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# Introduction: new directions in liquid crystal science

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While we are all familiar with liquid crystal displays, an industry currently worth more than \$60 billion $yr^{-1}$ and growing rapidly, fewer people are aware of the breadth of the subject of liquid crystals—one that represents the study of the fourth state of matter. Liquid crystals are found as essential elements in biological systems, soaps and detergents, sensor technologies and in the manipulation of electromagnetic radiation of various wavelengths. This meeting was designed to highlight both the truly multi-disciplinary nature of liquid crystal science and to feature those areas away from electro-optic displays; these issues are developed and summarized in more detail.

**Keywords: liquid crystals; introduction; biological systems; chemistry; applications**

## 1. Introduction

Everyone knows about liquid crystals, do they not? Or do they?

We are all very familiar with liquid crystals in the form of liquid crystal displays (LCDs), which now pervade many aspects of our lives. It is the display technology that has allowed the development of mobile phones, hand-held games and portable computers, and they are now driving the availability of high-quality flat-screen televisions. Yet, in these four different applications are five different configurations of LCD, each with different characteristics and each requiring different liquid crystalline materials and different control electronics. With this vast market place, the development of materials for electro-optic displays continues apace to feed an industry already worth more than \$60 billion $yr^{-1}$ and where the manufactured area of flat-panel displays is projected to more than treble by 2010. With the penetration of the market by LCDs reaching over 95%, the remarkable abilities of liquid crystals to modulate light in unique flexible, efficient and low-power-cost ways have

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One contribution of 18 to a Discussion Meeting Issue 'New directions in liquid crystals'.

ensured that liquid crystals have become the quintessential molecular electronic materials of the modern era with more LCDs in the world than there are people.

However, while the science and technology of electro-optic displays is manifestly an area of great current interest, our objectives in organizing this meeting were to show that liquid crystals are much more than just displays. They are to be found in a multitude of different situations from DNA and cell membranes to sensor technology and soaps, providing a truly multidisciplinary environment for research at the interfaces of chemistry, biology, physics and engineering. Their physical behaviour classifies them as a fourth state of matter, lying between the crystalline solid and disordered liquid states. As liquid crystals had not featured in a Royal Society Discussion Meeting since 1983 (*Liquid crystals: their physics, chemistry and applications*, Eds C. Hilsum and E. P. Raynes, the Royal Society, 1983), we felt that it was an opportune time to explore recent non-display research in this fascinating state of matter. For example, in addition to *thermotropic* liquid crystals used in the aforementioned displays, there are *lyotropic* systems, where the liquid crystal order is induced by the use of a solvent. Thus, our programme evolved to encompass liquid crystals in biology, newer classes of liquid crystalline materials and their phase behaviour, and then a raft of real and future applications.

In §2, we give a brief précis of each paper to provide a flavour of the range of topics covered, but before we do this, we would like to offer our thanks to a number of people who made the meeting possible.

First, of course, we acknowledge the Royal Society Hooke Committee, which approved our application; without them there would have been no meeting. We would also like to thank the speakers, all of whom accepted our invitation without hesitation, for providing such an interesting set of topics and doing so in such an engaging way. We were particularly grateful to Professor George Gray FRS for providing an incisive summary at the end of the meeting. We are also grateful that all the speakers were so cooperative and timely in producing final versions of their manuscripts. At the Royal Society, Katherine Hardaker and Chloe Sykes ensured that the organization was first class, while Cathy Brennan made all the editorial work very easy indeed. No doubt, all of these people were supported by a number of others before, during and after the meeting, and we offer our thanks to them, too. Thanks are also due to Nick Abbot in York for deciphering the written questions handed in by delegates… which brings us to our final 'Thank You', which goes to all those who attended the meeting. A Discussion Meeting is nothing without people who are prepared for scientific debate, and with attendances of more than 120 each day, the debate proved to be lively indeed.

## 2. Liquid crystals in biology

The first session was devoted to liquid crystals in biology and Cyrus Safinya (Safinya *et al.* 2006) presented results on cationic liposome-DNA complexes, which are liquid crystalline materials that mimic viruses in the way they transport DNA across cell membranes. The importance of the liquid crystalline structures to biological function was discussed and he described how the mechanism of gene release from complexes in the cell cytoplasm is dependent on their precise liquid crystalline nature. Next, Richard Templer (Baciu *et al.* 2006) stayed with the theme of crossing cell membranes, presenting evidence that drugs actually 'eat' their way through model membranes without the need to bind at conventional binding sites. Françoise Livolant (Livolant *et al.* 2006) then went on to consider nucleosome core particles (NCPs), charged colloidal particles formed from the coiling of a DNA fragment around a histone protein octamer. Under the conditions found in the cell nucleus, these NCPs can organize to form liquid crystal phases. The formation of these phases and their potential relevance to biological processes were discussed. The biological session closed with a paper from John Seddon (Seddon *et al.* 2006) who described structural studies of liquid crystalline lipid structures and the effect of external influences such as pressure- and temperature-jump and hydrostatic pressure. Such influences induce phase transitions and the relationship between these and membrane processes was explored.

## 3. Non-classical molecular types

The afternoon session was devoted to the liquid crystal phase behaviour of non-conventional mesogens and began with a fascinating discussion of the still new field of bent-core liquid crystals, presented by Wolfgang Weissflog (Weissflog *et al.* 2006). In particular, he emphasized the electrical field induced switching that can take place in the phases of these achiral materials, symmetry breaking arising from a combination of molecular geometry and layer organization. The bent-core systems were central to the next presentation by Ed Samulski (Dingemans *et al.* 2006) who discussed the evidence, principally from $^2$H NMR spectroscopy, for the biaxial nematic phase in a series of oxadiazole and related materials. Discotic liquid crystals formed the basis for a presentation by Cammidge (2006) who showed how the mesomorphism of triphenylene liquid crystals may be manipulated when one has total control over the synthesis of such materials. Finally, in this session, Percec (2006) described his elegant work on the self-assembly of a variety of fragments, mostly dendritic in nature, to form a range of structures akin to those found in biological systems.

## 4. Applications of liquid crystals

Tuesday morning's lectures had a different feel and the emphasis was now on new applications of liquid crystals. Wilkinson *et al.* (2006) started by describing applications of liquid crystals in optical interconnects for data transmission between printed circuit boards. Optical methods are increasingly necessary to deal with the very high band widths required and the adaptive optics based on liquid crystal constructs offers a viable way forward. Sambles *et al.* (2006) then discussed the use of liquid crystals for the control of radiation well away from the visible domain and showed how metal slit/liquid crystal constructs may be employed to control microwave radiation. Next, Palffy-Muhoray *et al.* (2006) offered an insight into liquid crystals and photonic materials and discussed the lasing observed from chiral nematic phases doped with dye molecules. The morning session ended with Li & Keller (2006) describing how liquid crystal elastomers may mimic the mechanical behaviour of muscle. Thus, cross-linking to give elastomer in an aligned state leads to materials that undergo a significant and reversible change in dimensions (35–40%) on passing from nematic to isotropic phase. Slightly smaller changes in dimension (*ca* 20%) may be achieved photochemically if a photoisomerizable chromophore is included in the elastomer. The first part of the afternoon continued the theme of applications and started with McCulloch *et al.* (2006) describing the synthesis and properties of liquid crystalline semiconductors based on a thiophene core. Gleeson *et al.* (2006) then described 'laser tweezers' and showed how they could be used both to rotate droplets of chiral nematic liquid crystal and manipulate micron-sized particles suspended in liquid crystal media.

## 5. Liquid crystals and inorganic chemistry

The final two papers took us into the domain of inorganic chemistry and Henk Lekkerkerker (Mourad *et al.* 2006) first described the lyotropic liquid crystalline properties of gibbsite particles when suspended in organic solvents, after which Antonietti (2006) gave us a grand tour of 'nanocasting', starting with Attard's work on the templating of mesostructured silicates on pre-formed lyotropic phases and then showing how a conceptually similar approach could be extended to a range of organized soft matter situations.

The meeting concluded with a personal summary and overview from Gray (2006).

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