Editorial – liquid crystals

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Over the past thirty years liquid crystals have become the quintessential molecular electronic materials of our present day era. The ease with which they can be reoriented in electrical, magnetic and mechanical fields has led to the development of a plethora of high technology applications, resulting, for example, in the dominance of the flat-panel displays market – now valued in excess of $60B. Yet, even though the field of displays may appear mature, there is still considerable interest in the development of 3D-displays, trans-reflective mode displays which utilise the ability of LCDs for daylight viewing, and colour frame sequential devices which in combination with LEDs could lead to brighter displays.

However, in a broader sense, liquid crystals (LCs) are also the prototypical self-organizing molecular materials of today. Their applications, importantly encompass research activities in the fields of surfactants and detergents, membranes, high yield strength polymers, photonics, thin films, semi-conductors *etc.*, where the anisotropic shapes of the materials can be specifically targeted towards application. Fig. 1 depicts how the basic molecular shapes of liquid-crystalline materials can be utilized in self-organization and related applications.[1]

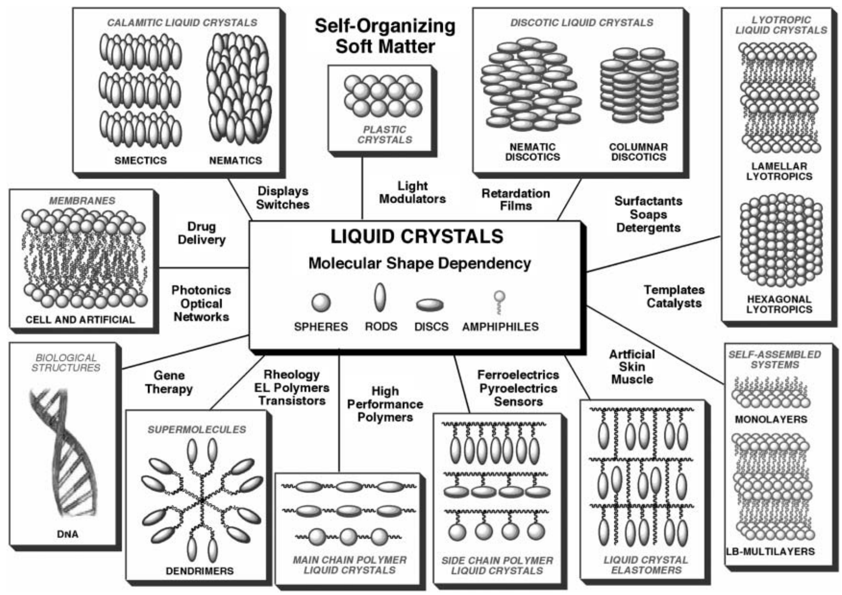

Fig. 1 Structural design in, and applications of, liquid crystals. The molecules are shown as molecular materials of defined shape.

New, and future, materials research in liquid crystals is projected to be focused on topics that reflect our increasing ability to control self-organising and self-assembling processes. Materials themselves will be 'property designed' with smart and often with *multifunctional and parallel operational* characteristics, where applications are expected spread across the boundaries from advanced technological devices through to smart biological and pharmacological uses. For example, the engines of living systems are based on supermolecular and supramolecular self-organising and self-assembling systems of discrete structure and topology, where supermolecular describes a giant molecule made up of covalently bound smaller identifiable components, and supramolecular means a system made up of multiple components that are not covalently bound together. For example, proteins, although peptide polymers, have defined and reproducible primary compositions of amino acids, specified α-helical and β-pleated secondary constructions, and gross topological tertiary structures. Moreover, highly specific functionality, and thereby the ability to perform selective parallel chemical processing, is in-built into such molecular machines. Concomitantly, the study of materials that self-assemble into supramolecular structures with desirable functionality and physical properties at nano- and

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meso-scopic length scales is currently an exciting area of intense research, and provides a "bottom-up" approach to the design and synthesis of functional materials.

Thus the study of liquid crystals is an example of multidisciplinary research at its best, requiring chemists, physicists, engineers, materials scientists, theoreticians, simulators and biologists to combine their skills and expertise in order to drive research forward. Consequently the concept of 'laboratories without wall's' has proved to be the launching pad for a new breed of scientist with a much broader background.

The commercial successes of liquid crystals yet often obscures the view that liquid crystals are essentially a collection of 50 or more states of matter that are sandwiched between the 'Solid' and 'Liquid' states. Indeed there are many who take the view that, because they pervade all classes of materials, collectively liquid crystal mesophases should be considered as a separate state of matter, the *Fourth State of Matter*. Fig. 2 shows a demonstration at a Café Scientifique event of the phase transition from the nematic liquid crystal to the amorphous liquid for 4-pentyl-4′-cyanobiphenyl (5CB). Some researchers have even sought to include liquid crystals within the class of *Soft Matter Materials*, where weak intermolecular interactions are the key properties leading to softness.[2] It is interesting that cells and tissues, whose mechanical properties are determined mainly by polymer networks and lipid bilayers, are also included in this category. Thus it is apt to recall the observation made by Dervichian.[3]

Liquid crystals stand between the isotropic liquid and the strongly organised solid state,

Life stands between complete disorder, which is death, and complete rigidity, which is death again.

Thus this set of *Critical Reviews* and *Tutorials* has been compiled to reflect recent broader developments in the chemical aspects of liquid crystals. Seven Critical Reviews span the following topics:

Fig. 2 Demonstration of the transition from a nematic liquid crystal phase to the amorphous liquid. BA Festival of Science, Café Scientifique, Mansion House, York, September 2007.

- Molecular recognition in chiral smectic liquid crystals
- Synthesis of sulfur-based five-membered heterocyclic liquid crystals
- The properties and applications of fluorinated liquid crystals
- Liquid crystalline organic semiconductors
- Liquid crystalline glycolipids
- Liquid crystal engineering – nanoscale patterning and crystal engineering
- Liquid crystal dimers and higher oligomers

and four Tutorials cover the following issues:

- Liquid crystals for holographic optical data storage
- Liquid-crystalline physical gels
- Dendrimers, dendrons, dendronized and hyperbranched polymeric liquid crystals
- Understanding of bulk structure and the prediction of material properties by molecular simulations of liquid crystals

The subject areas range from low molar mass to polymeric liquid crystals; synthesis to physical property evaluations and simulation; molecular to supramolecular materials, and basic science through to application. Throughout this collection of articles, one underlying theme appears and reappears time and again; that of controlled and predictive self-organization. Thus in a way we are learning at the basic level the complex rules developed by Nature for the combined process of self-assembly and self-organization in the creation of structured multifunctional and parallel processing materials. As noted below by John Gribbin in *Stardust the Cosmic Recycling of Stars, Planets and People*,[4] Nature has exquisitely developed such beautiful techniques over a long period of time.

"In January 2001, scientists from NASA's Ames Research Centre and the University of California, Santa Cruz, surprised many of their colleagues and created headline news by announcing the results of experiments carried out in laboratories here on Earth which produced complex organic molecules under conditions resembling those which exist in interstellar clouds of gas and dust. In these experiments, a mixture of the kind of icy material known to exist in those clouds (composed of water, methanol, ammonia and carbon monoxide frozen together) was kept in a cold vacuum and dosed with ultraviolet radiation. Chemical reactions stimulated by the radiation (typical of the kind of radiation from young stars which zaps real interstellar clouds) produced a variety of organic compounds which, when immersed in water, spontaneously created membranous structures resembling soap bubbles. All life on Earth is based on cells, bags of biological material encased in just this kind of membrane…………"

References

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