a stabilising polymer network within the liquid crystal, without significantly compromising the advantageous properties of FLCs with respect to speed and optical modulation depth.

To quantitatively assess the influence of polymer networks on ferroelectric liquid crystals, we will carry out systematic and high-resolution measurements of the two most fundamental physical parameters, the tilt angle and the polarisation. Employing the theoretical description of the generalised Landau theory for FLCs, temperature and electric field dependent experiments allow the determination of the complete potential. Quantitative knowledge of the potential will enable us to predict the electro-optic behaviour of polymer modified FLCs for a large range of application parameters on a quantitative basis.

Title*: *A Molecular Approach Towards Flexoelectricity

Supervisor: Dr Ingo Dierking

Flexoelectricity, the electric field induced occurrence of a deformation of the director field of a liquid crystal composed of shape-polar molecules with a dipole moment, is the most fundamental, but probably also the least understood of all effects in liquid crystal research. Conversely, a mechanical splay or bent-deformation leads to a polarisation, which can couple to an applied electric field. Both of these effects are equivalent and intrinsically not related to chirality, i.e. they can in principle be observed in all liquid crystalline materials. Despite the discovery of flexoelectricity more than 30 years ago, a quantitative relation between molecular shape and macroscopic flexoelectric properties still has to be developed.



Point defect in the texture of a nematic liquid crystal.

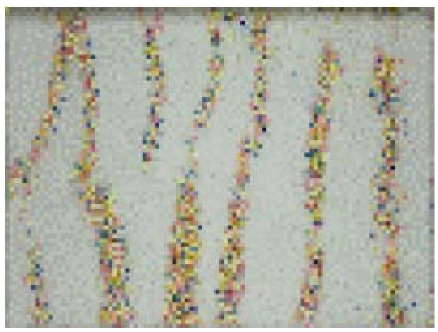
The recent discovery of liquid crystalline phases formed from bent-core molecules, the 'banana phases', provides a large pool of adequate shape-polar molecules to be used as dopant molecules for quantitative flexoelectric studies. In a first stage, we will dope standard nematic liquid crystals with such bent-core molecules to investigate their effect on the flexoelectric behaviour. This will be done in a cell geometry, which is called the hybrid aligned nematic (HAN). Effective flexoelectric coefficients can be obtained from electro-optic experiments on such cells, which allow a screening of various dopant molecules with respect to bent-angle and dipole moment, presumably the two most important parameters in the development of a geometrical description of flexoelectricity.

Having developed an understanding of the effects of various molecular parameters, we will proceed to demonstrate adequately doped mixtures for novel liquid crystal display applications. These will consist of bent-core molecule doped commercial cholesteric liquid crystalline mixtures, subjected to the uniform lying short helix geometry. These materials behave like an optically uniaxial birefringent medium, but with the great advantage that the direction of the optical axis can be changed linearly, depending on the amplitude of the applied electric field. The applicational advantages of such materials are increased switching speed and especially the linear light modulation, which allows for easy gray-scale generation and thus colour displays.

Title: Pattern Formation in Granular Materials and Colloids

Supervisor: Professor Tom Mullin

When a binary mixture of dry granular materials are vibrated from side-to-side, de-mixing takes place so that the two particle species separate out into the clusters of the constituent components. This process can often lead to the formation of interesting striking patterns with properties which have some similarities with phase transitions. Mathematical models which describe this behaviour are not well established but the universality in the observed behaviour suggests there are simple underlying principles. These have been used to good effect to classify and help understand the observed behaviour.



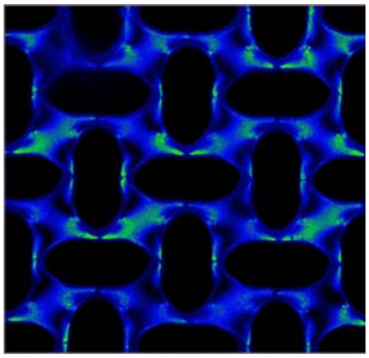
Pattern formation in a granular system

The objective of this new research is to take this work in the direction of segregation phenomena in colloidal mixtures which are suspended in a fluid medium. Preliminary investigations in our group have shown the existence of novel intriguing patterns at the microscopic level. The length scales involved suggest that Brownian effects will be important in this problem whereas they are not relevant to granular materials. These and the role of the intervening fluid are expected to give rise to novel interesting effects where contact can be made with modern ideas from soft condensed matter physics. These include the self assembly of networks, crystals and other soft structures.

Title: Pattern Transformation in Foams

Supervisor: Professor Tom Mullin

A physics of foams has become a hot topic in recent years as they form an interesting class of materials. Their structural properties are also of significant practical interest in areas ranging in scale from the formation of strong light metallic structures to photonic and phononic crystals. Very recently, I have shown that a pattern switch can occur in elastic foams which contain a square array of holes when they are placed under a simple load. Surprisingly, this has not been noticed previously and the finding could be of tremendous technological importance since it points to a way of imprinting specific patterns in these complex materials. An example of such a pattern is given below.



Title: Transient Turbulence

Supervisor: Professor Tom Mullin

The most common type of fluid motion is turbulent and yet a deep understanding of turbulence remains elusive despite over a century of research effort. One way to obtain an understanding of some aspects of turbulence is to begin with a known laminar flow and test its stability to perturbations. This is a well established field which has enabled progress to be made in a variety of problems ranging from thermal convection to pipe flows. Progress is most often made with a combination of theory and experiment and this approach forms the basis of much of our work in Nonlinear Physics.

The objective now will be to take a relatively simple flow and study the transient evolution of turbulence from a laminar flow and vice versa. Specifically, the investigation will involve an experimental study of the spin-up and spin-down of the flow in a torus or doughnut. The flow will hence evolve between the well-defined states of rest and solid body rotation. It is anticipated that the transient behaviour in the on and off-set of turbulence will be qualitative different and comparison will be made with modern theoretical ideas from dynamical systems theory. Laser Doppler techniques will be used to investigate the temporal development of the flow and there may be opportunities to carry out some numerical investigations.