BOOK REVIEW

**Nanoscience with liquid crystals**, edited by Quan Li, Cham, Switzerland, Springer, 2014, 420pp., £149, $180, 170,- Euro (Hardcover), ISBN-10:331904866X

The subtitle of the book *Nanoscience with Liquid Crystals*, edited by Quan Li from the Liquid Crystal Institute of Kent State University, Kent, OH, USA, covers the development from Self-Organized Nanostructures to Applications. It is aimed at undergraduate and graduate students, but also researchers, to provide an up-to-date overview of aspects of the topic, which is a truly interdisciplinary field of science. Also covering applications, it is of interest to researchers from industry as well as those from academia, coming from fields as diverse as synthetic chemistry, physics, liquid crystals, polymer science, colloid and material science, all the way to engineering. A range of aspects are touched on, like nanotechnology, photonics, electro-optics and optoelectronics, all the way to drug delivery and medical applications.

The widely different topics are covered in 12 chapters, which could arguably have been accumulated in a different order, but in the end this is probably simply a question of personal choice. In any case one could argue that one or two introductory chapters about different liquid crystals, phases, ordering phenomena and fundamental properties would have benefitted the book, especially as it is not solely aimed at the experts of liquid crystal science, but also at students, who at this point of their education or career may well not have encountered liquid crystals before, as they are not part of the standard curriculum of any undergraduate degree.

But this aside, the coverage jumps in straight at holographic liquid crystals for nanophotonics. This first chapter is written by Tim Wilkinson, Haider Butt and Yunuen Montelongo. The authors provide the basis of computer-generated holography, before they briefly discuss preparation techniques of nanotubes, the optics of nematic liquid crystals, carbon nanotubes (CNTs) on silicon substrates and their use in plasmonic devices. Also the quasi-crystalline diffraction patterns (Penrose diffraction) of nanotube arrays are demonstrated and discussed. Combining all these aspects, it is then shown how nanoscale arrays of nanotubes, grown perpendicular to the substrate, can be used in computer-generated holography. Alternatively, producing nanophotonic structures parallel to the substrates can lead to nano-antennas.

Chapter 2, contributed by Apiradee Honglawan and Shu Yang, has the self-explanatory title: ‘Directing 3D topological defects in smectic liquid crystals and their applications as an emerging class of building blocks’. The discussion covers the control of topological defects, generally focal conic domains, in smectics for the use in displays, sensors and generally self-assembly of nanostructures. The control is practically achieved via confinement, with chemically patterned surfaces or topographical surfaces, thus control via boundary conditions. Discussed applications include superhydrophobic, self-cleaning surfaces, microlens arrays and self-assembled quantum dots.

Hari Krishna Bisoyi, Sandeep Kumar and Quan Li added Chapter 3 on ‘Liquid crystalline 1D and 2D carbon materials’. The contribution relates to CNT and graphene derivatives forming liquid crystalline phases, which enable spontaneous self-ordering, the possibility of drawing-oriented fibres or drying-ordered sheets, leading to improved mechanical or electrical performance. These liquid crystalline phases are of the lyotropic type. Starting with CNT-based liquid crystals, different aspects of functionalisation are discussed: acid functionalised-CNTs, protonated-CNTs, biopolymer functionalised-CNTs and generally polymer functionalised-CNTs. Similarly, different graphene-based liquid crystals are pointed out, protonated-graphenes, graphene oxide, reduced graphene oxide, but also thermotropic liquid crystals from large polycyclic aromatics which can be considered as nano-graphene sheets.

Chenming Xue and Quan Li wrote an interesting materials-related chapter (Chapter 4), which signifies ‘Liquid crystal-gold
nanoparticle hybrid materials’, creating novel advanced functional materials for a variety of applications such as displays, through device performance, optoelectronics, sensors or metamaterials with negative refractive indices. In the introductory part the chapter actually provides a brief overview of different thermotropic phases, like nematic, smectic, but also discotic. Dispersion mechanisms of gold nanoparticles in a liquid crystal host are also outlined, before hybrid materials are discussed, such as gold nanoparticles coated with cigar-shaped mesogens, bent-core mesogens, dendritic and discotic mesogens. In this context not only gold nanoparticles are discussed but also gold nanorods.

From the same group comes Chapter 5 on ‘Photoresponsive chiral liquid crystal materials’, written by Yannian Li and Quan Li. Also here, the introductory part provides some of the basics of liquid crystals, chirality, cholesteric or chiral nematic phases, chiral smectic C* phases with their helical superstructure and ferroelectric polarisation in the surface-stabilised state, but also three dimensionally ordered phases of double-twist cylinders, such as the Blue Phases. A range of photoresponsive compounds or chemical groups are presented, and their properties to shift the selective reflection wavelength, or even handedness (twist inversion) are discussed, also in terms of devices, such as reflective displays and colour changing devices with cholesterics. Also paraelectric to ferroelectric transitions can be changed by photo-illumination, as can be the occurrence regime and colour of Blue Phases.

Chapter 6 by Philip Chen, Jana Ou and Shaw Chen provides an overview of ‘Glassy liquid crystals as self-organized films for robust optoelectronic devices’. Processes and materials for liquid crystalline glasses are introduced before applications in optoelectronic devices such as circular polarisers, optical notch filters, reflectors, photoswitchable nematic and cholesteric glassy films, polarised fluorescent organic light emitting diodes and cholesteric solid state lasers are discussed.

The previous authors Hari Krishna Bisoyi and Quan Li also wrote Chapter 7 on ‘Directing self-organized columnar nanostructures of discotic liquid crystals for device applications’. After a short introduction to discotic mesogens and phases, alignment mechanisms are outlined for homeotropic and planar alignment of columns. For the first orientation thermal alignment methods are presented, along with chemical structure modification, substrate surface modification, electric and magnetic fields, and optical/infrared (IR) illumination. The discussed methods for planar alignment include mechanical shear, magnetic fields, alignment layers, the Langmuir–Blodgett technique, zone casting and melting. Further, discotic alignment in micro- and nanopores and channels is pointed out.

The theme on discotic materials continues with Chapter 8, which is contributed by Yo Shimizu and entitled ‘Discotic liquid crystalline blends for nano-structure formation toward bulk heterojunction active layer in organic photovoltaics’. The chapter introduces liquid crystalline semiconductors, the effects of miscibility and phase separation of different discotic mesogens during blending, and their application in organic photovoltaics.

Hiromitsu Maeda introduces a different field, ‘Ion-based liquid crystals: from well-defined self-organized nanostructures to applications’, in Chapter 9. Different possibilities of charge assemblies are discussed, together with actual molecular structures, which are largely of the discotic type, as investigated by x-ray diffraction and textures. Charge-by-charge assemblies (alternating positive and negative discs), intermediate assemblies and charge-segregated assemblies (charges segregated into individual molecular columns) can be found for different molecular structures.

‘Nanotechnology and nanomaterials in photodeformable liquid crystalline polymers’ are discussed in Chapter 10 by Li Yu, Haifeng Yu and Quan Li. These are materials that respond to light illumination by a mechanical deformation. The mechanism of deformation is through trans–cis isomerisation, resulting in a contraction or elongation of the actuator, but can also be geared towards left and right bending. Like in everyday rubbers, this is also connected to a photothermal effect. Examples of applications include IR-triggered artificial arms and walker devices.

Benedict San Jose and Kazuo Akagi then carry over to the penultimate chapter (Chapter 11) with ‘Self-assembled liquid crystalline conjugated polymers’, where they discuss their synthesis and advanced electro-optic properties. Self-assembly of conjugated, helical polymers leading to whiskers is demonstrated, as are materials showing switchable circular polarised luminescence.

The concluding chapter (Chapter 12) by Nissim Garti, Dima Libster and Abraham Aserin covers the topic of ‘Solubilization and delivery of drugs from GMO-based lyotropic liquid crystals’. Due to the complexity of especially the cubic phases, lyotropic liquid crystals are ideal candidates for drug delivery, also because they are most often formed by using water as a polar solvent. The chapter starts with the characterisation, classification and structures of lyotropic liquid crystals formed by amphiphilic molecules. Phase diagrams can be very complex, as can be the interactions of the liquid crystals with biologically relevant molecules, such as proteins and nucleotides. Transport and release of biologically relevant molecules such as DNA, by lyotropic liquid crystals, is discussed and illustrated with experimental data. Consequences for the administration and delivery due to solubility are discussed for different types of drug molecules.

The book is largely well written and does not overlap significantly from chapter to chapter. Each chapter is very well referenced, and the index is helpful. The book is very well illustrated, and colour is used within the text whenever necessary for reasons of clarity. It may appear that the chapters are somewhat heterogeneous and cannot be seen so much as an entity on the topic of nanoscience with liquid crystals, but then again, this has to be somehow expected when such a large number of authors are contributing. All in all, this is a very interesting account of
the present state of the art of what can be done in the field of nanotechnology by exploiting the self-organisation and self-assembly of liquid crystals. In some places the materials aspect and the conceptual ideas may dominate slightly over the demonstration of the realisation and actual experimental measurements, but in the end, all of these aspects are of significant importance. Concepts and ideas cannot be realised without the appropriate materials; materials alone cannot directly lead to applications; and applications without an understanding of why they work cannot lead to a positive feedback loop for development. It all has to come together, an idea, materials development, a concept based on fundamental understanding, the realisation of a demonstrator, transfer into application and then development. And this in a way is nicely shown by the present publication. The book provides a good overview of many aspects of nanoscience with liquid crystals and should certainly be of interest for anyone who is in tendency leaning towards applicational work.

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