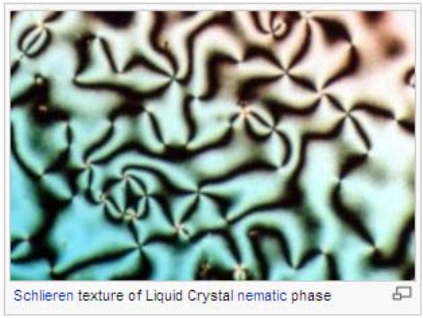
But, soft! What nymphs are these?

8. LIQUID CRYSTALS AND DEVICES

Source
No Spec: Text
W: Wikipedia

Liquid Crystals

Properties of LC
Fluidity
Anisotropy
E & M – optic property
Stir Opalescence

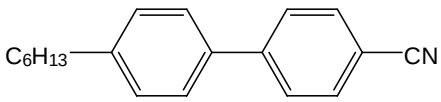


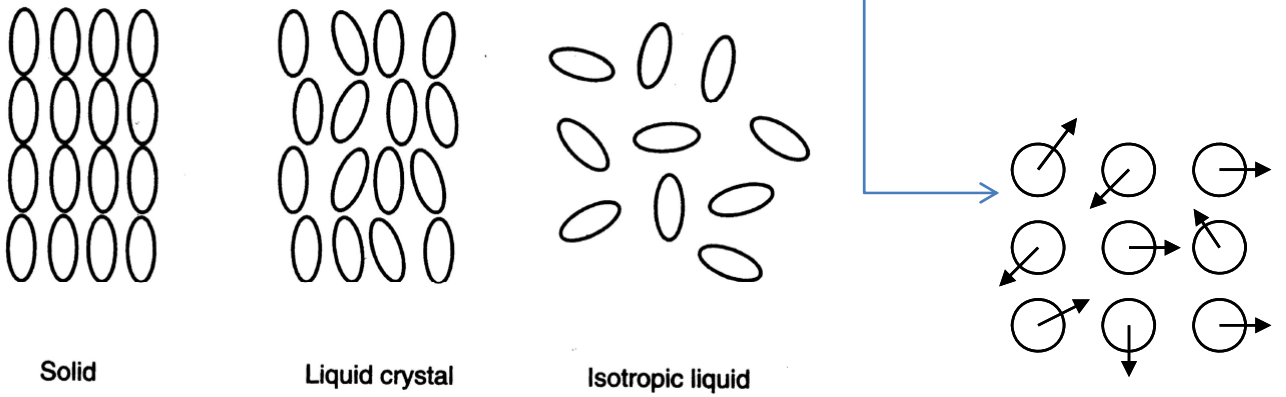
1st order transition (melting)

Crystal → (1st order transition) → Liquid Crystal → (1st order transition) → Liquid

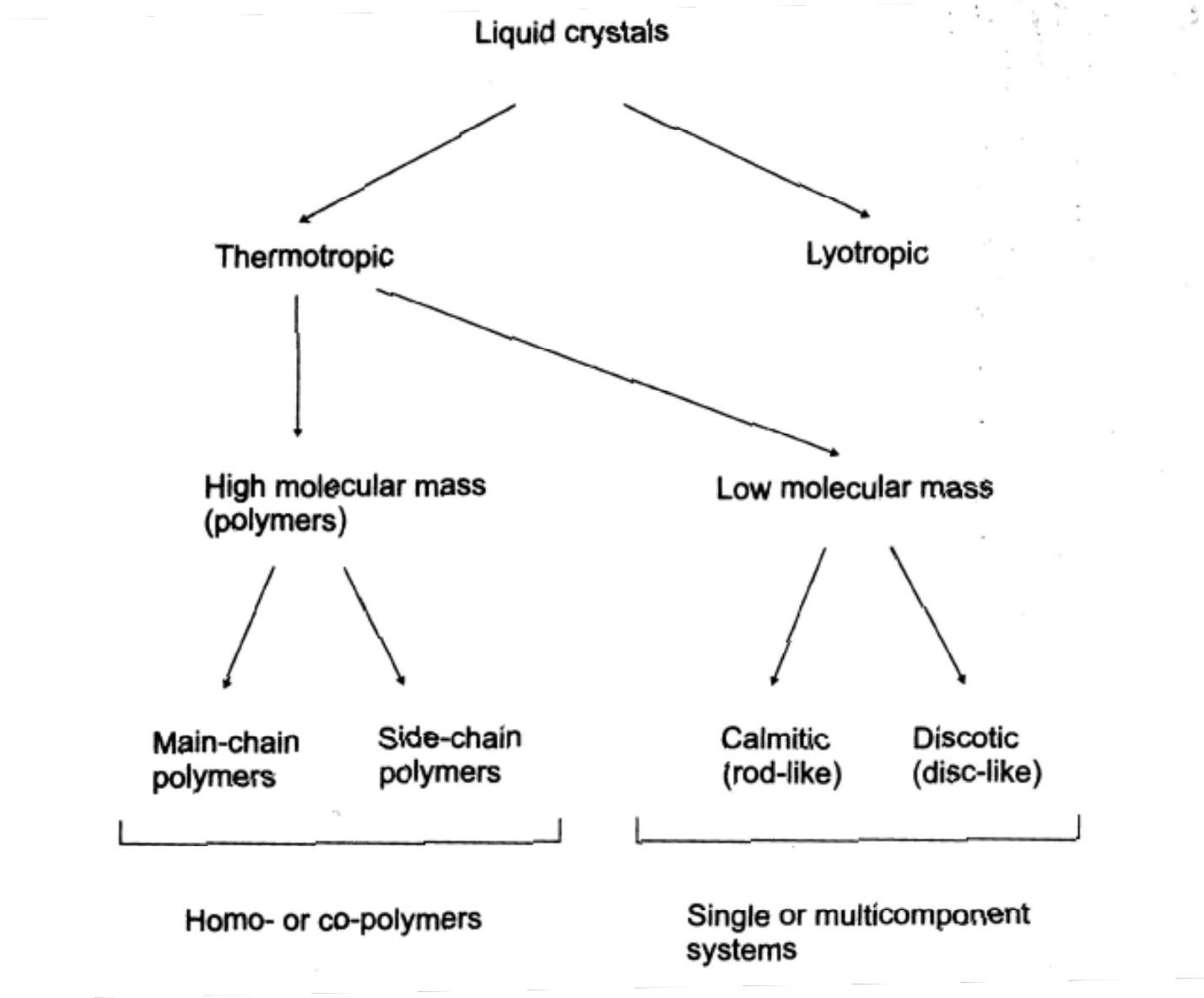
Crystal	Liquid Crystal	Liquid
3D order	1D or 2D order	zero order
Long range Positional & Orientational	(Orientational) "Mesophase"	None

Cf. (Positional) Plastic crystal





LC Categories



Nematic Phase

Oder Parameter (S)

$$S=\frac{1}{2}\left\langle 3\cos^2\theta-1\right\rangle$$

S=0 for no orientational order to

S=1 for perfect orientational order

(Typically 0.3-0.9 for nematic LC)

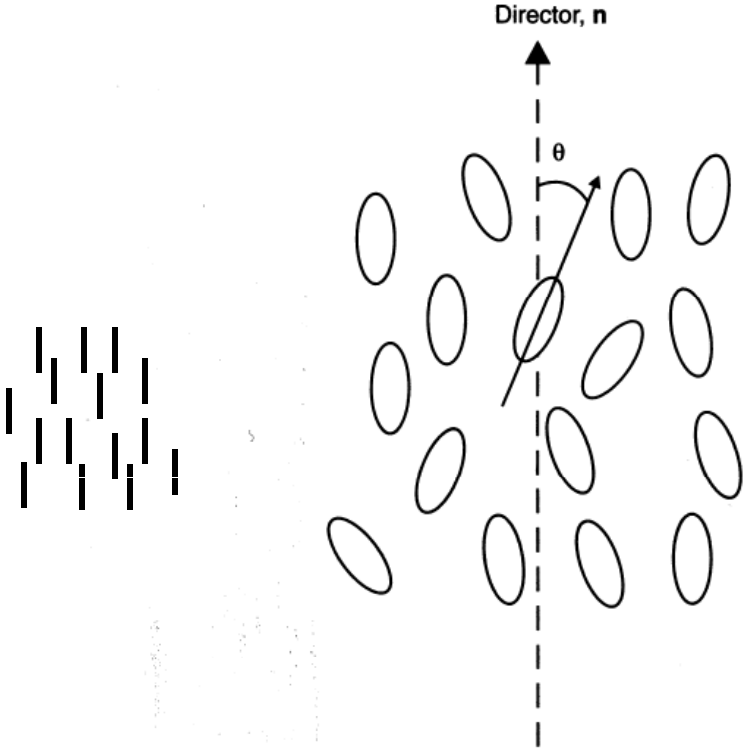
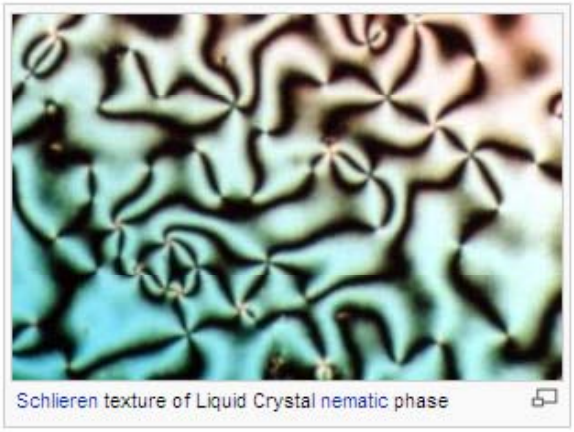
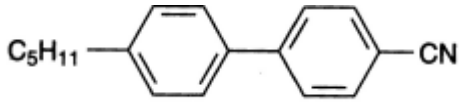


Figure 8.3 Arrangement of rod-shaped molecules in a liquid crystalline phase. The long axis of each molecule makes an angle θ with the director **n**.



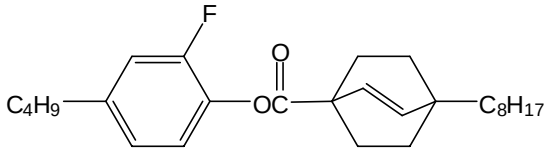
Schlieren texture of Liquid Crystal nematic phase

W



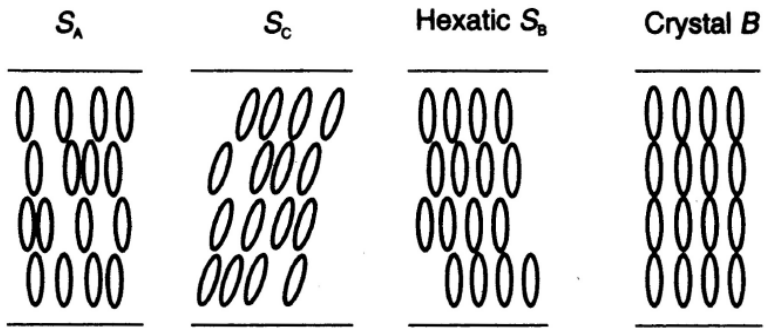
Solid ⇌ Nematic ⇌ Isotropic liquid

22.5 °C 35 °C

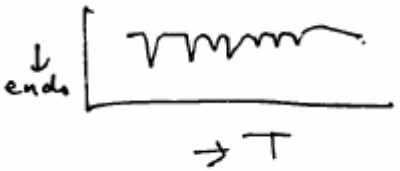


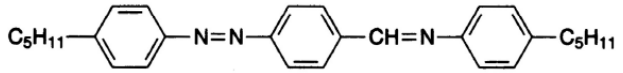
Smectic Phase

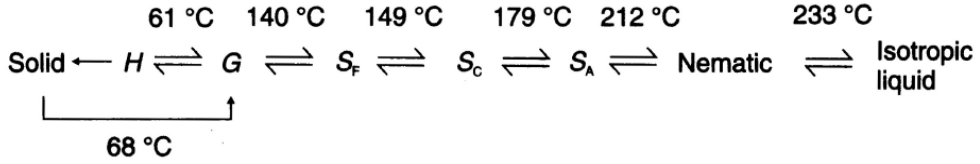
- In addition to the orientational order, smectic phase possess 1-D translational ordering into layer.
- 12 different types: S_A, S_B(hexatic S_B and Crystal B) etc up to S_K



	S_A	S_C	Hexatic S_B	Crystal *B*
Within the layers	No order	No order	Order	Order
Between the layers	No order	No order	No order	Order

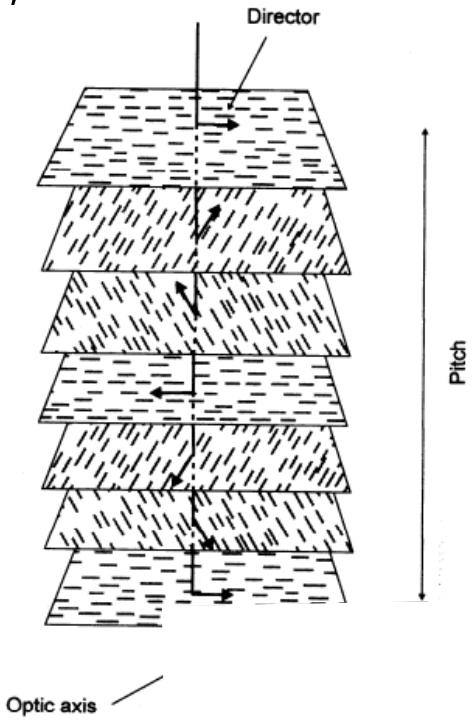


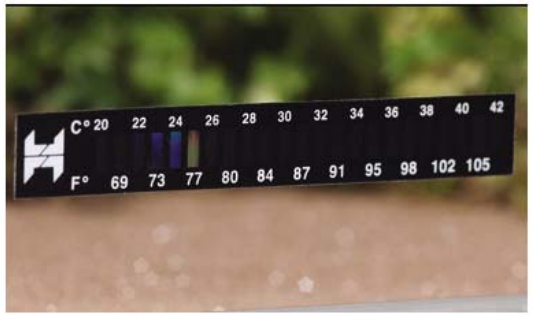




Cholesteric Phase

- Cholesteric phase = Chiral nematic phase
- Pitch; selective reflection of light





articles about Temperature Control

- Temperature and Herp's Health
- Temperature & Lighting Needs
- Heating Equipment Review
- More...

Liquid Crystal Thermometer

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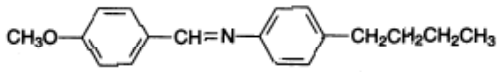
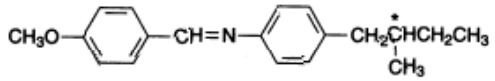
http://www.drsfostersmith.com/Product/Prod_Display.cfm?pcatid=9770&c=



(a)



(b)

Figure 8.8 (a) An organic compound, 4-methoxylbenzylidene-4′-butylaniline, that exhibits a nematic liquid crystal phase. (b) A similar compound, now incorporating a chiral centre, which shows chiral nematic (cholesteric) behaviour. The chiral centre is denoted by an asterisk.

Discotic LC Phases

Figure 8.9 Discotic liquid crystal phases. (a) Columnar; (b) nematic.

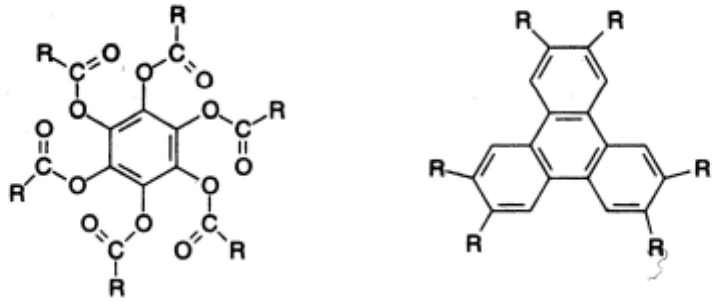
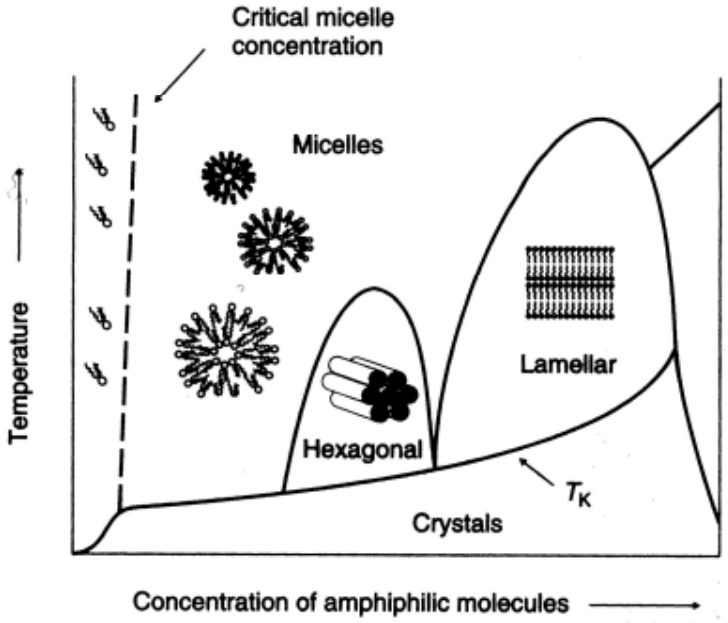
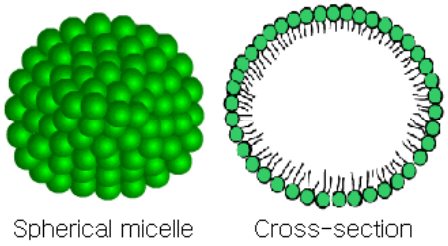


Figure 8.10 Examples of discotic liquid crystalline compounds. (a) Hexa-substituted benzene; (b) triphenylene.

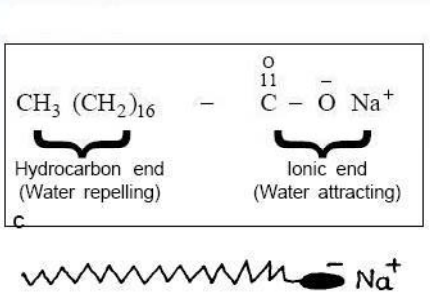
Lyotropic LC

- LC transition via influence of solvent
- Amphiphilic in nature; surfactants;
- Hollow spheres, rods, and sheets
- Critical micelle concentration
- Closely packed structures filling 74% (sphere), cylinder (91%) and bilayer sheet (100%)
- Soap: lowering the surface tension of water and allowing more material to enter it and be dissolved.
- Nanoreactor; Nanoparticle synthesis





http://plc.cwru.edu/tutorial/enhanced/files/llc/Phase/phase.htm



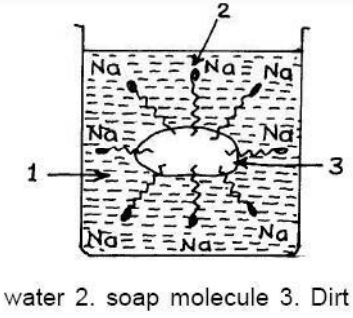


Figure 8.11 Phase diagram of a typical lyotropic liquid crystal. The nearly vertical dashed line on the left shows the minimum concentration for micelle formation. T_K is the Kraft temperature. Various liquid crystal phases occur in the region close to the 100% concentration axis.

W: Soap Action

Liquid Crystalline Polymers

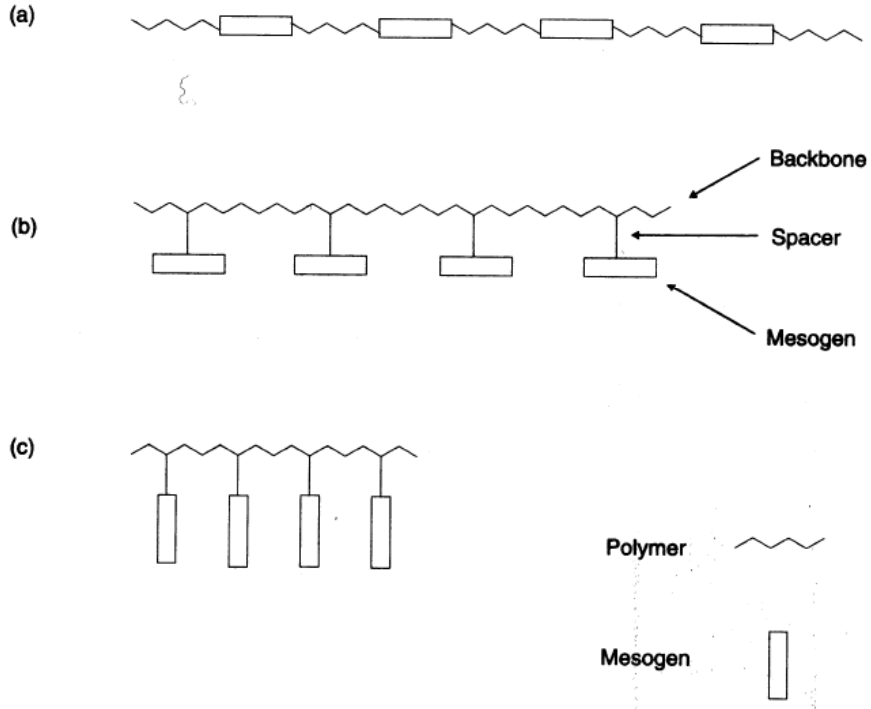
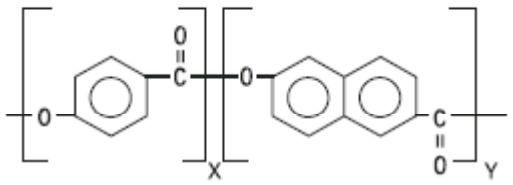


Figure 8.12 Examples of polymer liquid crystals: (a) represents a main-chain polymer liquid crystal and (b) and (c) are examples of side-chain liquid crystals.



Vectra® polymer

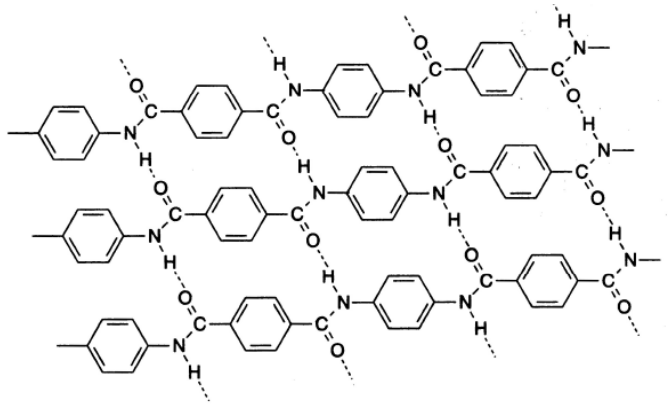


Figure 8.27 Chemical structure of Kevlar, poly(*p*-phenylene terephthalamide). Hydrogen bonding is depicted by dashed lines.

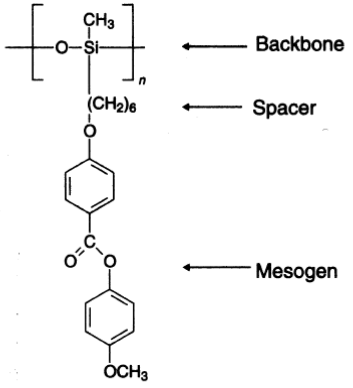


Figure 8.13 Molecular structure of a side-chain polymer liquid crystal based on a polysiloxane backbone.

Birefringence of LC

- Ordinary and extraordinary refractive index: o-ray and e-ray
- As the radiation propagates through the length of the sample, phase change is brought about when it gets out of the sample– 'phase retarder'-- generating elliptical polarization
- Crossed polarizers : transmission through the analyzer shown due to the elliptical polarization
- Rubbing and alignment
- Freedericksz Transition: Occurrence of a change from an aligned to a deformed state produced by the E or M field application: threshod 4×10^2 V/cm or 0.2 T

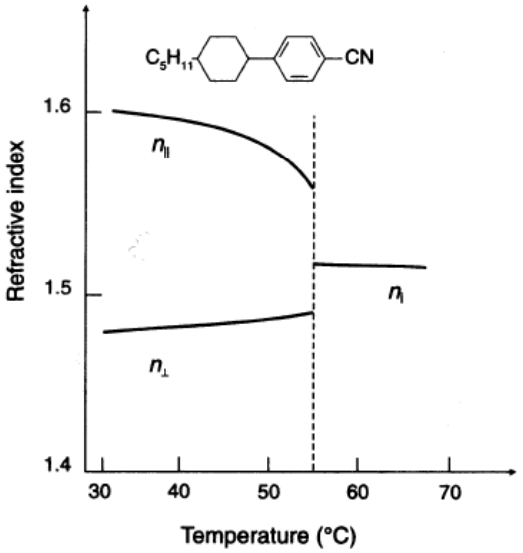


Figure 8.14 Temperature dependence of the birefringence of the liquid crystal molecule shown. The upper curve shows the extraordinary refractive index $n_{\|}$ and the lower curve the ordinary refractive index $n_{\perp}$. At the nematic liquid transition of around 54°C, both refractive indices merge into that of the isotropic liquid n_i. Reprinted from *Nanoelectrics and Information Technology*, 2nd ed., R. Waser (Editor), pp. 889–909. Copyright (2005), with permission from Wiley–VCH.

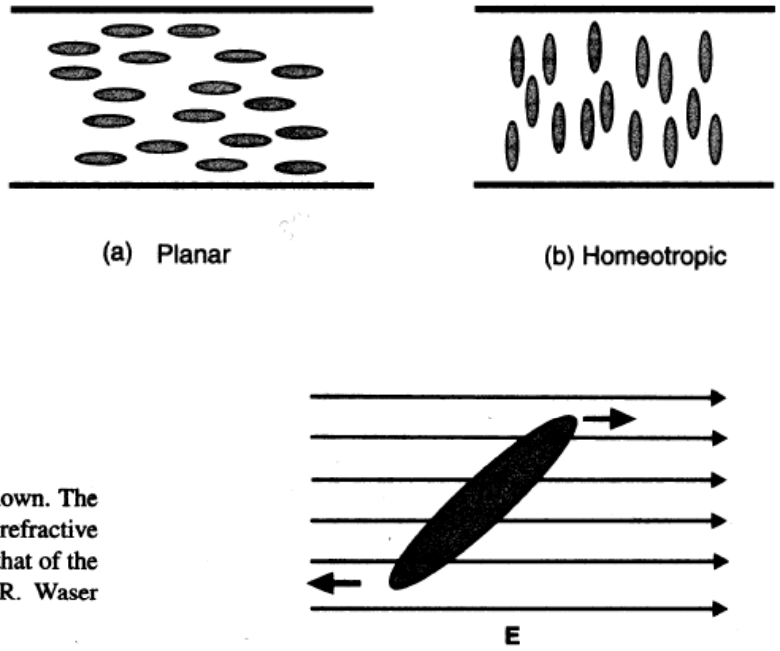


Figure 8.15 Effect of applied electric field on a dipolar molecule.

Twisted Nematic (TN) Display

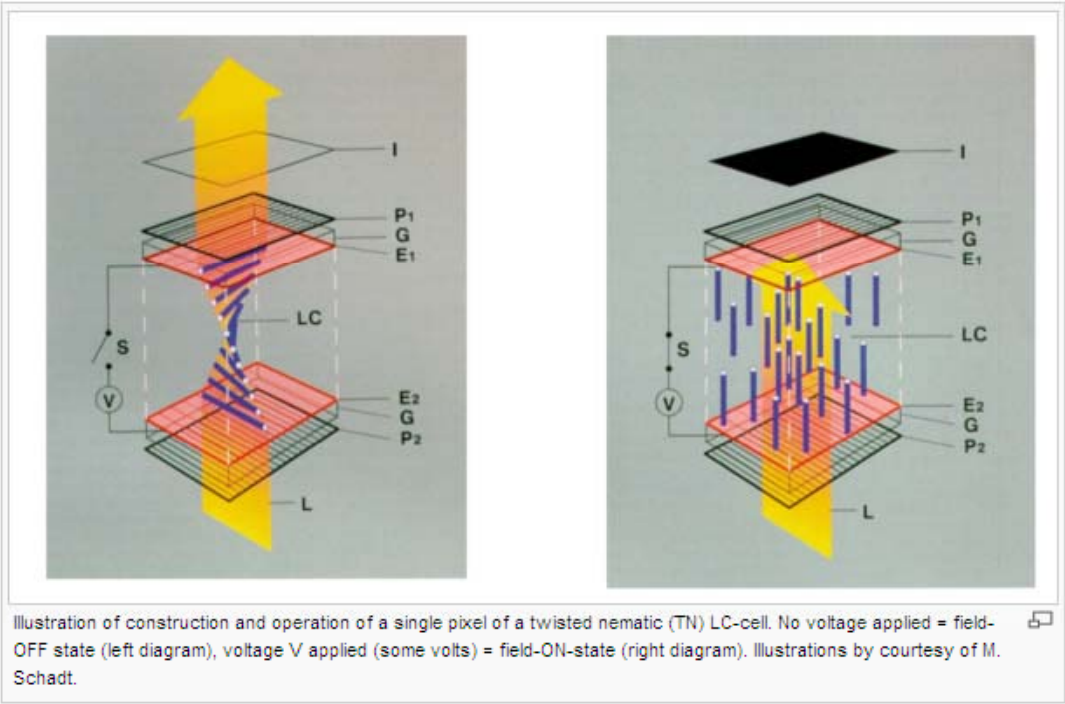
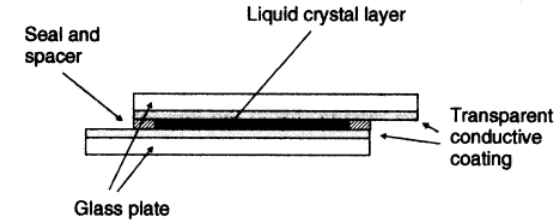


Illustration of construction and operation of a single pixel of a twisted nematic (TN) LC-cell. No voltage applied = field-OFF state (left diagram), voltage V applied (some volts) = field-ON-state (right diagram). Illustrations by courtesy of M. Schadt.



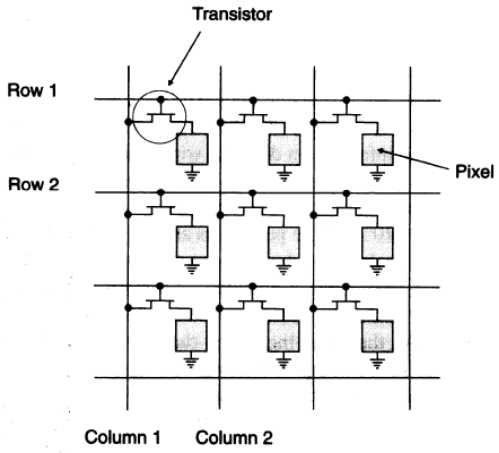
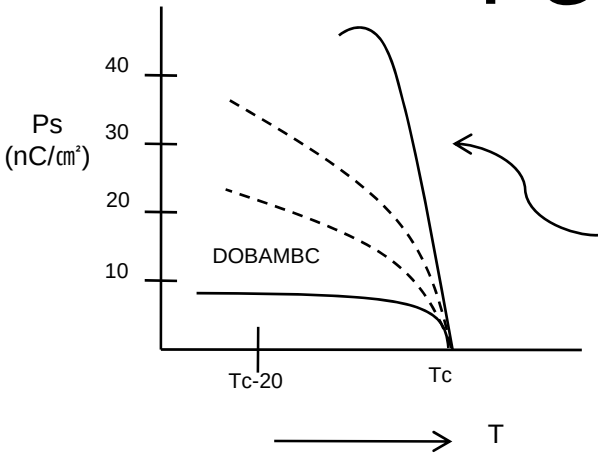


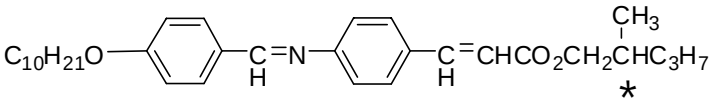
Figure 8.19 Active matrix display diagram. Each liquid crystal cell, or pixel, is turned on or off by a transistor.

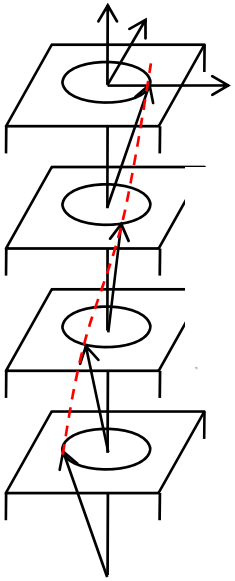
- Reflective System (calculator and watches) and Back Lighting System (display and TV)
- Seven segment, Pixel (for XGA 768x1024 =8x10^5 pixels)
- Passive matrix and Active matrix
- Scanning principle: time to scan the entire matrix is shorter than the turn-off time
- Color filters
- Super-Twisted Nematic (STN): improved multiplexing capability with steeper tilt vs. voltage characteristics but color compensation is needed

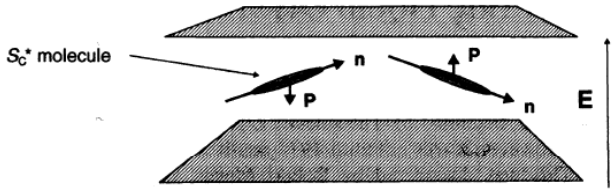
Ferroelectric LC

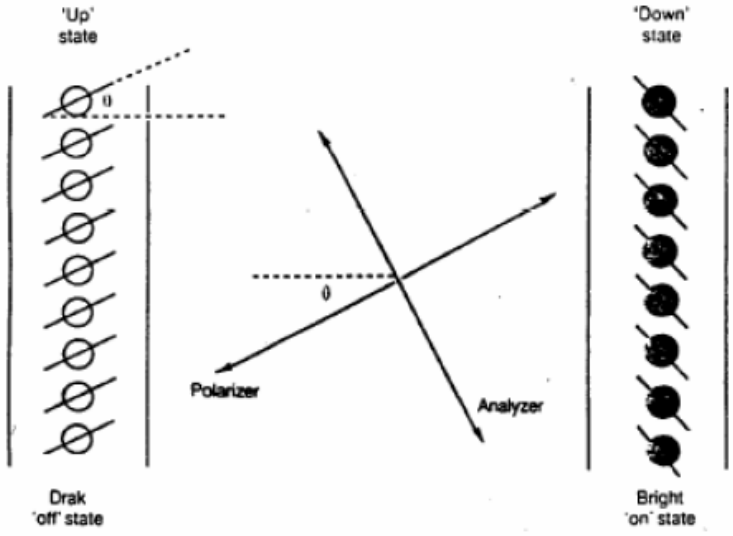


- Fast response, smaller pixel size
- Bistability is often detrimental to the accidental state change due to the external mechanical stress ; no recovery happens









Sc*

SSFLC (surface-stabilized FLC)

Polymer-Dispersed LC

- Switchable windows, projection display

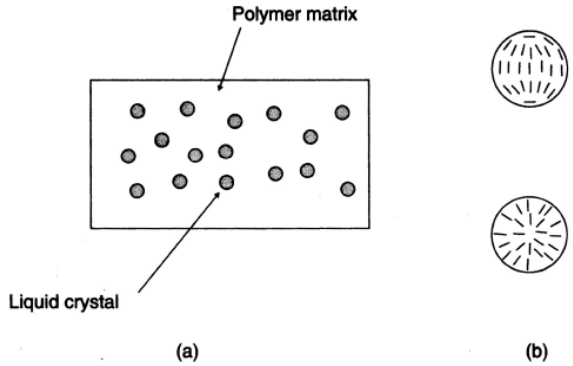


Figure 8.23 (a) Polymer dispersed liquid crystal with droplets of liquid crystal distributed throughout the polymer. (b) Two possible configurations for the directors, shown as lines, with respect to the polymer surface: top, parallel alignment; bottom, perpendicular alignment.

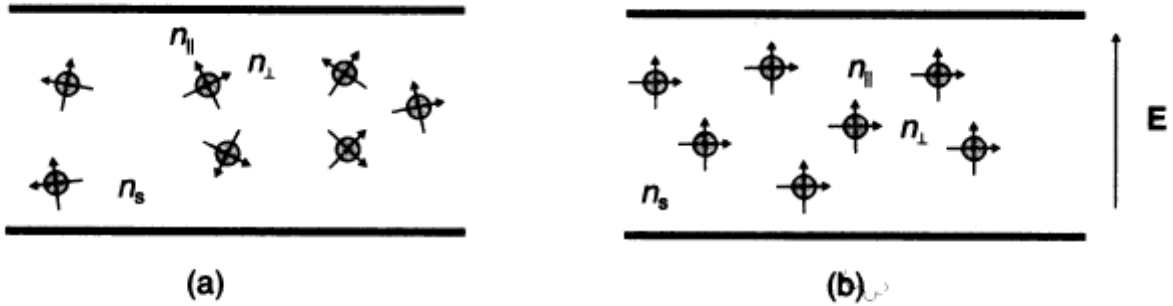
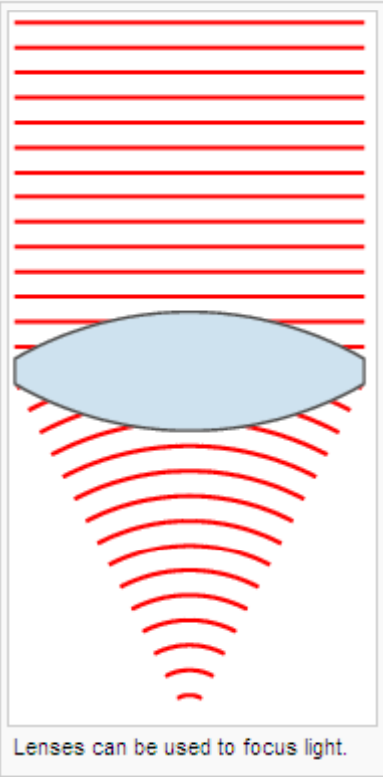


Figure 8.24 Reorientation of the director within a liquid crystal droplet in a polymer dispersed liquid crystal. $n_\parallel$ and $n_\perp$ are the extraordinary and ordinary refractive indices of the liquid crystal and n_s is the refractive index of the polymer. (a) With no applied electric field, the directors within the individual liquid crystal droplets are unaligned and incident light is scattered. (b) Application of an electric field aligns the directors and the cell appears clear if $n_\perp$ and n_s are equal.

Liquid Crystal Lenses

- Consists of a number of pixels in the form of rectangular grid or concentric rings: modulate the refractive index of the individual pixel



Lenses can be used to focus light.

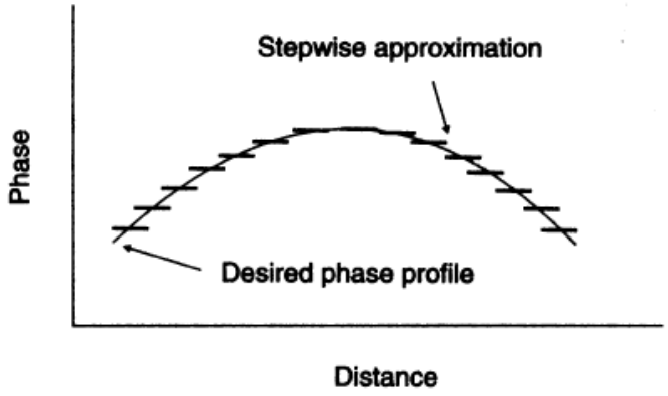


Figure 8.25 Approximation of a continuous phase profile (full line) with zonal (pixelated) liquid crystal elements.

W