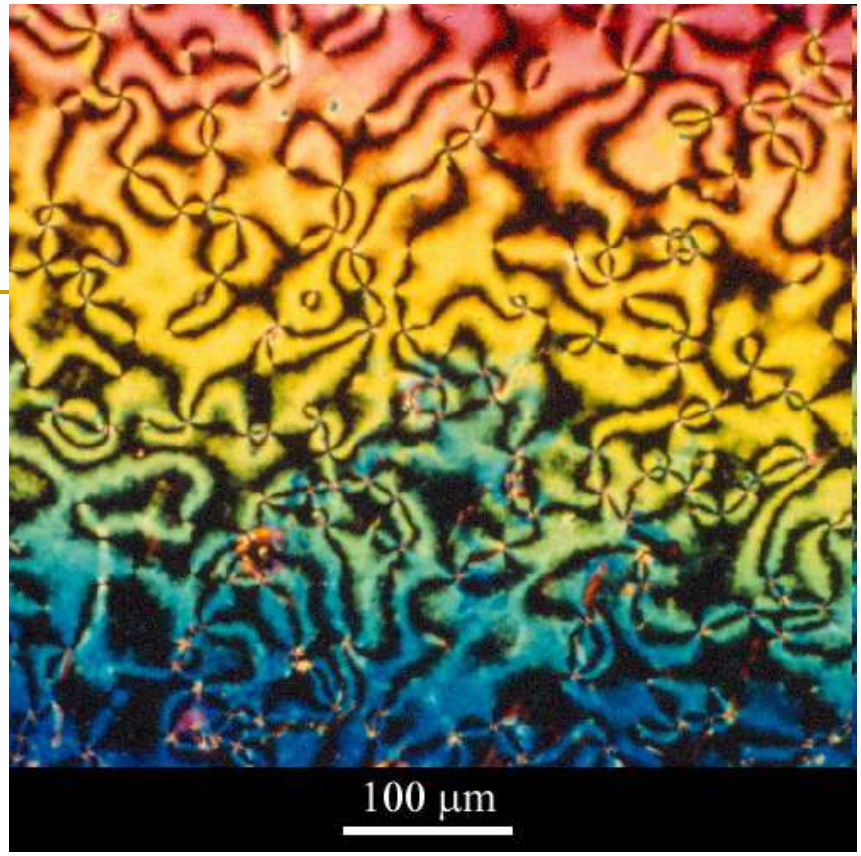
Liquid Crystalline Polymers

Matt Spencer

May 7, 2009



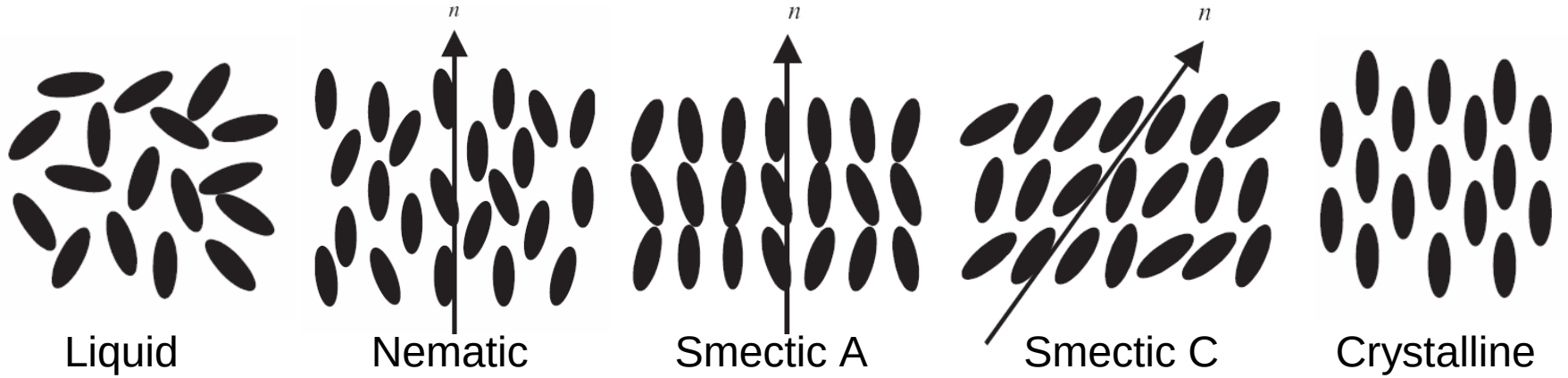
http://www.doitpoms.ac.uk/tlplib/anisotropy/images/image25.jpg

Outline

- Liquid Crystals
- Liquid Crystalline Polymers
- Synthesis
- Properties
- Applications
- Characterization

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Liquid Crystals (LC)

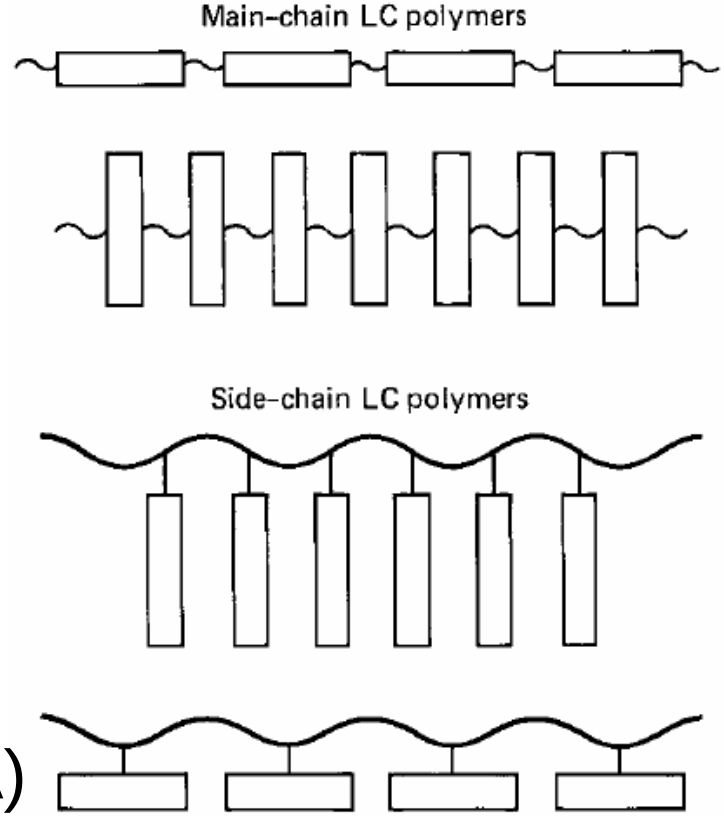


- Two Types
  - Thermotropic - Phase transitions occur as temperature changes
    - Aromatic polyesters
  - Lyotropic - Phase transitions are a function of concentration and temperature
    - Aramids
- Mesophases
  - Nematic
  - Smectic A, Smectic C
  - Others

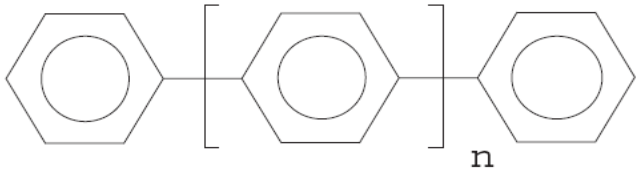
Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Liquid Crystalline Polymers (LCP)

- Mesogen - rigid, rod-like polymer group
  - Aromatic rings
  - Amide, ester linkages



poly(1,4-phenylene)



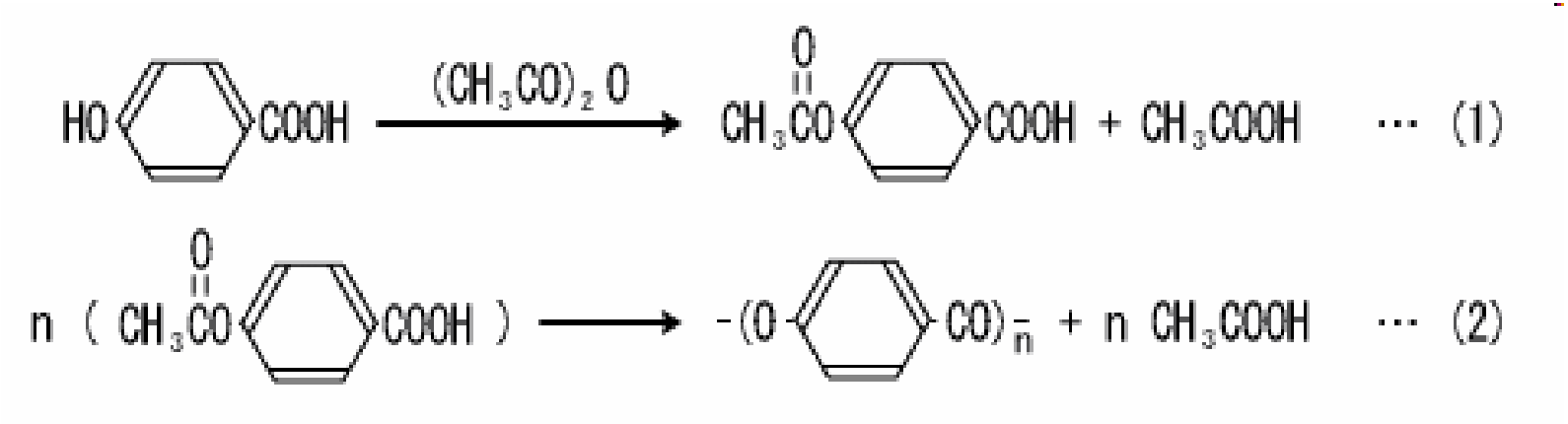
poly(4-hydroxybenzoic acid) (PHA)

Odian, G. *Principles of Polymerization*, 4th Ed. Wiley: New York, 2004.

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

LCP Synthesis

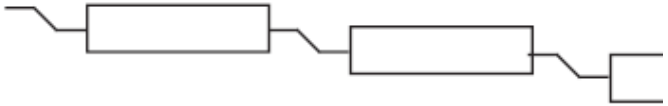
- 4-Hydroxybenzoic acid – mass-produced monomer
- Remove excess acetic acid
- Condense under higher temperature conditions to increase MW

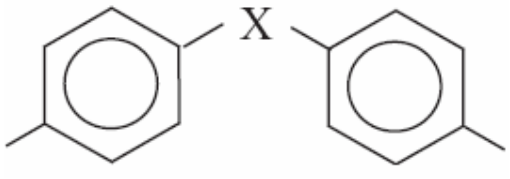


http://www.polyplastics.com/en/product/lines/lcp/index.html

Liquid Crystalline Polymers (LCP)

- Flexible units included for processability
  - Side-step
    - −COO−, −CH=N−, −N=N(O)−, trans −CH=CH−, −CONH−, and 2,6-naphthalene
  - Kinked
    - X = −O−, or −S−, or $-CH_2-$
  - Flexible Spacers
    - polymethylenes, polyoxyethylenes, polysiloxanes
  - Terminal or Lateral Substitution

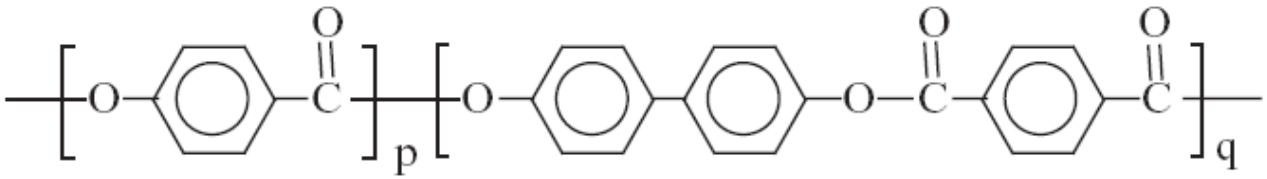




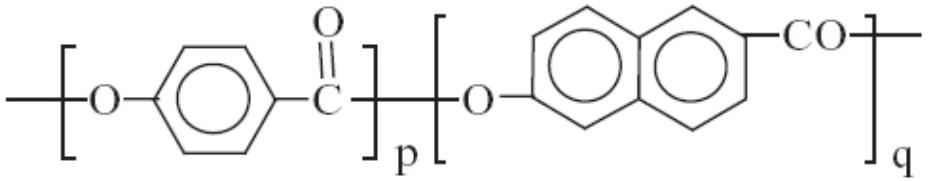
Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Liquid Crystalline Polymers

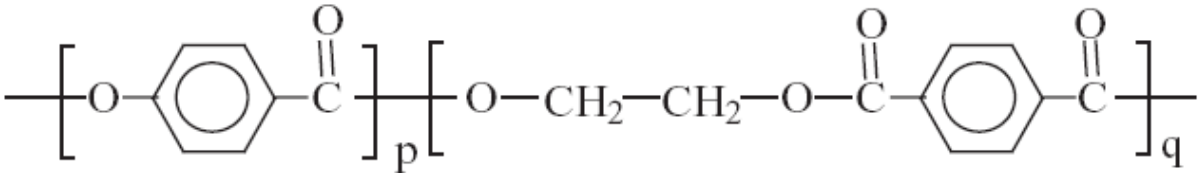
Xydar, Ekonol



Vectra



X7G, Rodrun



Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Properties

- Advantages of LCP
  - Good Chemical Resistance
  - High Heat Resistance
  - Good Moldability
  - Low Viscosity
  - Good Dimensional Stability
  - Flame Retardant
  - Good Heat Aging Resistance
  - High Vibration Absorbance
  - Thinner Parts → Higher Strength
    - Increased proportion of surface layer

- Disadvantages of LCP
  - Highly anisotropic properties
  - Drying required before processing
  - High cost

http://www.ides.com/generics/LCP/LCP_overview.htm

Applications

- Electrical/Electronic Applications
- Automotive Applications
- Chemical Pumps
- Distillation Towers
- Food Containers
- Appliances
- Surgical Devices
- Thin-walled Parts
- Ropes, Cables
- Protective Apparel









http://www.ides.com/generics/LCP/LCP_overview.htm

http://www.polyplastics.com/en/product/lines/lcp/index.html

http://www.ticona.com/products/vectra

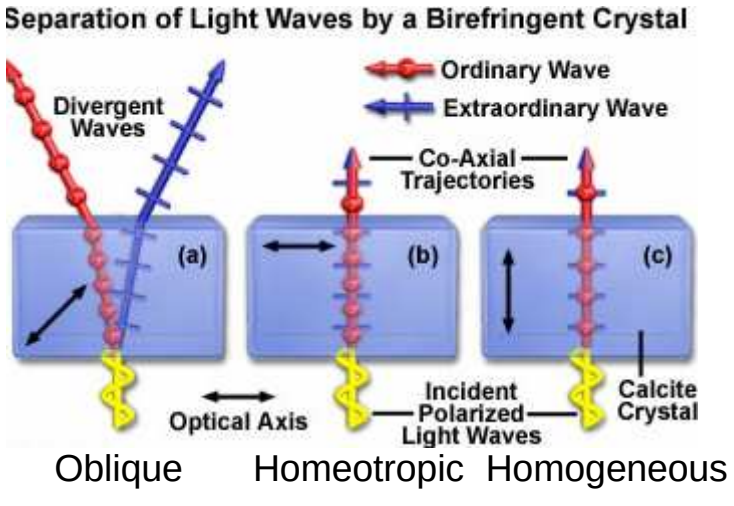
Characterization

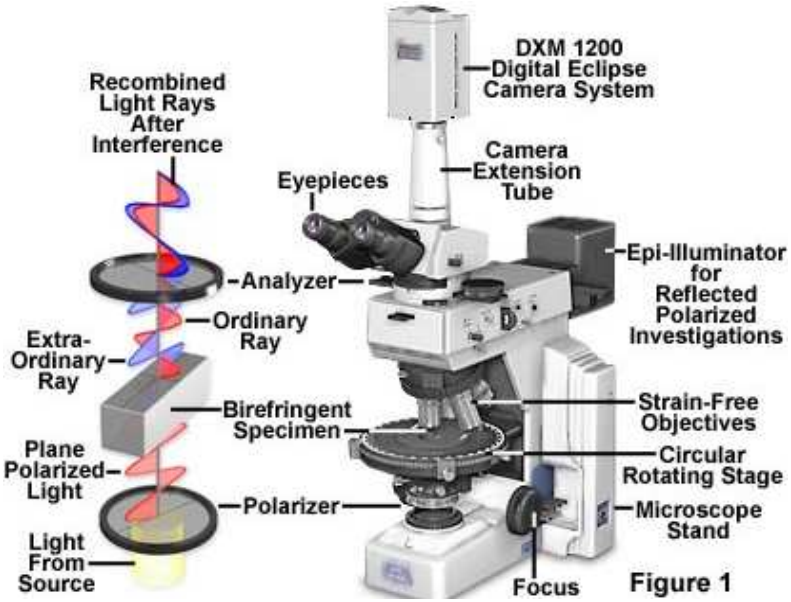
- Polarizing Optical Microscopy (POM)
- Differential Scanning Calorimetry (DSC)
- Differential Thermal Analysis (DTA)
- X-Ray Diffraction
- Miscibility Testing
- IR
- NMR
- Small-Angle Neutron Scattering (SANS)

Polarizing Optical Microscopy (POM)

- Orthoscopic observation
- Conoscopic observation

Bertrand Lens





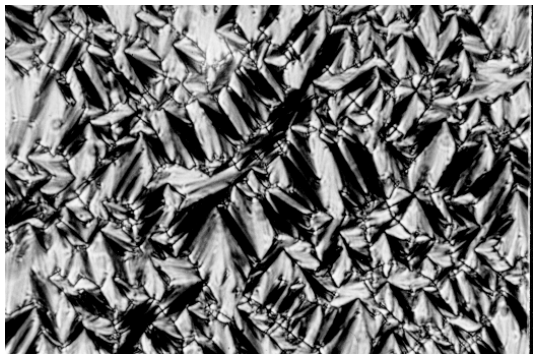
Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

http://micro.magnet.fsu.edu/primer/java/polarizedlight/crystalwavefronts/index.html

Polarizing Optical Microscopy (POM)

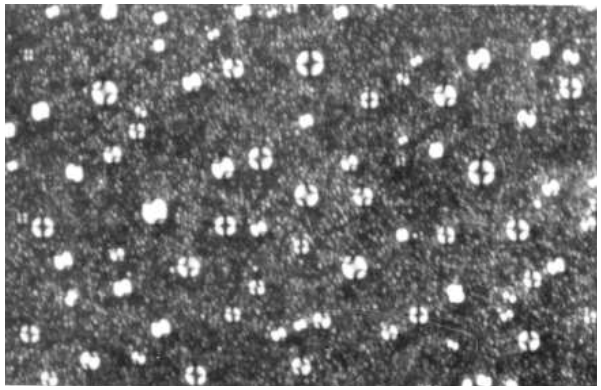
- Orthoscopic observation
  - Polarization colors, defects, orientation texture
  - Birefringence
  - Temperature of phase transition
  - Defects characteristic of mesophase
  - Complicated by high polymer viscosity

Smectic A

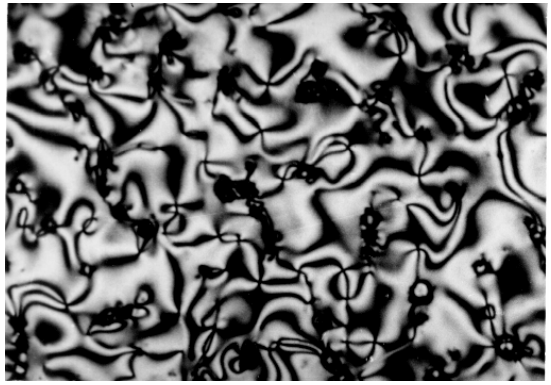


Focal-conic Fan Texture

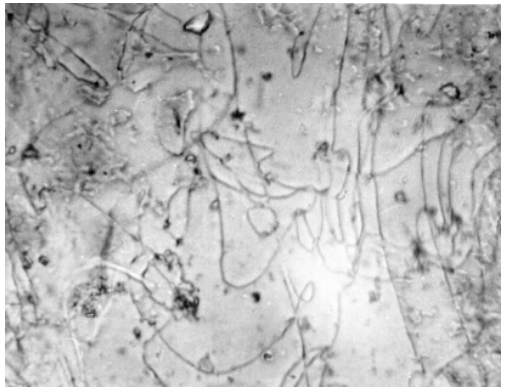
Nematic



Nematic Droplets



Schlieren Texture



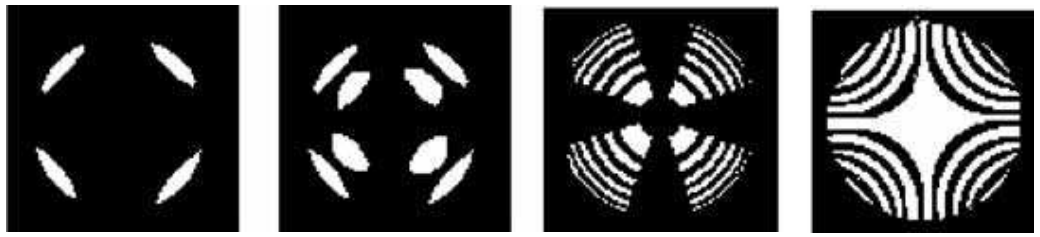
Threaded Texture

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Polarizing Optical Microscopy (POM)

- Conoscopic observation
  - Bertrand lens
  - Interference figures

Uniaxial Crystals Homeotropic Orientation



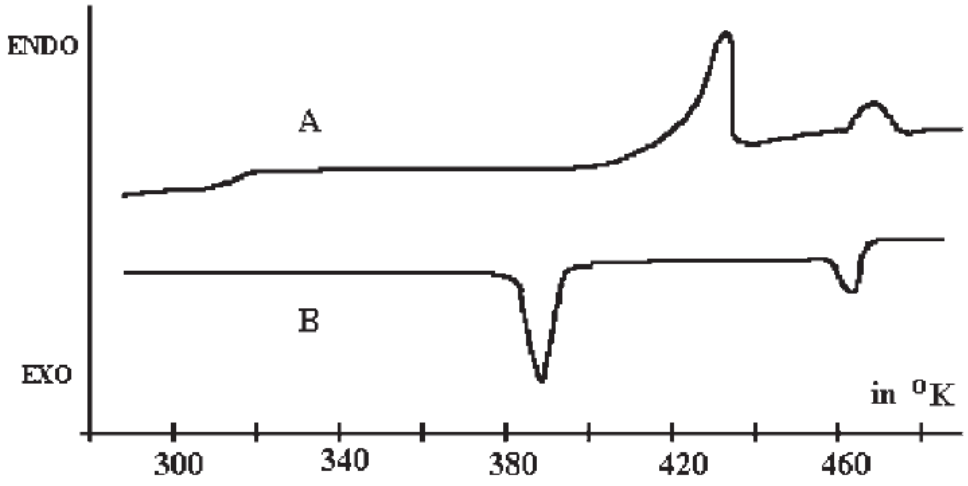
Increasing Thickness

Homogeneous

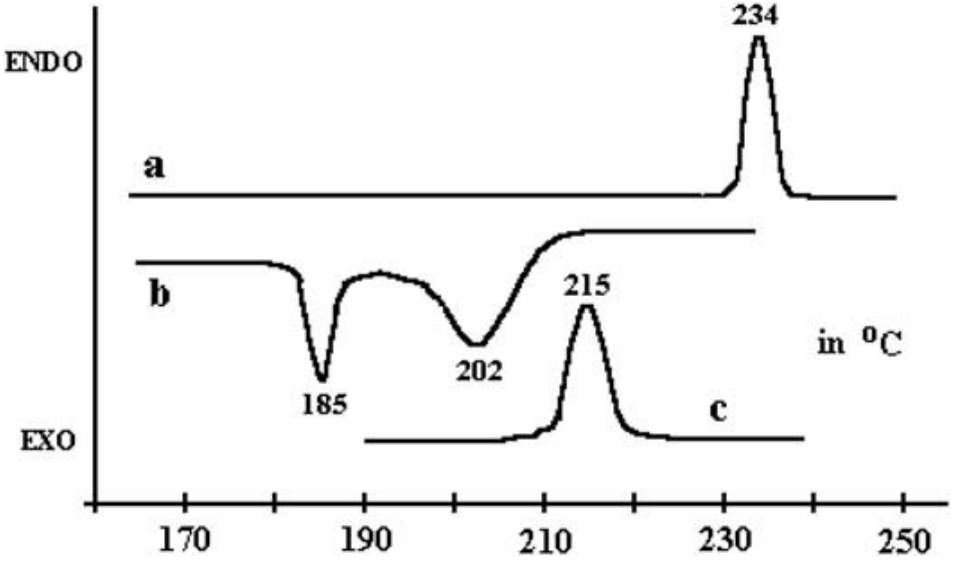
Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

DSC and DTA

- DTA – Constant heat flow
- DSC – Constant ΔT
  - Finds temperature and heat of phase transitions
  - Does not identify transition type



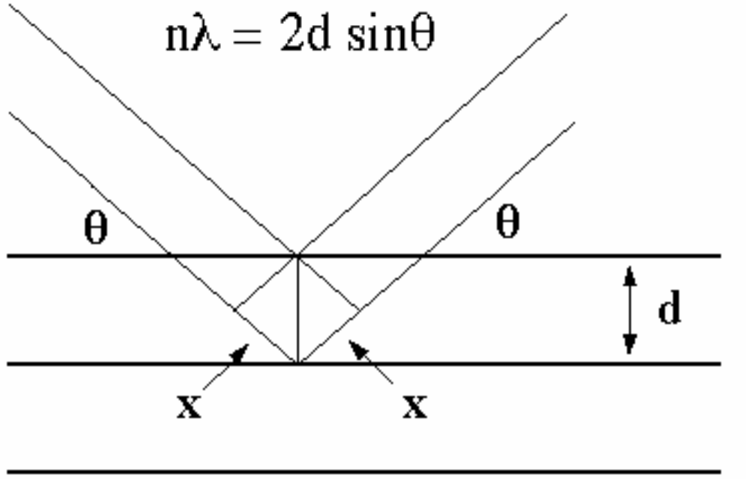
- Monotropic - LCs form in cooling process
- Enantiotropic LCs form in both heating and cooling processes

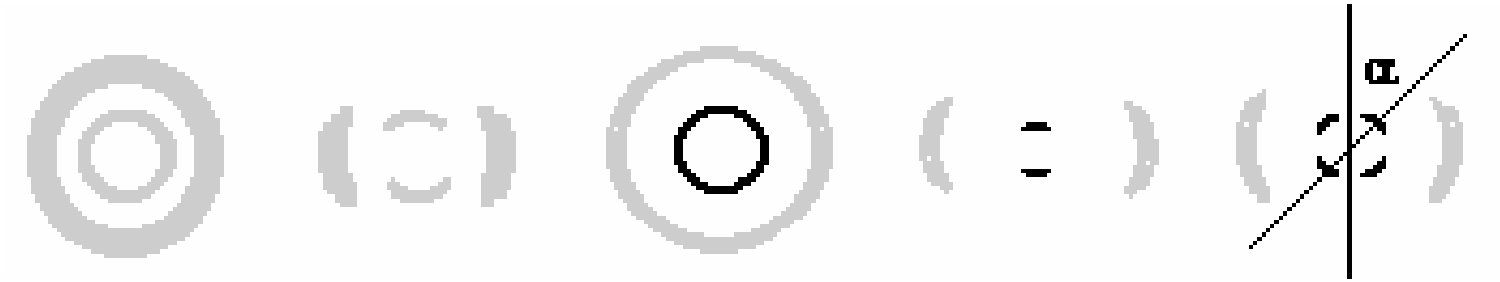


Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

X-Ray Diffraction

- Bragg Equation
- Used with POM
- Many variations
- Difficult to interpret





Unoriented Nematic | Oriented Nematic | Unoriented Smectic A or C | Oriented Smectic A | Oriented Smectic C

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

http://materials.binghamton.edu/444/part_I/sld032.htm

Miscibility Testing

- Use well-known model liquid crystals
- Different mesophases are imiscible
- Highly viscous – low mixing rates
- LCP and LC of same mesophase may be inherently incompatible
- Used for hard to determine mesophases

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Other Methods

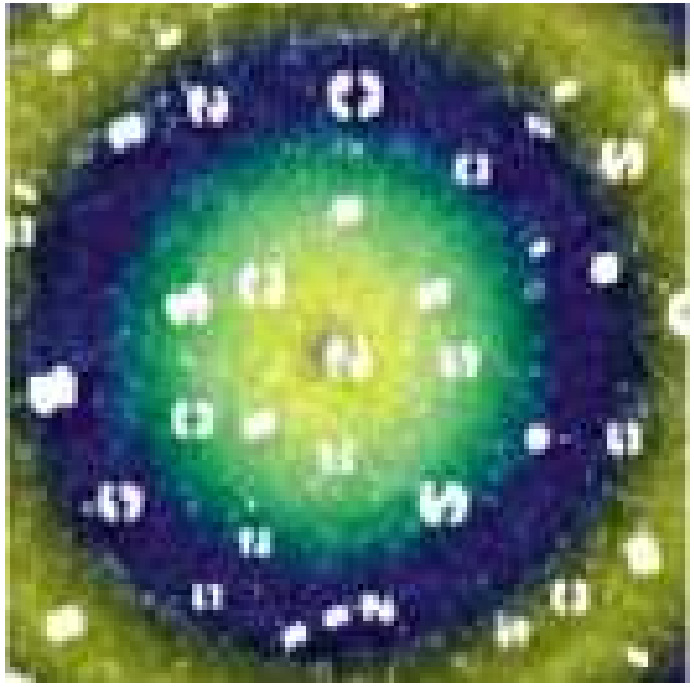
- IR
  - Bond conformation
- NMR
  - Identify relative motion of different parts of the polymer
- SANS
  - Measures global conformation of polymer

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Coates, D, *Liquid Crystal Polymers: Synthesis, Properties and Applications*, iSmithers Rapra, 2000.

Summary

- Though high in cost, LCPs have high strength and stability.
- LCPs are used in thin-walled parts, chemical equipment, and high-strength fibers.
- A combination of characterization techniques are required.



Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.

Thanks!

Questions?

Wang, X.; Zhou, Q. *Liquid Crystalline Polymers*. N.J World Scientific: Singapore, 2004.