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液晶光電研究室網址:
www.e-lcd.com.tw
140.138.140.197



Sharp

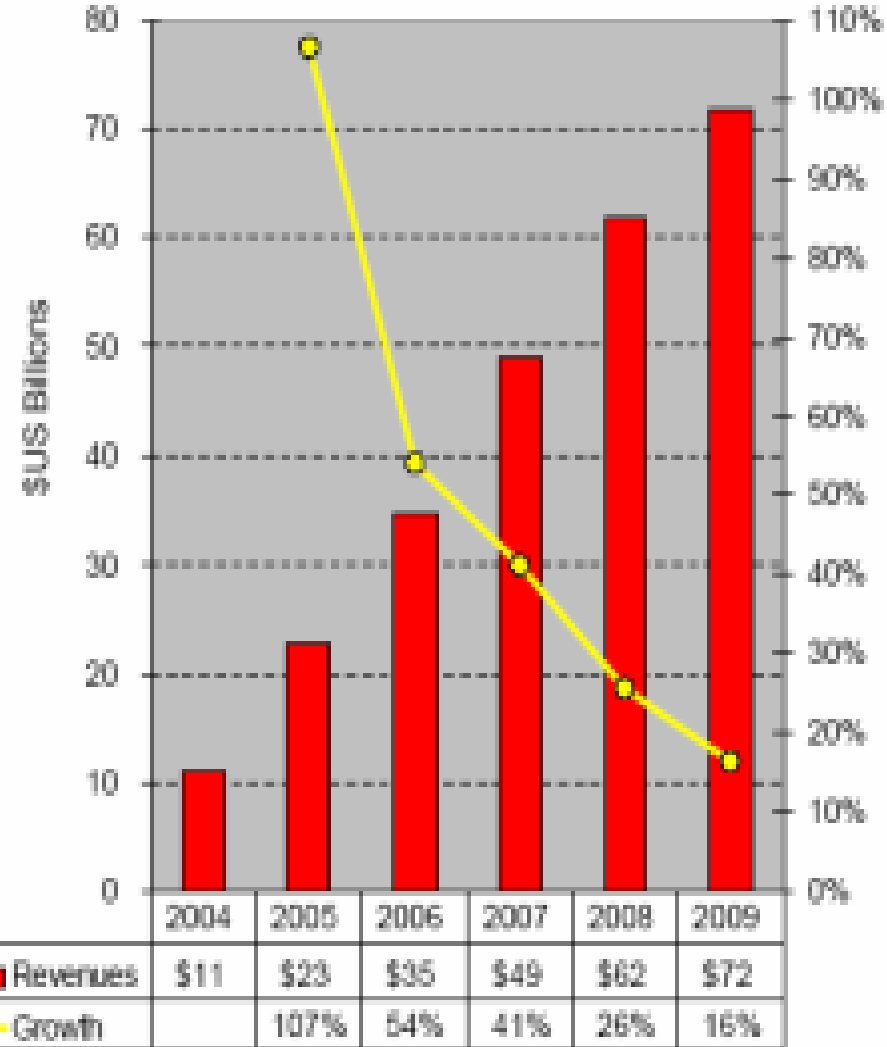
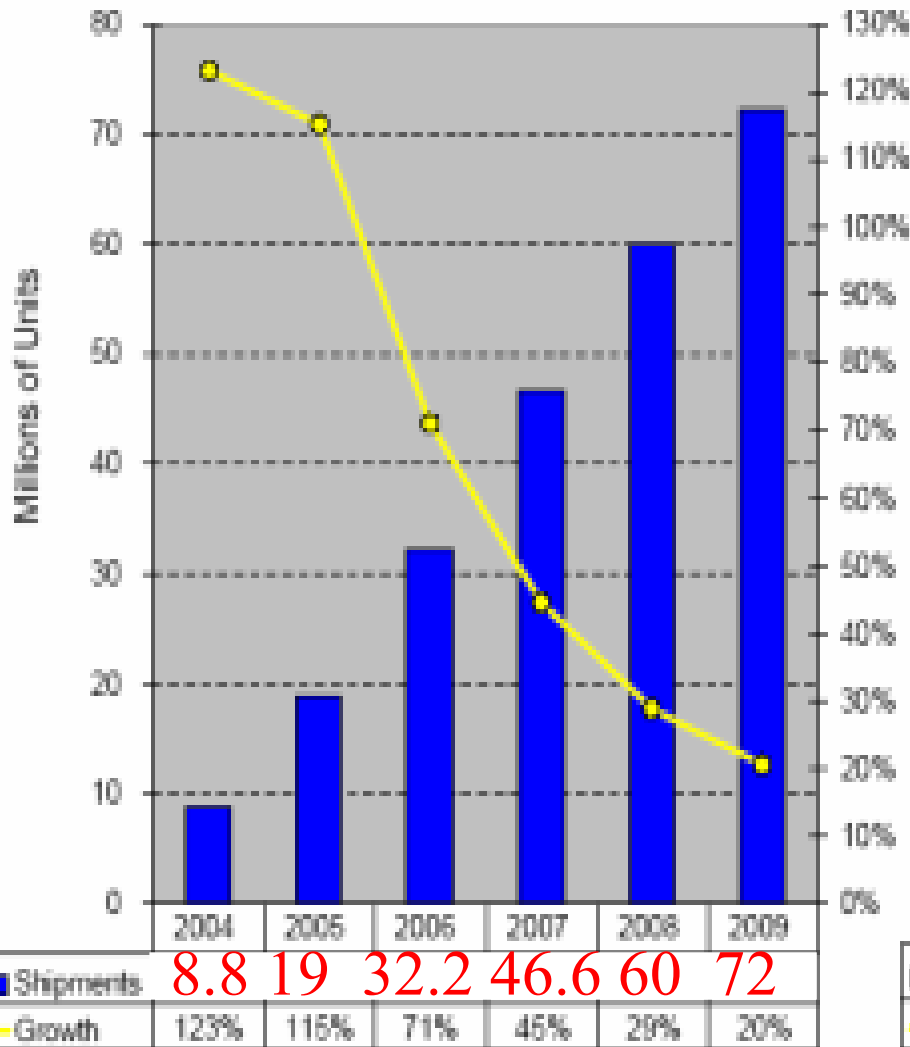
フルHD(1,920×1,080ドット)
対応AQUOSは、
65/57/45/37型の4サイズ、5
シリーズまで拡充される。
新たに発売される57V型
は、世界最速の応答速度
4msを実現。さらに、赤色
LEDと蛍光管の組み合わせ
により、色再現範囲を
NTSC比95%に拡大した
「ハイブリッド・バックラ
イト・システム」

37V型コントラスト比は
1,200:1、応答速度は6ms

152万2,500円(57V型)
54万6,000円(37V型)

LCD TV Units and Revenues

53" unit CAGR expected with revenues rising 46%.



液晶的發現

✦ 1888 F.Reinitzer 奧地利

膽石醇安息香酸

某一溫度白濁液體

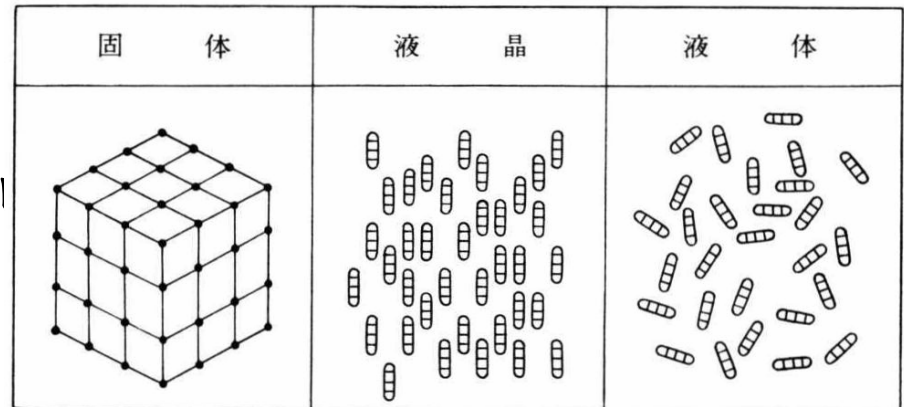
✦ 1889 O.Lehmann 德國

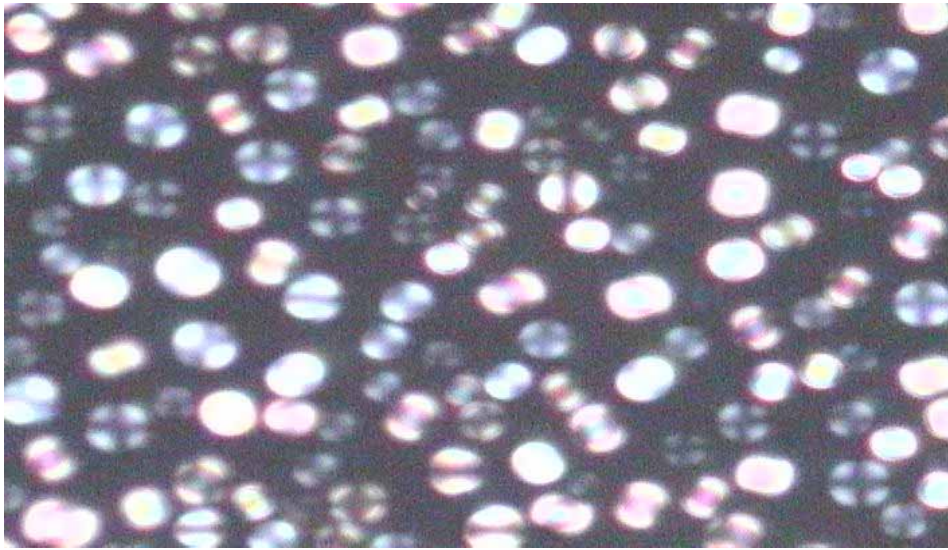
偏光顯微鏡 異方性結晶 雙折射率 多彩美麗

File Bende Krystalle

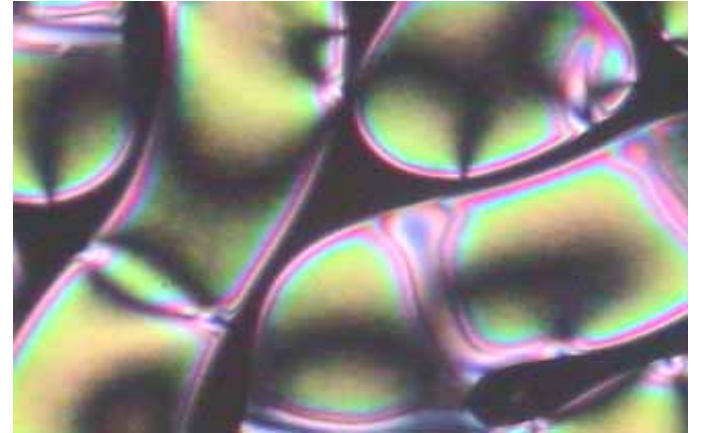
• 1922 G.Friedel

液晶光學形態

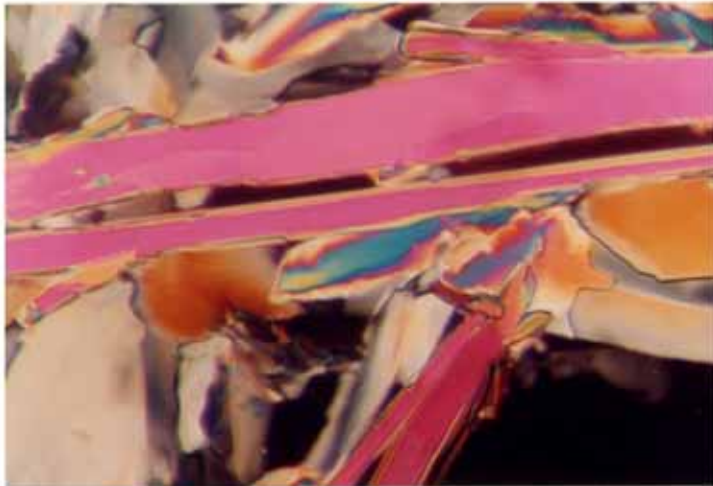




等方性相

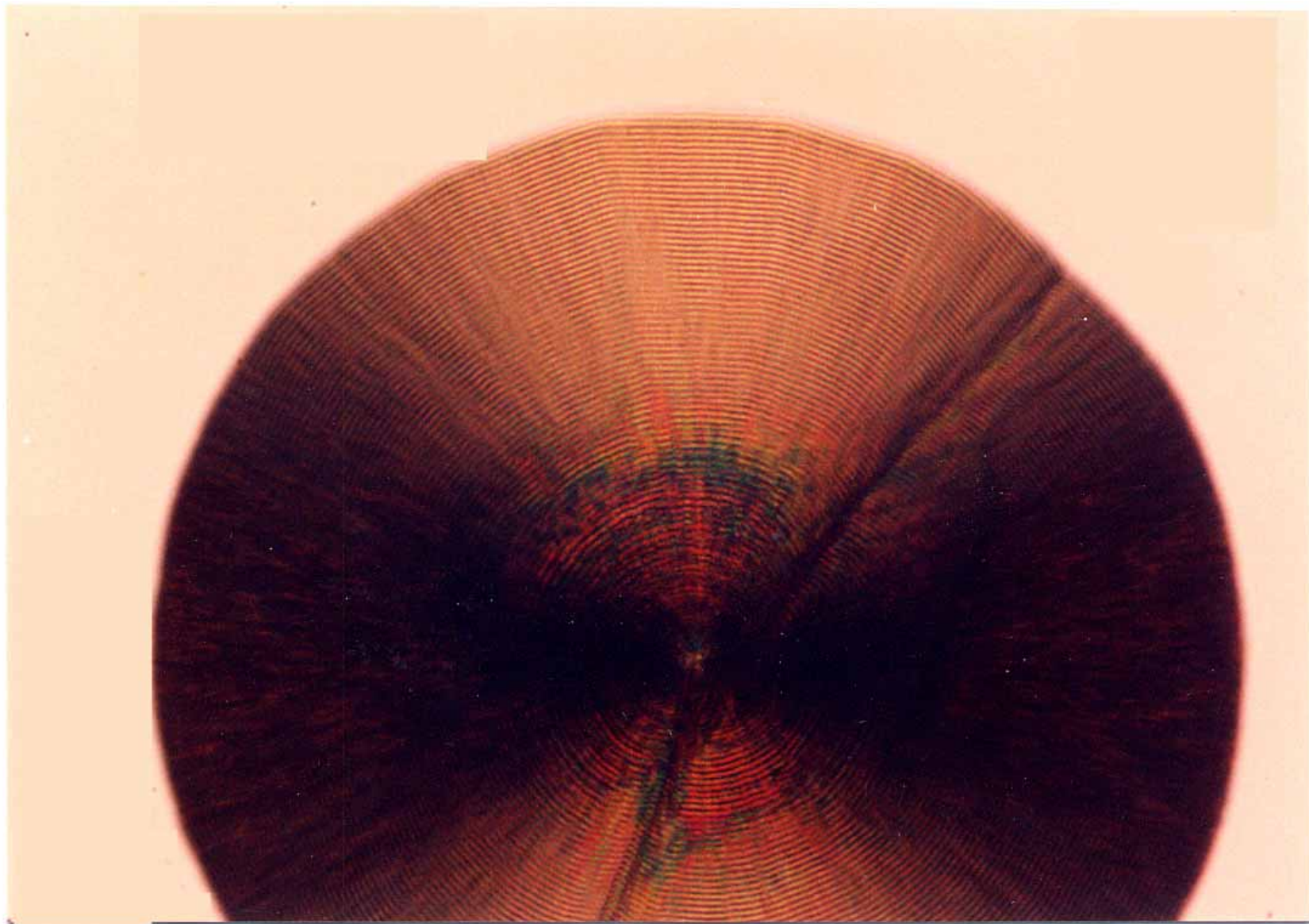


結晶



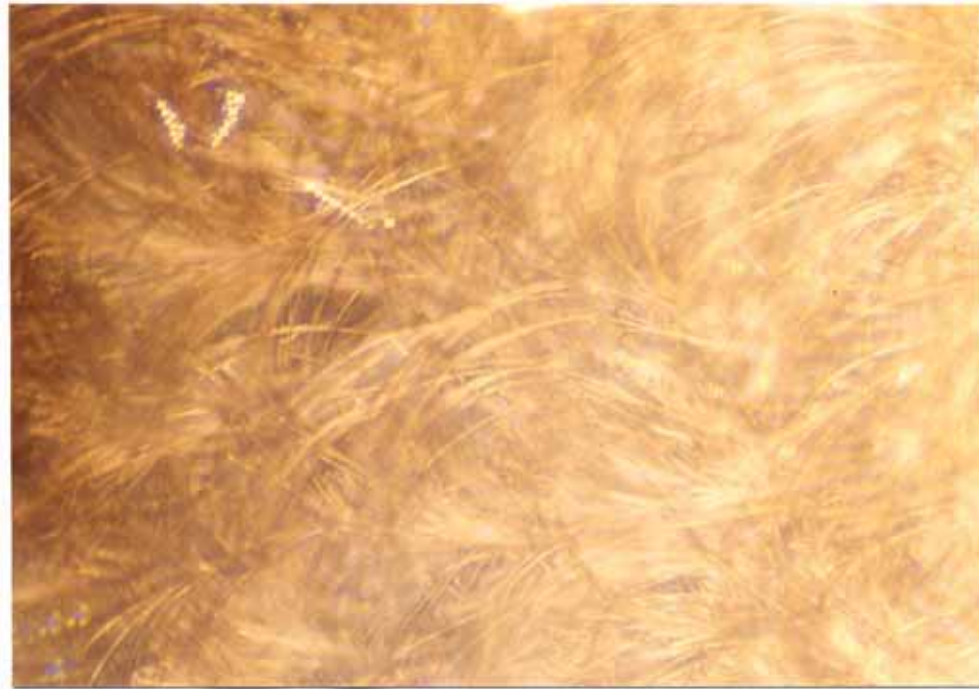
液晶相



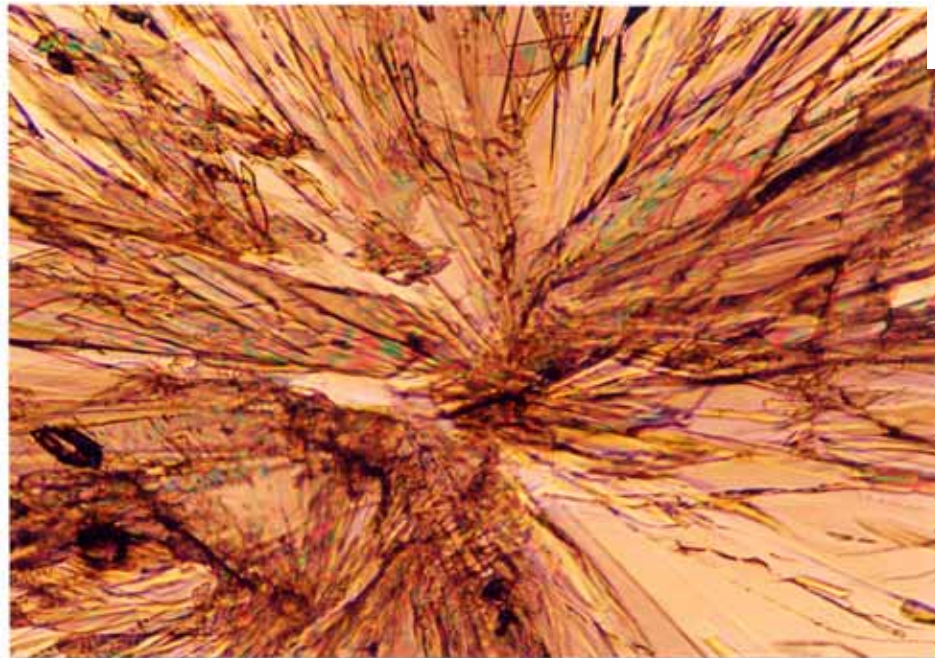


(a) 17°C 球晶態





(b) 25°C 絲狀



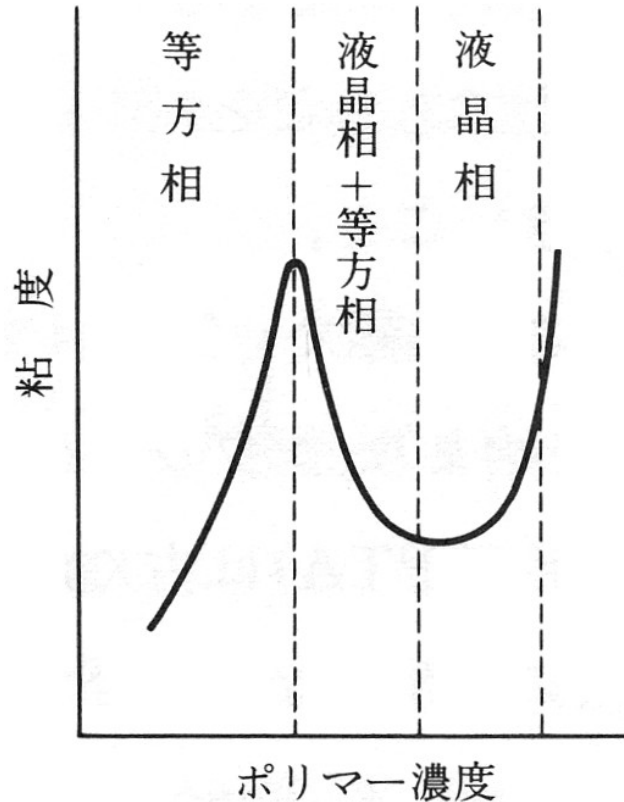
(c) 33°C 片狀



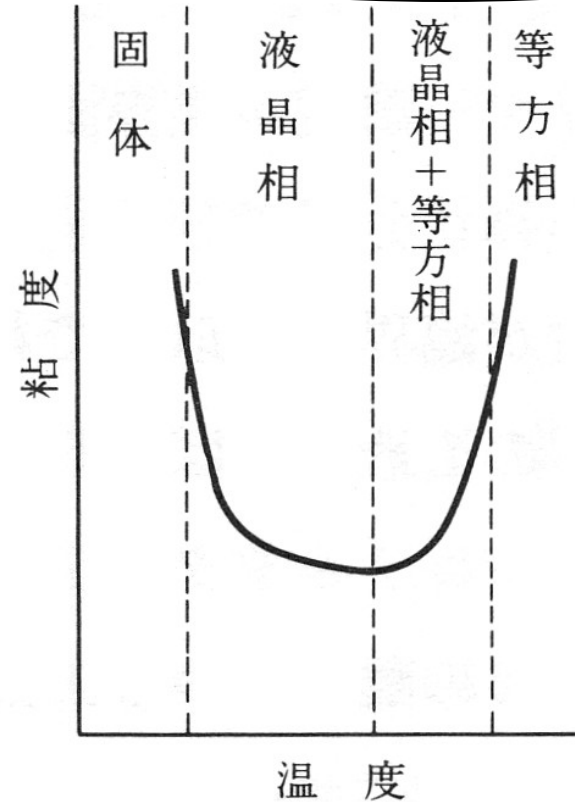
液晶的分類

液晶形成方式

液晶lyotropic



液晶thermotropic



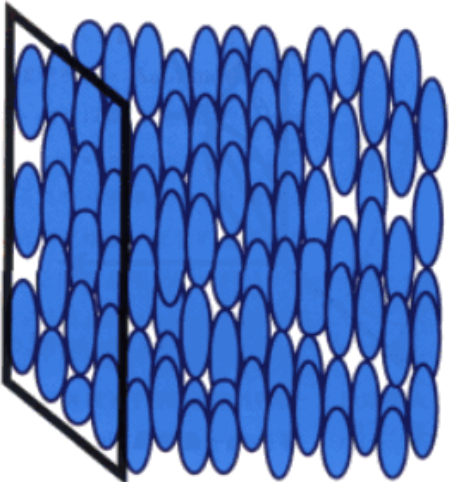
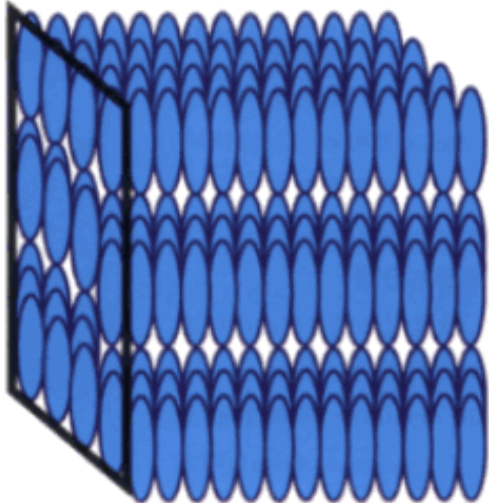
PPTA-H₂SO₄系の粘性挙動



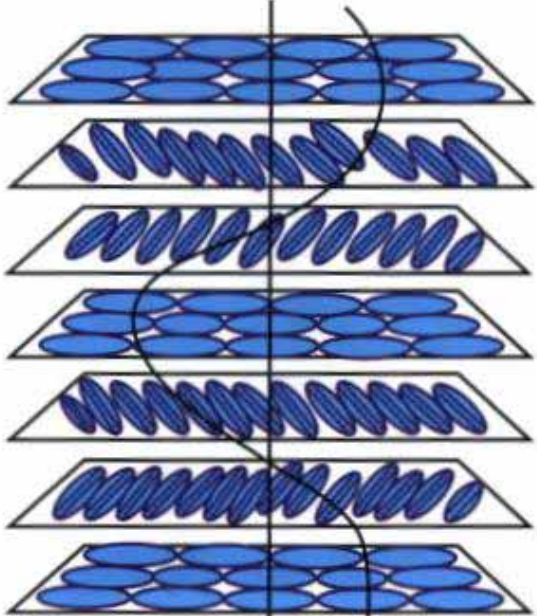
液晶分子排列 方式

smetic

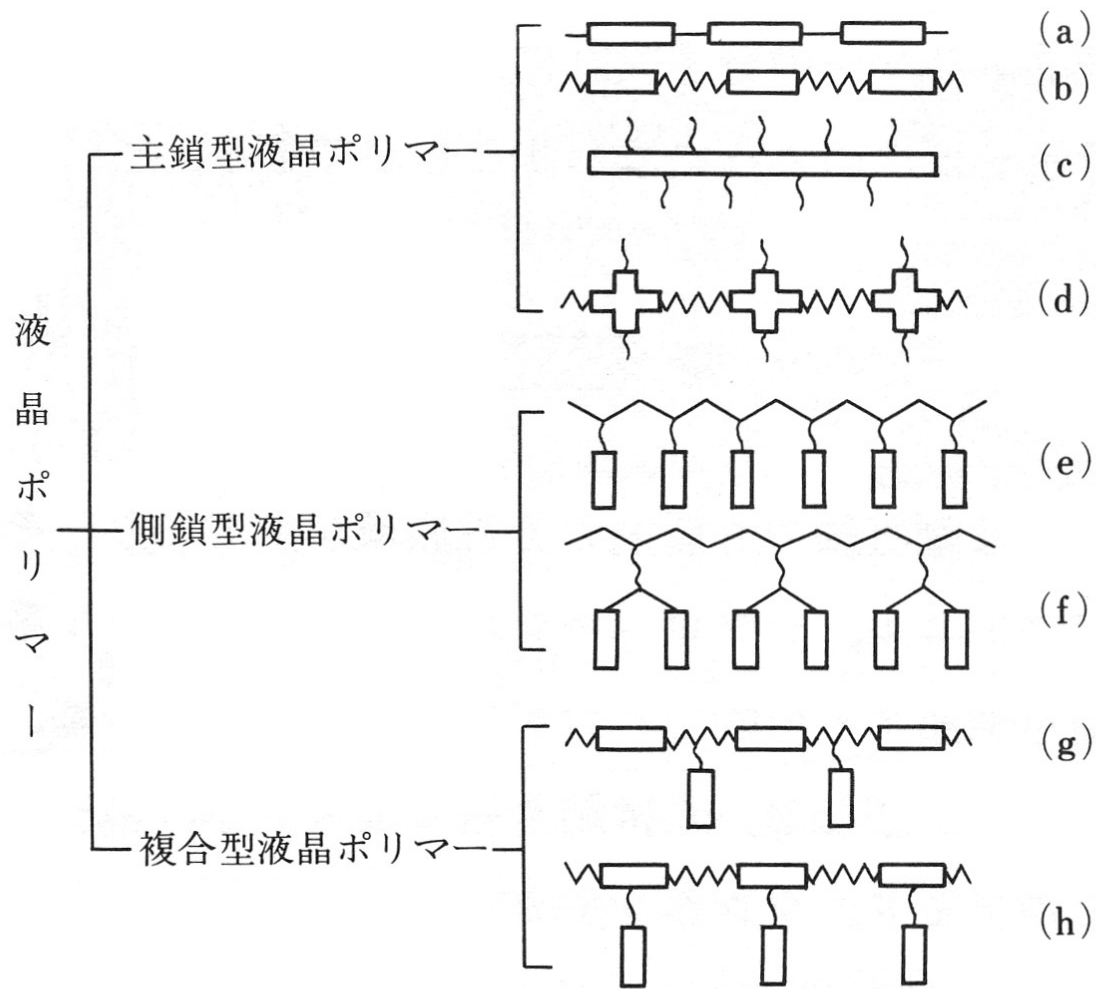
nematic



膽石醇型cholesteric

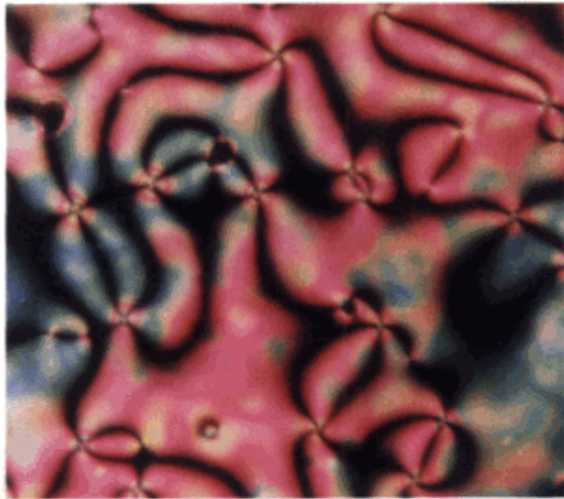


圖二(0-1)

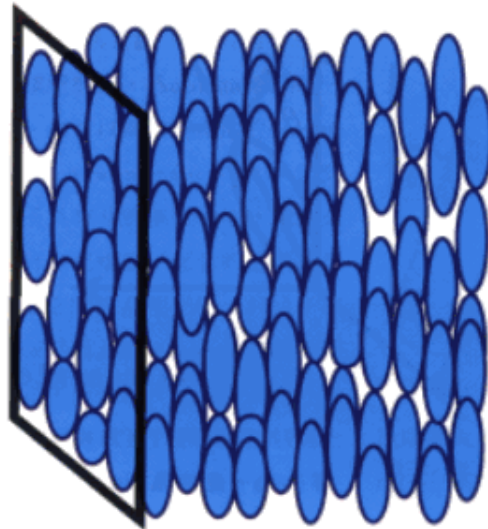


□ : 棒状あるいはディスコチック, $\sim\sim\sim$: 屈曲鎖 (含まれない場合もある)

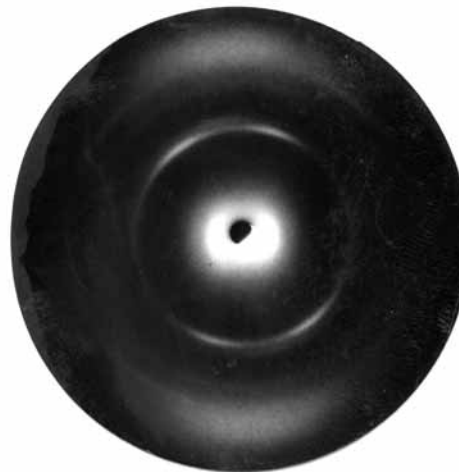
液晶ポリマーへのメソゲン基の配列模式図



圖二(a-2) 向列形液晶的 schlieren構造



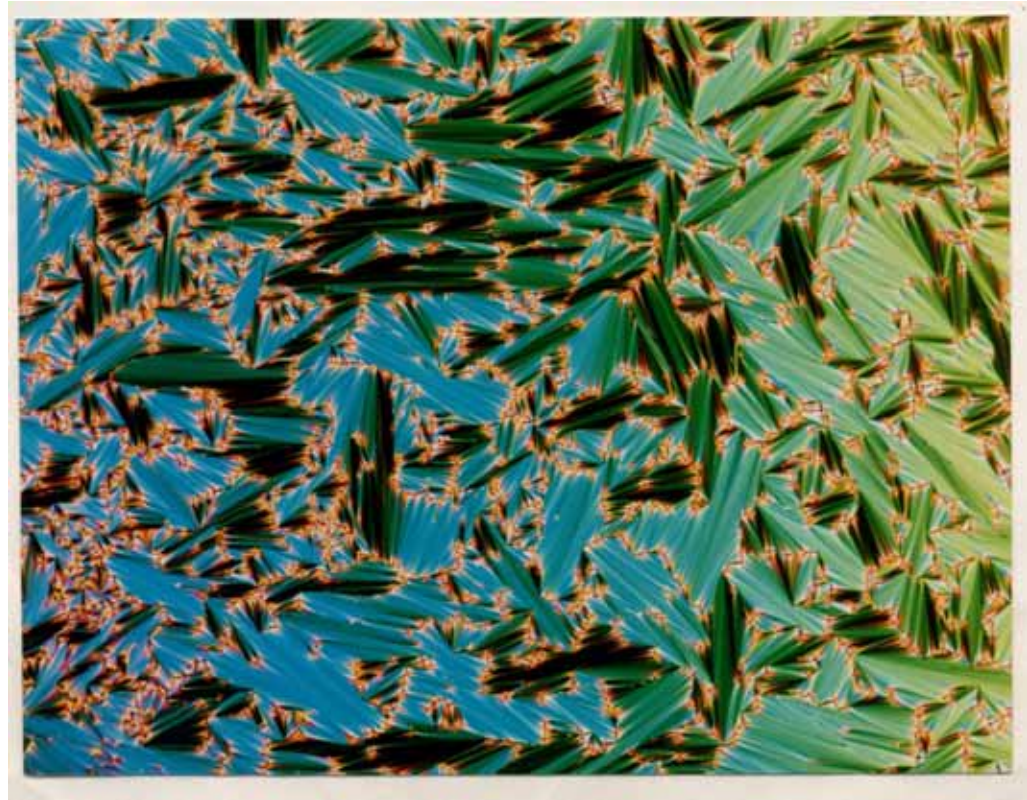
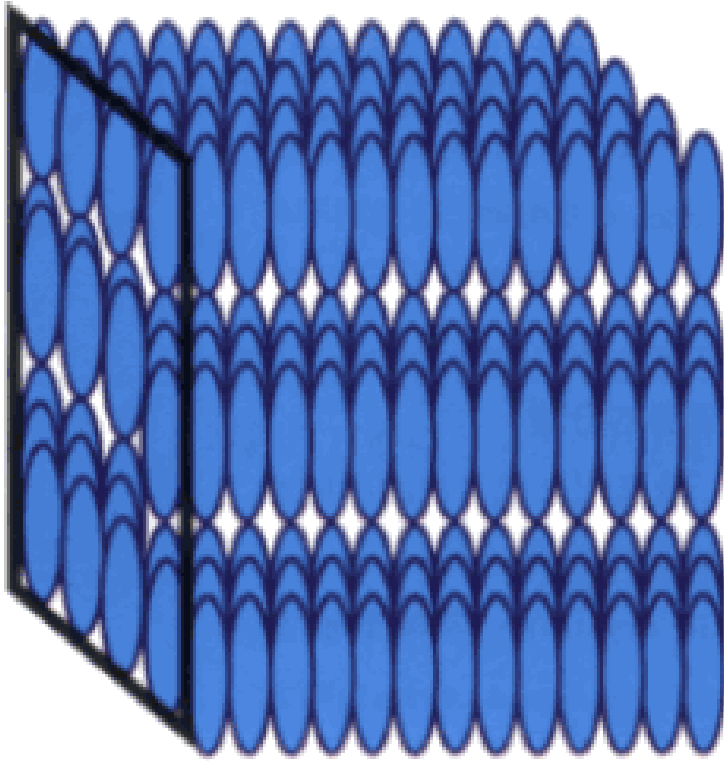
圖二(b-1) 層列型液晶分子的排列



— 0.44nm

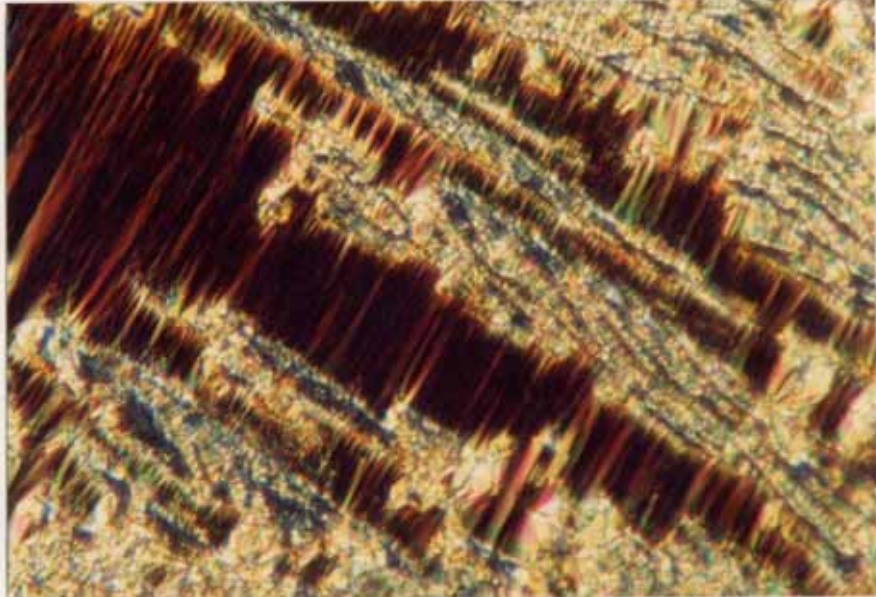
— 2.66nm





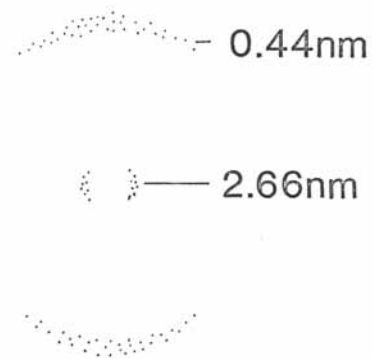
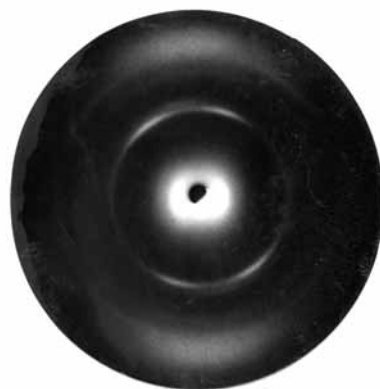
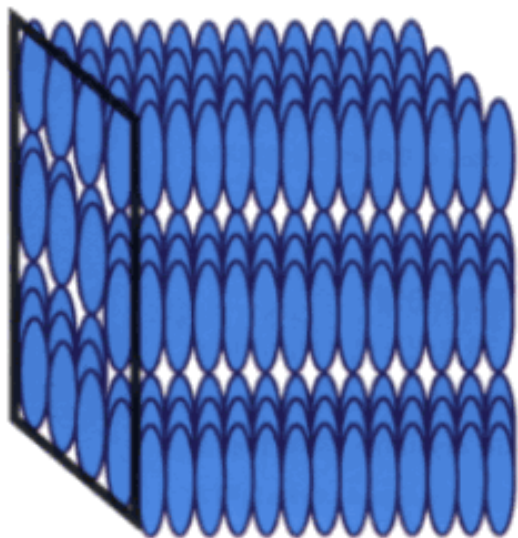
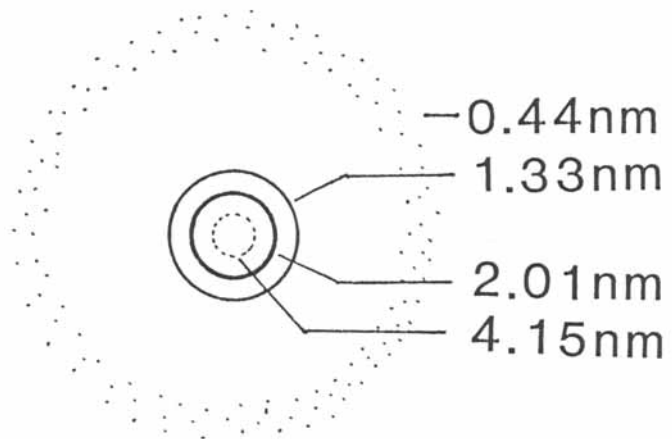
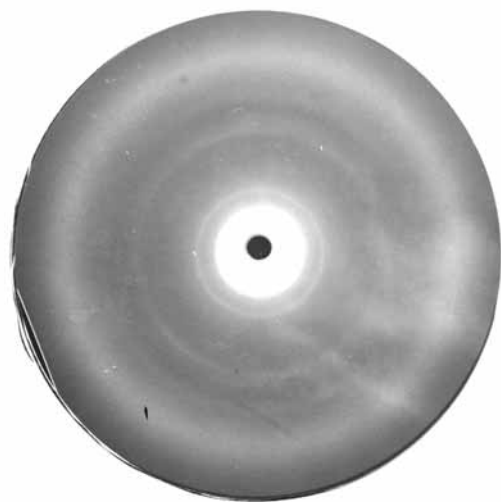
Fan texture

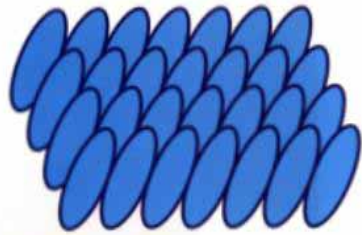
層列型液晶分子排列構造



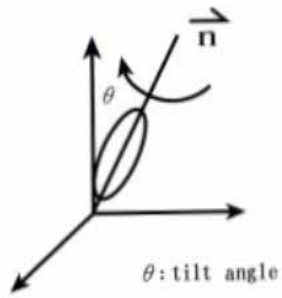
FUJICOLOR 88

X-ray 繞射圖





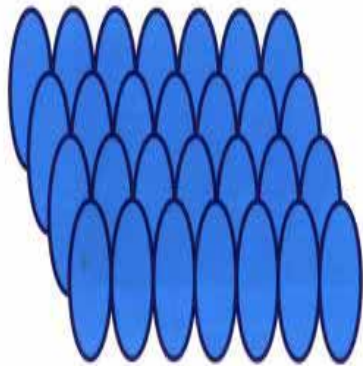
圖三(b) 層列C相的排列



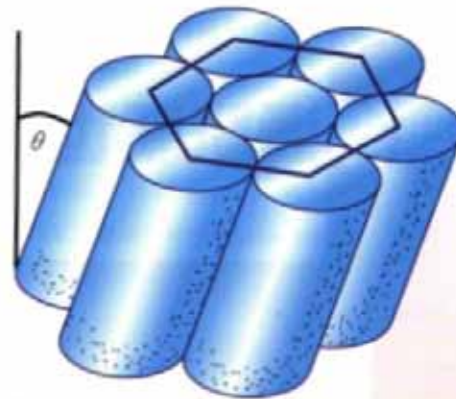
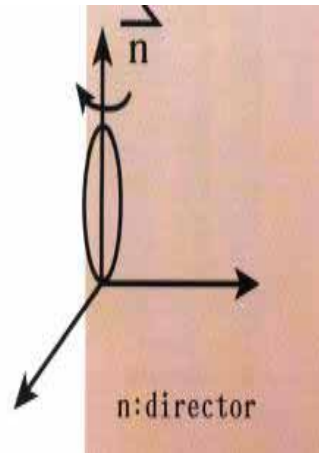
圖三(c) 層列B相的結構



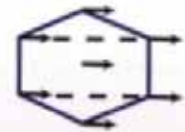
圖三(d) 層列E相的結構

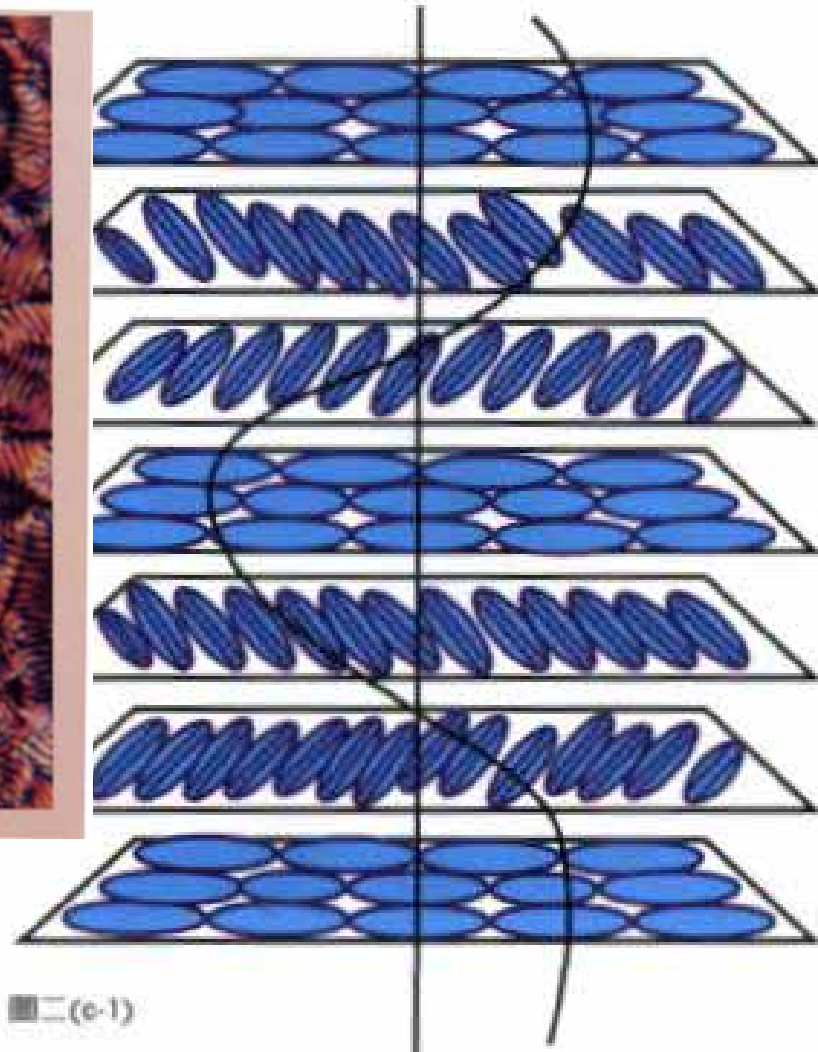
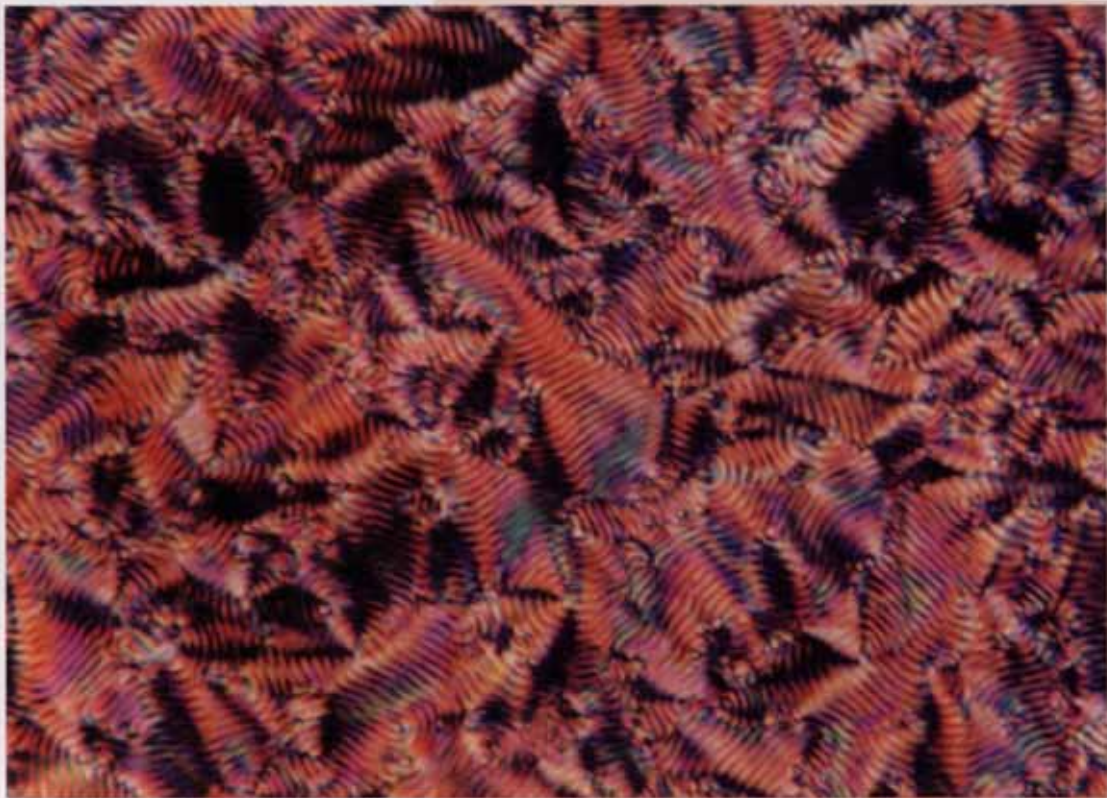


圖三(e) 層列A相的結構



圖三(f) 層列E相的結構

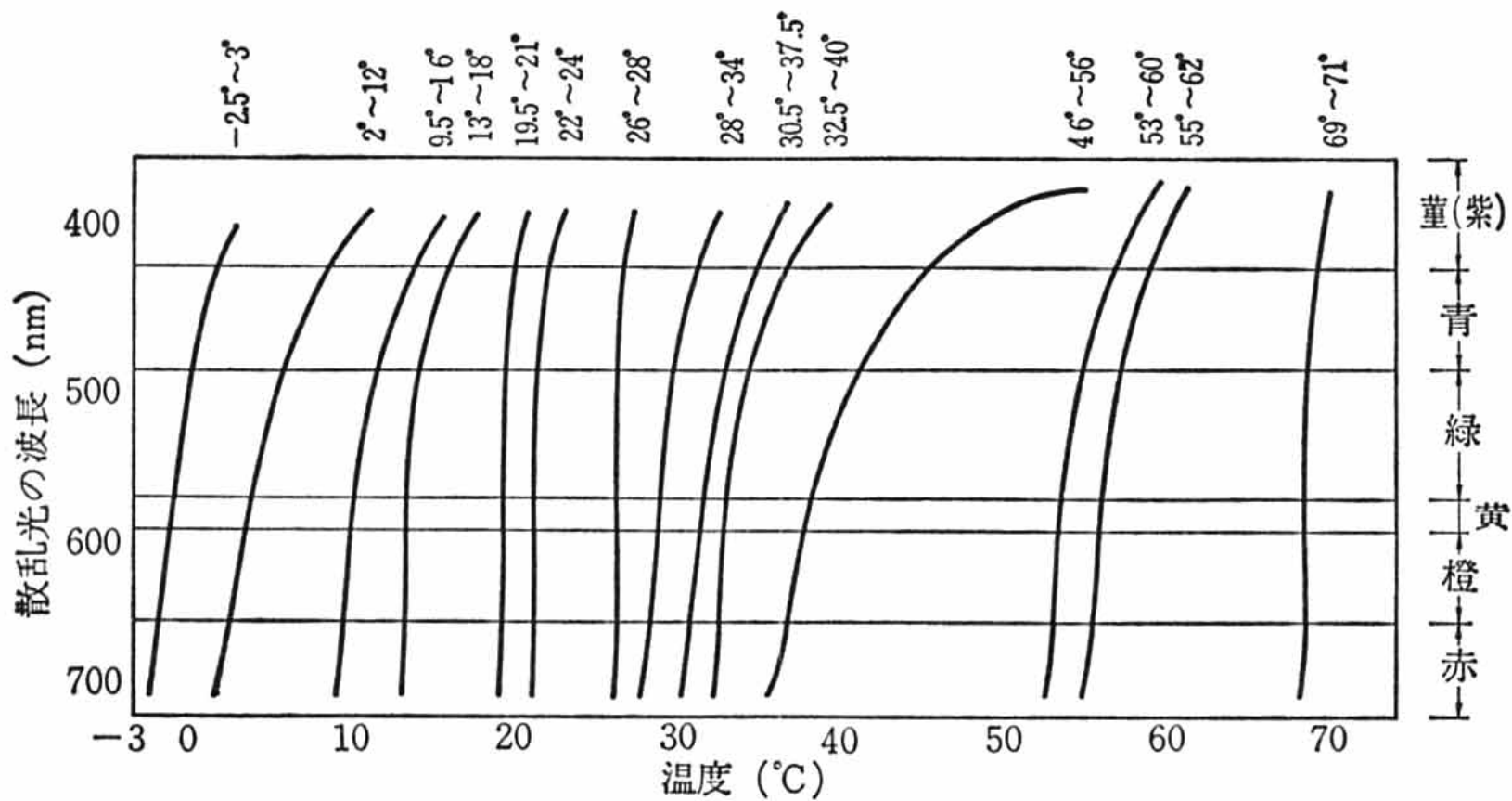




二(e-1)

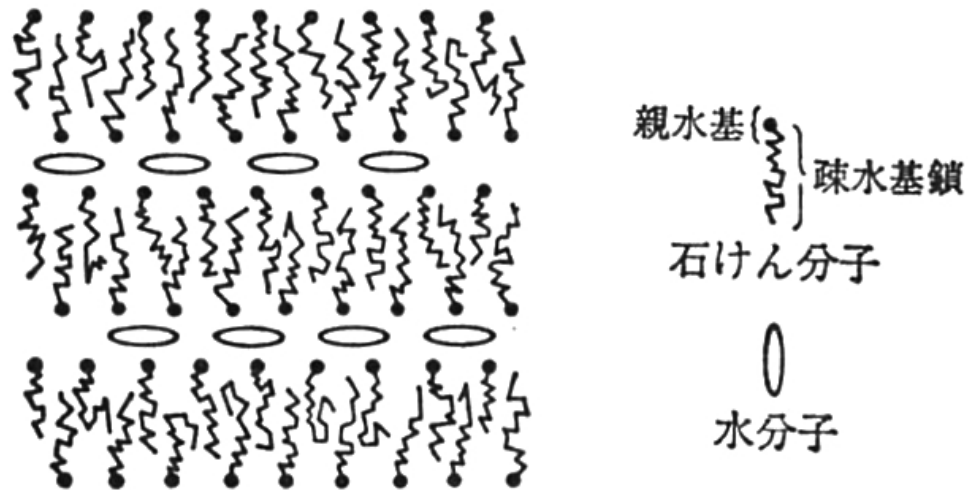
Chiral pitch

膽石醇液晶分子排列構造



各種の温度測定用コレステリック混合液晶の色相・温度特性

Lyotropic



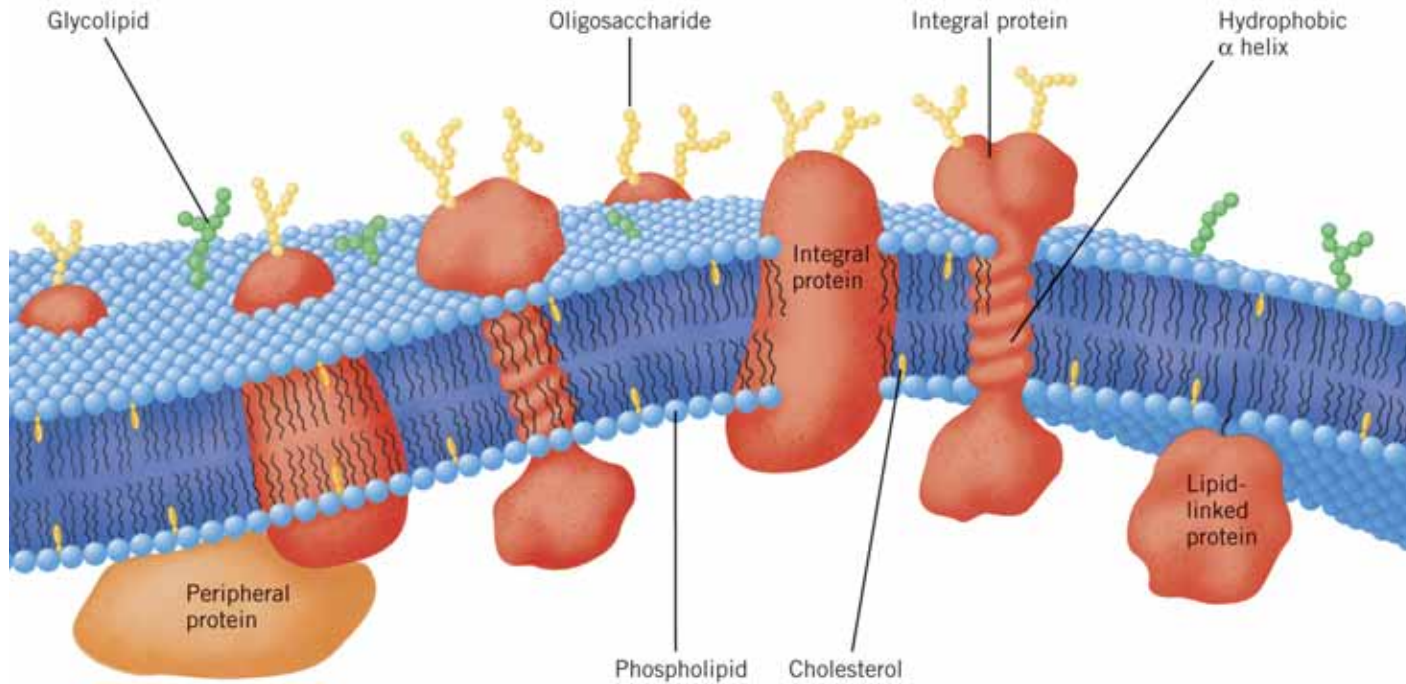
(a) ラメラ相



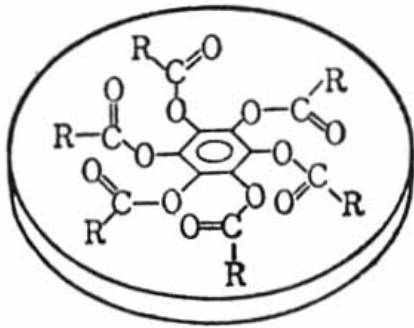
(b) ミドル相

石けんの濃厚水溶液からなるリオトロピック液晶の分子配列構造

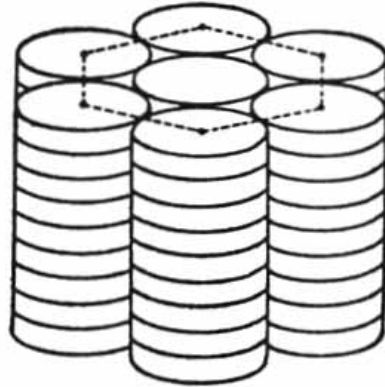
- Plasma membranes are primarily lipid bilayers with associated proteins and glycolipids
 - Cholesterol is also a major component of plasma membranes



Discotic

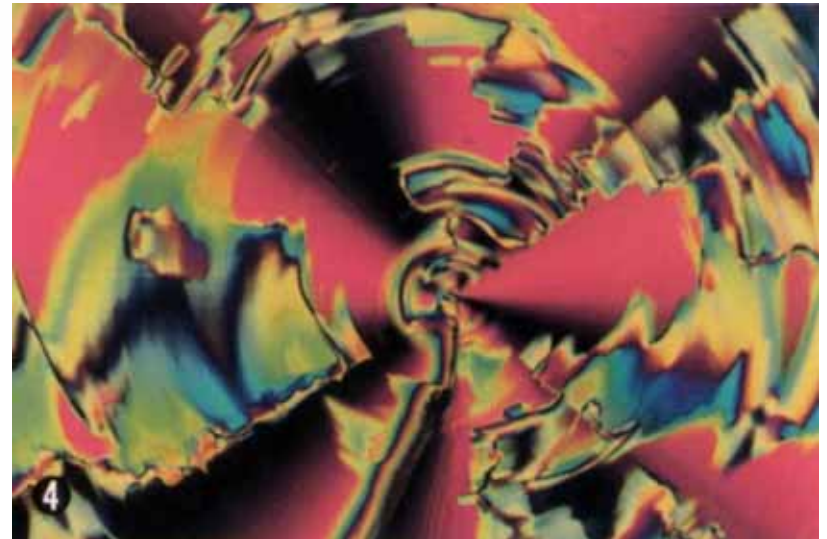


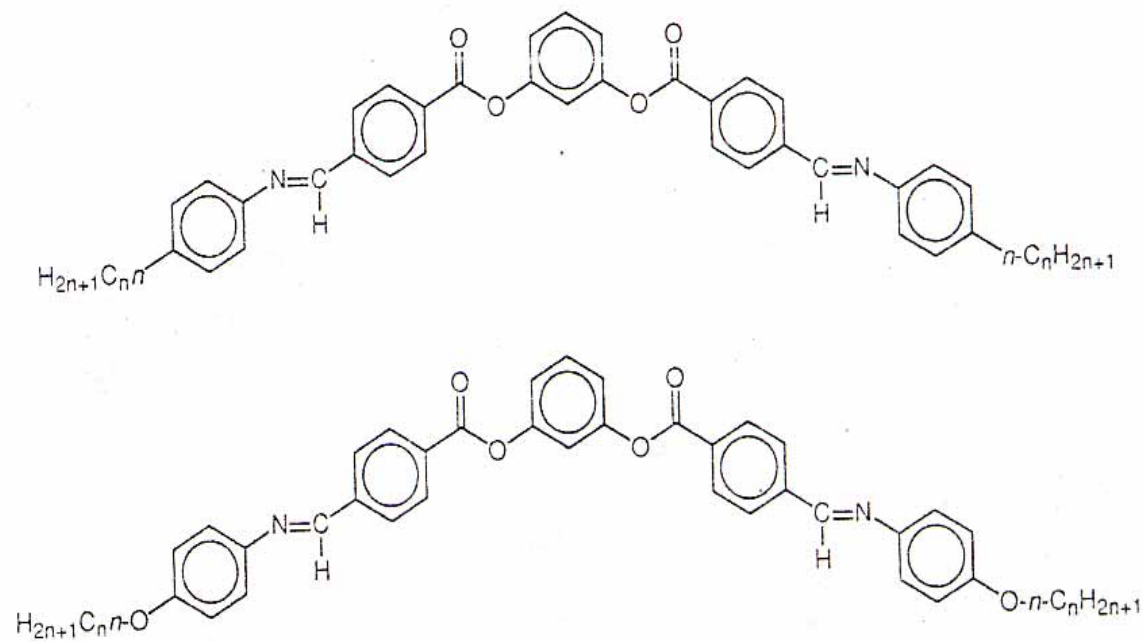
(a)



(b)

ディスコティック液晶の構成分子
(a)と分子配列構造(b)





旋光性
鏡像異構物

Fig. 1. Molecular structures of sample

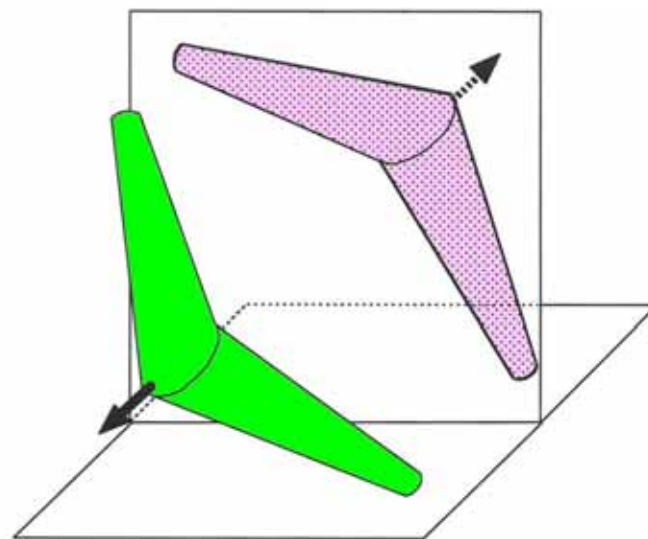


Fig.11 Schematic representation of the arrangement of the tilted bent molecules.

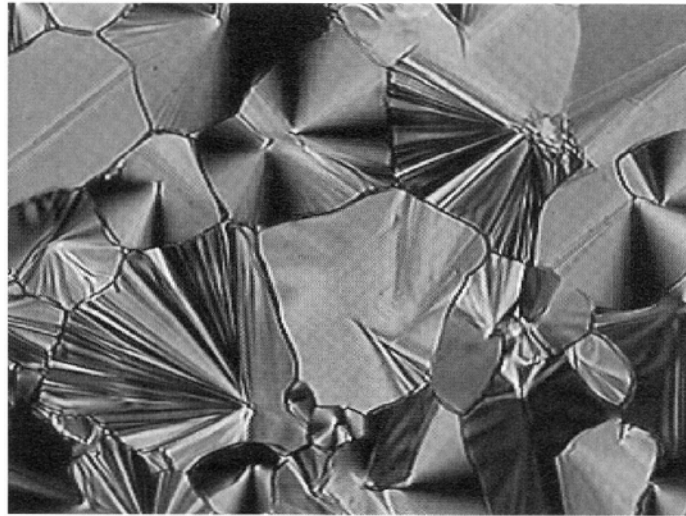
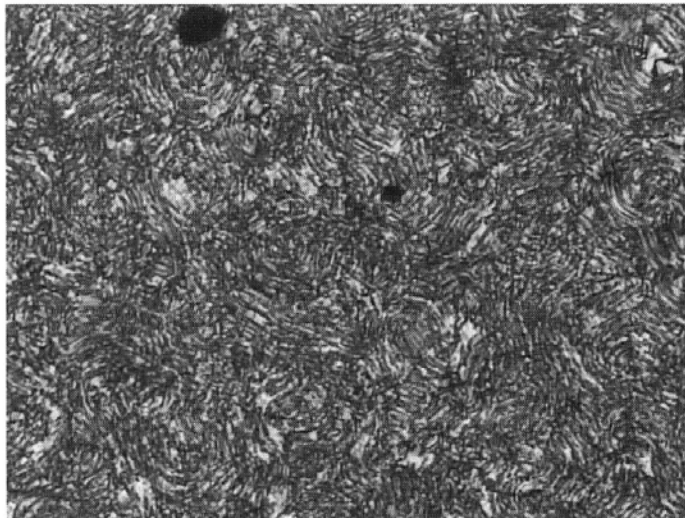


Fig.7 Polarised microscopic texture of B1 phase.



(a)



(b)

Fig.8 Typical textures of B2 phase in (a) racemic structure and (b) fan shaped domains.

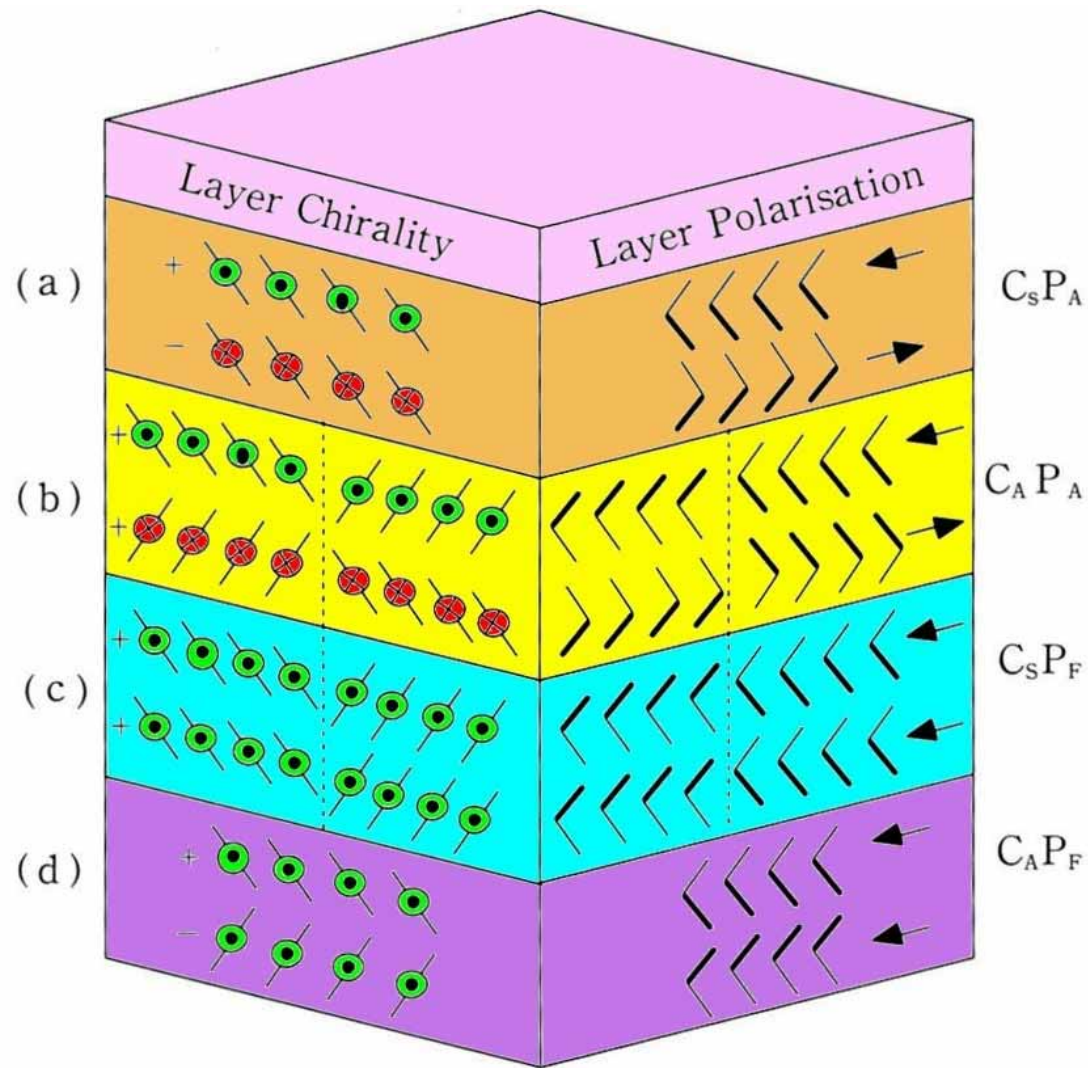
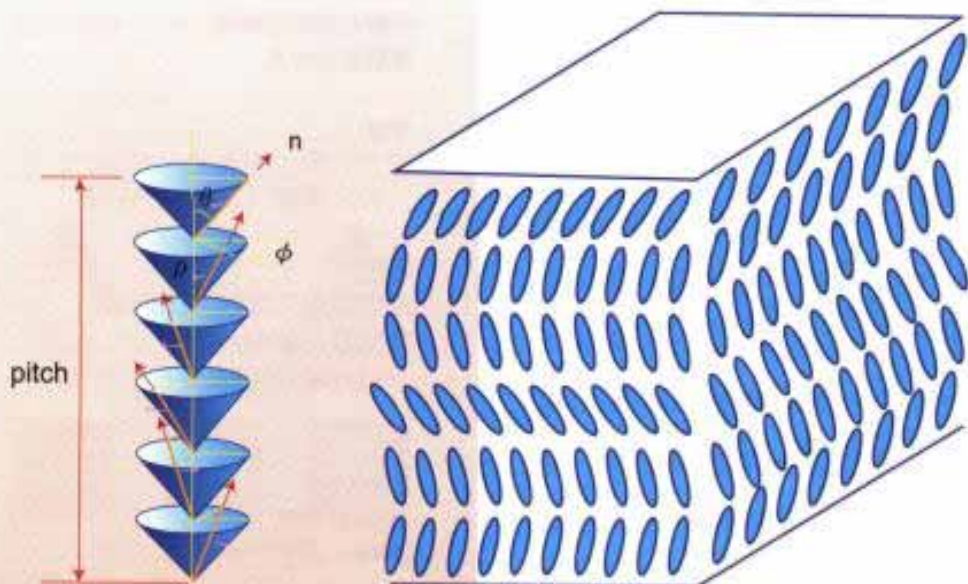
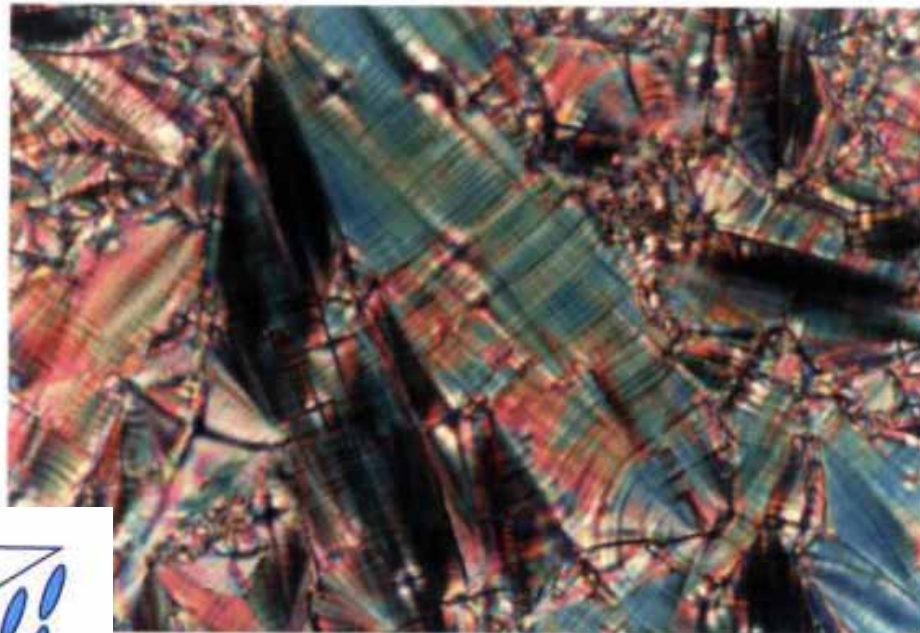


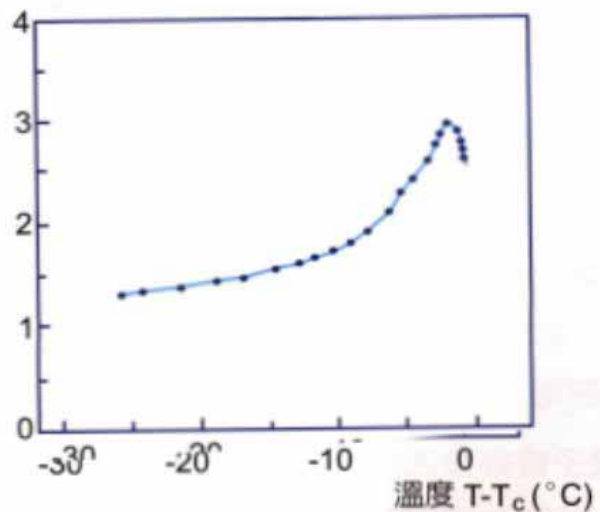
Fig.12 Schematic representation of the four arrangements of the bent molecules in the B2 phase.

強誘電性液晶

Ferroelectric LC
Chiral smectic C



圖二：強誘電性液晶的螺旋構造



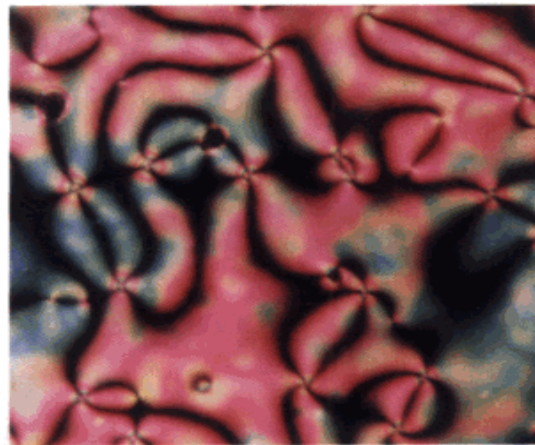
圖三：強誘電性液晶螺旋節距的溫度依存性

液晶材料物性

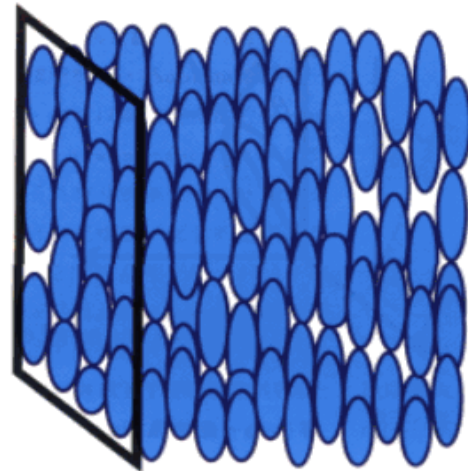
分子配列秩序 光學異方性

誘電異方性

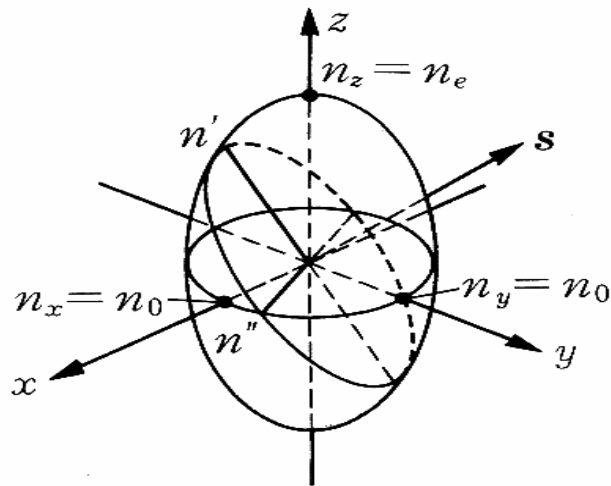
液體・彈性連續體理論



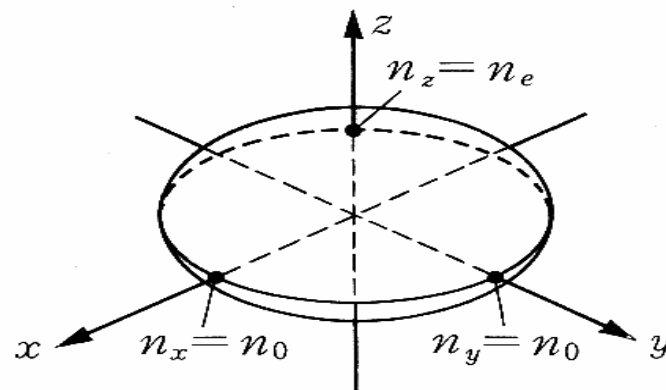
圖二(a-2) 向列形液晶的 schlieren構造



圖二(b-1) 層列型液晶分子的排列



(a) $n_z > n_x = n_y$



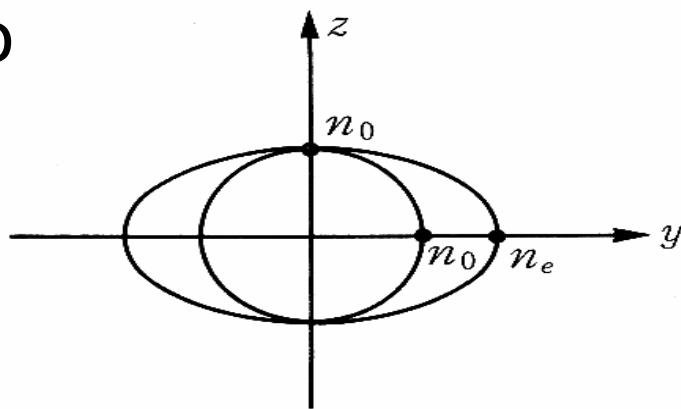
(b) $n_z < n_x = n_y$

ordinary
extraordinary

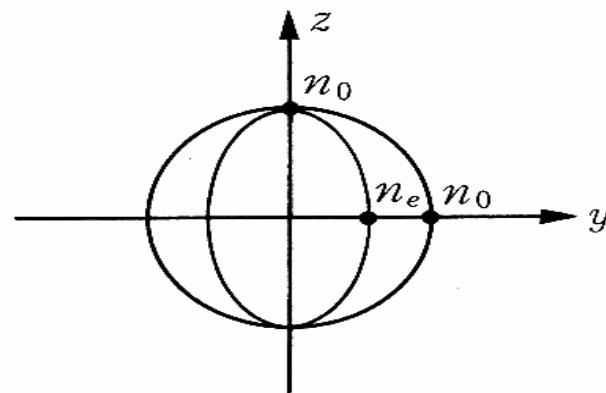
$$\Delta n = n_e - n_o$$

$$n_e = n_{||}$$

$$n_o = n_{\perp}$$



(c) $n_z > n_x = n_y$

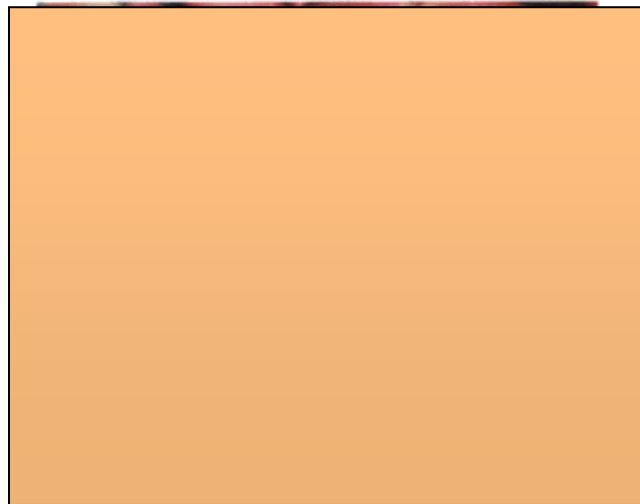


(d) $n_z < n_x = n_y$

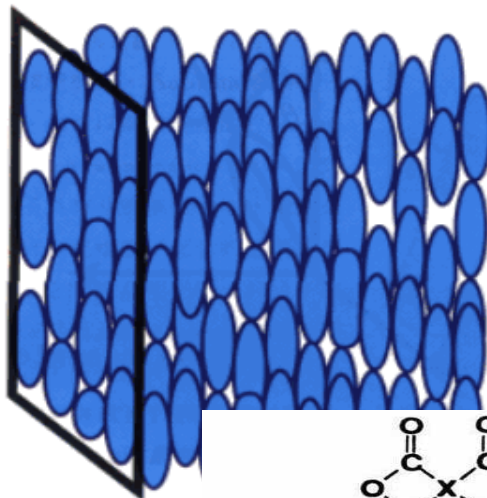
屈折率楕円体と波面法線面の断面



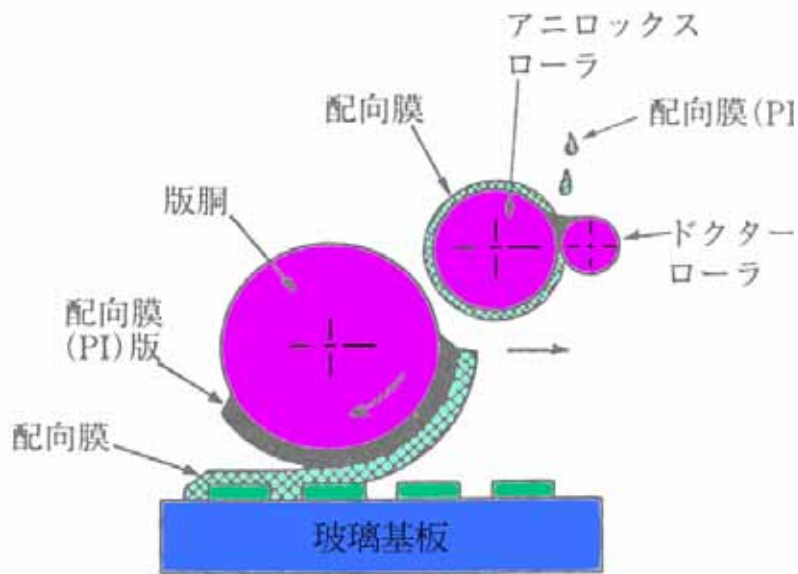
4. 配向膜塗布工程



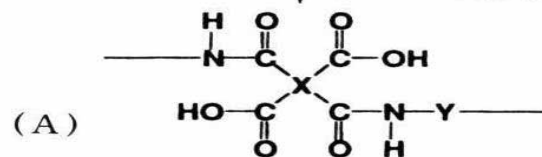
schlieren構造



図二(0-1) 層列型液晶分子

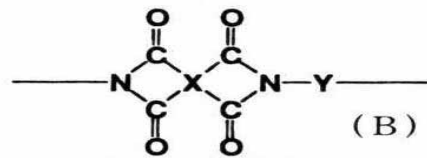


有機溶剤中で
等モルを混合



ポリアミック酸
(有機溶剤に可溶)

溶液中で化学的に
イミド化



可溶性ポリイミド

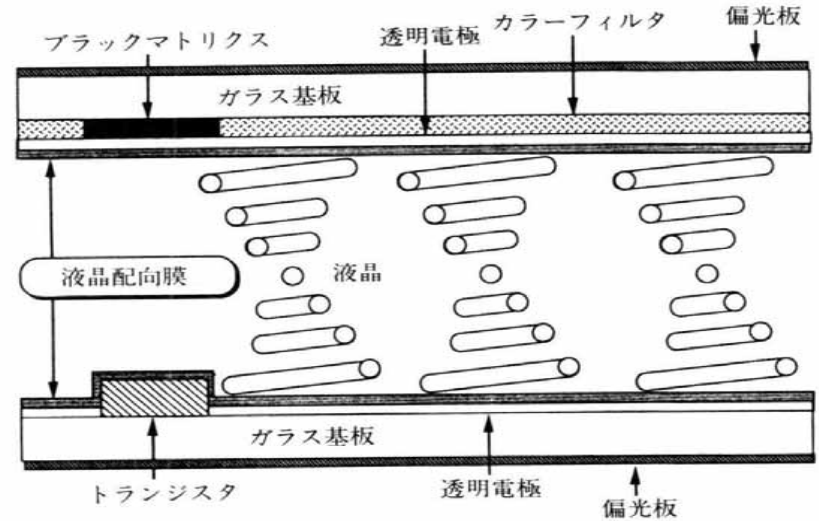
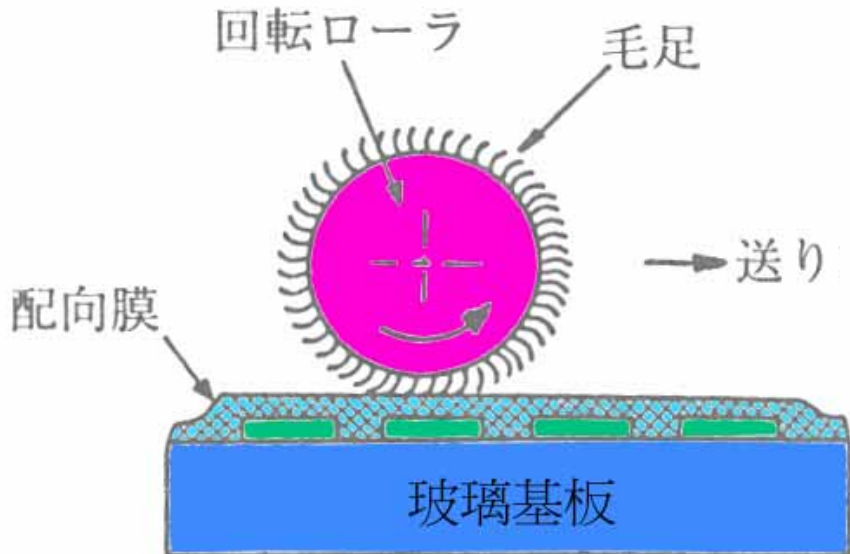
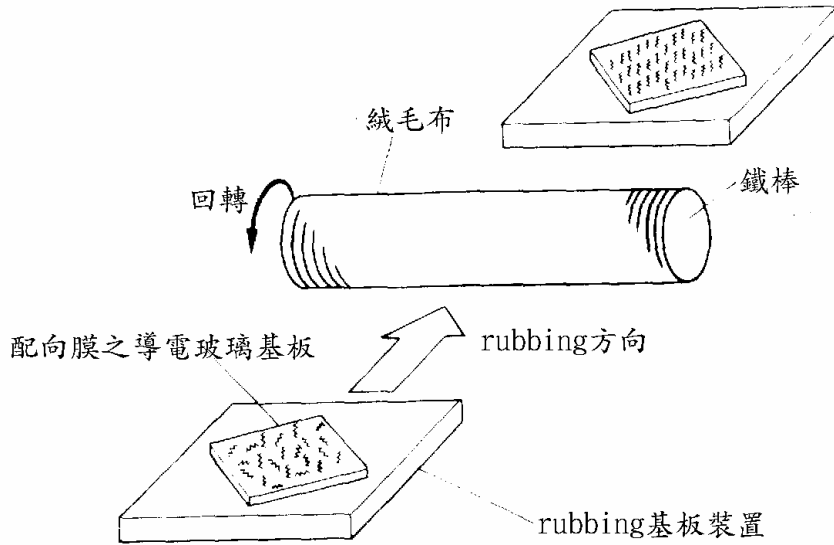
基板に塗布・加熱
(250~300°C)

基板に塗布・加熱
(200°C以下)

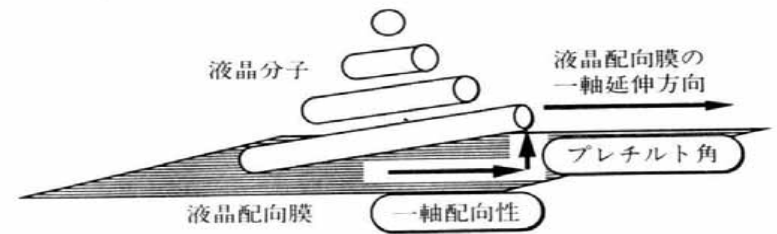
ポリイミドフィルム (液晶配向膜)

PI 液晶配向膜の作製方法

5. Rubbing工程



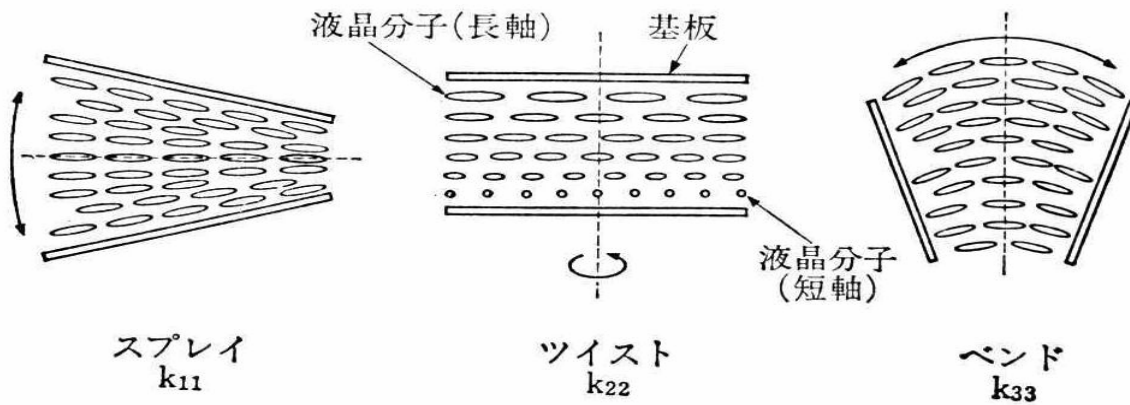
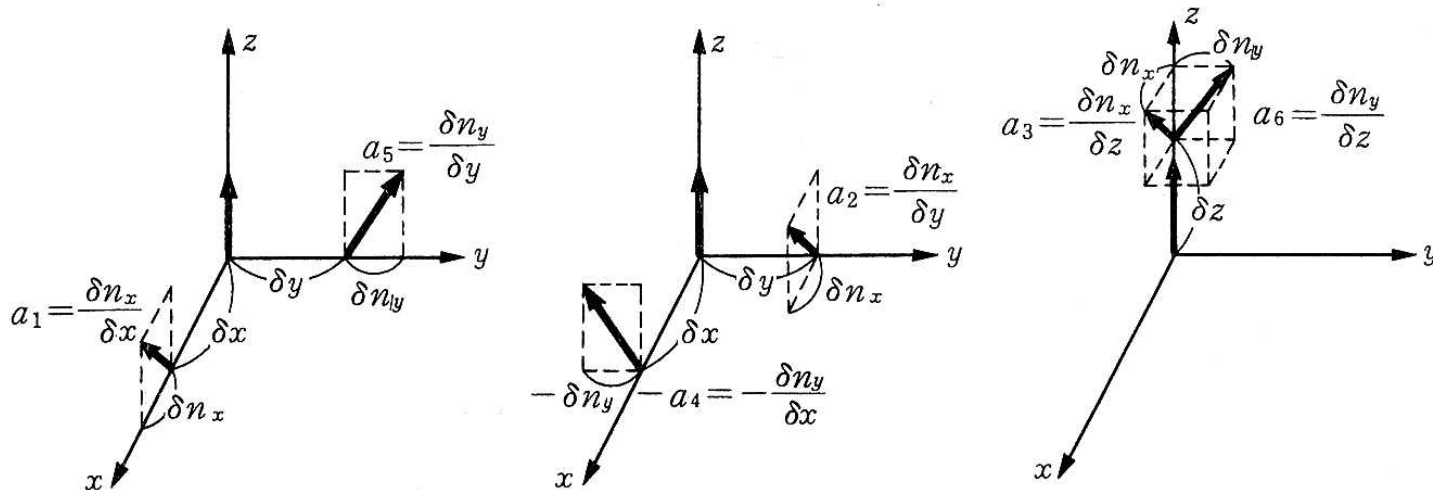
代表的なLCDの断面図



界面における液晶分子の配向

nematic連続弾性體

$$\frac{\partial n_x}{\partial x}, \frac{\partial n_y}{\partial y}, \frac{\partial n_x}{\partial y}, \frac{\partial n_y}{\partial x}, \frac{\partial n_x}{\partial z}, \frac{\partial n_y}{\partial z}$$

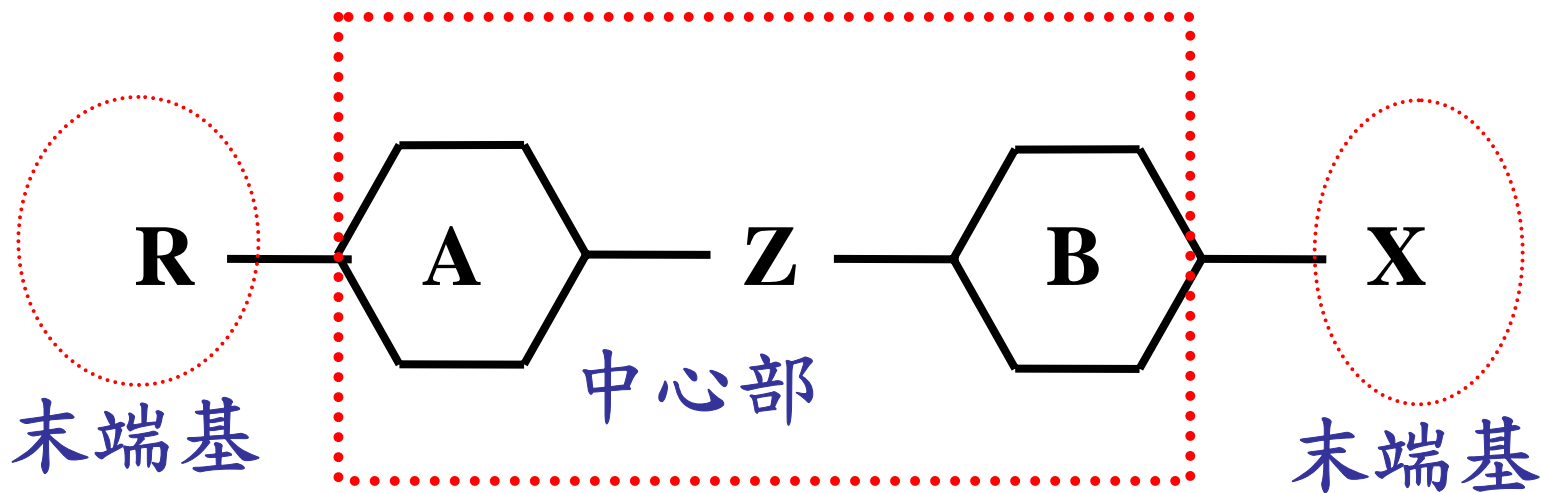


K33/k11

液晶の3種の基本変形歪み

$$g = \frac{1}{2} K_{11} (\nabla \cdot n)^2 + \frac{1}{2} K_{22} \{n \cdot (\nabla \times n) + q_0\}^2 + \frac{1}{2} K_{33} \{n \times (\nabla \times n)\}^2$$

液晶材料的分類



誘電率異方性

$$\Delta\varepsilon = \varepsilon_{\parallel} - \varepsilon_{\perp}$$

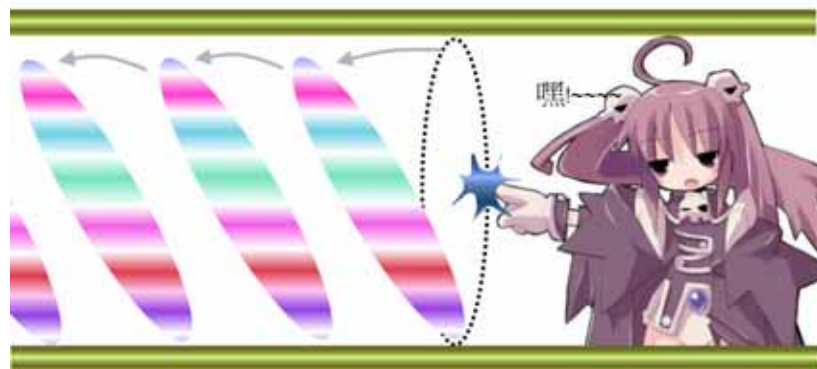
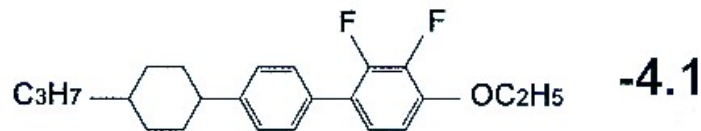
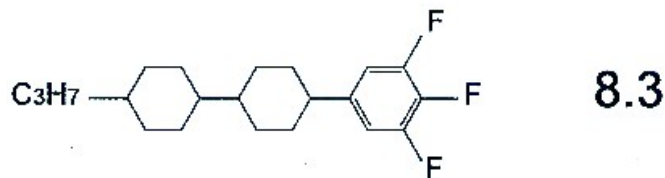
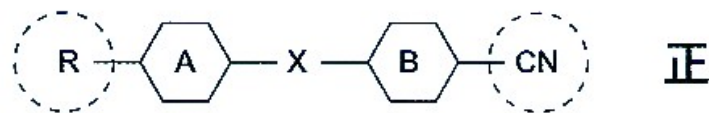
ε_{\parallel} 平行分子長軸

ε_{\perp} 垂直分子長軸



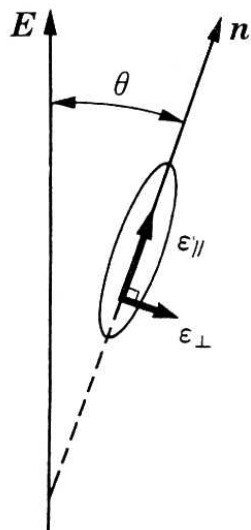
■ 液晶分子化學構造

液晶分子化學構造



電氣能量密度

$$g_{ele} = -\frac{1}{2} \varepsilon_0 \varepsilon_{//} (E \cos \theta)^2 - \frac{1}{2} \varepsilon_0 \varepsilon_{\perp} (E \sin \theta)^2$$



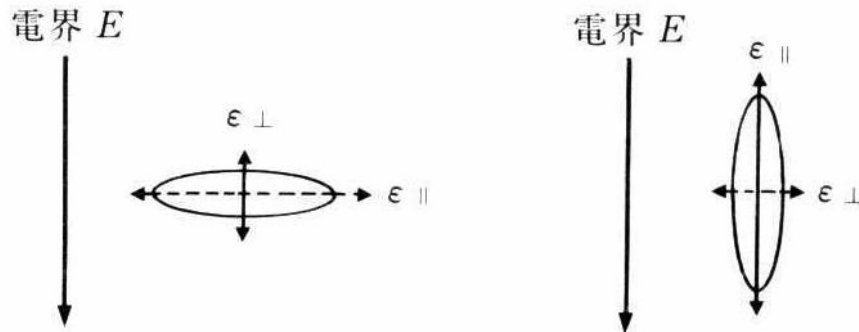
$$= -\frac{1}{2} \varepsilon_0 \varepsilon_{\perp} E^2 - \frac{1}{2} \varepsilon_0 (\varepsilon_{//} - \varepsilon_{\perp}) (E \sin \theta)^2$$

$$= -\frac{1}{2} \varepsilon_0 \varepsilon_{\perp} E^2 - \frac{1}{2} \varepsilon_0 \varepsilon_a (n \cdot E)^2$$

図 3.12 電界中の液晶ダイレクタ

$\Delta\varepsilon > 0$ $n \parallel E$ 分子長軸

$\Delta\varepsilon < 0$ $n \perp E$ 分子長軸

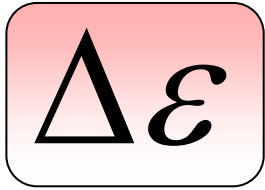


(a) 静電エネルギー： $-\frac{\varepsilon_0 \varepsilon_{\perp}}{2} E^2$ (b) 静電エネルギー： $-\frac{\varepsilon_0 \varepsilon_{\parallel}}{2} E^2$

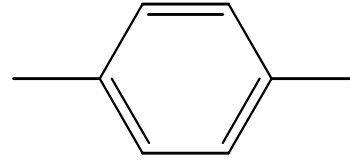
誘電率異方性が正 ($\varepsilon_{\parallel} > \varepsilon_{\perp}$) の場合には静電エネルギーの点で (b) の配列形態が安定。負 ($\varepsilon_{\parallel} < \varepsilon_{\perp}$) の場合には (a) が安定。

電界中でのダイレクタの配列形態と静電エネルギー





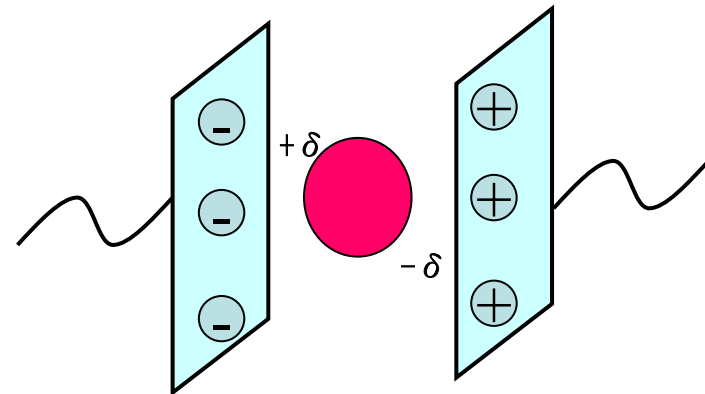
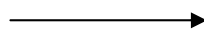
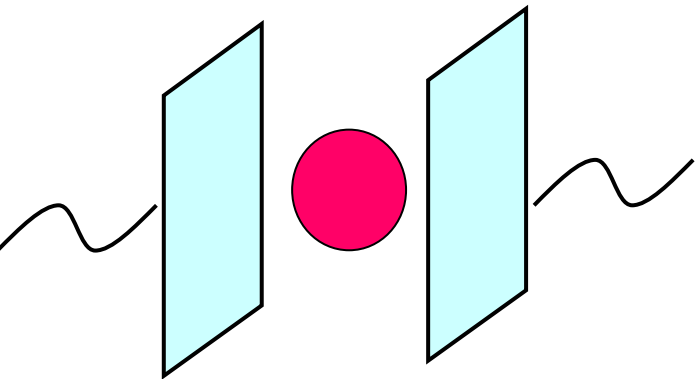
電子分極



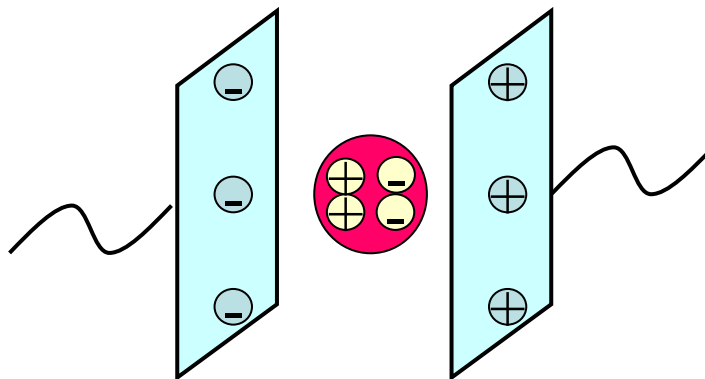
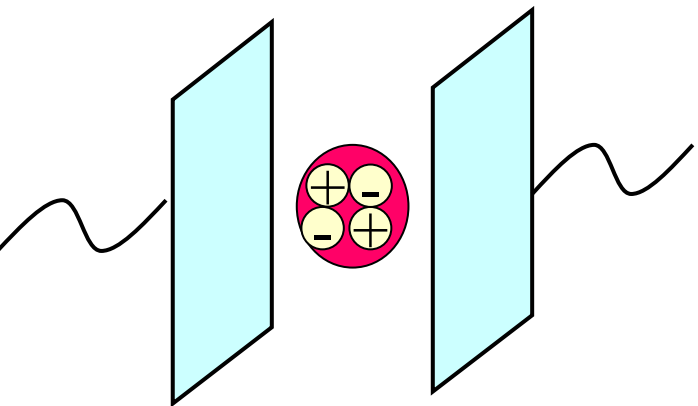
μ 永久雙極子力矩的配向分極



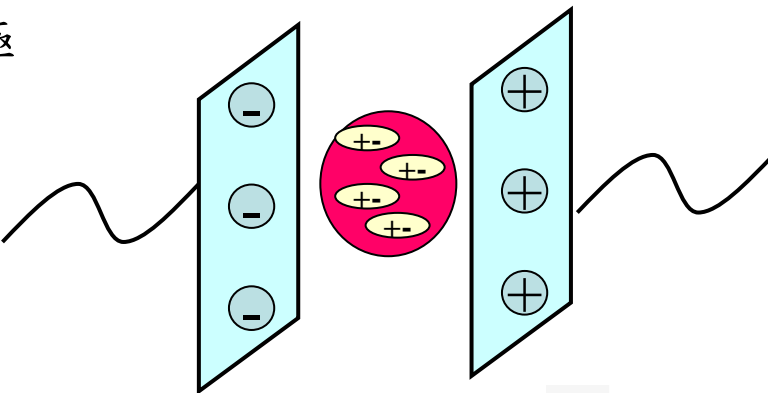
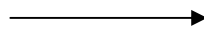
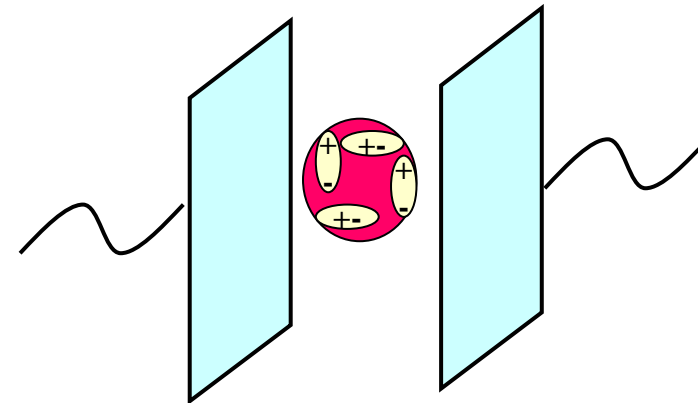
電子分極



原子分極

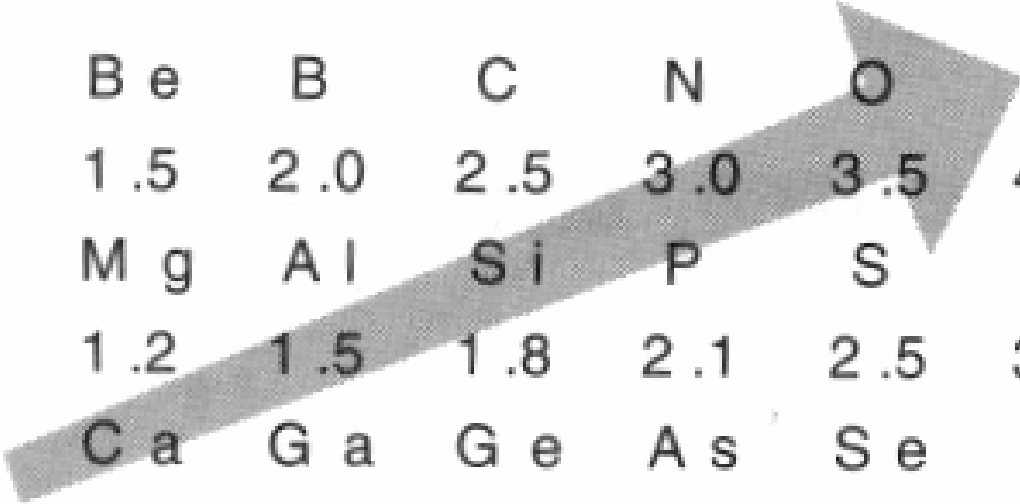


雙極子分極



陰電性度

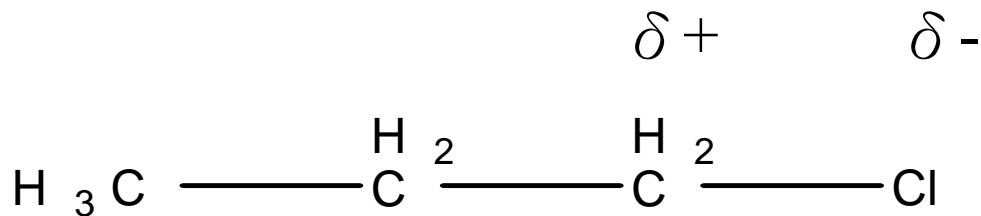
H								He
2.1								
Li	Be	B	C	N	O	F		Ne
1.0	1.5	2.0	2.5	3.0	3.5	4.0		
Na	Mg	Al	Si	P	S	Cl		Ar
0.9	1.2	1.5	1.8	2.1	2.5	3.0		
K	Ca	Ga	Ge	As	Se	Br		Xe
0.8	1.0	1.3	1.8	2.0	2.4	2.8		



X=2.1 2.1



X=2.5 3.5



$$\Delta \varepsilon_{\alpha} \left\{ \Delta \alpha - \frac{c \mu^2}{2kT} (1 - 3 \cos^3 \beta) \right\} S$$

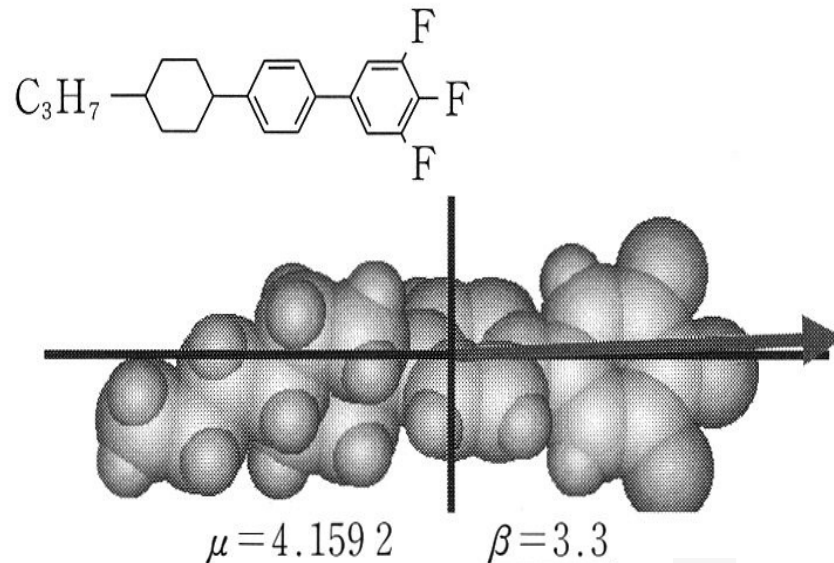
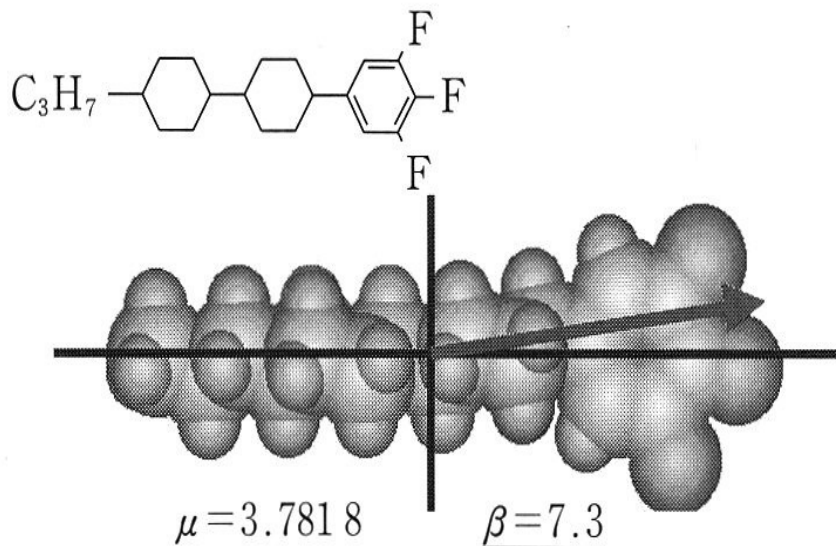
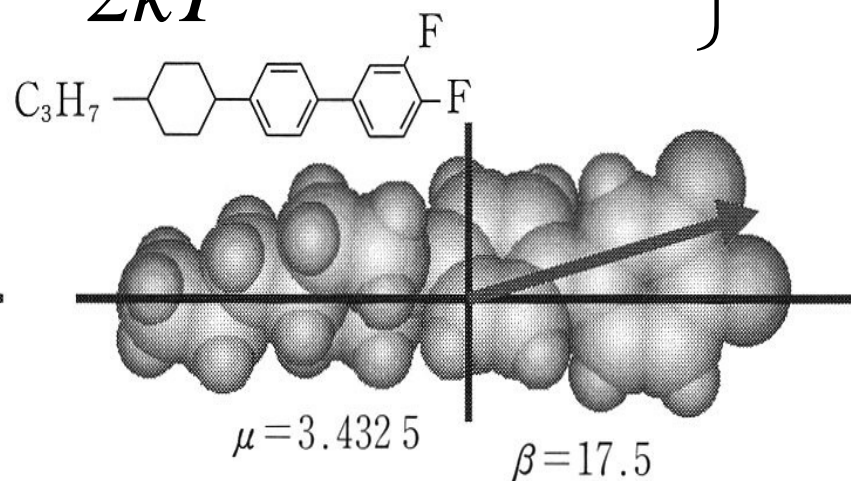
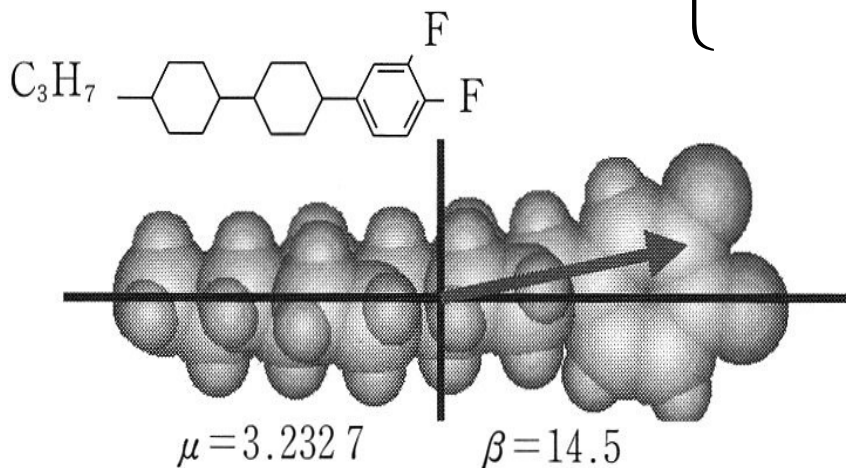


表-1 各フッ素化合物の双極子の大きさと向き

	μ (Debye)	β (deg.)	$\Delta\epsilon_{\text{ext}}$		μ (Debye)	β (deg.)	$\Delta\epsilon_{\text{ext}}$
<chem>CCCCCc1ccc(F)cc1</chem>	2.002 2	8.3	4.3	<chem>CCCCc1ccc(cc1)-c2ccc(F)c(F)c2</chem>	3.420 1	18.0	9.0
<chem>CCCCc1ccc(F)c(F)c1</chem>	3.239 0	14.2	7.7	<chem>CCCCc1ccc(cc1)-c2cc(F)c(F)c2</chem>	4.167 6	3.2	11.7
<chem>CCCCc1ccc(F)c(F)c1</chem>	3.782 3	8.0	11.0	<chem>CCCCc1ccc(cc1)C(=O)Oc2cc(F)c(F)c2</chem>	6.114 1	7.2	24.3
<chem>CCCCc1ccc(cc1)-c2ccc(F)cc2</chem>	2.124 3	3.5	6.3				

計算手法; MOPAC Ver. 6.0 AM1¹⁴⁾



$$\tau_{off} = \frac{\gamma_1 d^2}{\pi^2 k_2} = \frac{\gamma_1}{\varepsilon_0 |\Delta \varepsilon| E_c^2}$$

$$\tau_{on} = \frac{\gamma_1}{\varepsilon_0 |\Delta \varepsilon| E^2 - \frac{\pi^2}{d^2} K^2}$$

液晶分子扭轉
彈性係數

$$= \frac{\gamma_1}{\varepsilon_0 |\Delta \varepsilon| (E^2 - E_c^2)}$$

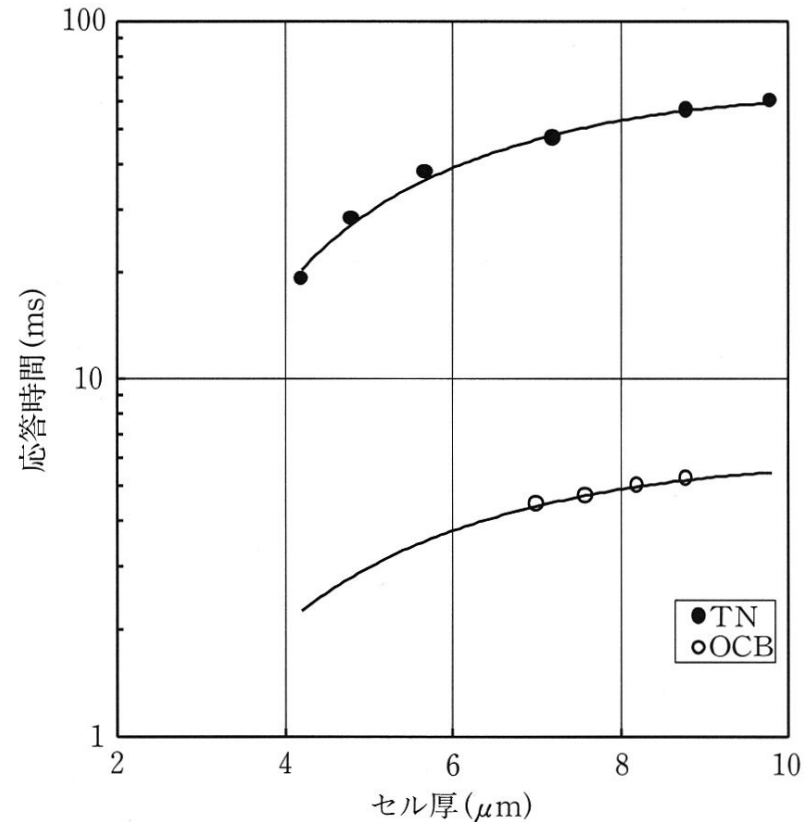
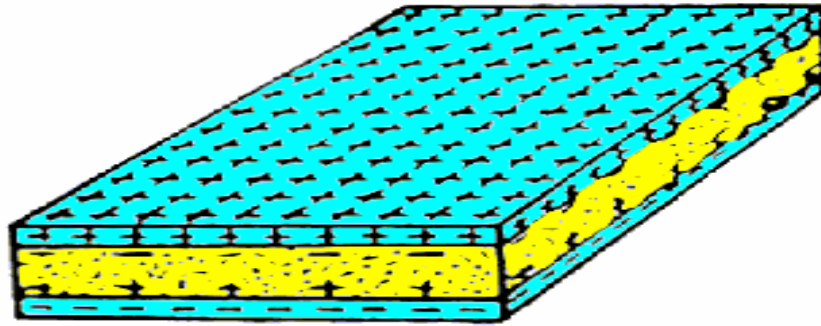


図-9 セル厚と応答時間の関係¹⁹⁾



誘電率測試



真空容體的電容：

$$C_0 = \epsilon_0 A/d$$

其中： $\epsilon_0 = 8.854 \times 10^{-12}$ (F/m)，稱為真空電容率 (permittivity of free space)

A 為電極板面積

d 為兩電極板間距離



若誘電物質放入一平行電容器

$$C = \epsilon A/d = \epsilon_0 \epsilon_r A/d = \epsilon_r C_0$$

$$\epsilon_r = C/C_0$$

ϵ_r : 稱為Permittivity(電容率)
dielectric constant (誘電率)



ε'' ：損失因數(Loss factor)，其值亦代表系統中的功率損失大小，當電壓、頻率、容器形狀、尺寸相同時，誘電損失由此值決定。

$$\varepsilon'' = \sigma'' / \omega C_0 = \sigma'' / 2\pi f C_0$$

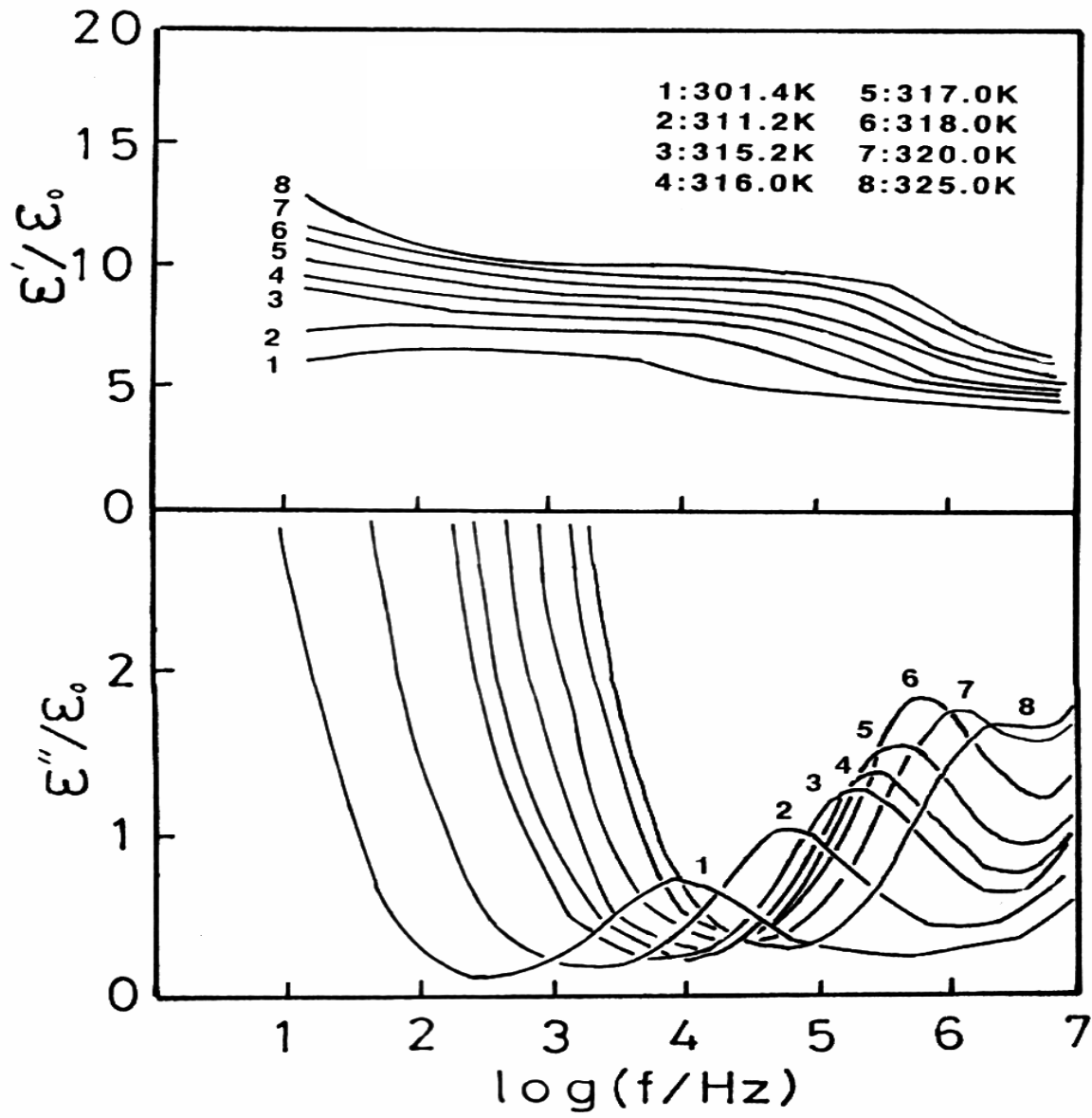
σ'' 電氣傳導率 ω 角周波數 f 周波數

$\tan \delta$ ：誘電正切(dielectric loss tangent) 散逸因子(Dissipation factor)，其值代表系統中的功率損失大小。

$$\tan \delta = \varepsilon'' / \varepsilon' , \sigma'' / 2\pi f C$$

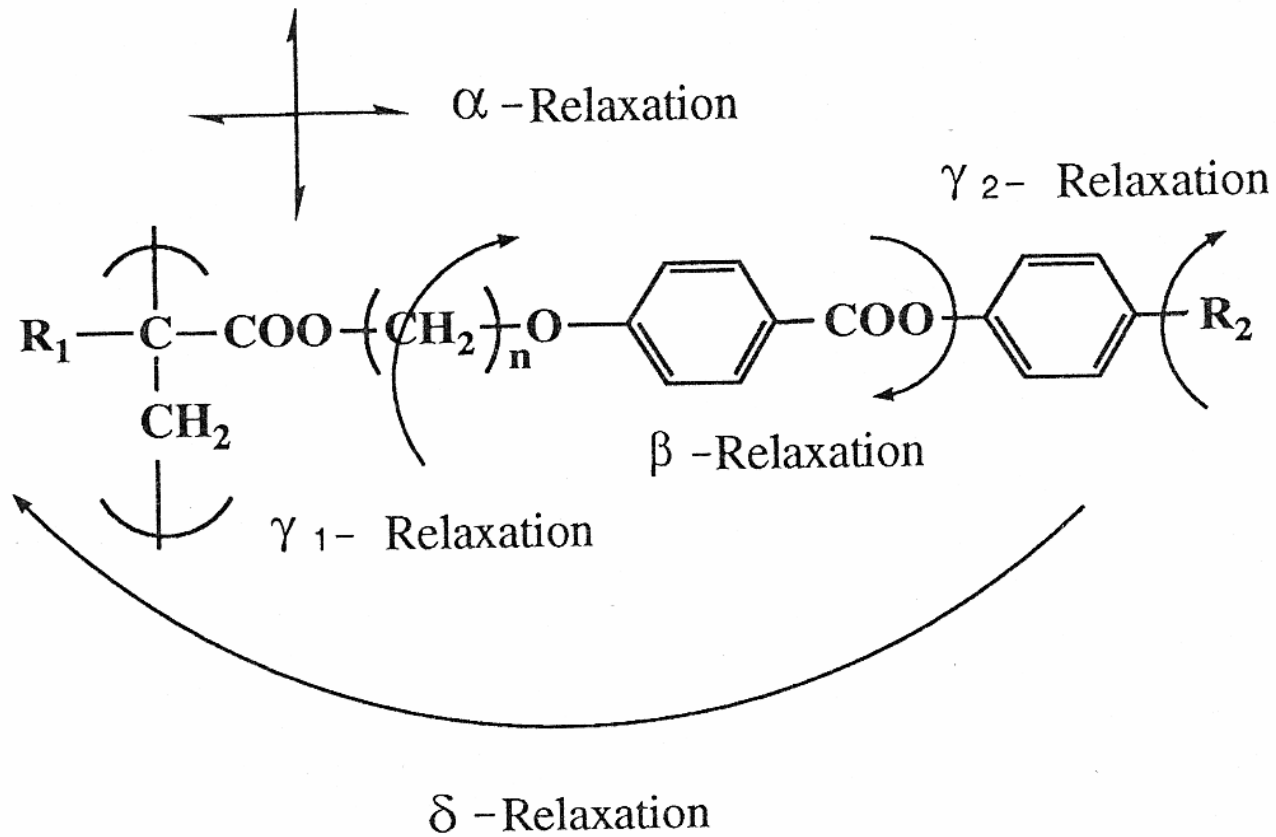
δ 損失角(loss angle) 全電流與變位電流的位相差

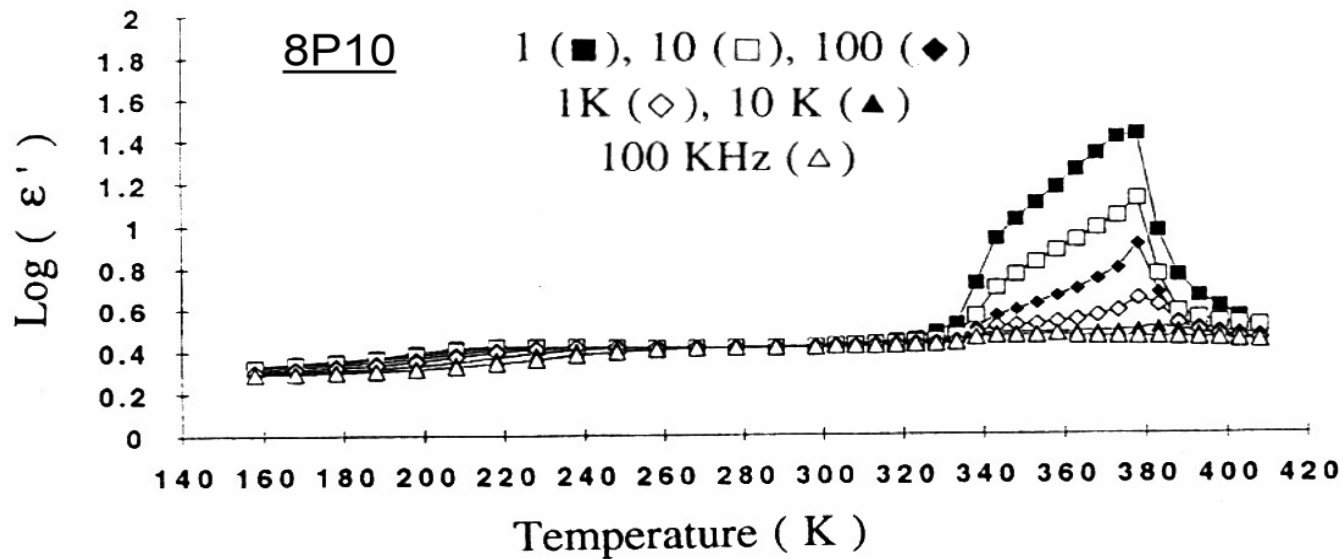




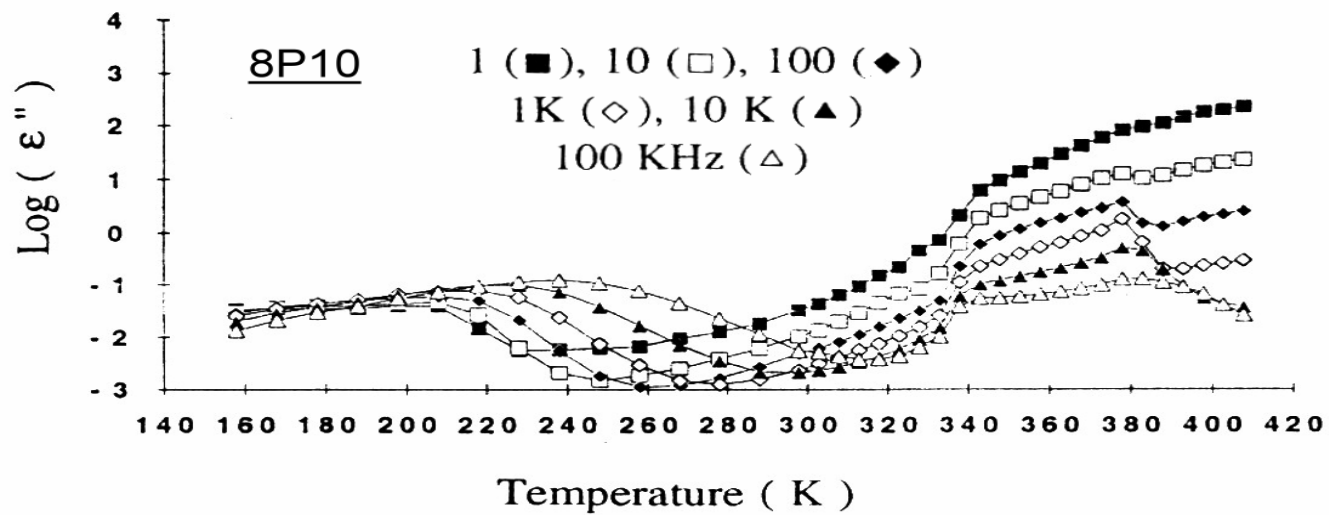
誘電率及び誘電損率の周波数分散







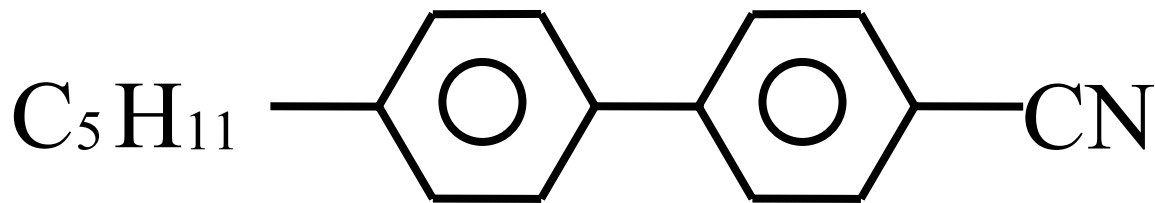
(a)



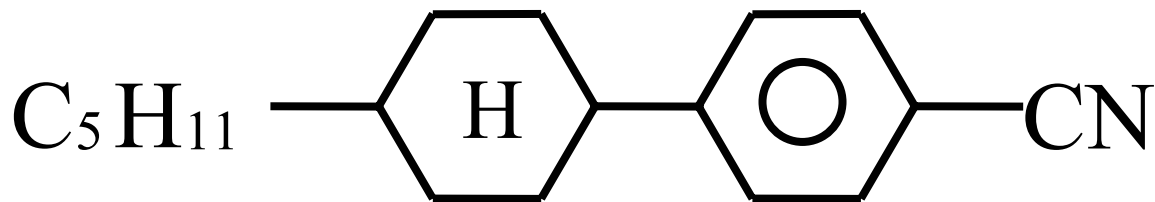
(b)

非氟素系液晶化合物

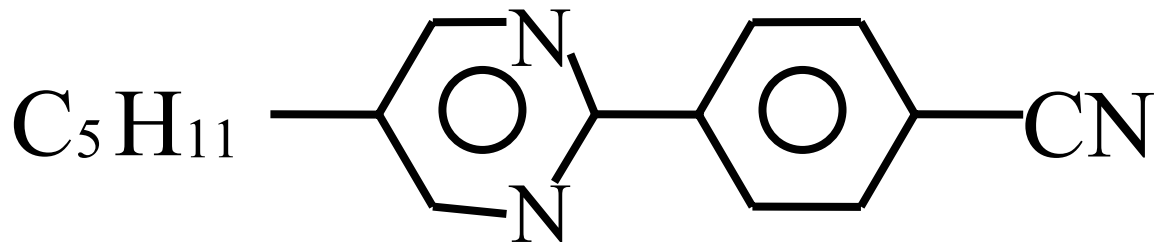
$\Delta \epsilon$



12



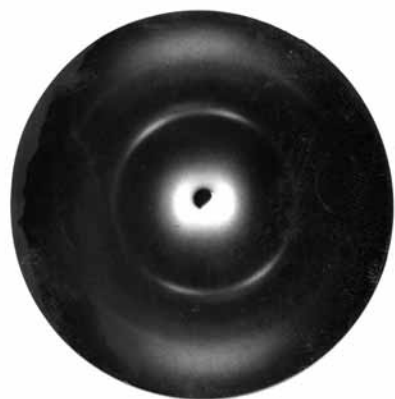
11



20

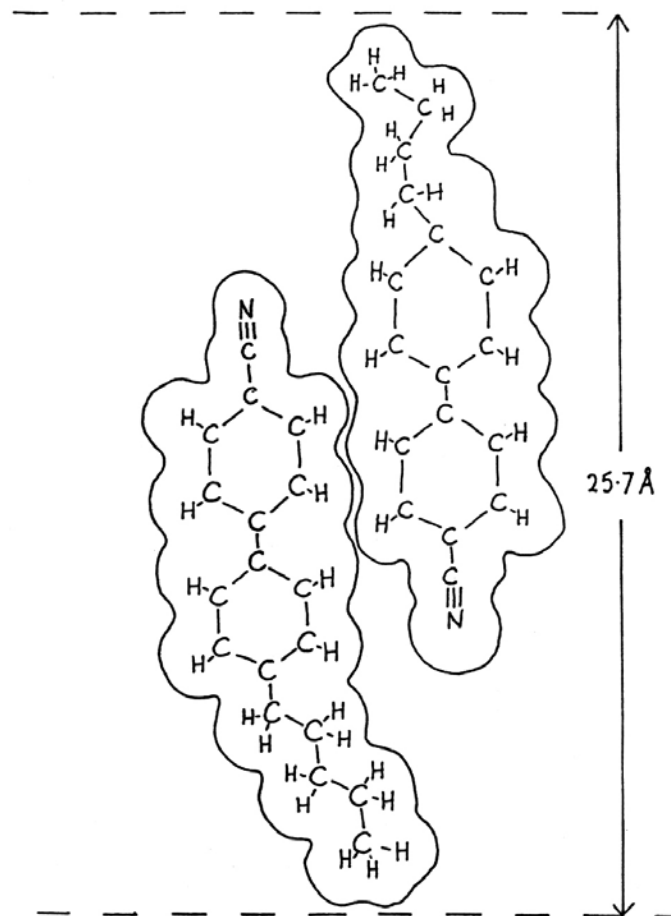
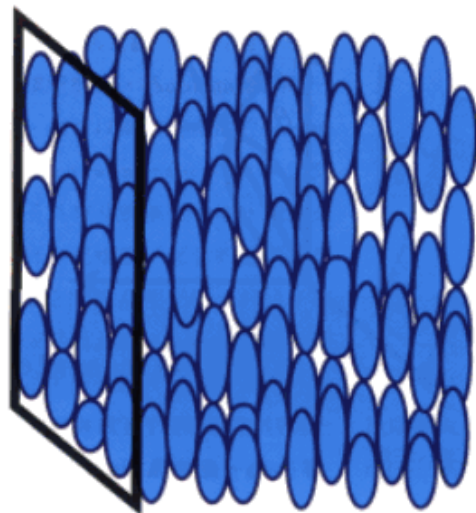


X-ray 繞射圖

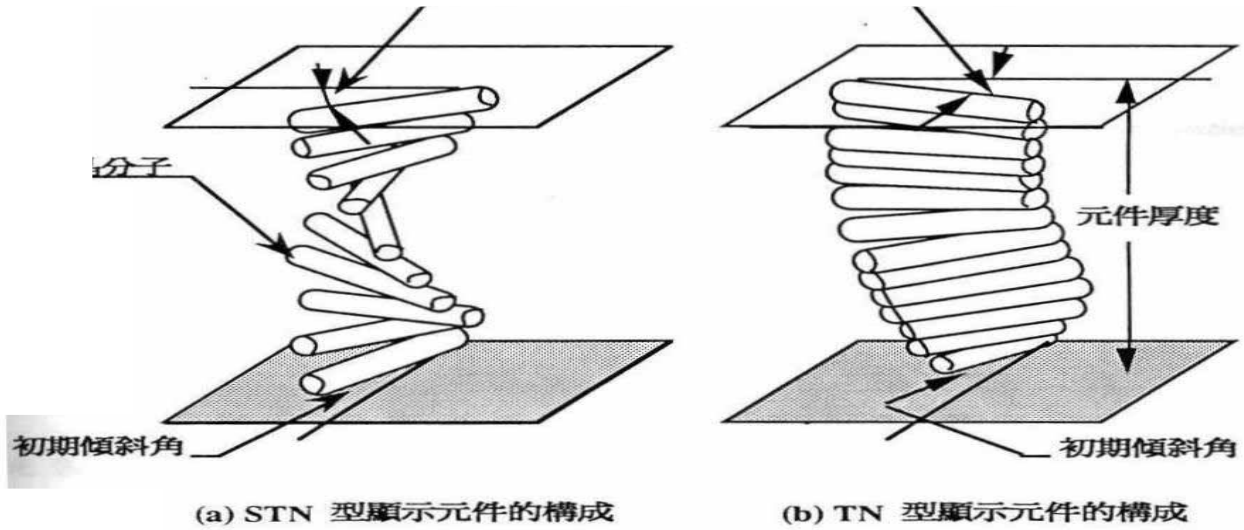
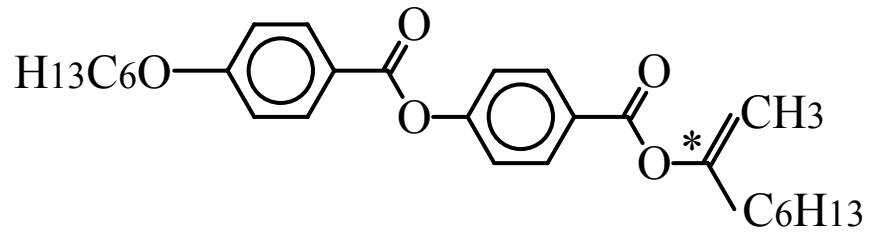


0.44nm

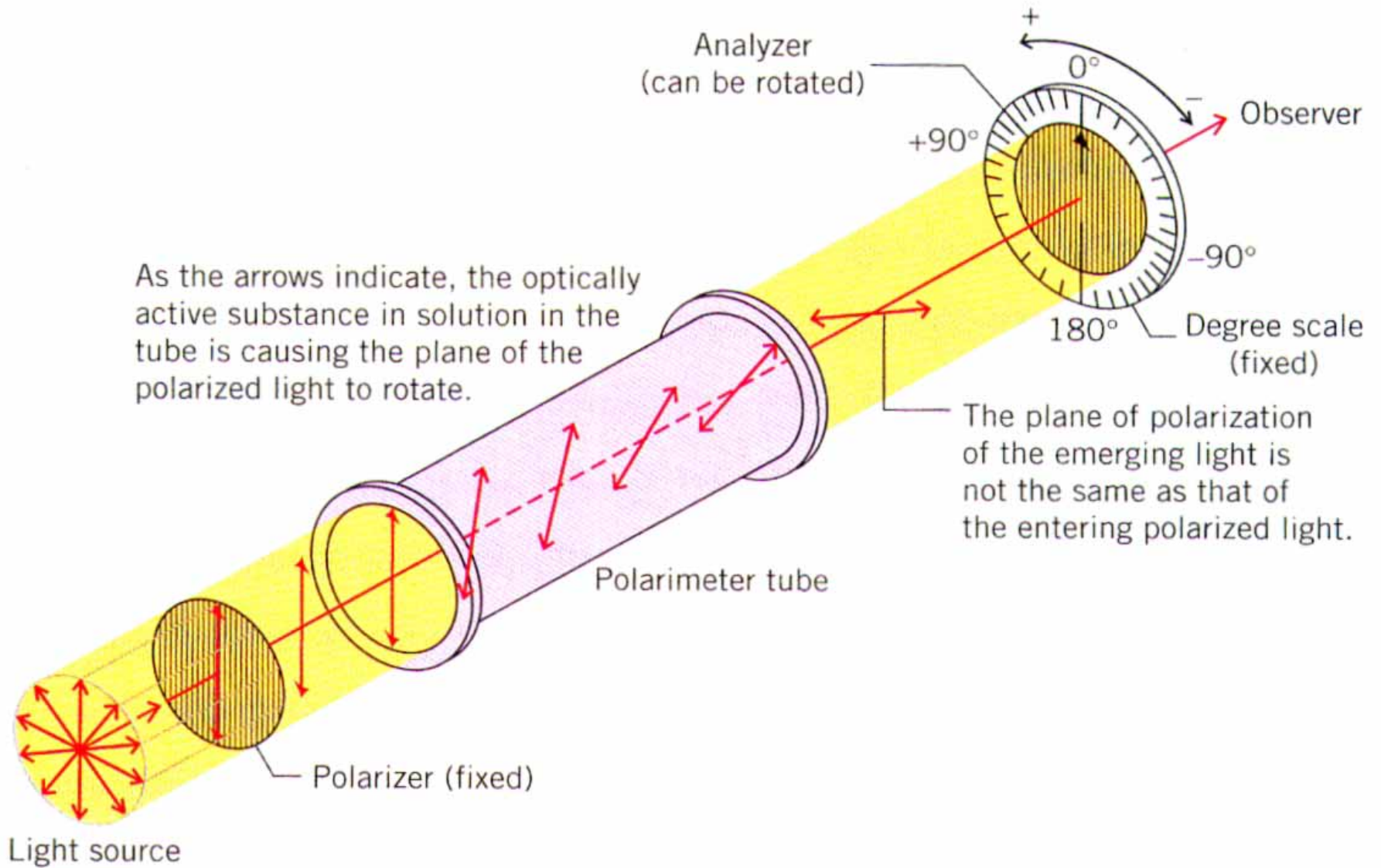
2.66nm



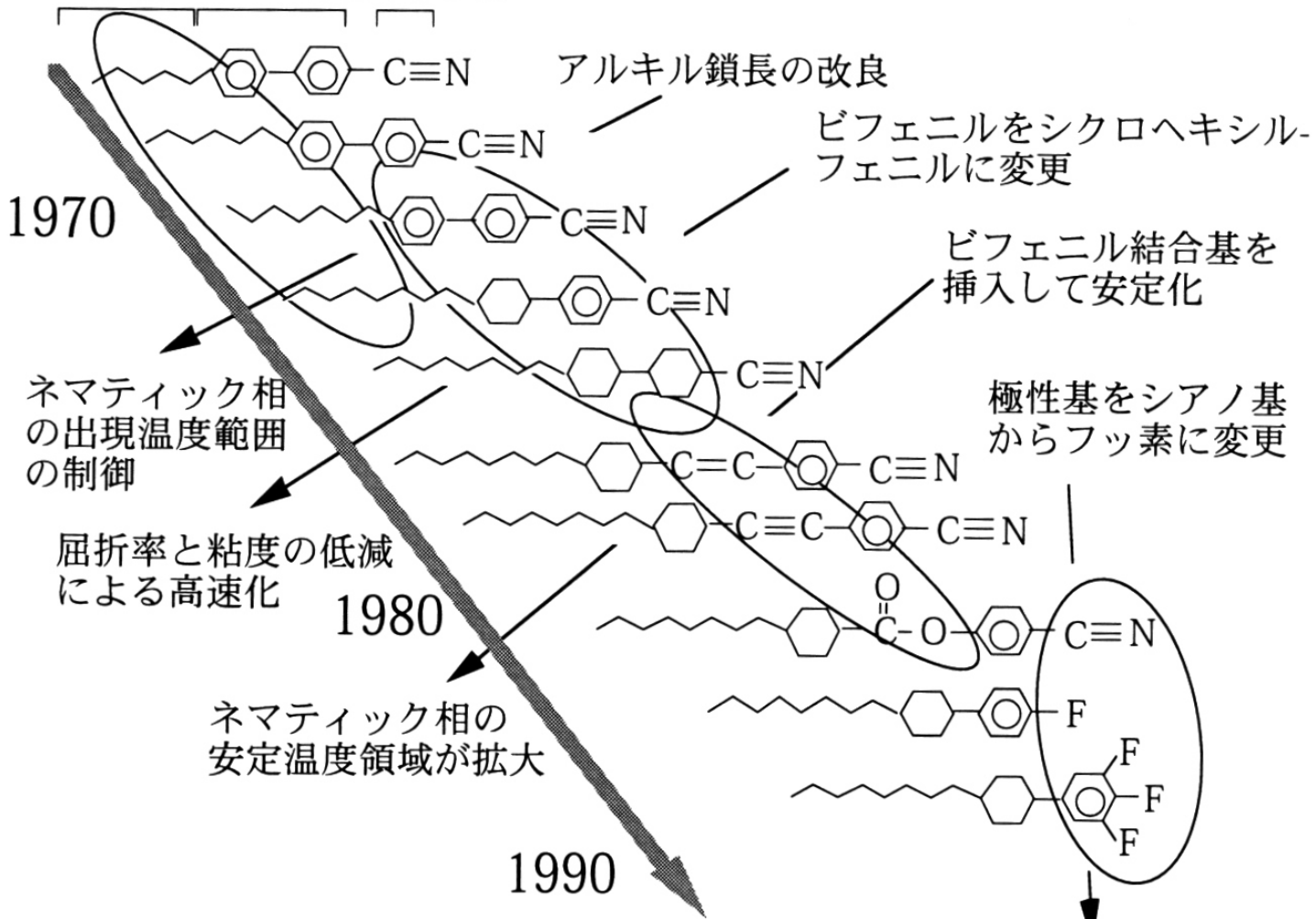
Nematic liquid crystals



STN型與TN型液晶分子的扭曲狀態



アルキル基 ビフェニル基 シアノ基

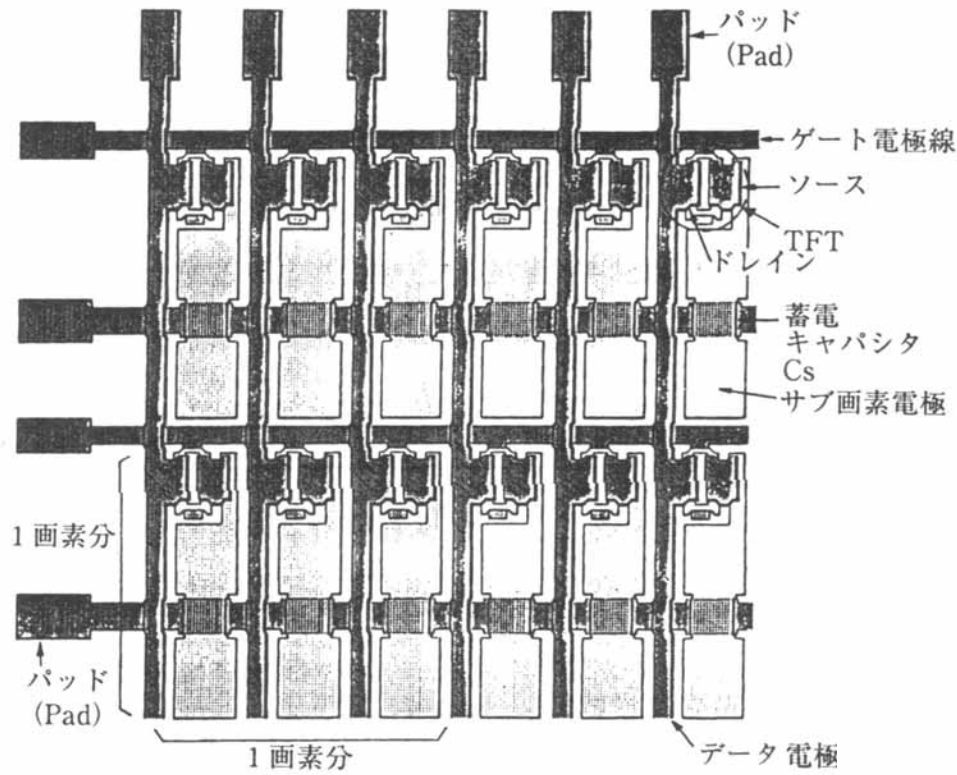


TFT液晶の開発

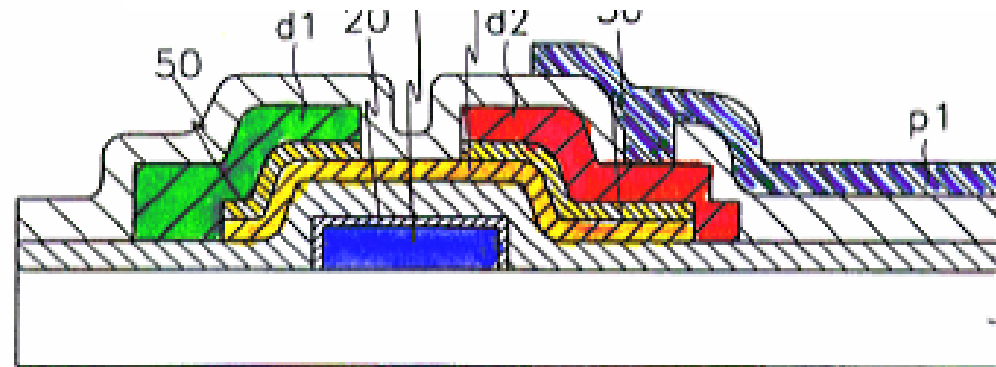
低粘度化・高速駆動を実現

液晶分子の構造設計

Thin film transistor TFT



立体化した画素パターン



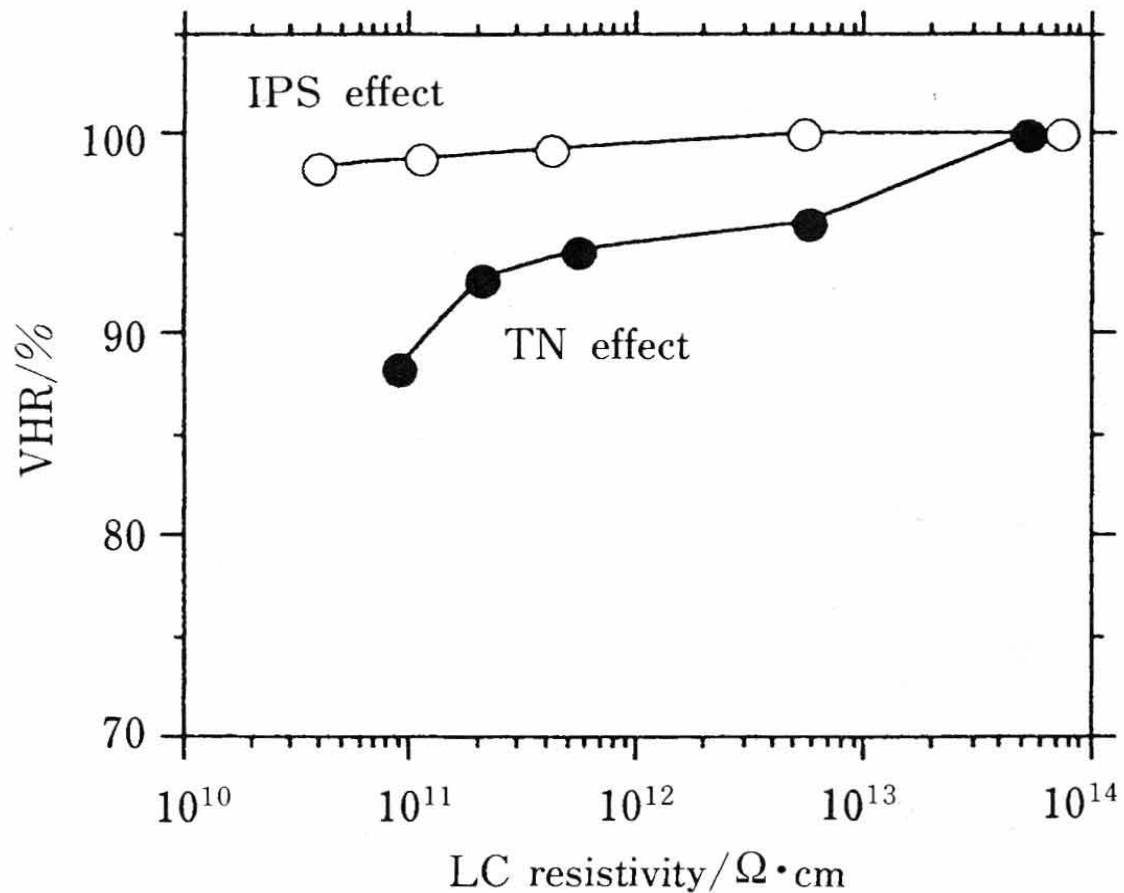
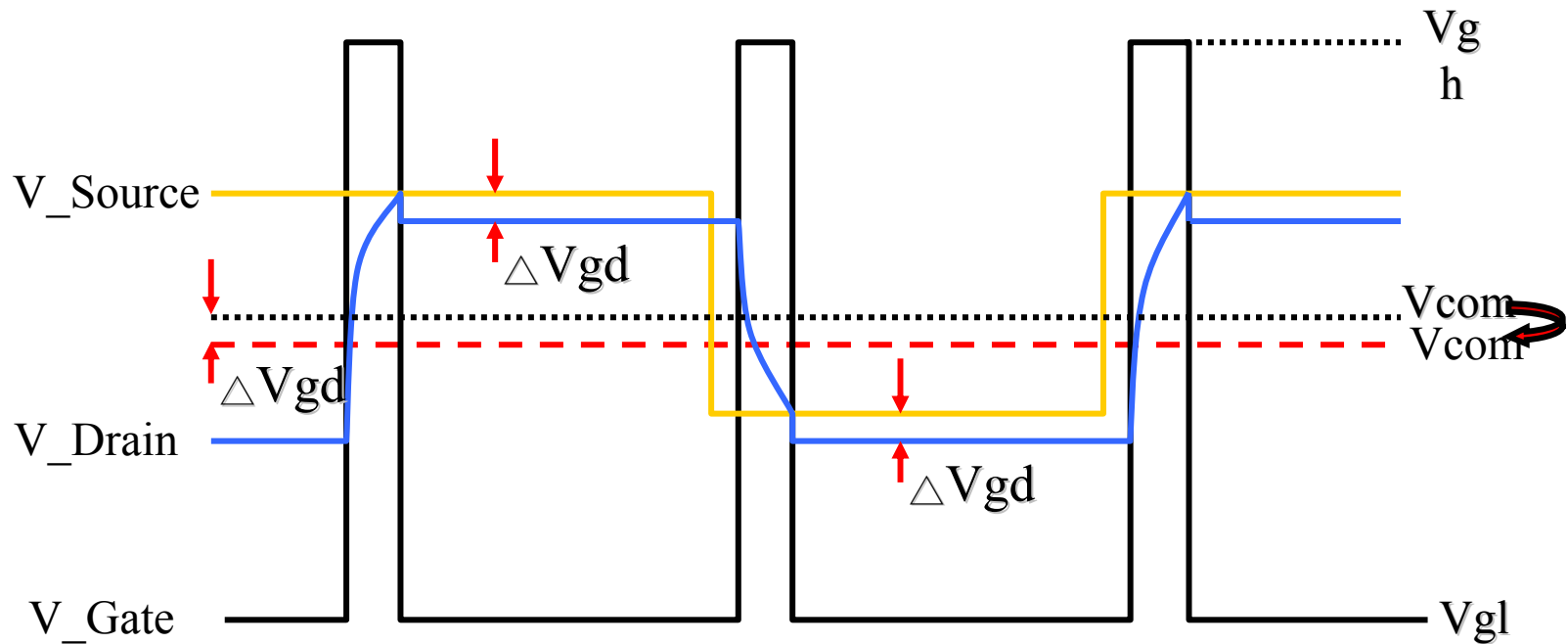


Fig. 13 Relationships of the VHR characteristics and the resistivity of liquid crystals using the IPS and TN effects, respectively. The resistivities of liquid crystals used were varied by doping 1-(4-cyanophenyl)-

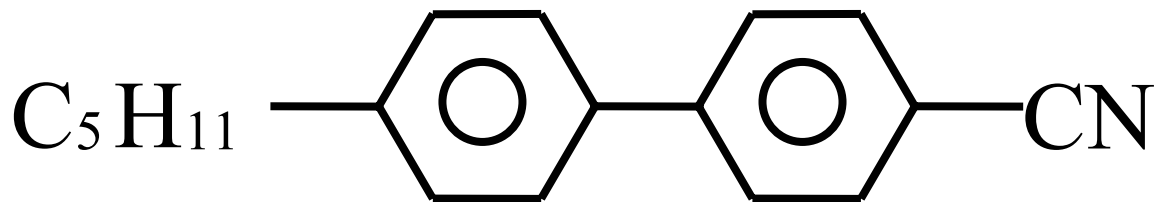
2-Level Driving Method (III)

- Cs on Common

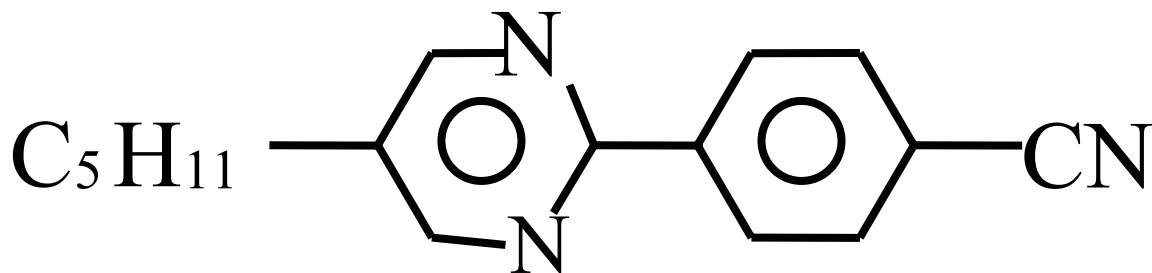
Com voltage is constant



非氟素系液晶化合物

 Δn 

0.184



0.224





TFT-LCD パネルの視角特性

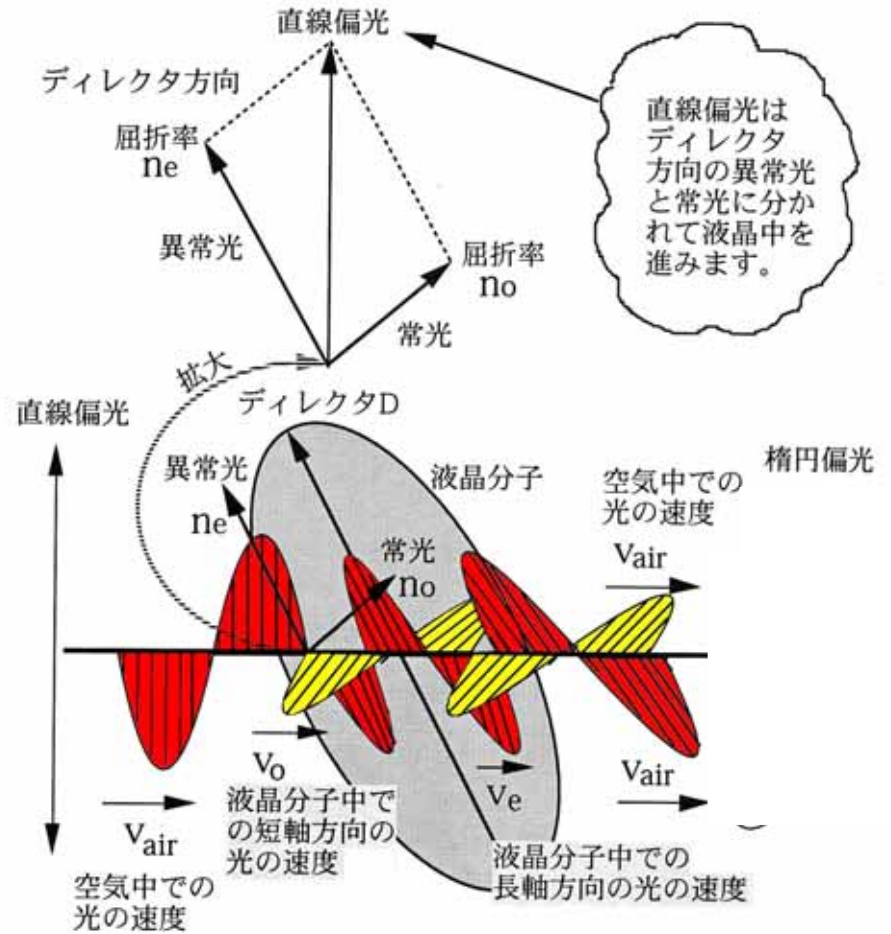
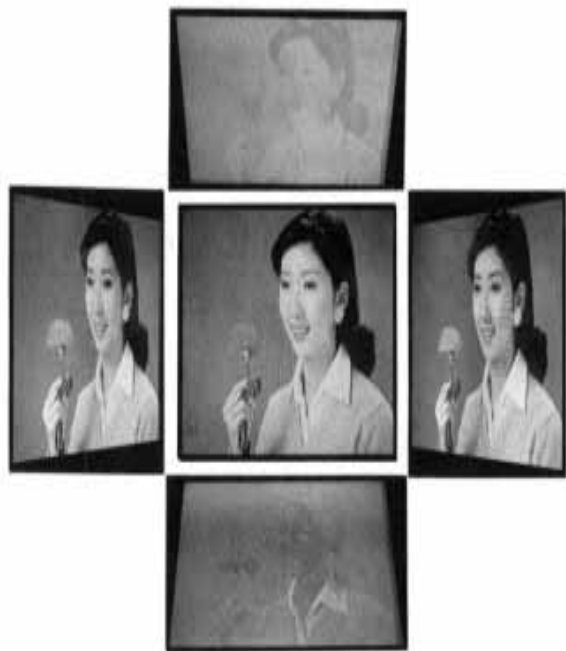
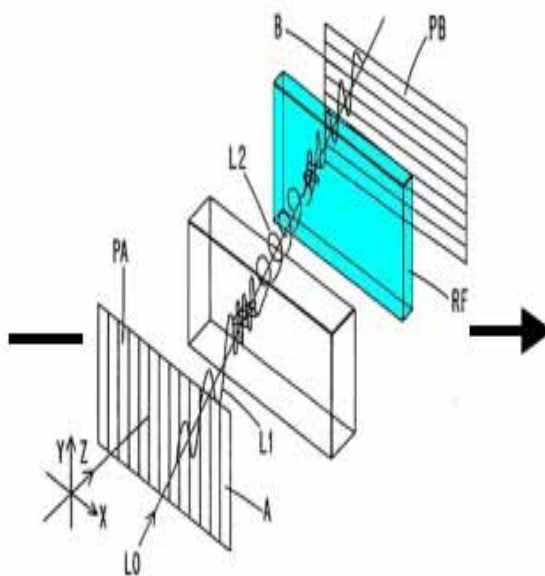


図2.18 液晶分子を通過する光

分子的雙折射率



未使用光學補償膜

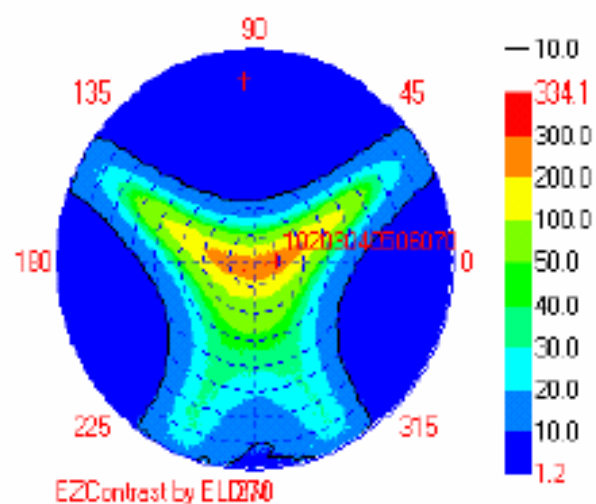


使用光學補償膜

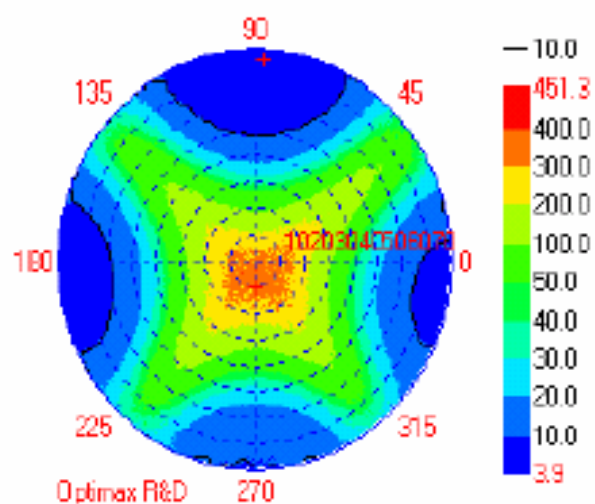


使用光學補償膜

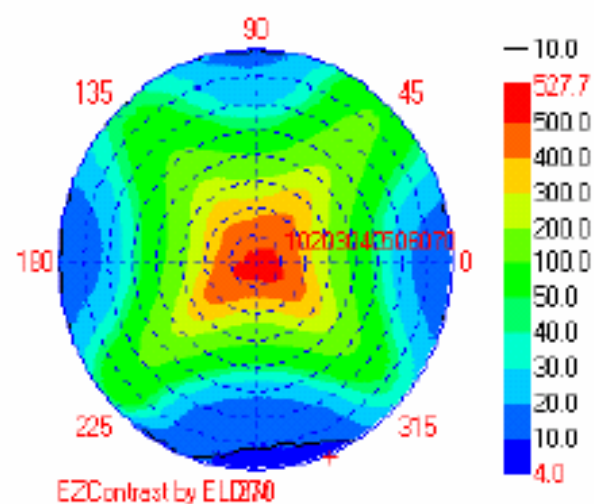




Without WV

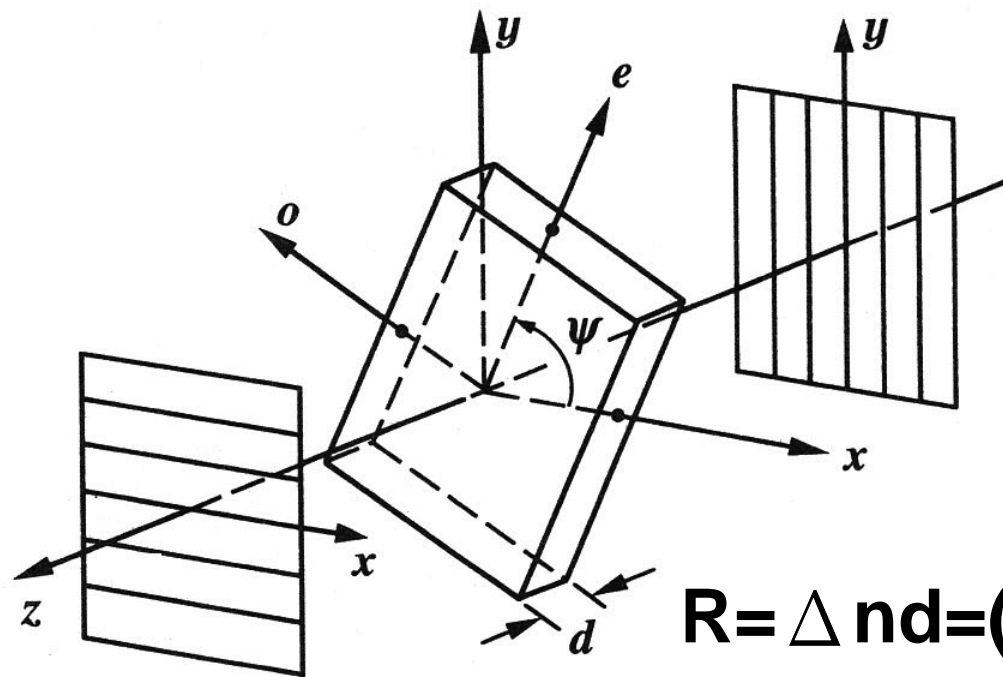


Standard WV



Super WV

	視角特性			
	左視角	右視角	上視角	下視角
Without WV	45	45	45	15
Standard WV	60	60	60	30
Super WV	80	80	80	45



$$R = \Delta n d = (n_e - n_o) d$$

$$R = \Delta n d \text{ retardation}$$

$$I = \left| -\frac{i}{\sqrt{2}} \sin 2\psi \sin \Gamma / 2 \right|^2 = \frac{1}{2} \sin^2 2\psi \sin^2 \frac{\pi \Delta n d}{\lambda}$$

基礎光學-1

繞射效應

=光並非直線前進

縫隙越小，成像面越大。

光經過狹縫會有發散現象。

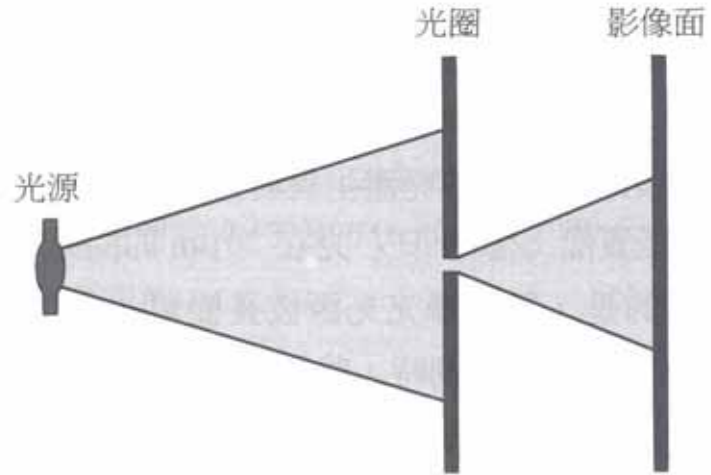


圖 繞射效應的簡單實例。光線經過一個狹窄光圈。所形成的影像比較起利用簡單直線光描繪的區域要大很多。

縫隙越小，光散播現象範圍越廣，以球型往外傳輸。

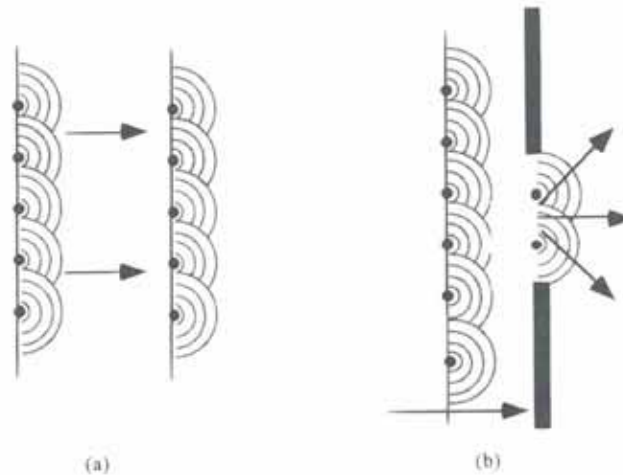


圖 平面波在 (a) 真空和 (b) 透過一狹縫的傳遞，當它在傳遞時產生的波前可以利用 Huygens-Fresnel 原理來說明。

基礎光學-2

圓孔繞射之位置

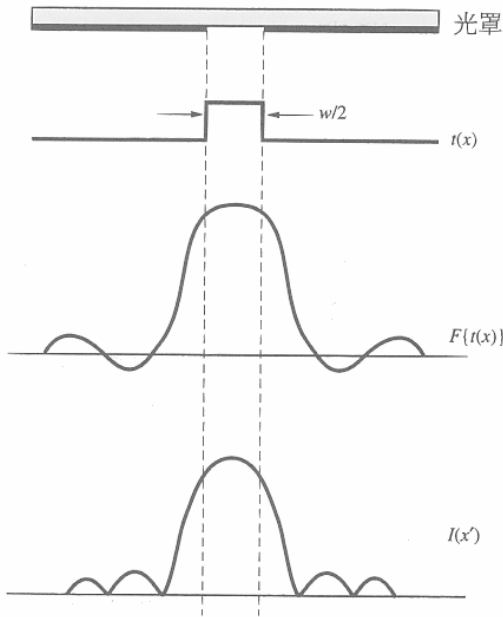
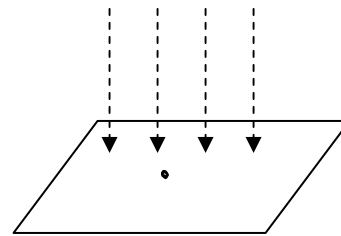
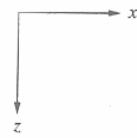


圖 光罩中的矩形光圈和所導致的遠場 Fraunhofer 繞射圖案以及光強度圖案

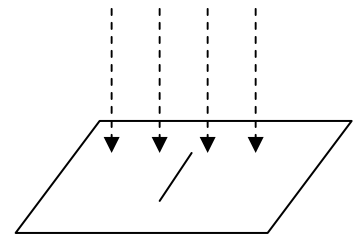
光強度橫軸波形 = $\sin\theta$
(由 Bessel 函數導出)

單位 = λ/d

(d = 聚焦鏡的直徑，
 f = 焦距， λ = 波長)



$$1.22 \lambda f/d$$



$$1.00 \lambda f/d$$

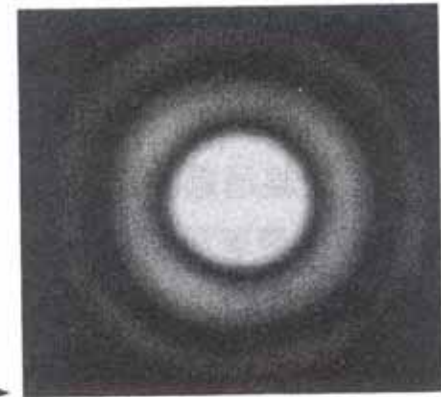
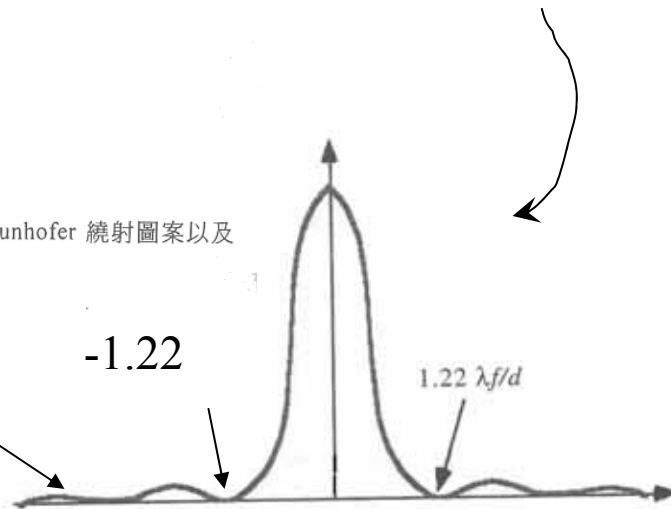
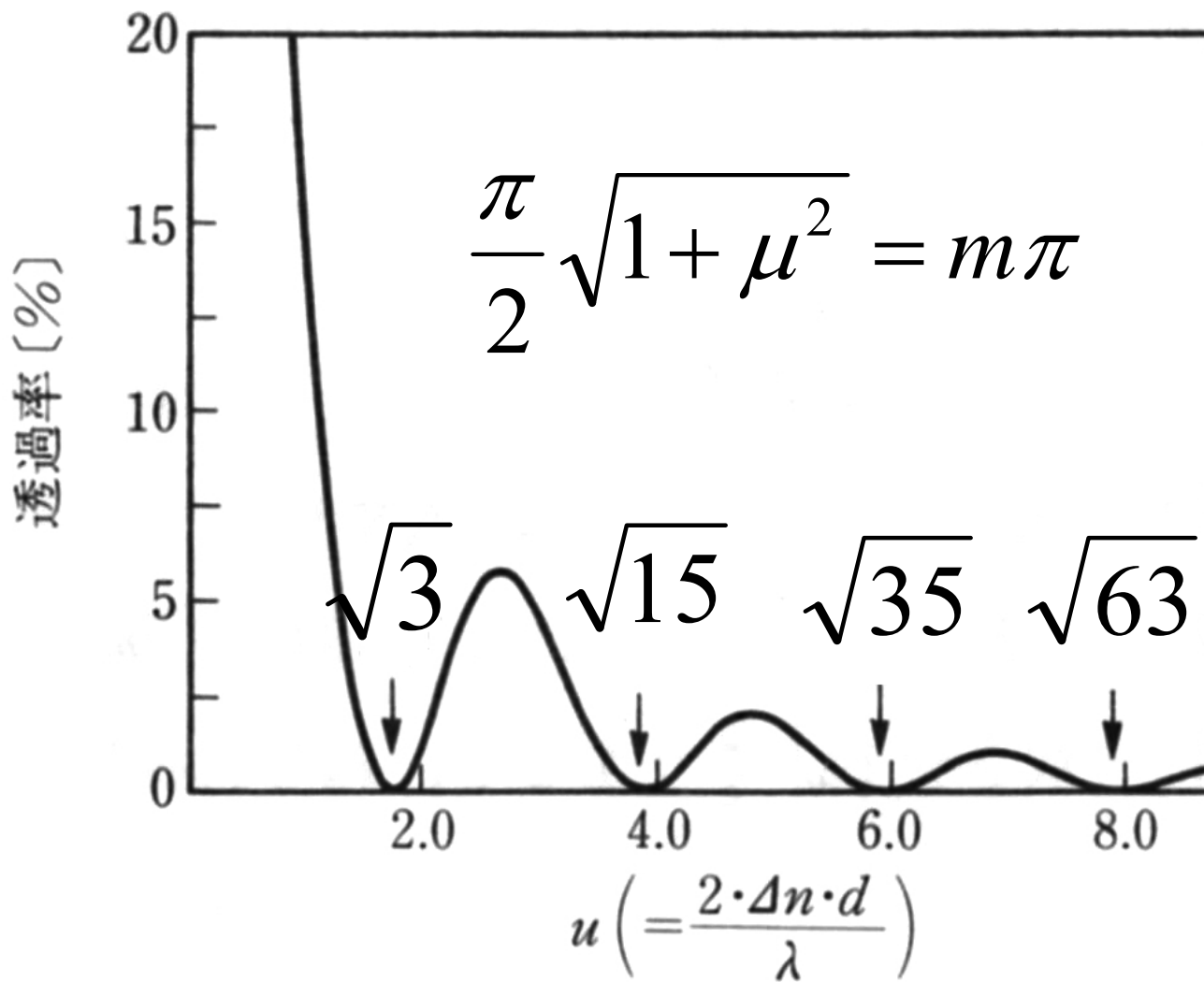


圖 在影像面上一個圓形光圈的影像強度 (Fraunhofer 繞射圖案)。影像強度是沿著左圖中任意一直徑所繪成。右邊所示的圖案顯示的是 2D 影像。

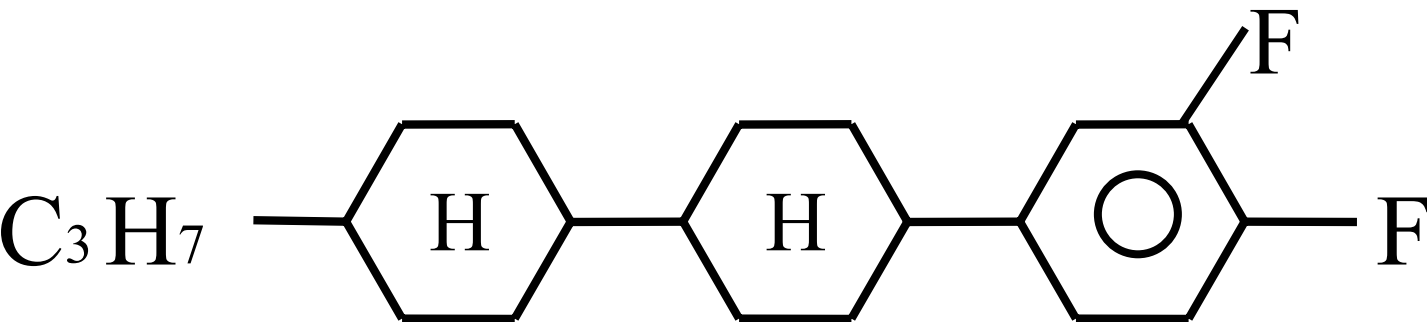
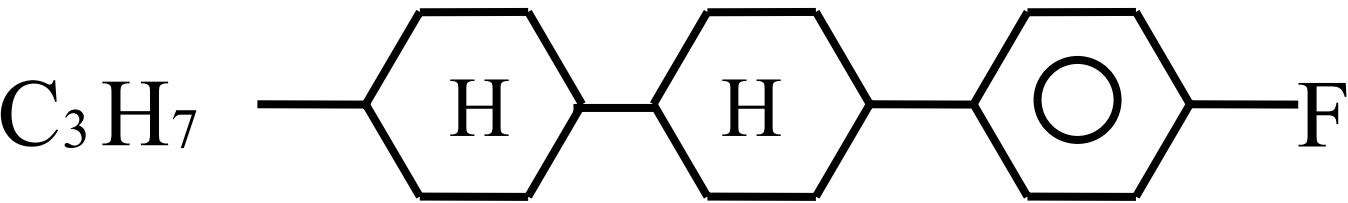


$$\frac{2 \Delta n \times d}{\lambda}$$



氟素系液晶化合物

Δn



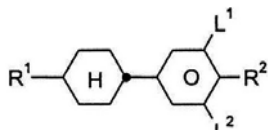
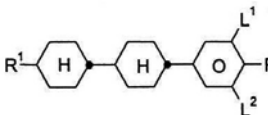
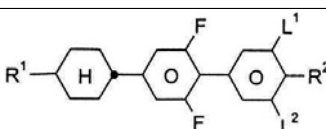
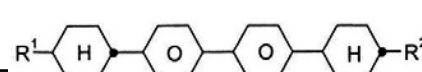
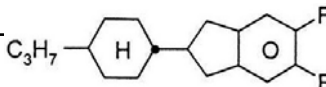
TFT用液晶材料的要求物性

- 使用溫度 — **30 °C** -- **80 °C**
- 廣視角
-
- 配向性



Example 2

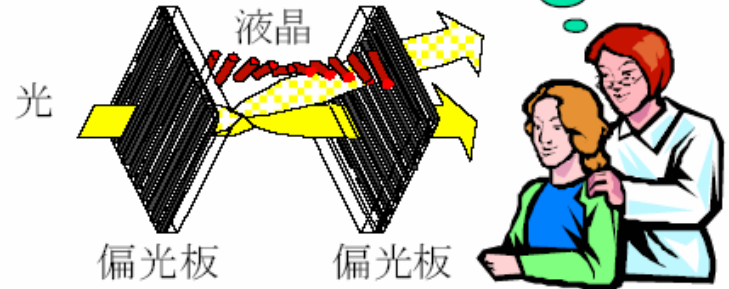
A liquid-crystalline medium comprising

	PCH-5-F	3.59 %	Clearing point [°C]:	97.2
	CCP-20CF2.F.F	19.12 %	$\Delta \varepsilon$ [1kHz, 20°C]	+8.2
	CCP-30CF2.F.F	17.95 %	$V_{(10,0,20)}$ [V]:	1.38
	CCP-50CF2.F.F	19.12 %		
	CUP-2F.F	6.01 %		
	CBC-3F.F	6.01 %		
	CBC-33F	6.01 %		
	CBC-53F	6.01 %		
	CBC-55F	5.92 %		
	IS5501	10.24 %		



廣大視野角的技術

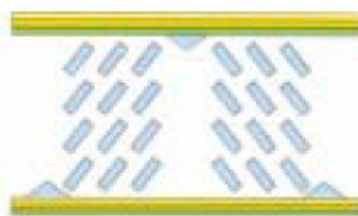
如果從傾斜的方向觀看、不能看清顏色



IPS



Multi-domain

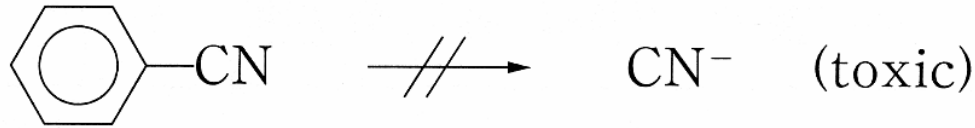


MVA

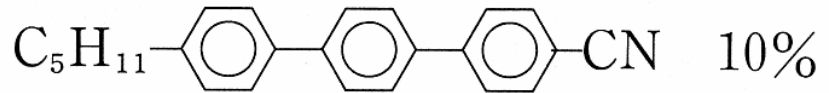
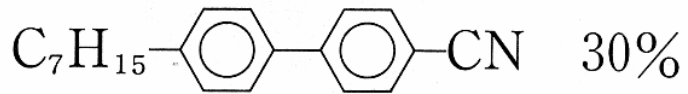
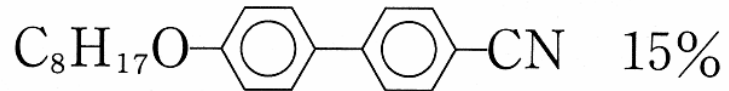
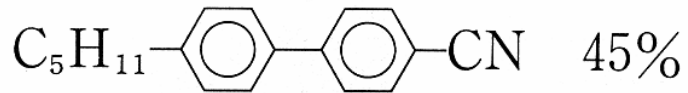


OCB

液晶有毒性?



サンプル A (Biphenyl & Terphenyl Mixture)



サンプル B (PCH Mixture)

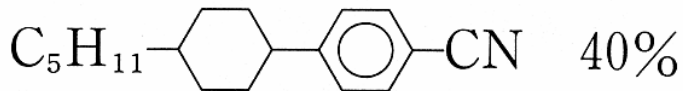
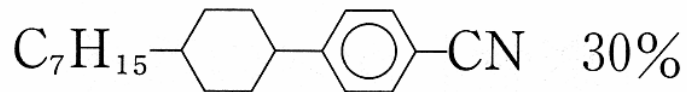
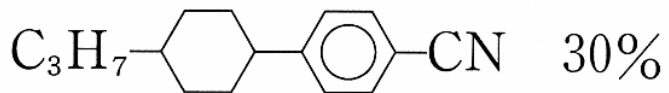


表3 「劇物」からの除外の適用を受けるための安全性試験とその基準値
 (中央薬事審議会基準)

試験項目	ガイドライン	補足
急性経口毒性:LD50	>300mg/kg	
皮膚刺激性	フェノール等よりも弱い刺激性	1994年から追加
吸入毒性(ミスト・ダスト): LC50	>1.0mg/l	1999年から追加

表6 CN基を有する液晶化合物の安全性試験のまとめ

経口急性毒性LD50

76液晶化合物全て	:	> 300 mg/kg (ガイドライン)
76液晶化合物全て	:	> 1,000 mg/kg
76液晶化合物中 72化合物	:	> 2,000 mg/kg

皮膚刺激性

10液晶化合物全て	:	刺激性無し又は非常に弱い刺激性 (フェノールより弱い刺激性)
-----------	---	-----------------------------------

吸入毒性試験(LC50)

3液晶化合物全て	:	> 1.0 mg/l
----------	---	------------

変異原性試験(Ames Test)

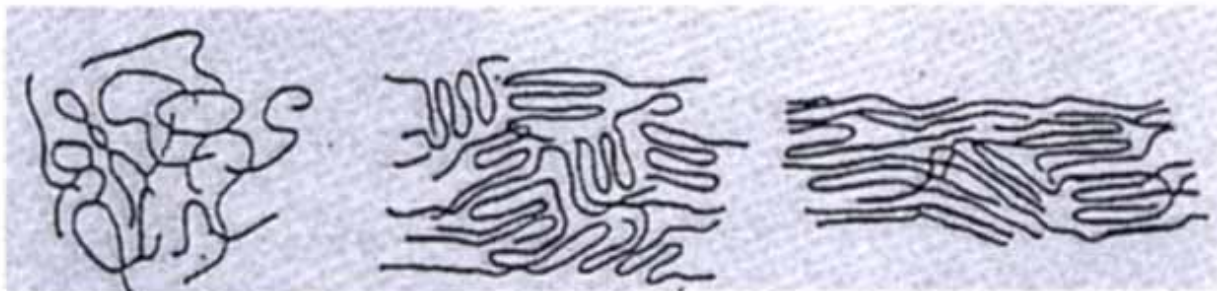
76液晶化合物全て	:	陰性
-----------	---	----



液晶材料的應用



Rods in Liquid Nematic State
 Crystalline Arrays for One Array
 [polymer]-----[as-spun fiber]-----[heat-treated fiber]
 Fiber formation of thermotropic liquid crystal polymer



Random Coils
 [polymer]-----[as-spun fiber]-----[drawn fiber]
 Fiber formation of flexible polymer

图-3 Schematic diagram of fiber formation



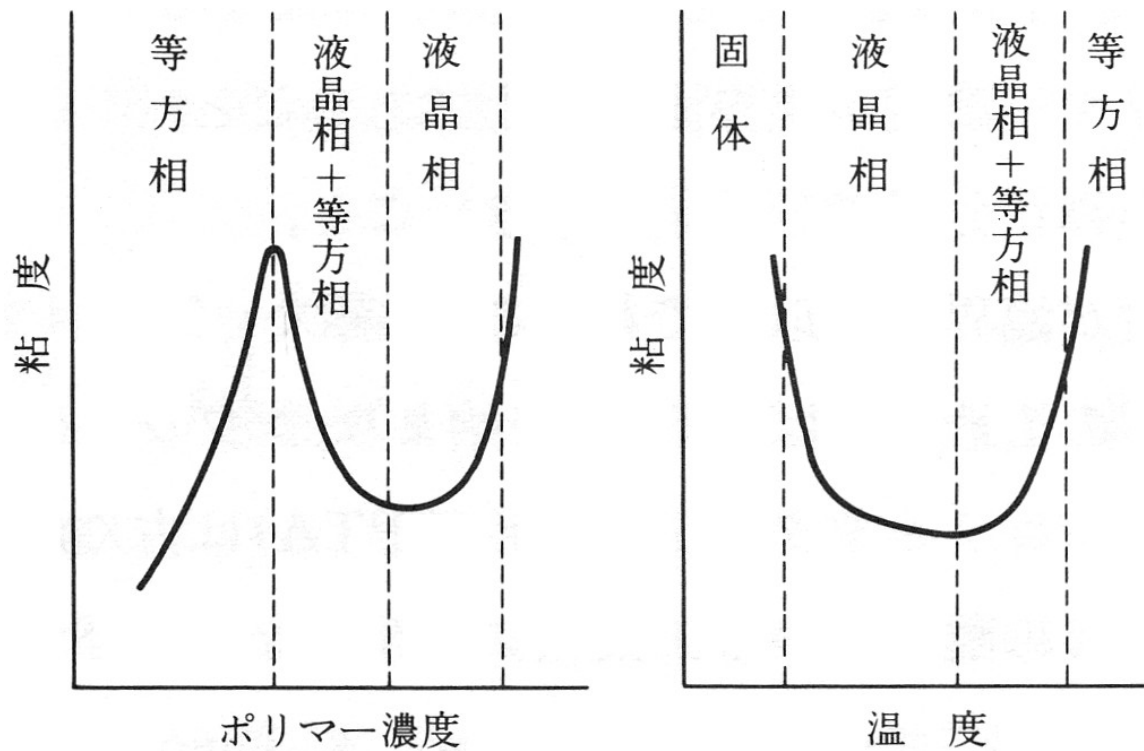
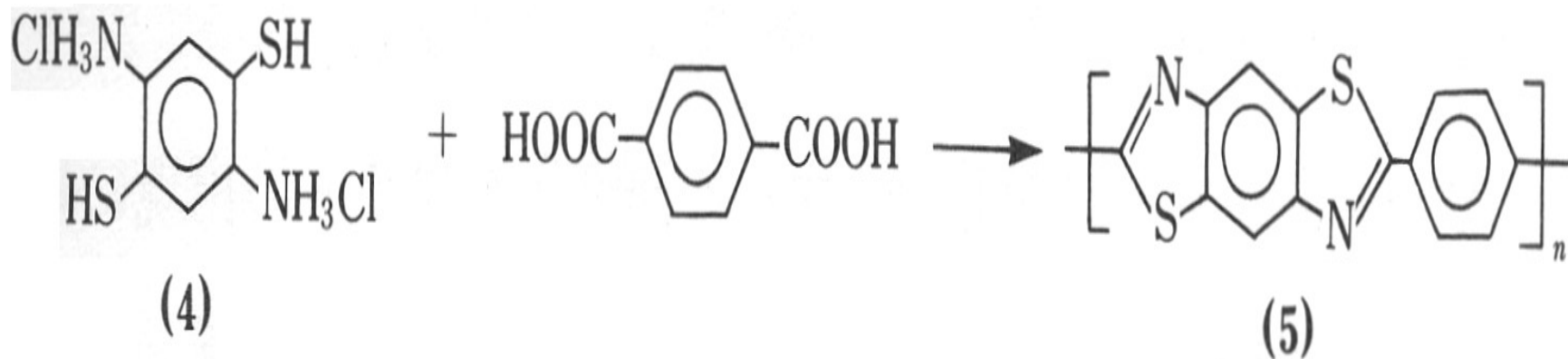
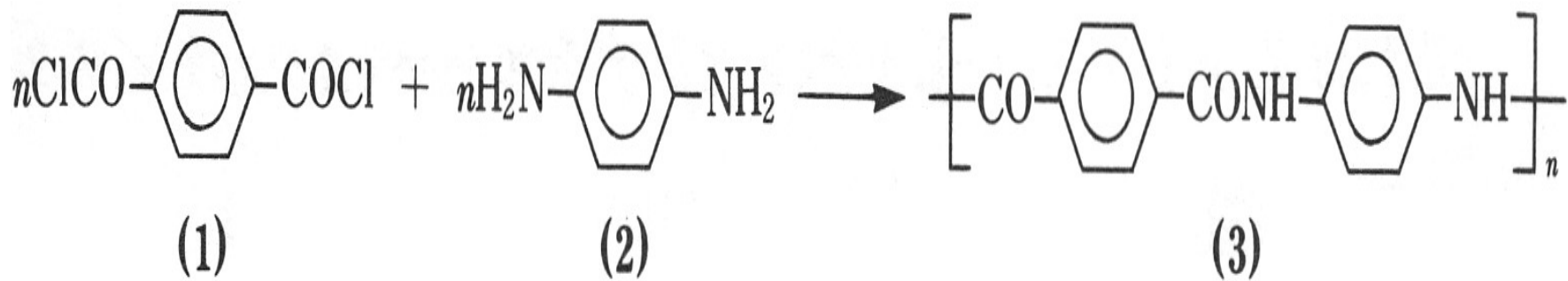
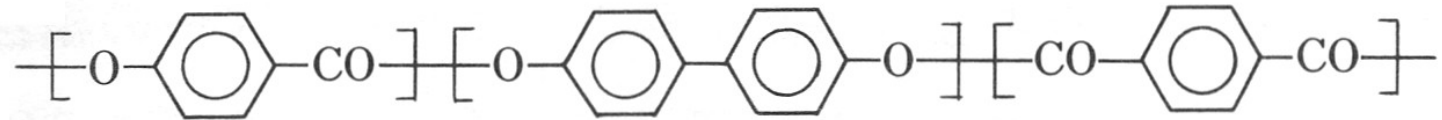


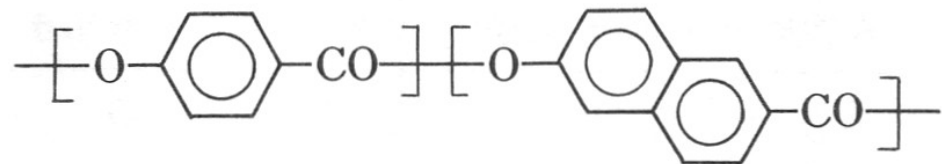
図 3.1 PPTA-H₂SO₄系の粘性挙動



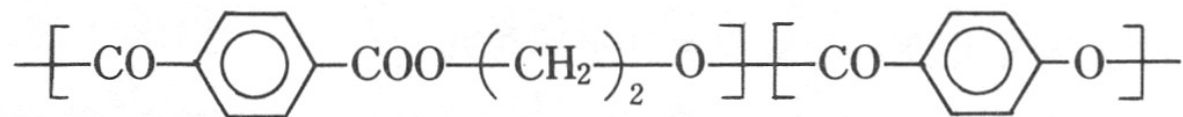
1) エコノール系：エコノール（住友化学），ザイダー（ダートコ，日本石油化学）

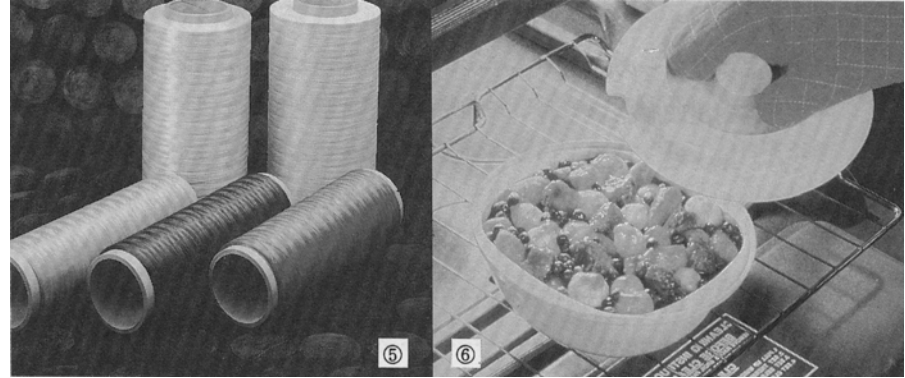
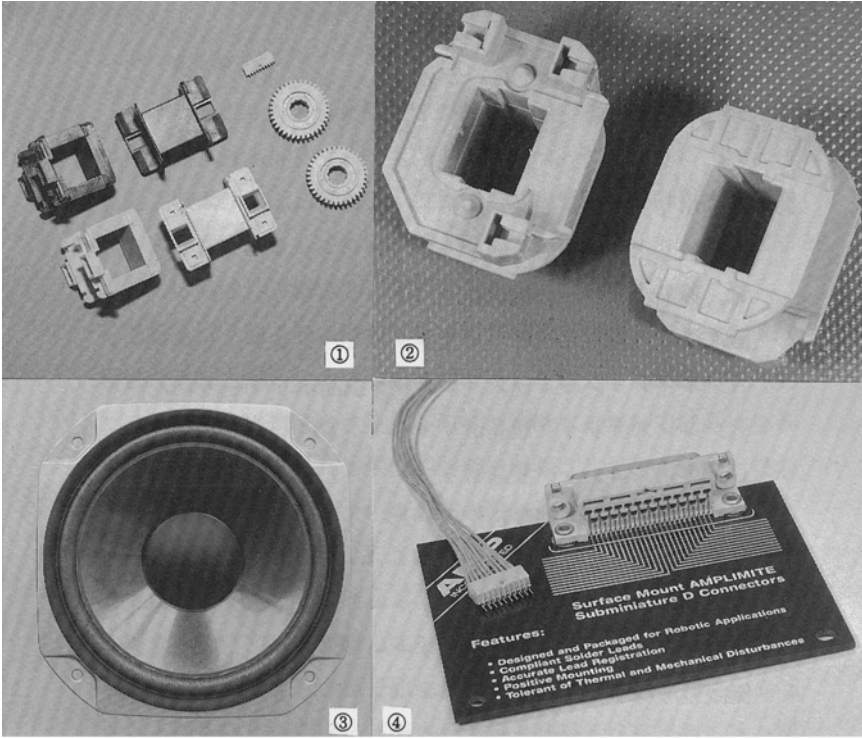


2) ベクトラ系：ベクトラ（ヘキスト・セラニーズ，ポリプラスチック）

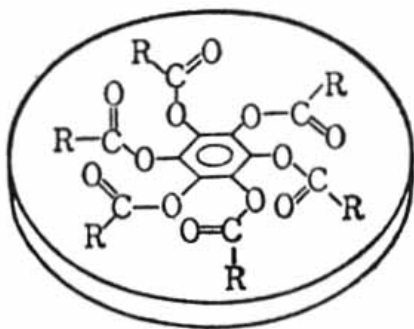


3) X7G系：X7G（イーストマンコダック），ノバキュレート（三菱化成），ロッドラン（ユニチカ），出光 LCP（出光石油化学）

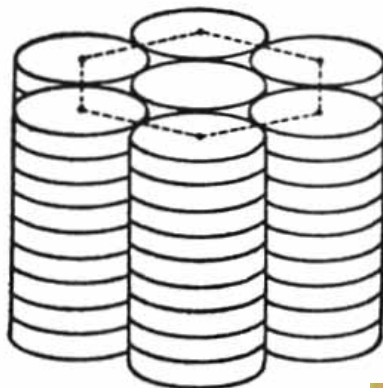




Discotic

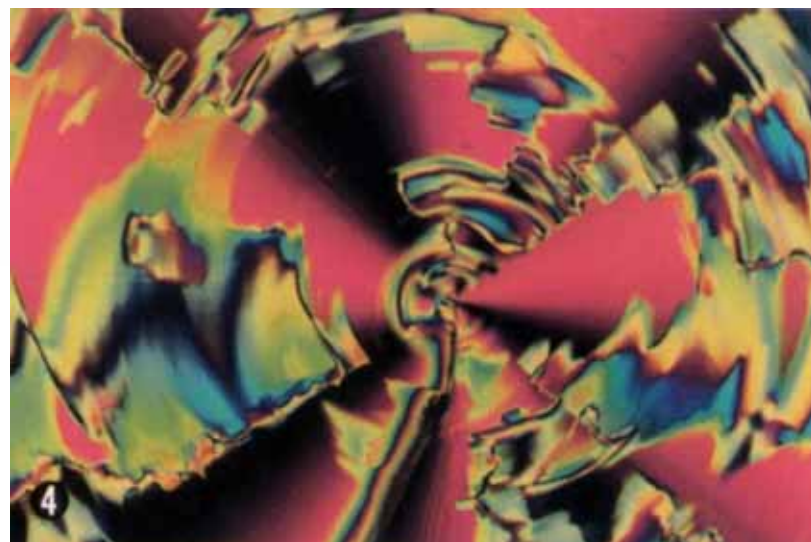


(a)

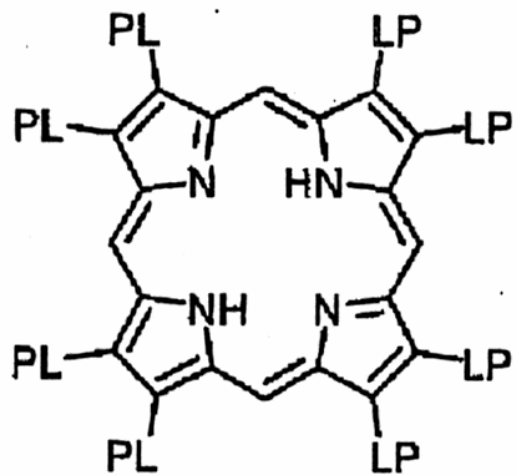


(b)

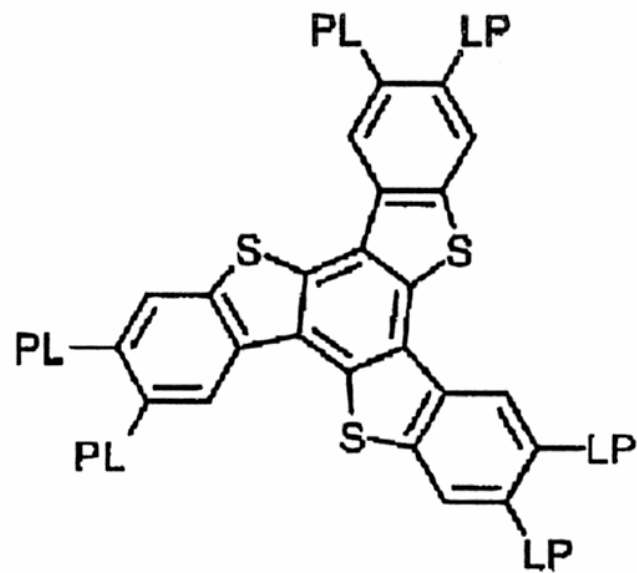
ディスコティック液晶の構成分子
(a)と分子配列構造(b)



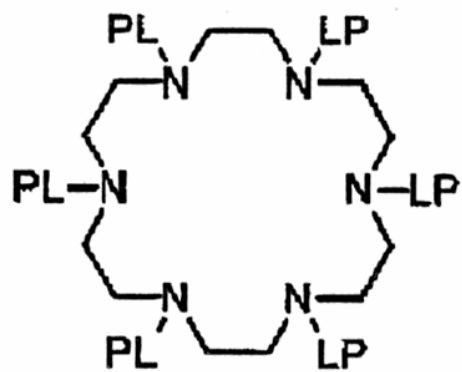
(D1)



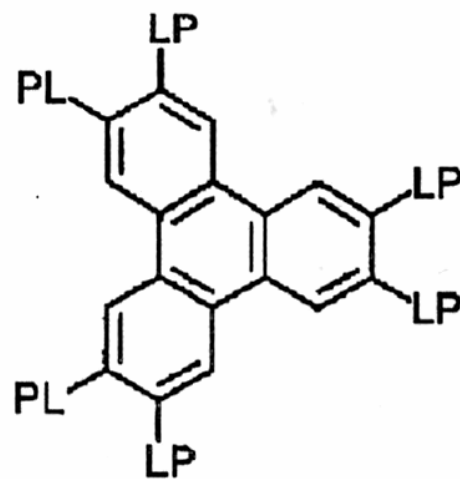
(D2)



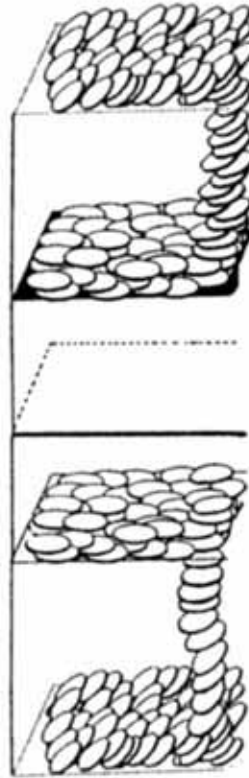
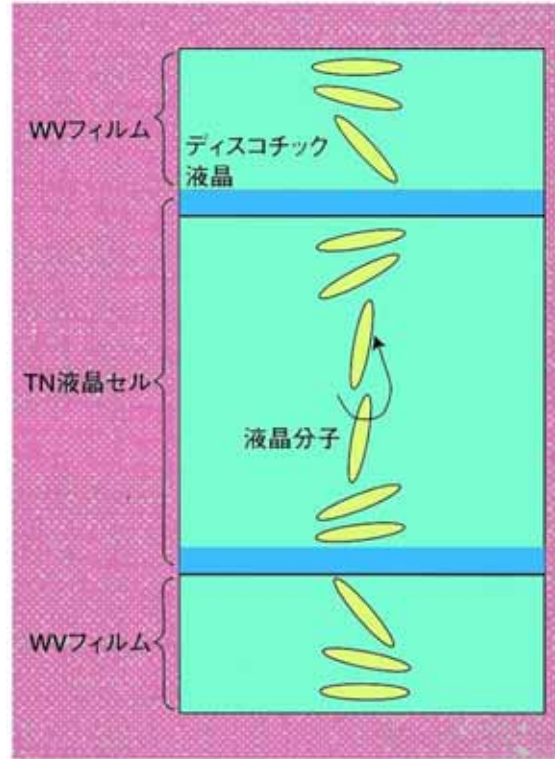
(D3)



(D4)



視野角に対する位相差を連続的に変えて、視野角を補償する。



廣視角膜

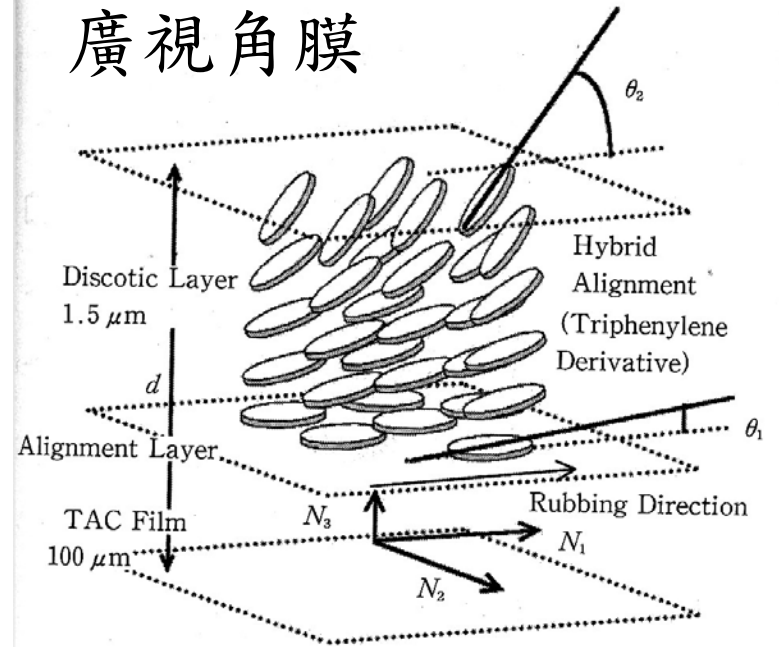
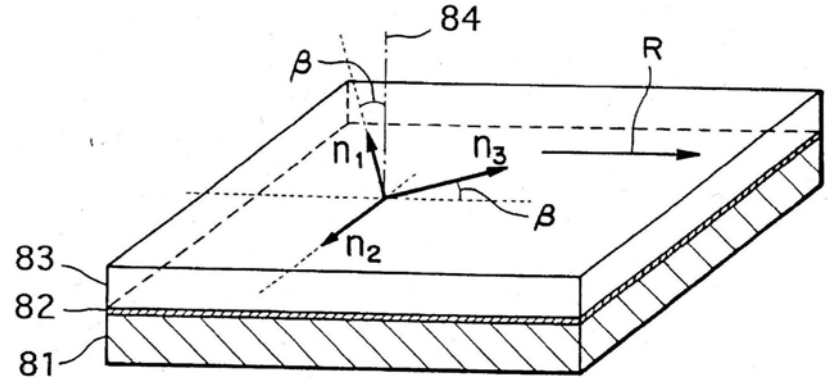


FIG. 8

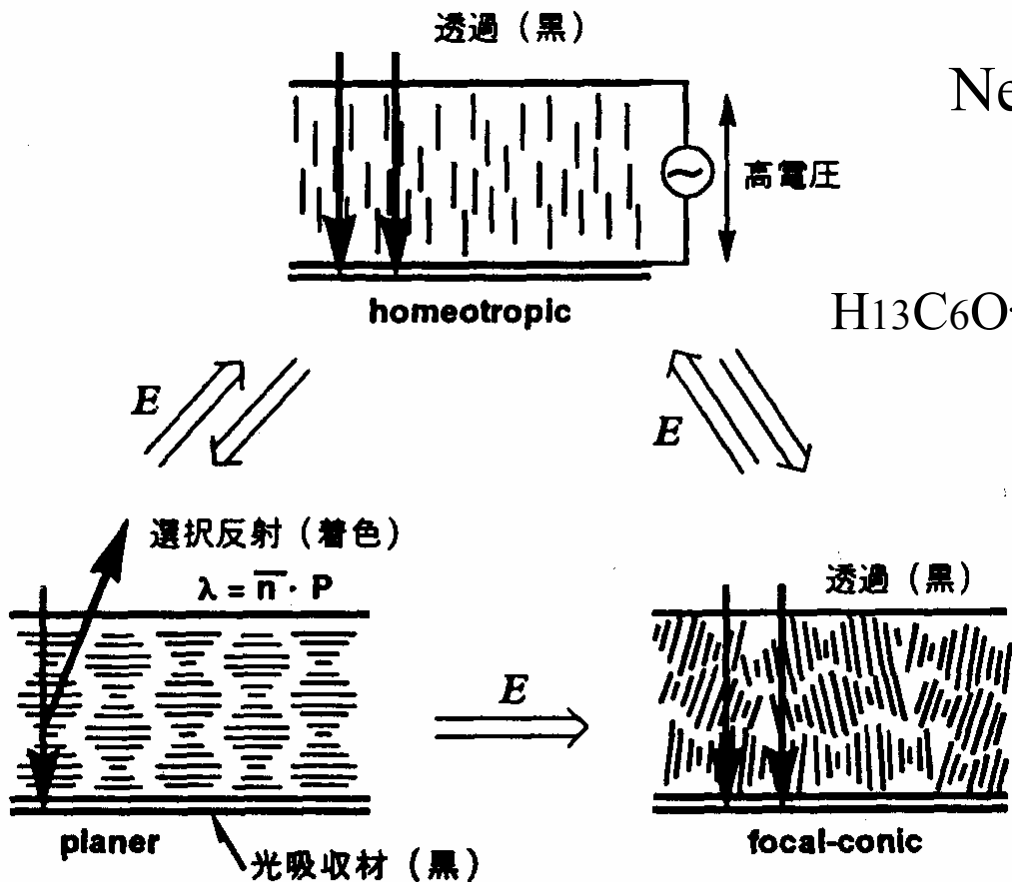


- 84 normal
- 83 transparent film
- 82 orientation layer
- 81 discotic liquid crystal

$$n_a = n_c - n_b$$

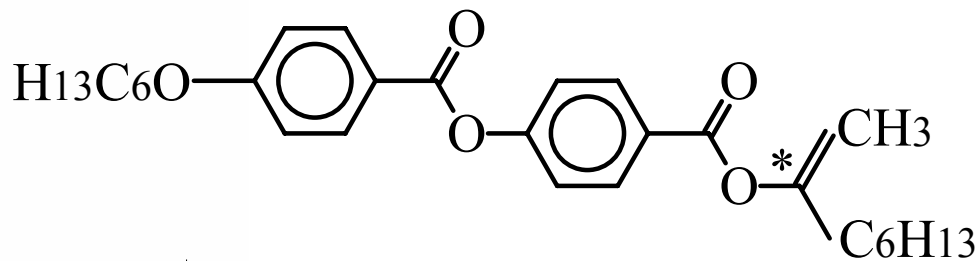
$$(n_c - n_b) * d = 80 - 250 \text{ nm}$$

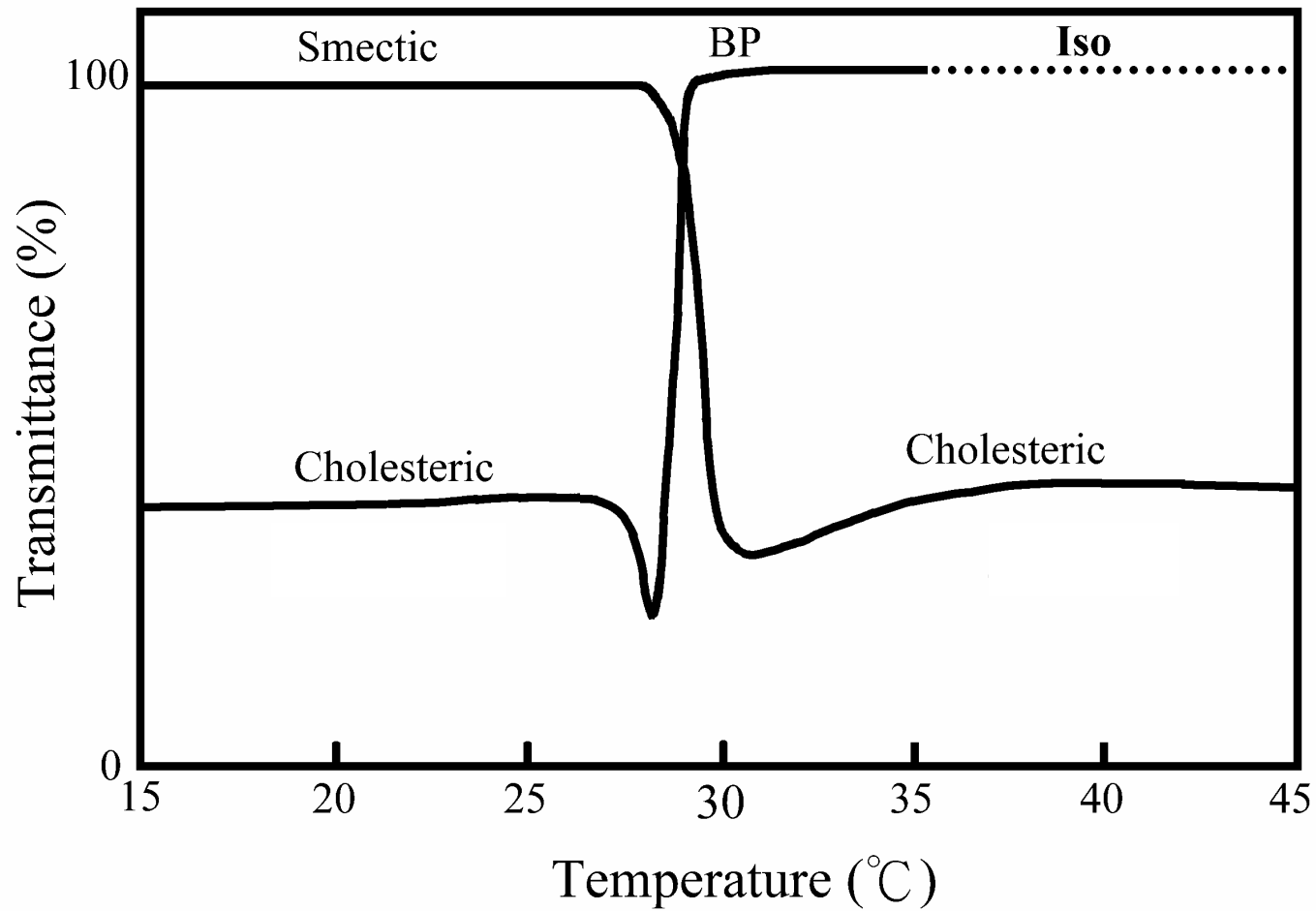
Cholesteric系液晶的電子書與感溫光閥應用

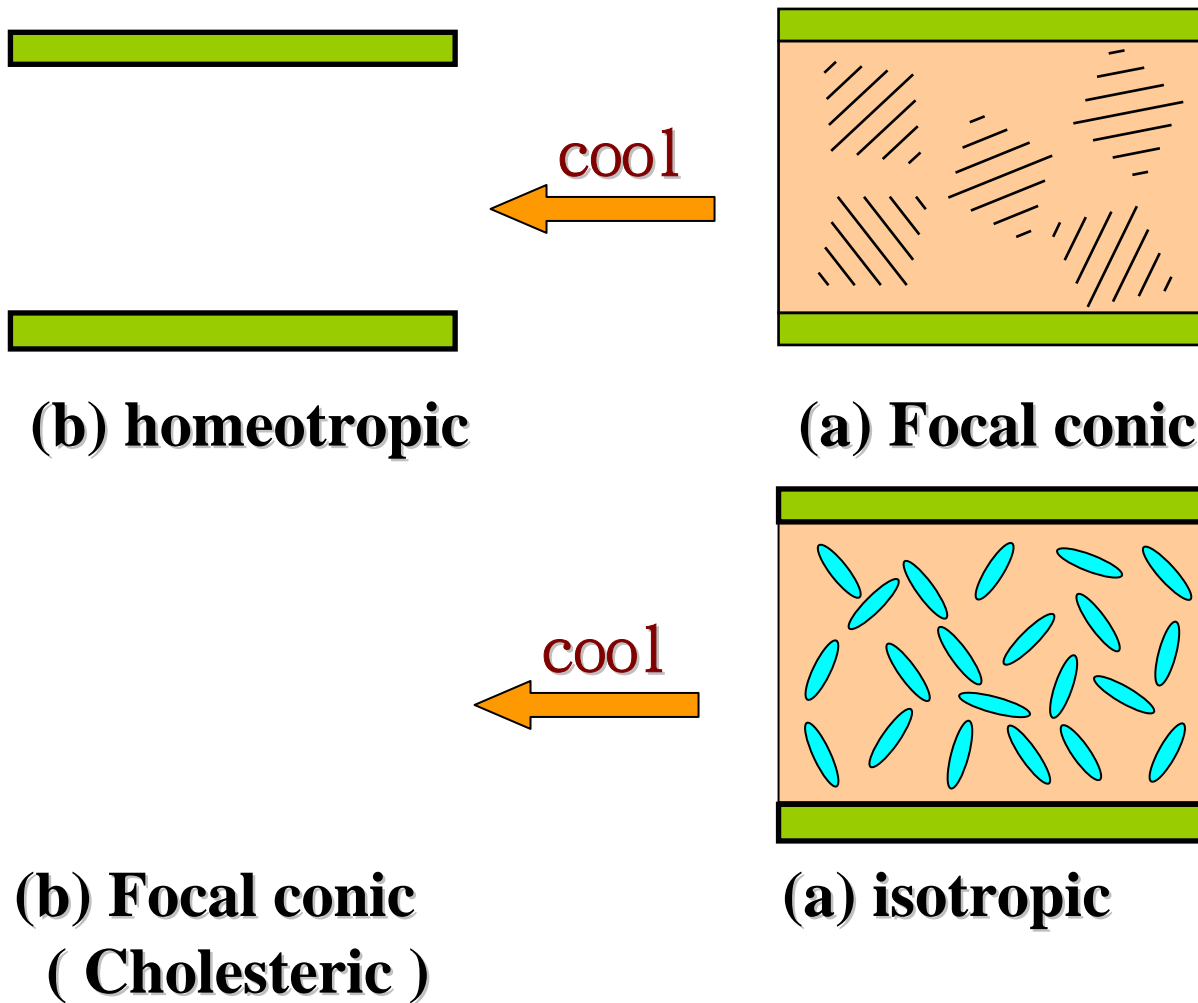


Reflective Cholesteric LCDs

Nematic liquid crystal







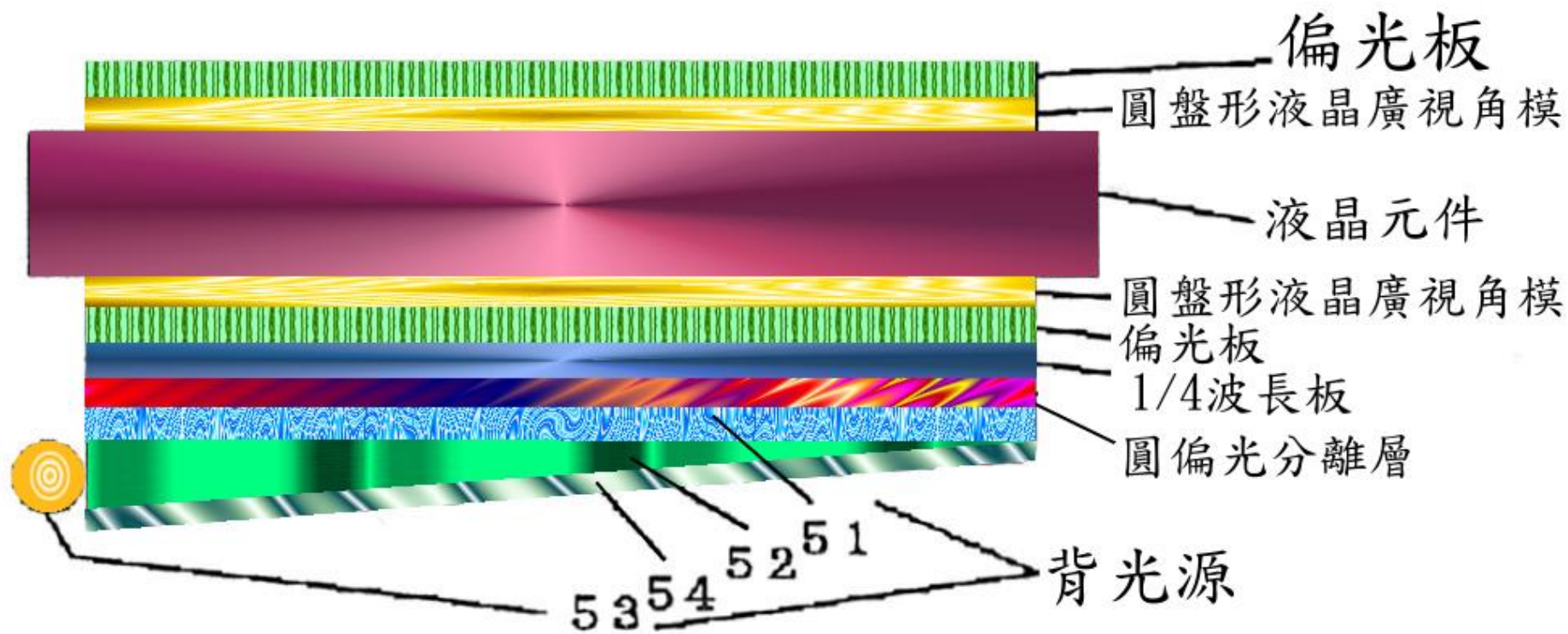
液晶分子排列示意圖

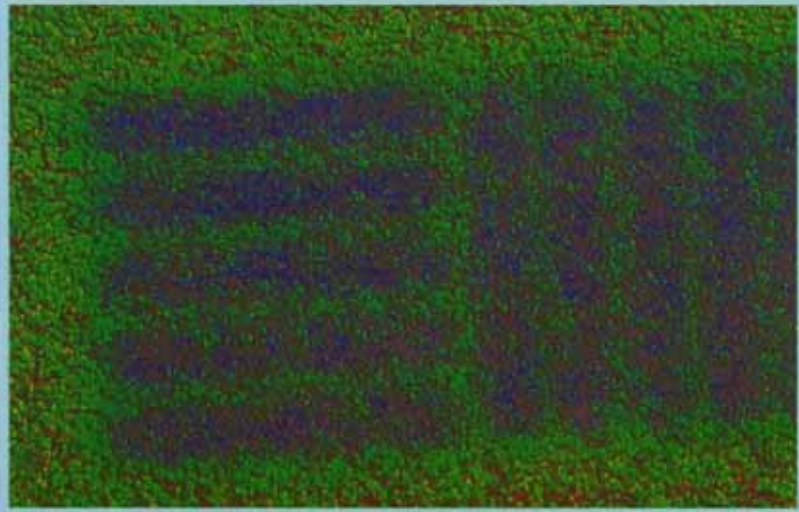
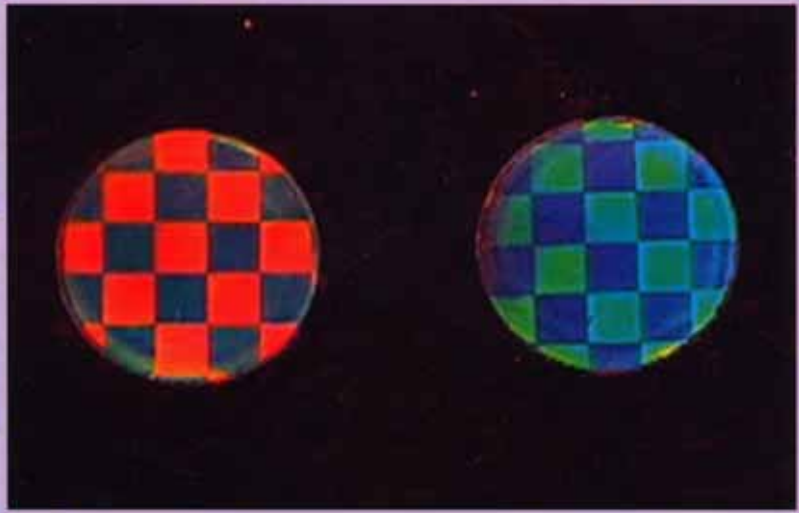
3.感溫光閥的應用



26°C時呈現光散亂狀態

35°C時呈現光透明狀態

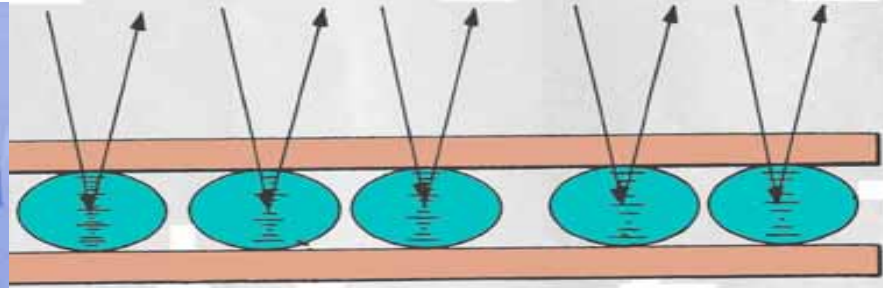


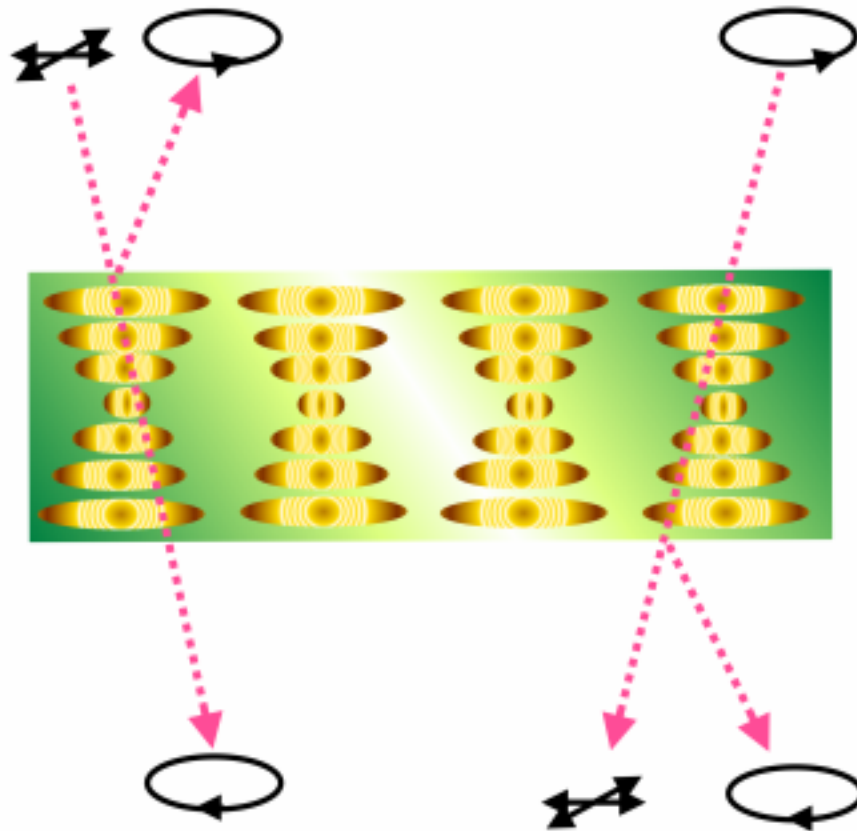


blue

green

red



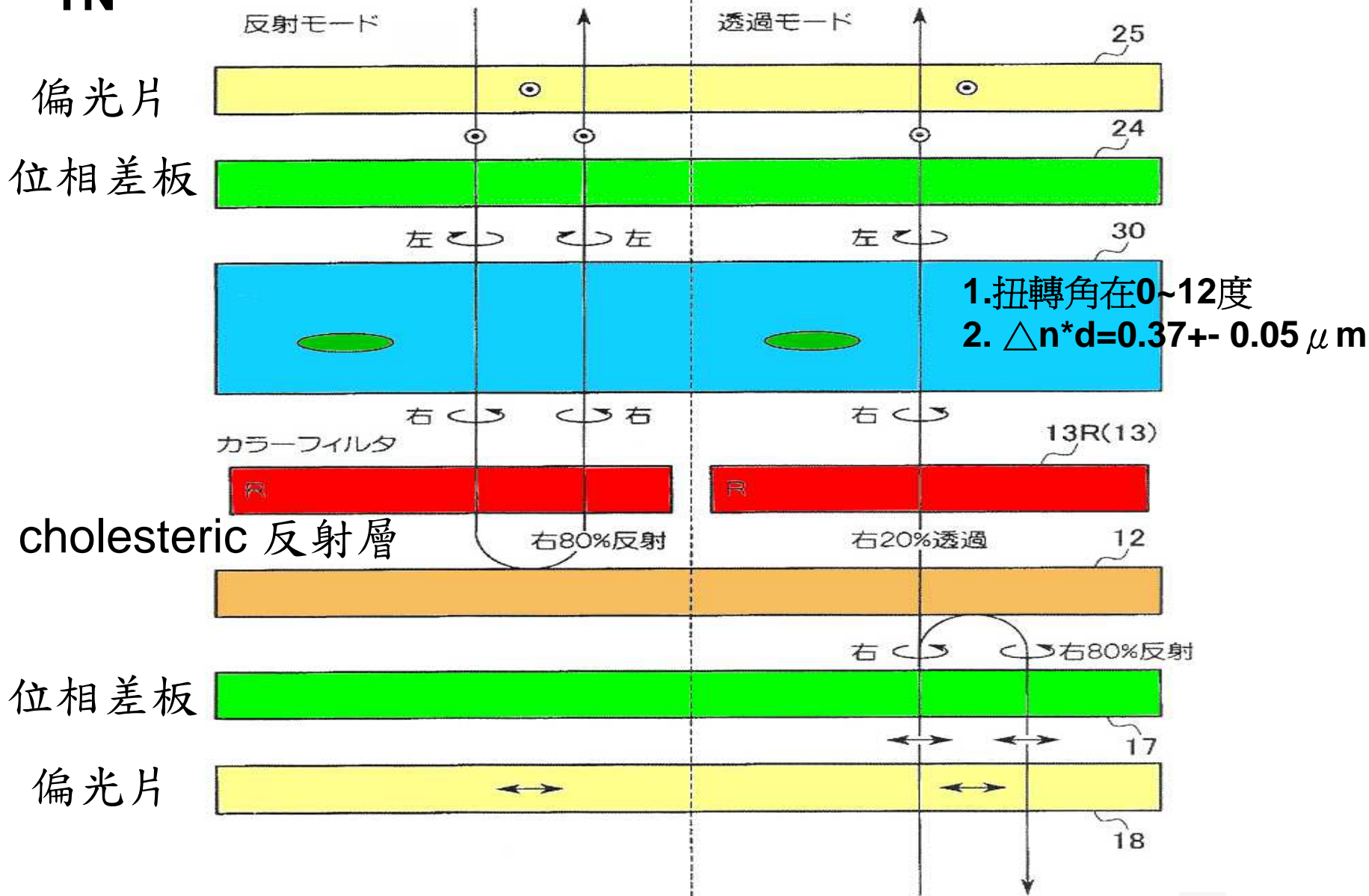


- ⤵ 左圓偏光
- ⤴ 右圓偏光
- ↔ 自然光

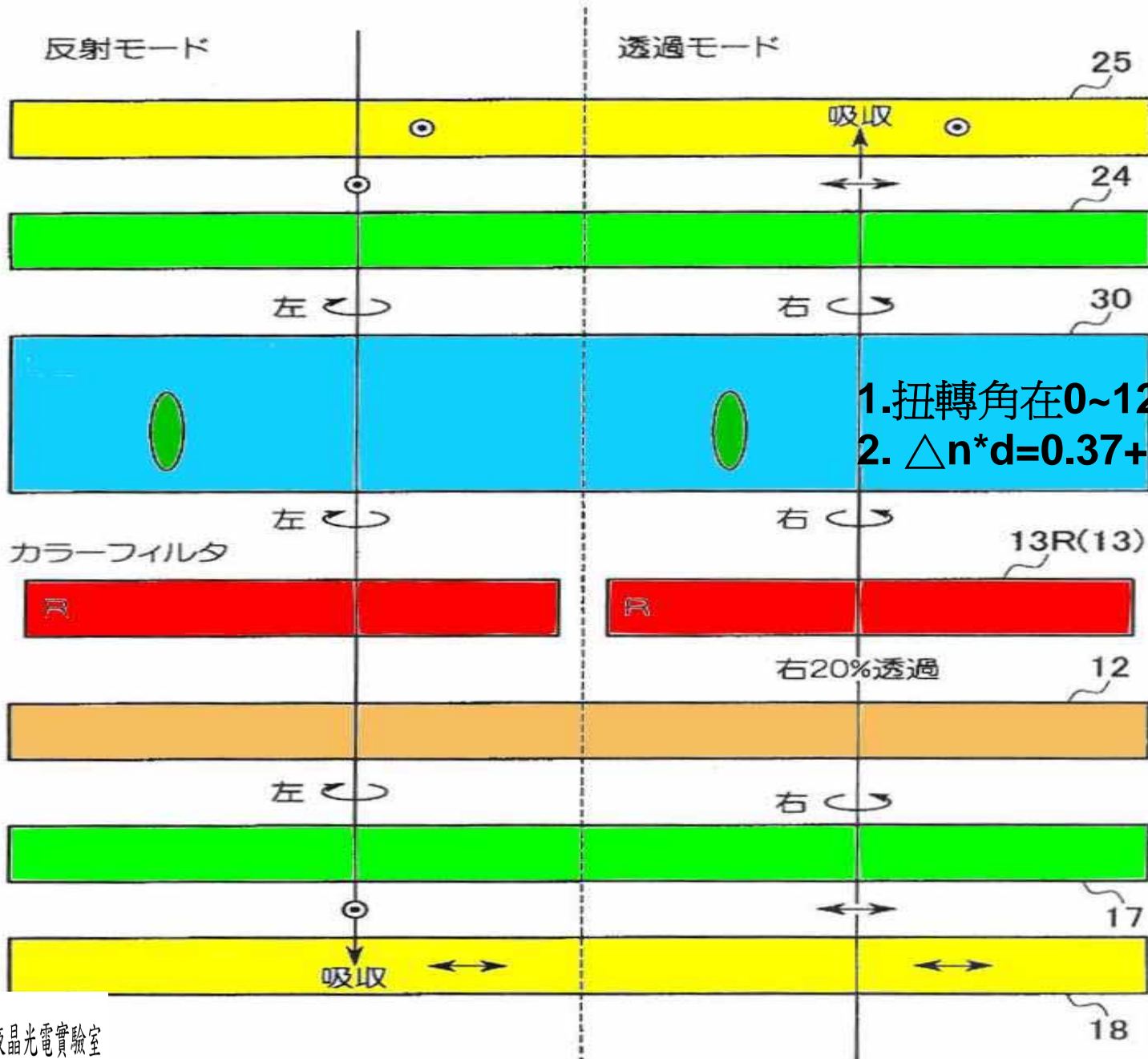
cholesteric

TN

低ツイスト条件 明表示時（非選択電圧印加時）

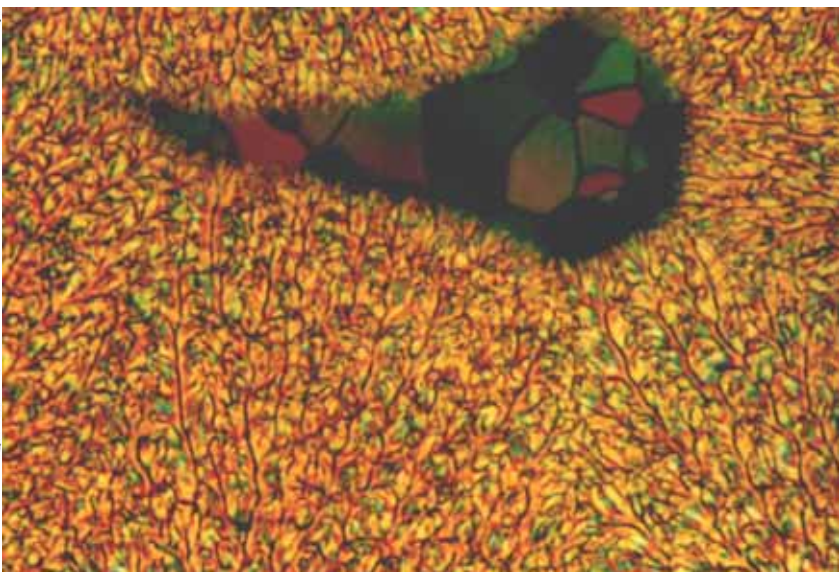
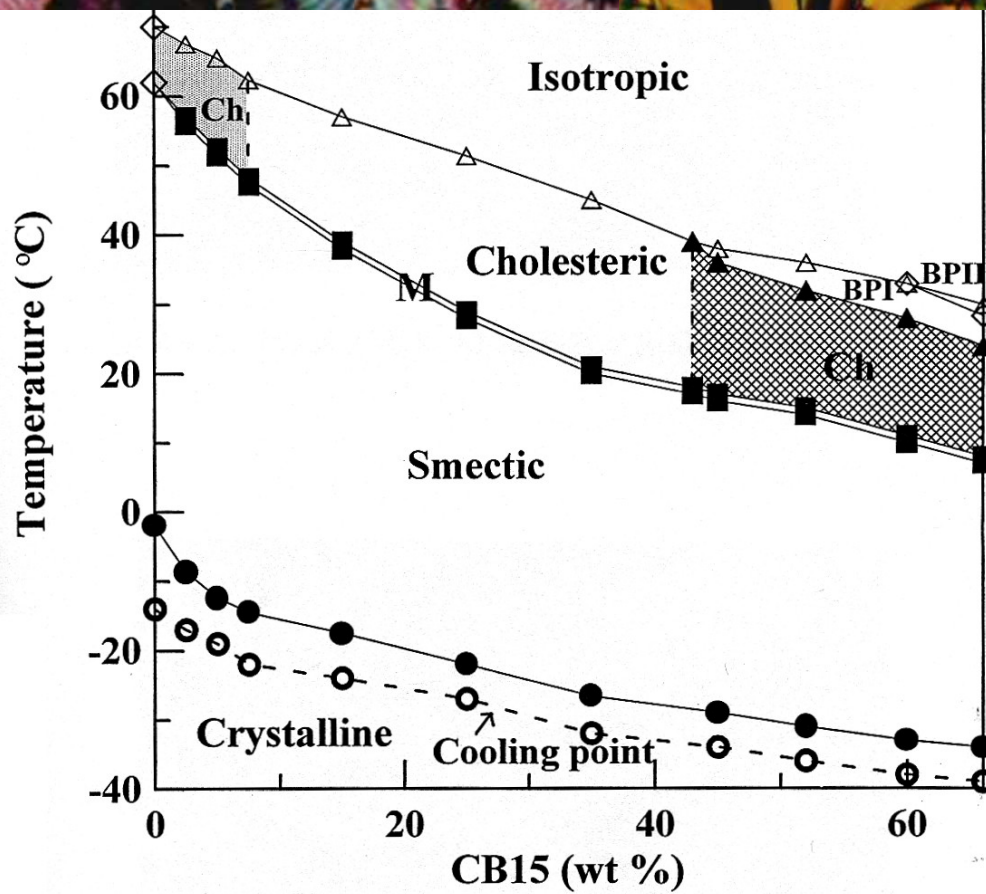
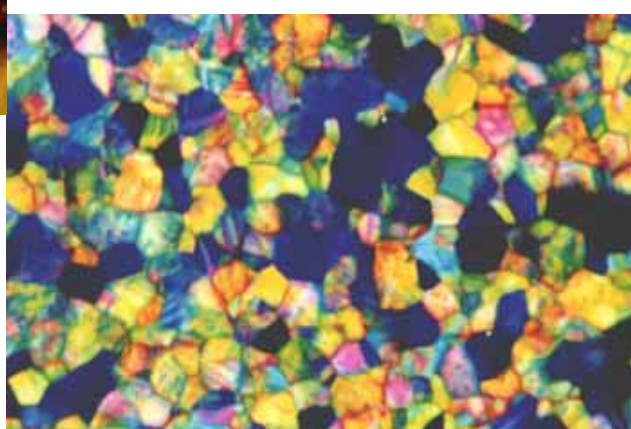
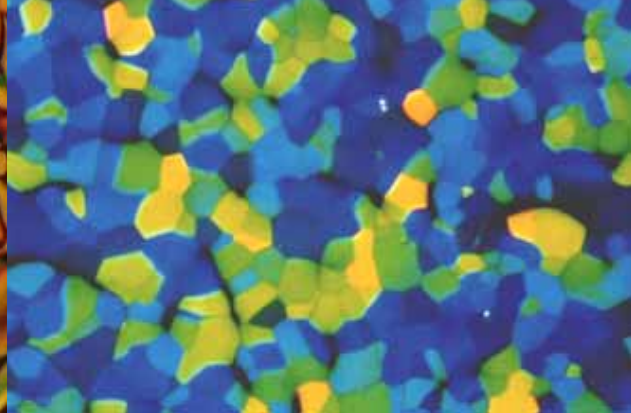
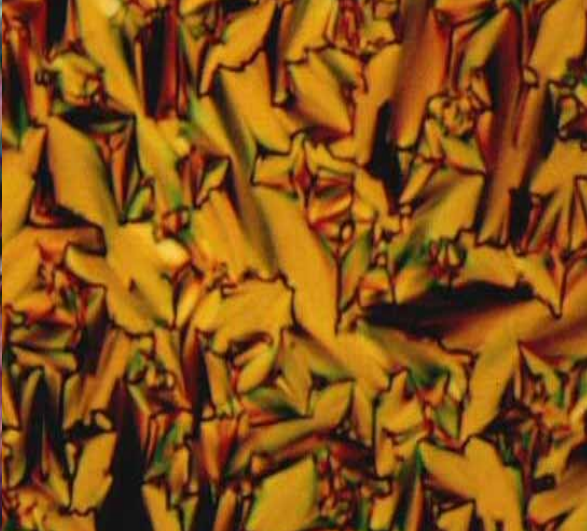


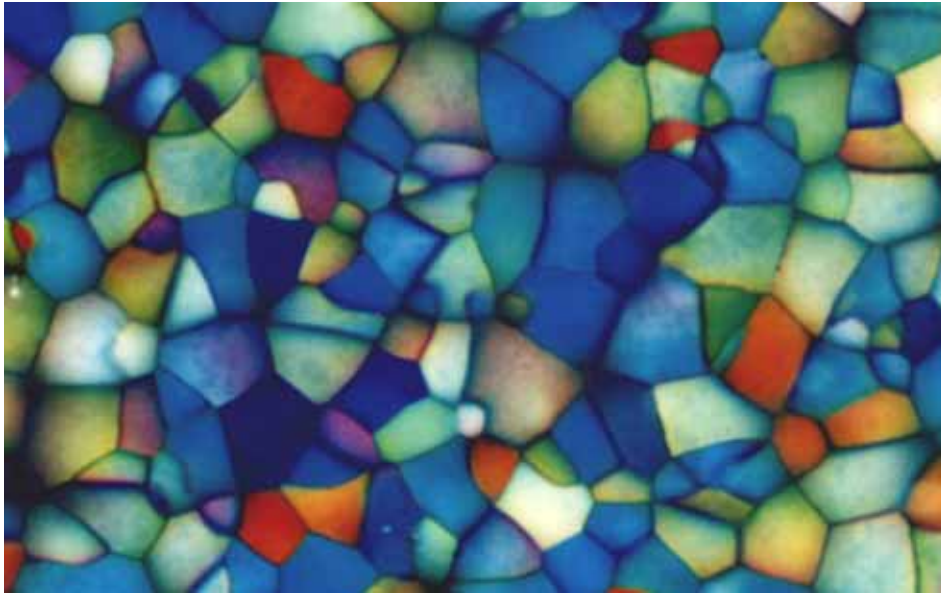
低ツイスト条件 暗表示時（選択電圧印加時）



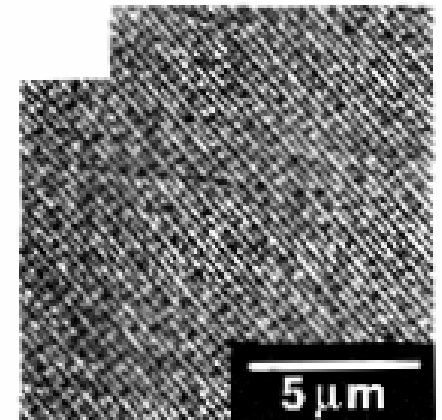
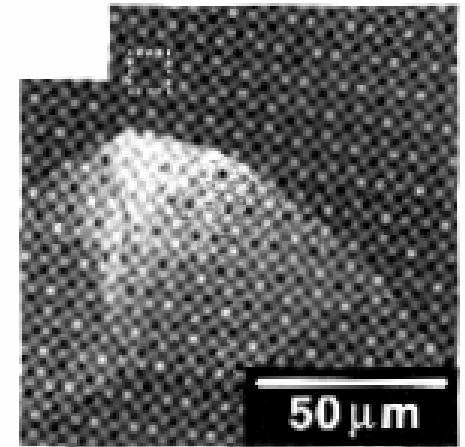
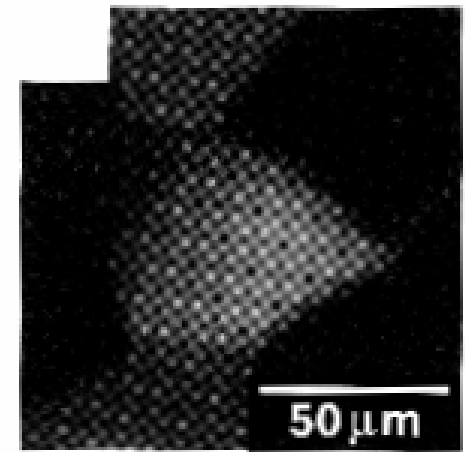
1. 扭轉角在0~12度
2. $\Delta n \cdot d = 0.37 \pm 0.05 \mu m$







平板狀BP相



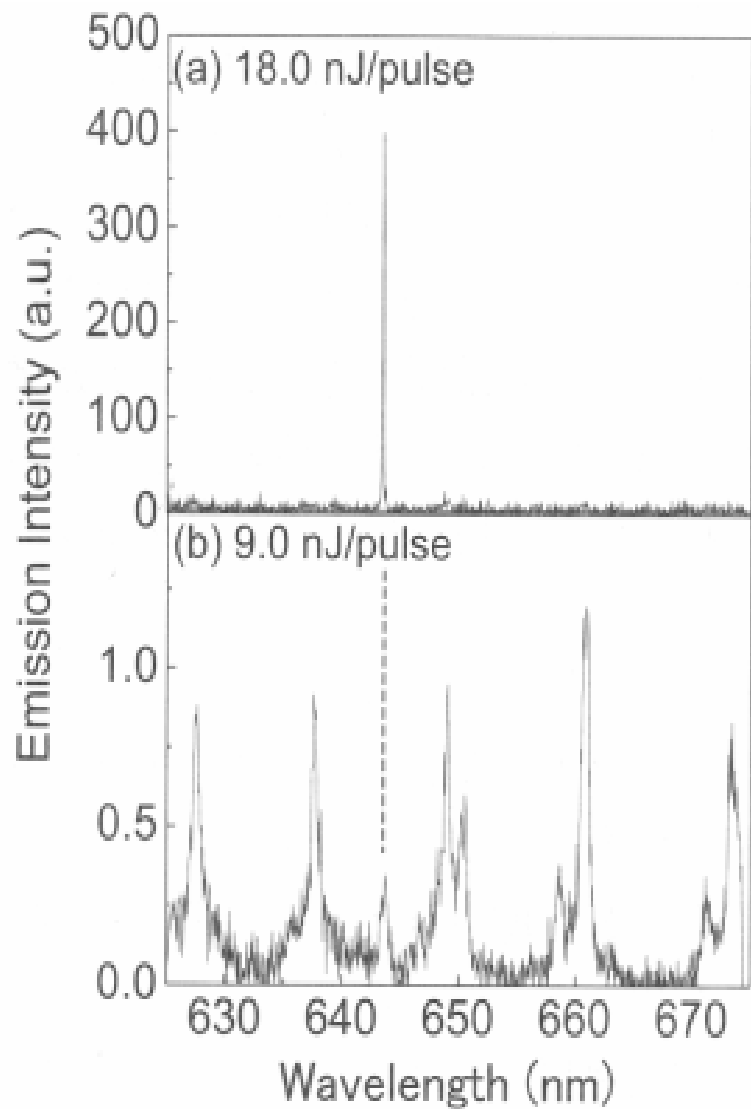
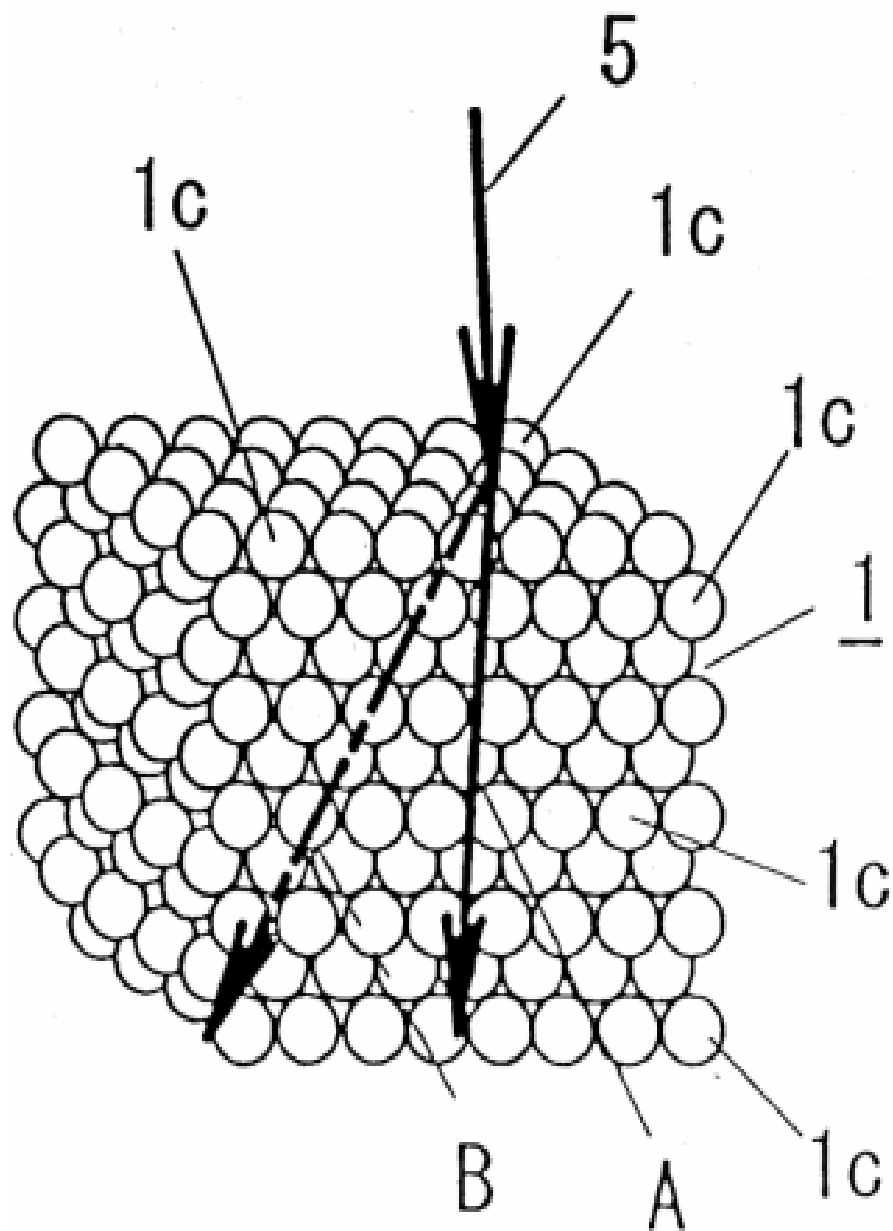
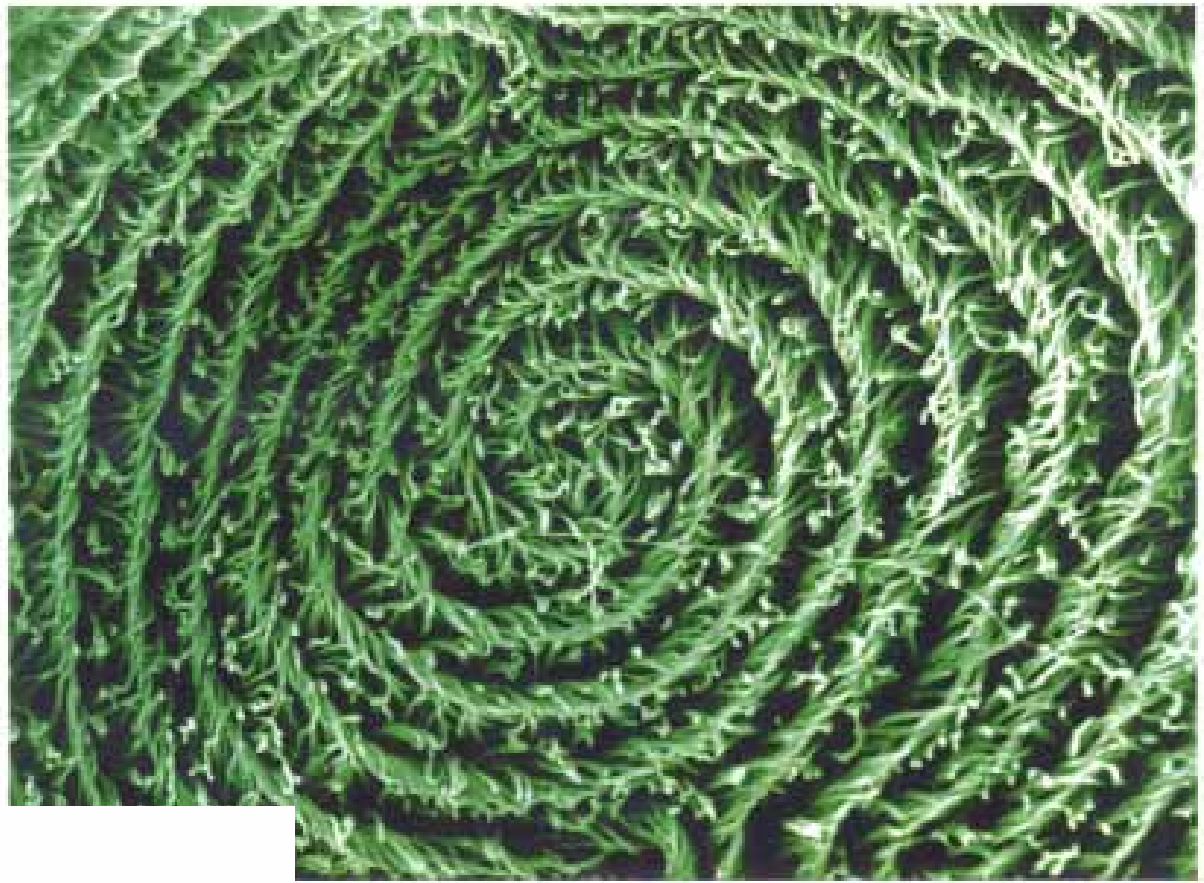
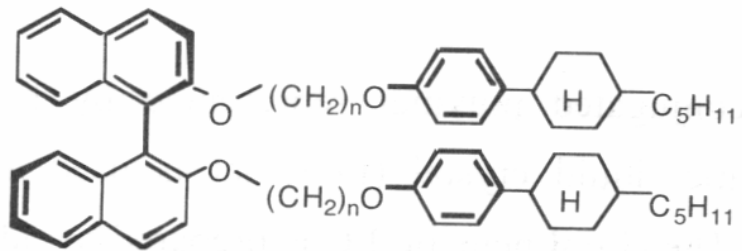


図 3 複合型フォトニック結晶の発光スペクトルの励起光強度依存性



2 μm

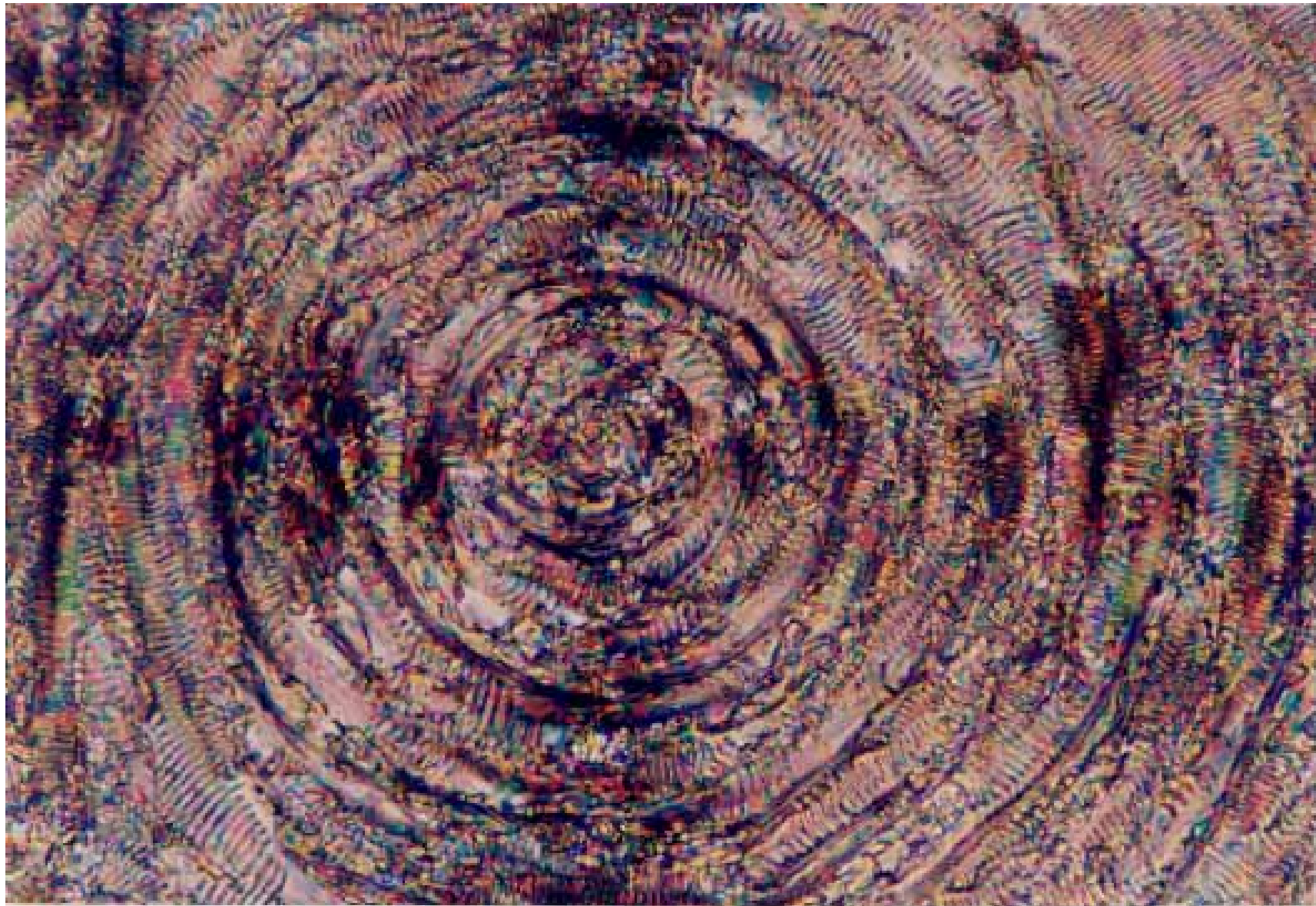


1 ($n = 6$), **2** ($n = 12$)

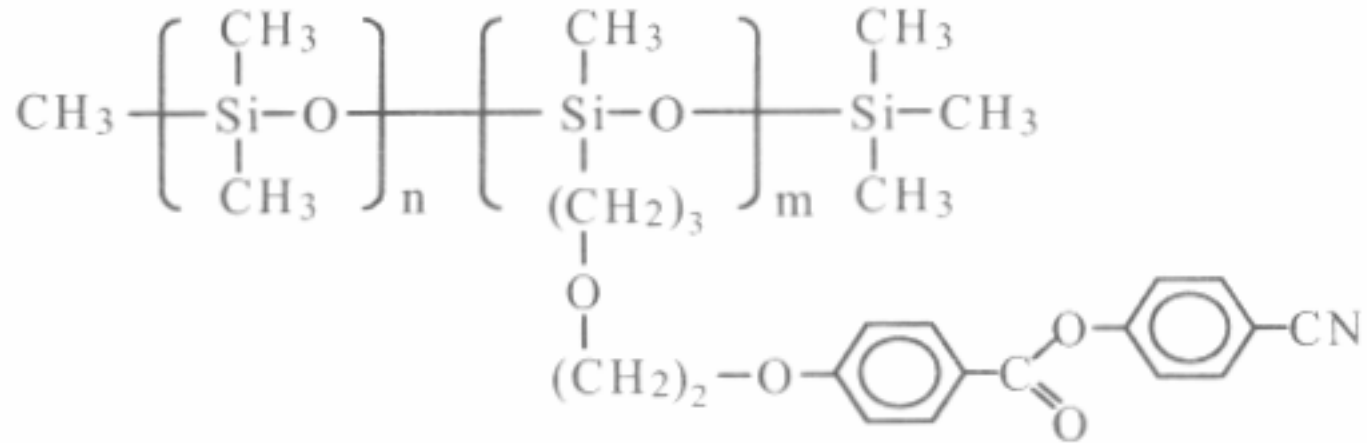
リアセチレン薄膜の走査型電子顕微鏡 (SEM) 写真



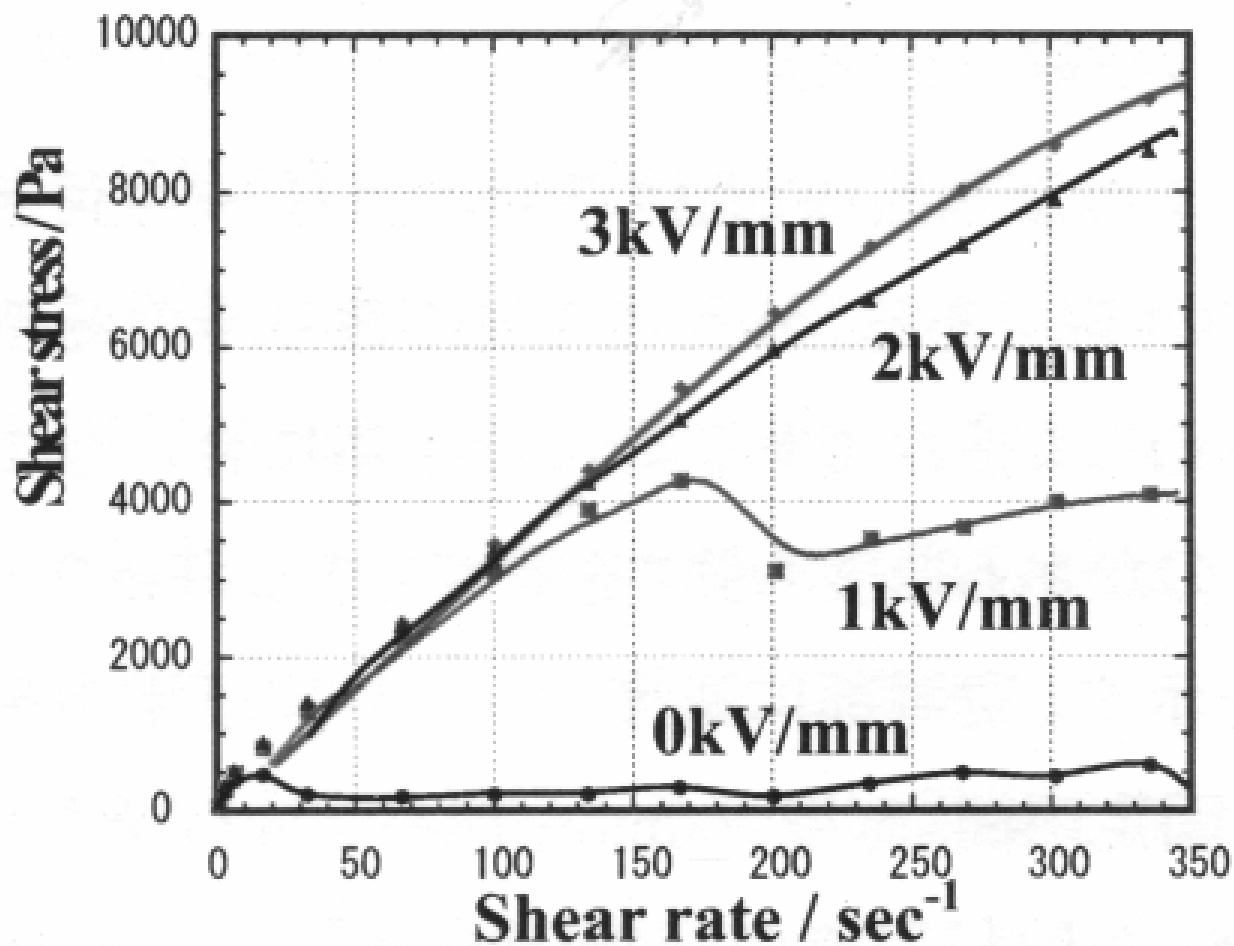




Electro-Rheological fluids based on liquid crystalline polymer

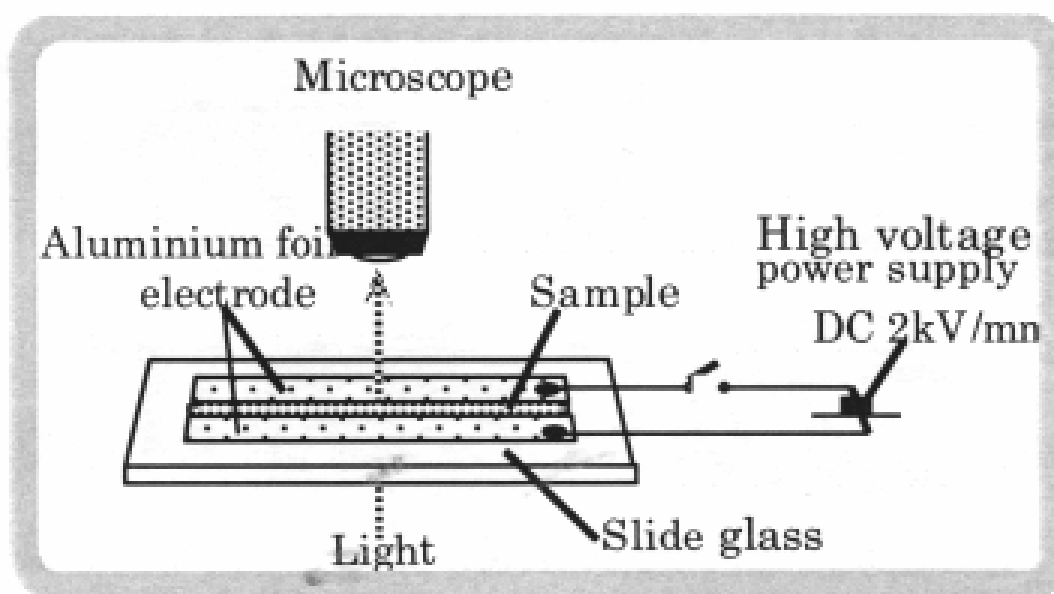


Basic molecular structure of LCS

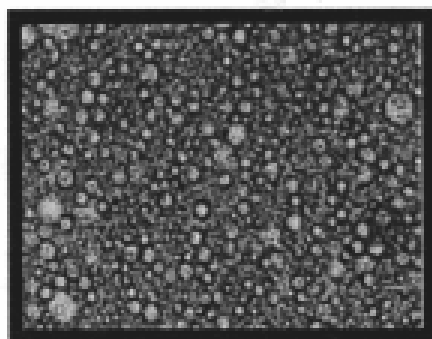


ER effect of LCS diluted with DMS.





< Before application >

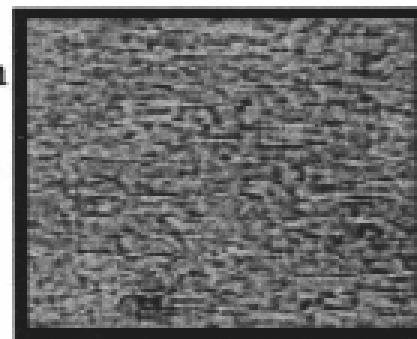


Application



Electric field

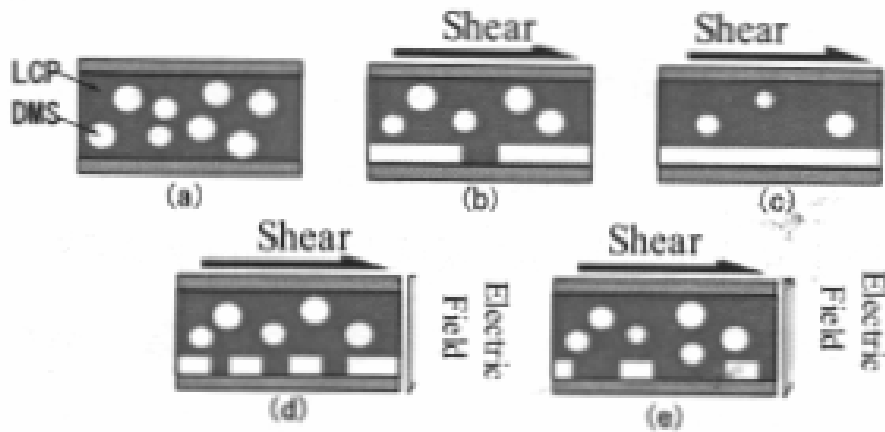
< After application >



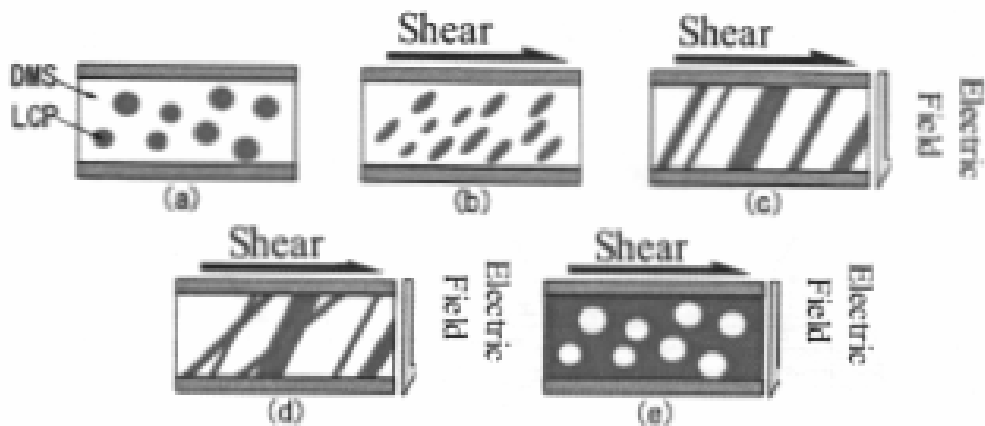
Field direction

Microscopic observations of morphological changes of Type B

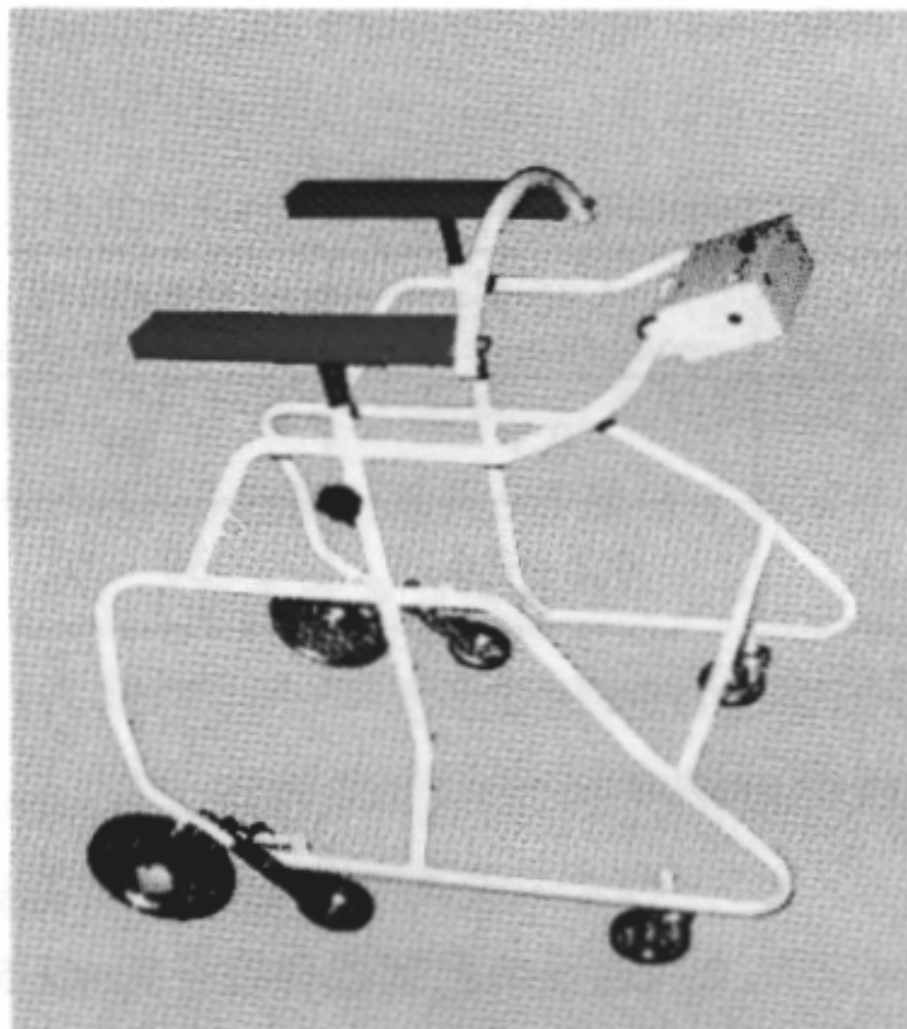




1) ER effect generation mechanism of type A

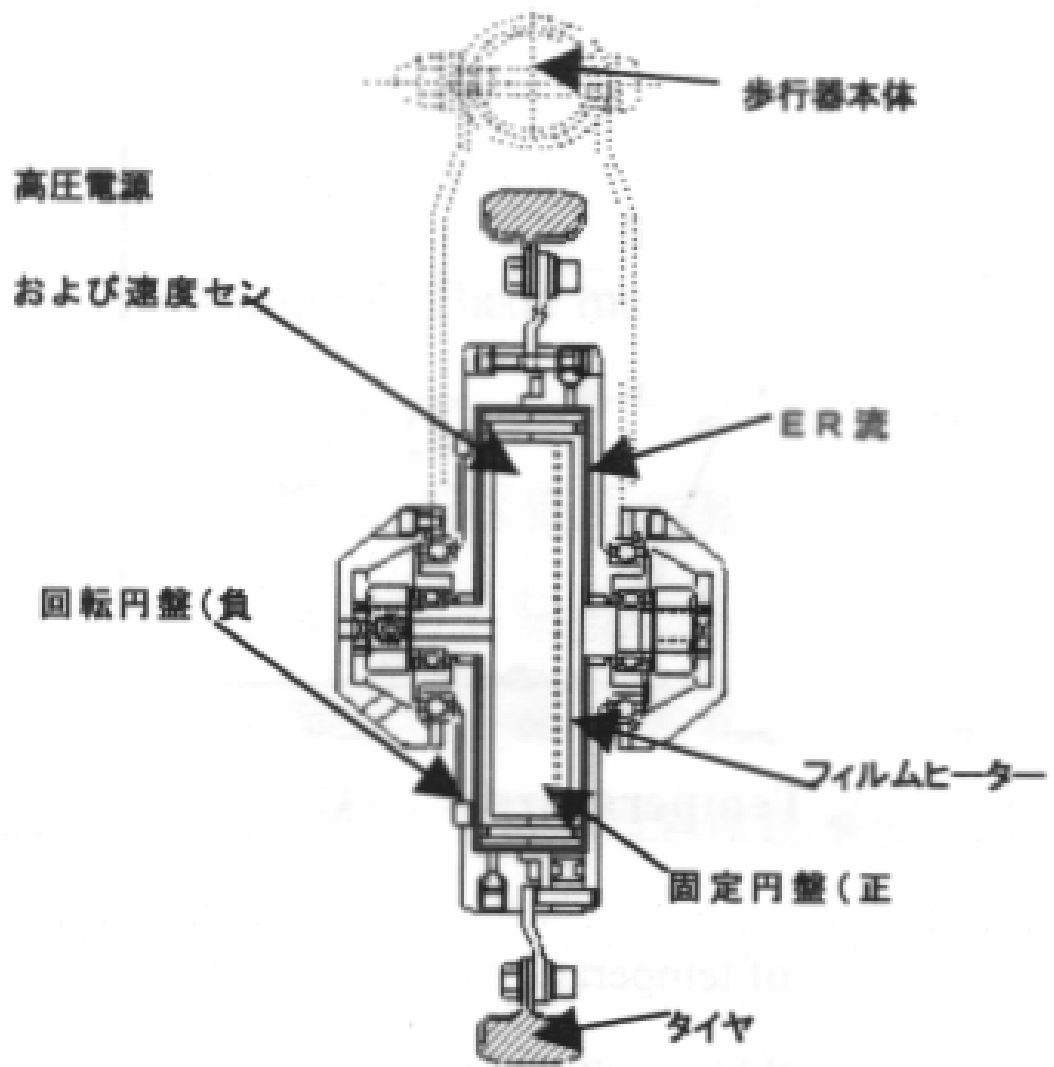


2) ER effect generation mechanism of type B



Caster walker with ER fluid brakes

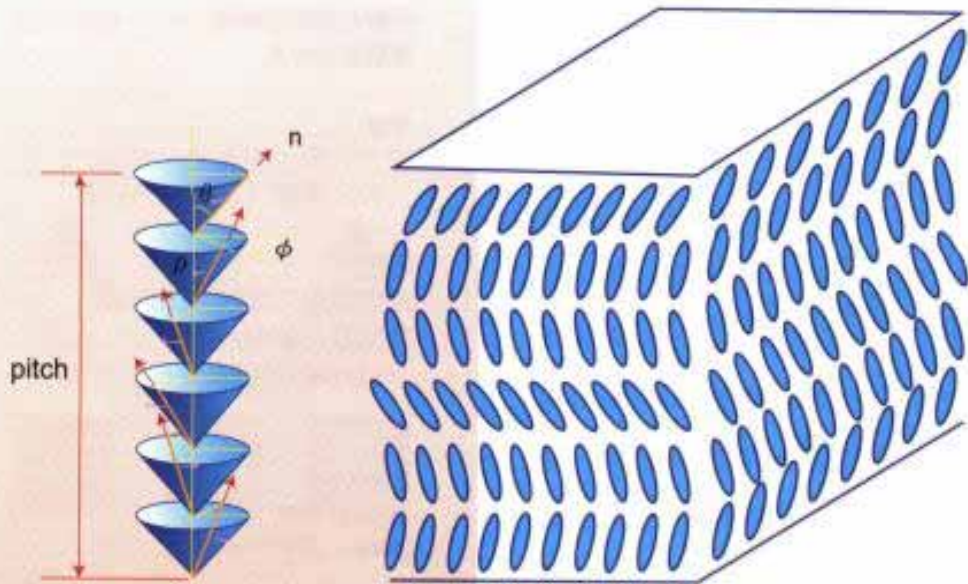
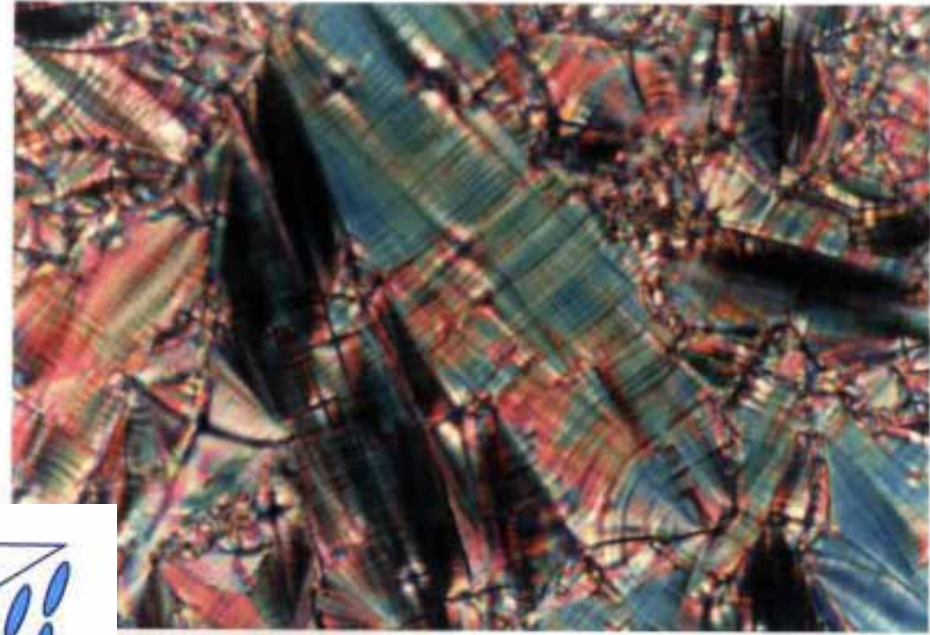




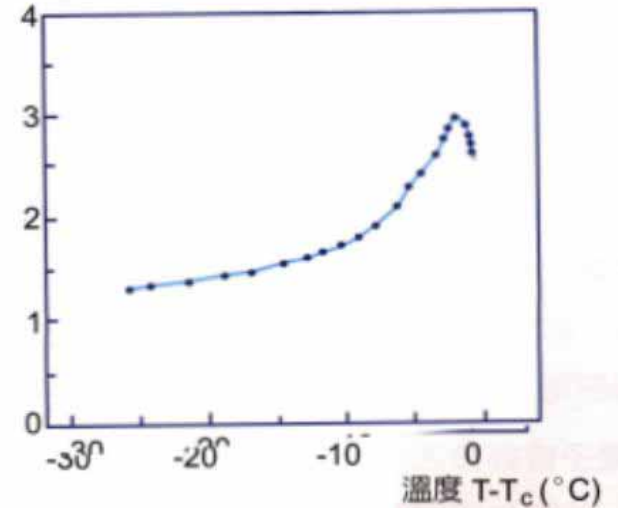
Cross sections of brake and wheel

強誘電性液晶

Ferroelectric LC
Chiral smectic C

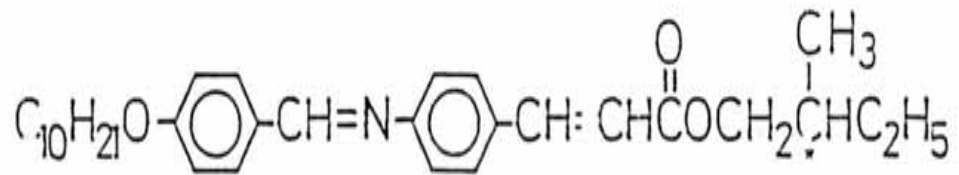
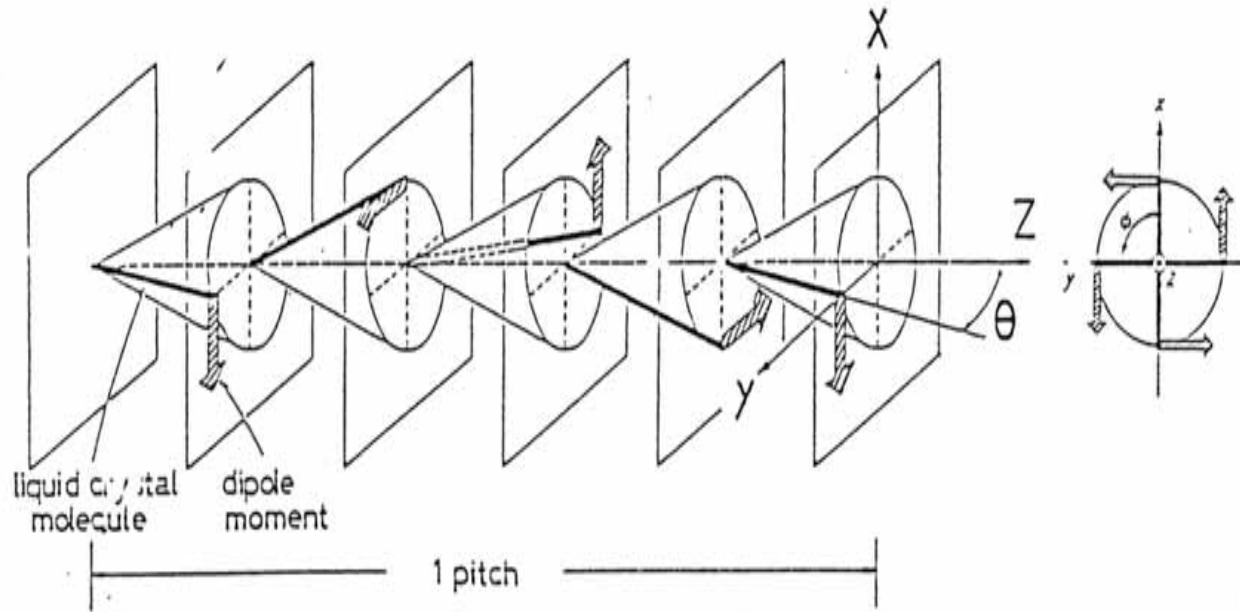


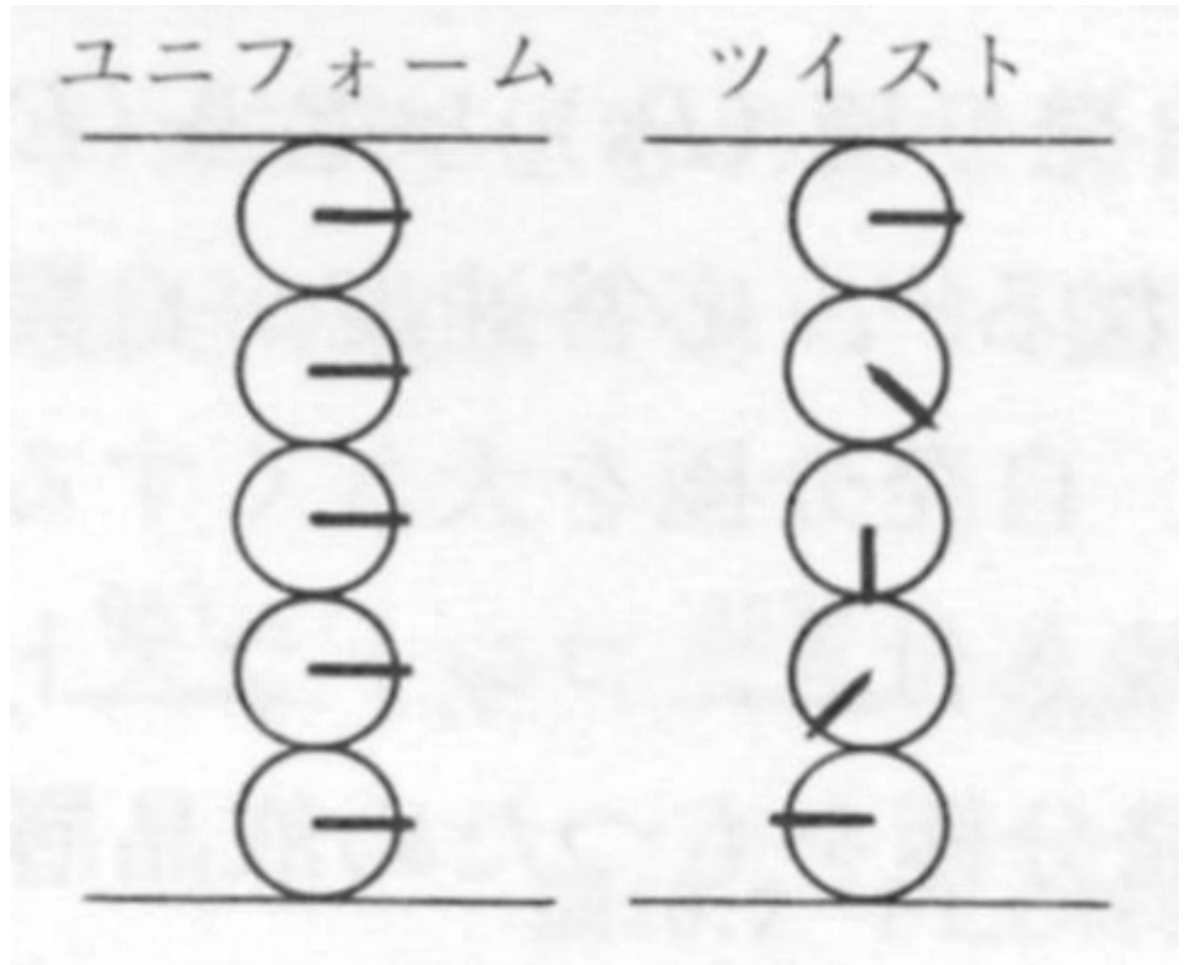
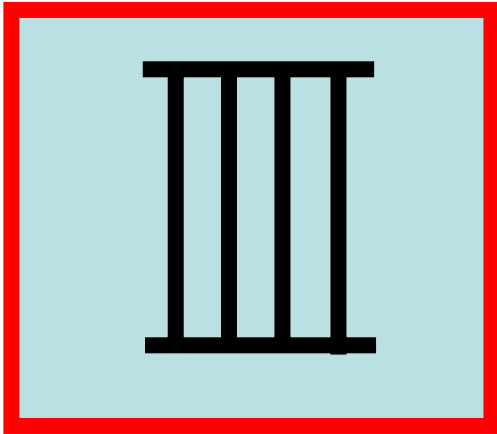
圖二：強誘電性液晶的螺旋構造

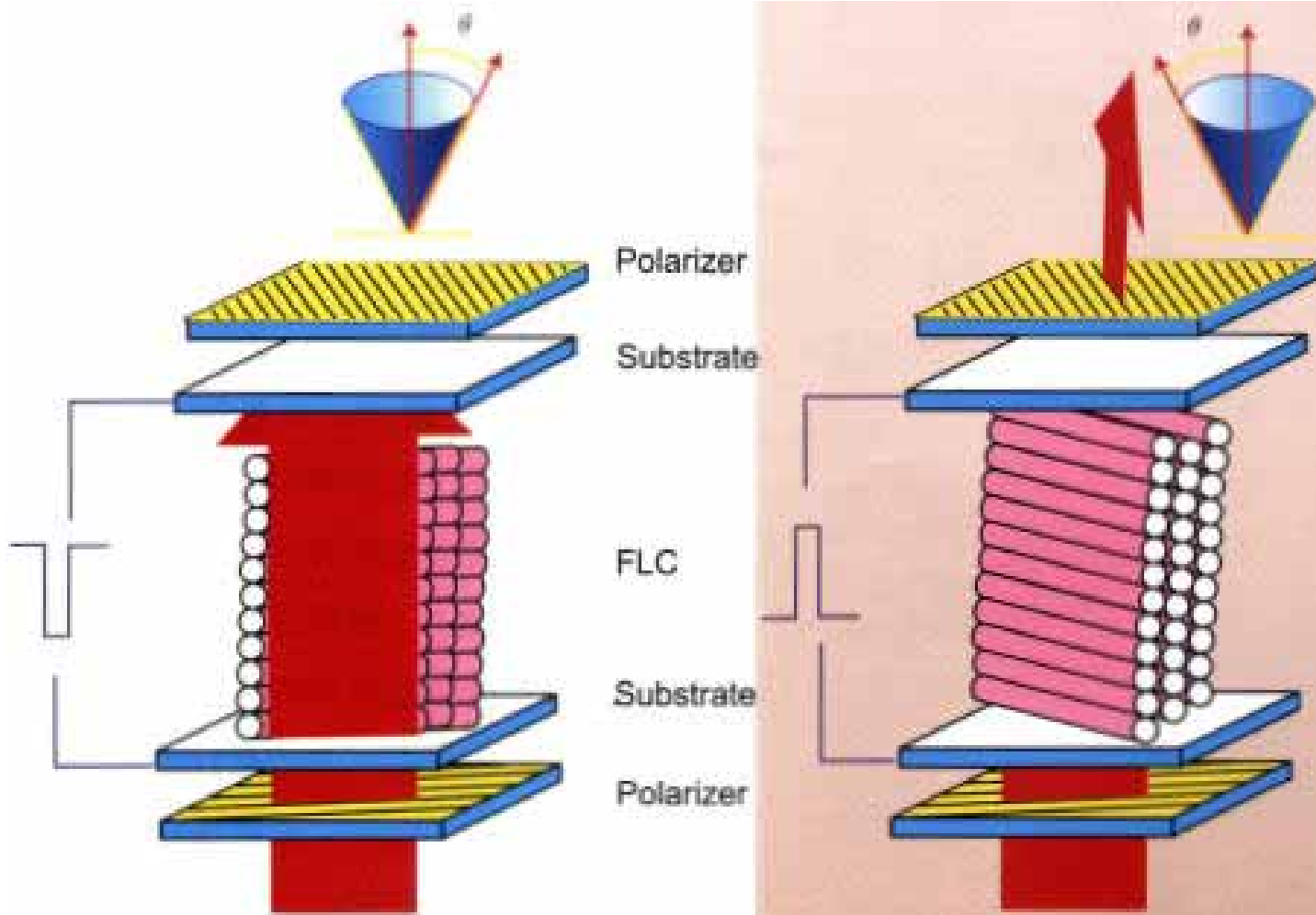


圖三：強誘電性液晶螺旋節距的溫度依存性

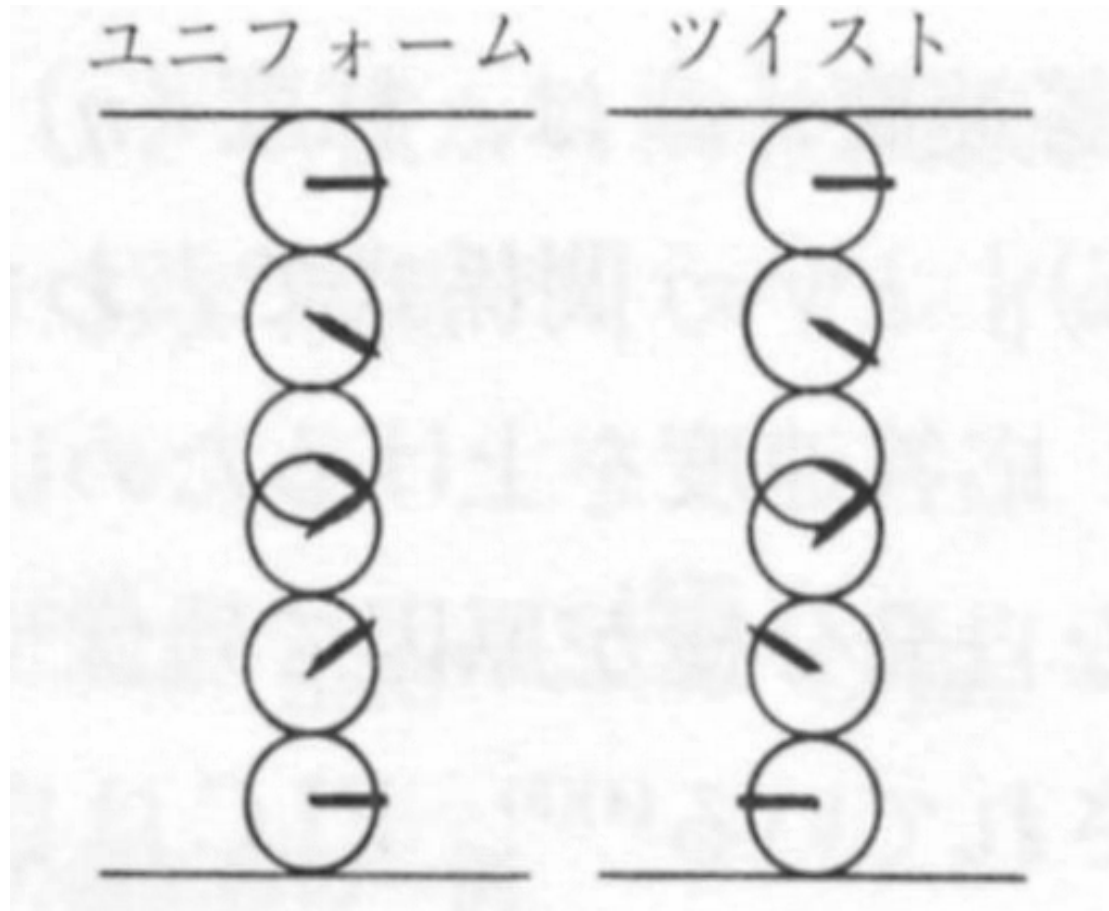
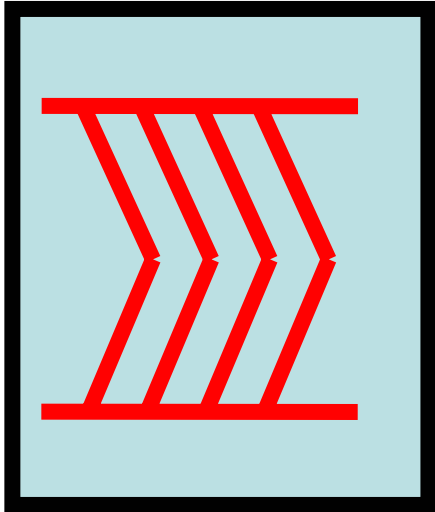


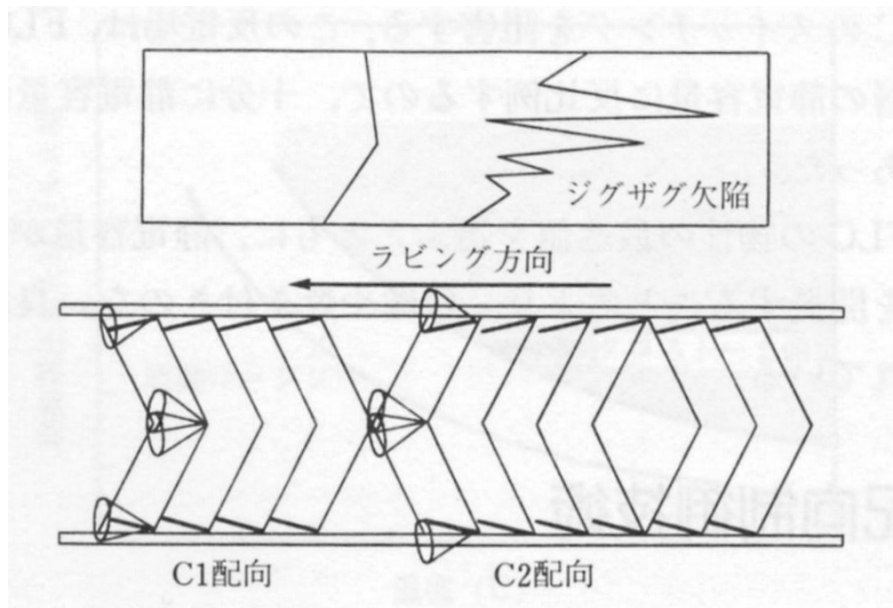




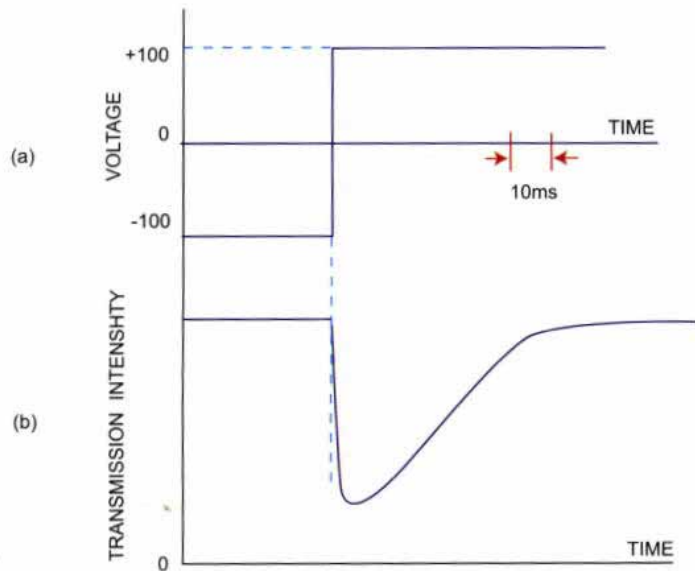


圖四：表面雙安定的強誘電性液晶顯示器

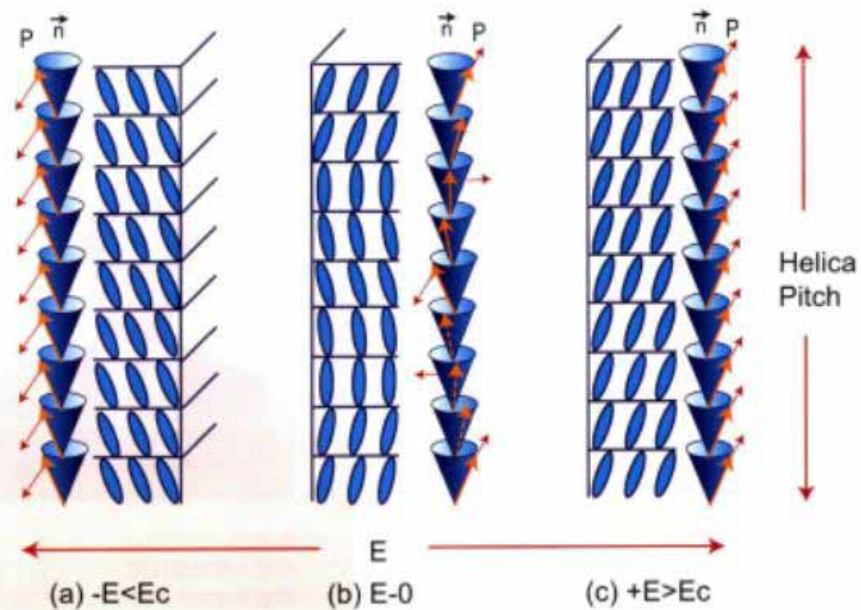




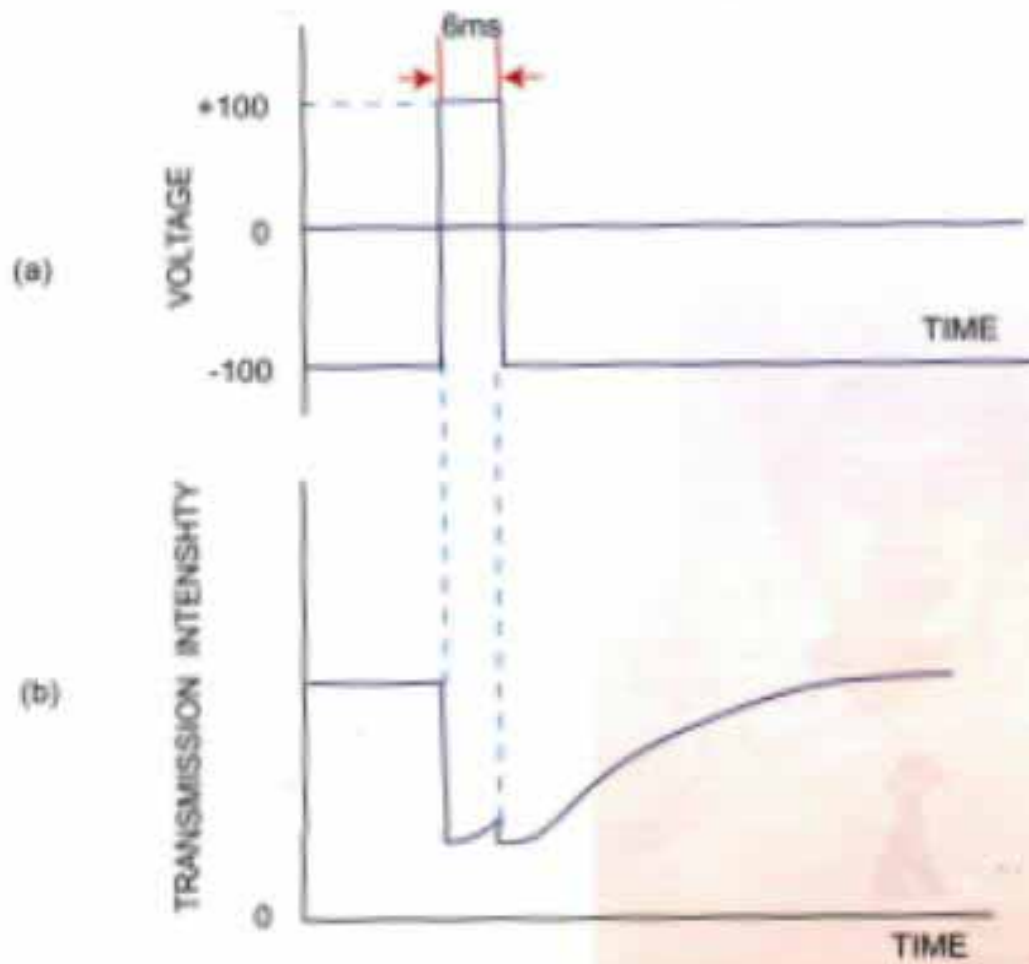
■ 正負電場切換的光場強 (圖一)



■ 分子運動模型 (圖二)



■ 單一脈衝電壓響應 (續)



■ TSM元件 (■三)

