Using In-Situ Optical Microscopy and Micro-Focus X-ray Diffraction to Probe Textured Liquid-Crystal Samples

PNC/XOR-CAT

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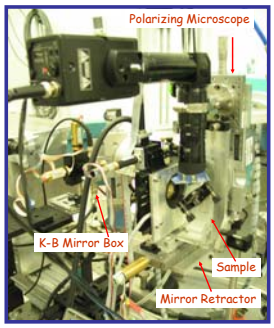
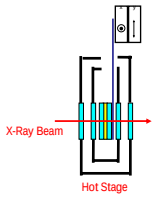
Introduction

16 KeV X-rays from a bend magnet source at Sector 20 of the Advanced Photon Source were micro-focused to a 14μmx14μm cross-section and used in conjunction with an in-situ polarizing optical microscope to measure the diffraction from select areas in textured liquid crystal samples between thin glass plates. The utility of the technique is illustrated by two examples:

- Mapping the concentration and length dependence of liquid crystal phases exhibited by short DNA oligomers
- Selecting monodomain regions from a conducting porphyrin-derivative liquid crystal sample for structural analysis

Experimental Set-Up on APS Sector-20 Bend Magnet Beamline



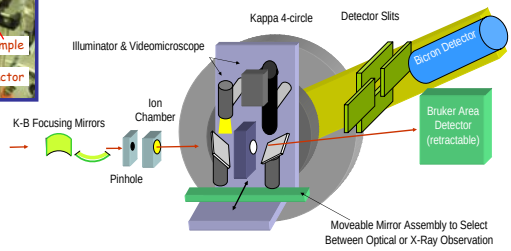


Temperature control and xy-sample positioning provided by a motorized INSTEC Microscope Hot Stage

50 μm thick glass is used to contain sample (~5 μm thick) and to cover hot stage apertures.

Total glass thickness = 300 μm, 75% transmission at 16 KeV

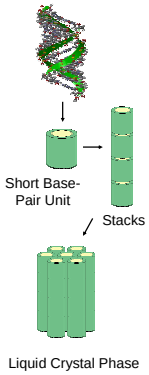
Optical microscope resolution = 3.5 μm

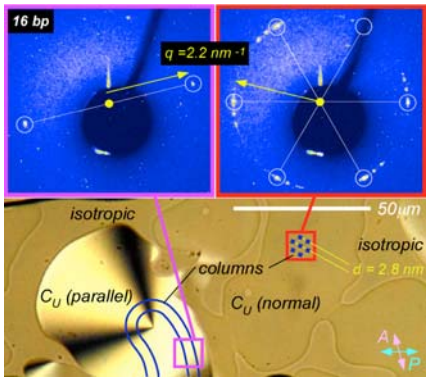


Beam size at sample: 14μm x 14μm
Flux : 3 x 10^7 ph/sec

The Hexagonal Columnar Phase in Short DNA-Oligomers

In collaboration with: M. Nakata, C.Jones, and N. Clark, *Univ. of Colorado*



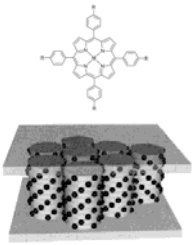


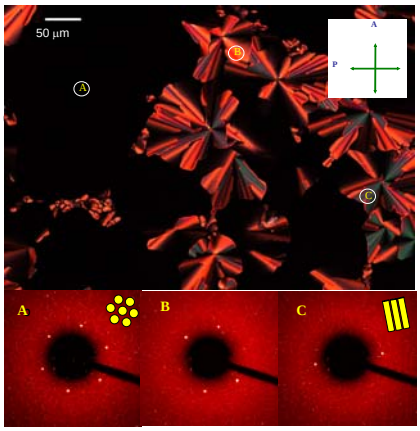
The square boxes in the (*lower*) video-micrograph indicate the regions of focused beam exposure. The diffraction patterns from these regions are shown in the (*upper*) panels.

Porphyrine-Containing Discotic Liquid Crystals

In collaboration with: S. Kumar and Shin-Woong Kang, *Kent State Univ.*

Aligned ordered discotic liquid crystals exhibit quasi 1D charge transport with a μ ~ 0.1 cm^2 / V s





Homeotropic domain | Tilted domain | Planar domain

- In the (*upper*) video-micrograph the white circles indicate the spots of focused beam exposure
- Dark domains under crossed polarizers (regions A & C) indicate that the observation direction is parallel or perpendicular to the hexagonally ordered discotic columns. This is confirmed by the (*lower*) diffraction patterns
- Birefringent domains (region B) indicate a tilted orientation of the discotic columns

Results - Short DNA Oligomers

Double helical deoxyribonucleic acid (B-DNA) is a water soluble semi-flexible polymer found in vivo generally at high molecular weight. In solutions of DNA polymers of 50 nm (persistence length) and longer, DNA exhibits a chiral nematic liquid crystal phase in which the chains order in a locally parallel fashion and a columnar liquid crystal phase where they align and pack in a hexagonal array. In this study we focused instead on the collective behavior of very short DNA oligomers, of 6 to 16 base pairs (2-5 nm) in length, and discovered liquid crystal phases in concentrated suspensions. Depolarized transmission light microscopy and micro-beam x-ray diffraction from aligned regions of textured samples showed that the ordered phases were columnar, i.e. similar to those of the DNA polymer. However, hard-rod models predict that such short oligomers cannot be forming liquid crystal phases on the basis of their steric (repulsive) shape, which ranges from roughly spherical to only slightly elongated. On the other hand, models of systems of rod-shaped particles with additional interactions point clearly to end-to-end molecular adhesion as the origin of the small oligo liquid crystal ordering. Thus it appears that the short DNA oligomers are a "living polymer" of linear chains of end-to-end aggregates, which can become of length sufficient to order in liquid crystal phases according to the hard-rod criteria.

Results - Discotic Liquid Crystals

The mesophase structures of three novel mesomorphic porphyrin derivatives were examined by micro-focus synchrotron x-ray diffraction at various temperatures. The x-rays were diffracted from microscopic monodomains in thin glass cells while simultaneously observing the optical textures. The results confirmed a hexagonal arrangement of discotic columns in the liquid crystalline phases. At a lower temperature, a highly ordered plastic crystal phase was observed.

Acknowledgements

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