光電科學與工程學系
Department of Optics and Photonics

節能型液晶光電元件與應用

Bistability!!

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Why Bistability?

http://www.nipic.com

Why Bistability?

Zero Power LCD Technology

- A bistable state, maintained without energy consumption, represents a storage or a memory effect. Thus, bistable displays are able to realize an image memory at zero field, similar to a page of a book.
- Bistable liquid crystal displays can be developed by utilizing ferroelectric, cholesteric, or nematic liquid crystals.

electronic tags

bistability at zero voltage,
low driving voltage,
contrast ratio, etc.

Why Bistability?

E-Papers, E-Books, Watches

http://big5.51base.com/electron/adhibition/biaoqian/20090410115265.shtml

Brief introduction to LCs

大型、薄型、窄邊框與高解析度顯示器

LCD持續朝大尺寸與高解析度發展，群創光電(Innolux)展示了全台灣最大的100吋4K2K (3840x2160畫素)LCD電視模組，另有85吋(預計明年Q2量產)及75吋(已量產)的4K2K LCD TV。繼去年展出台灣首發之65吋8K4K (7680x4320畫素)LCD面板後，群創此次展示了量產型的65吋8K4K LCD。

量產型的65吋8K4K LCD http://www.materialsnet.com.tw/

Brief introduction to LCs

LCD持續朝大尺寸與高解析度發展，群創光電(Innolux)展示了全台灣最大的100吋4K2K (3840x2160畫素)LCD電視模組

100吋4K2K (3840x2160畫素)LCD電視模組

http://www.materialsnet.com.tw/

Brief introduction to LCs

友達光電(AUO)展出全球第一個無邊框(Bezel-less)的65吋曲面8K4K LCD電視，曲率半徑為4公尺(需夠薄才能彎曲)。

http://www.materialsnet.com.tw/

Brief introduction to LCs

凌暉在商品櫃前設置透明顯示器，不但能呈現商品的原貌，也可以動態的方式展現產品的特性，並在吸引消費者目光時達到廣告的效果

使用透明顯示器的商品櫃

材料世界網 http://www.materialsnet.com.tw/

Brief introduction to LCs

醫學領域之應用

今年的展會上，友達與群創兩大公司都展出了醫學用的2Mega Color(即一般稱為FHD的1920×1080)及3Mega Color (即QXGA 2048 × 1536)顯示器；Mega Color簡寫為MC，其數值是將兩軸畫素數目的乘積取約略的數而得，例如1920×1080≈200萬=2Mega。下圖為友達展示的3MC顯示器，具有非常清晰而美麗的畫面。

http://www.materialsnet.com.tw/

Brief introduction to LCs

車用面板位置功能示意圖

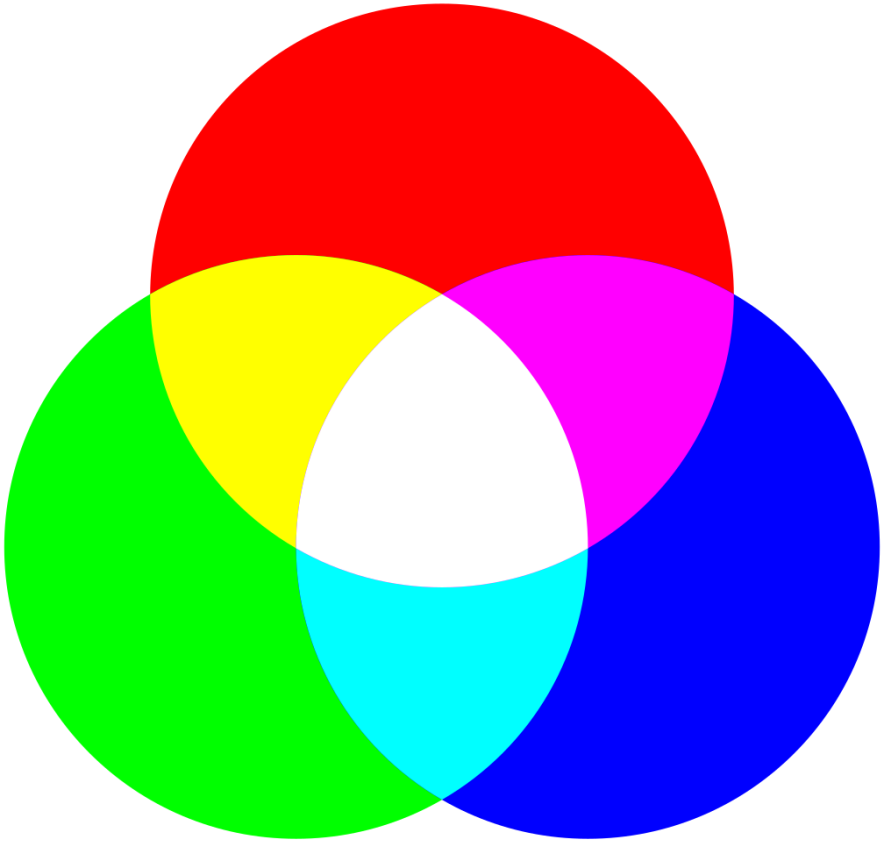
Audi A6L
儀錶板
顯示功能

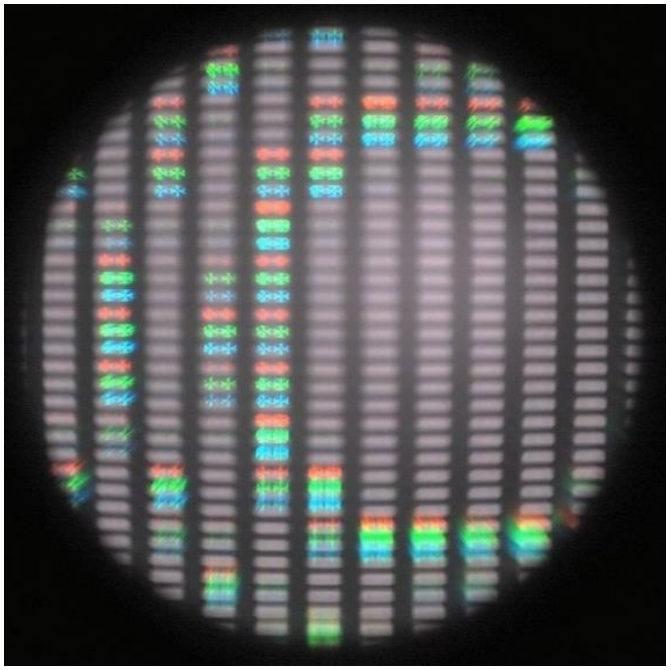
TESLA Model S
中央控制面板
顯示+觸控

Mercedes-Benz S-Class
後座娛樂裝置面板
前座雙顯示螢幕
顯示+觸控

http://www.materialsnet.com.tw/

Brief introduction to LCs

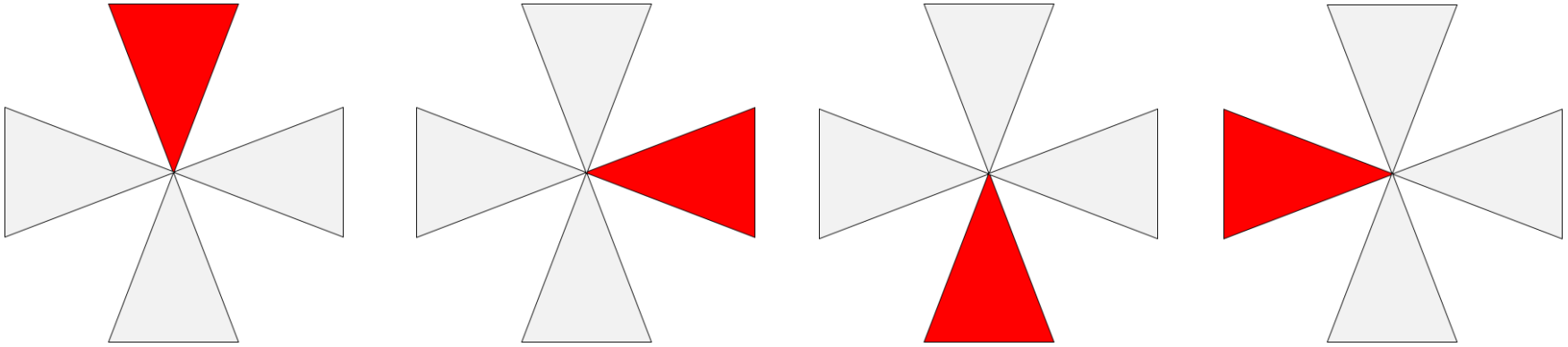




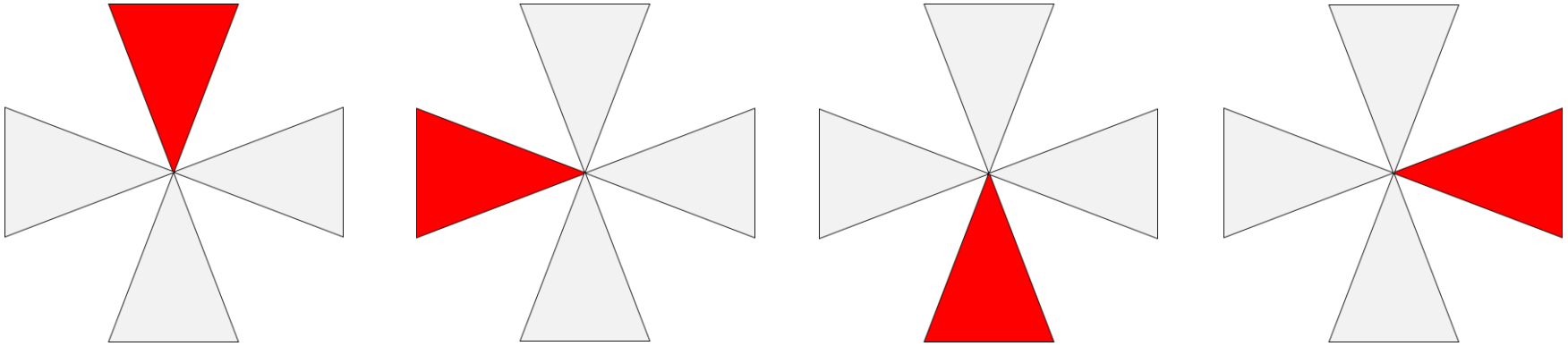
RGB + W/Y?

Brief introduction to LCs

0.25 cycle / unit time

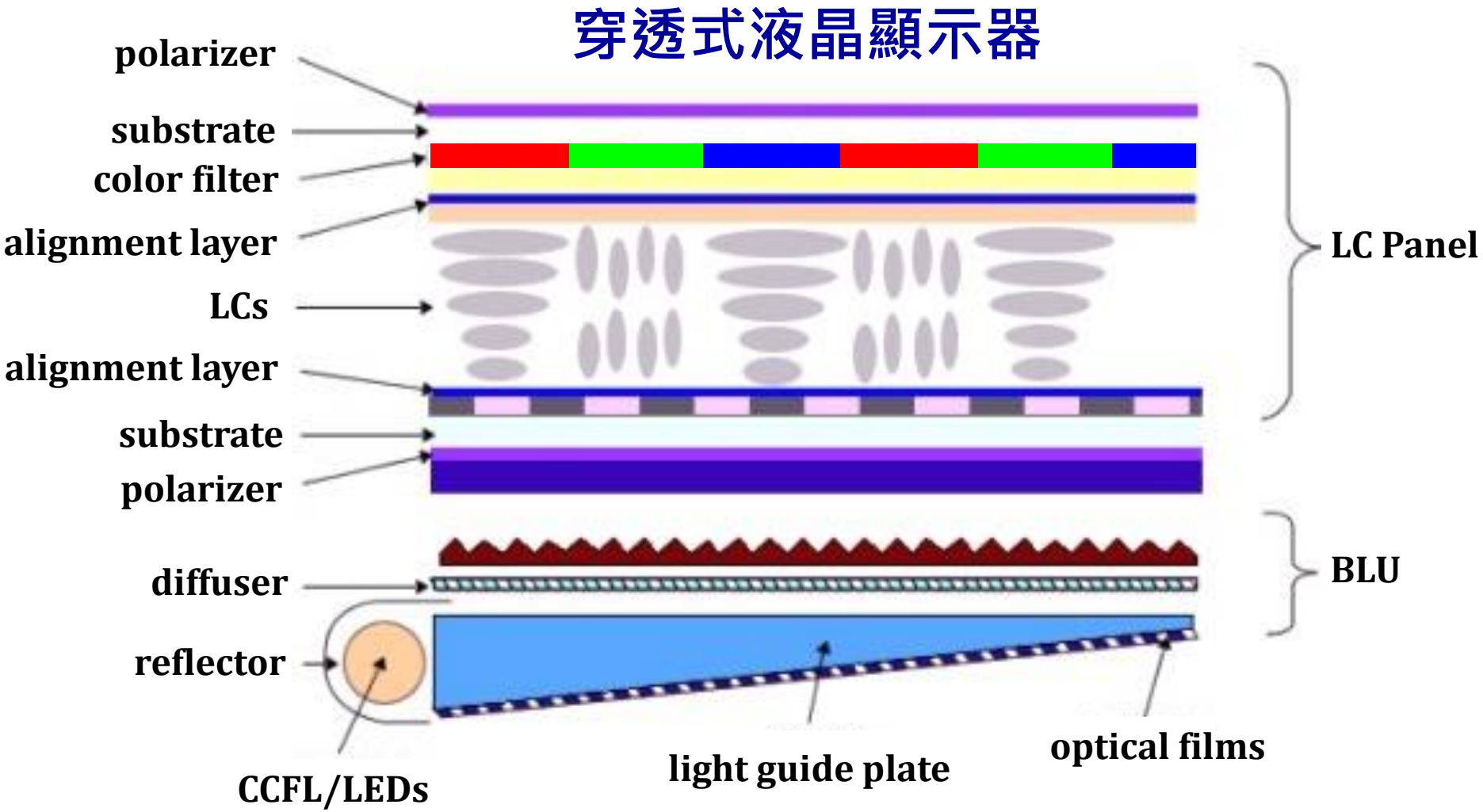


0.75 cycle / unit time



Clockwise rotation!!

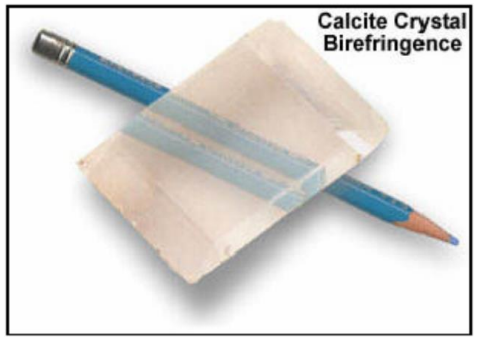
Brief introduction to LCs



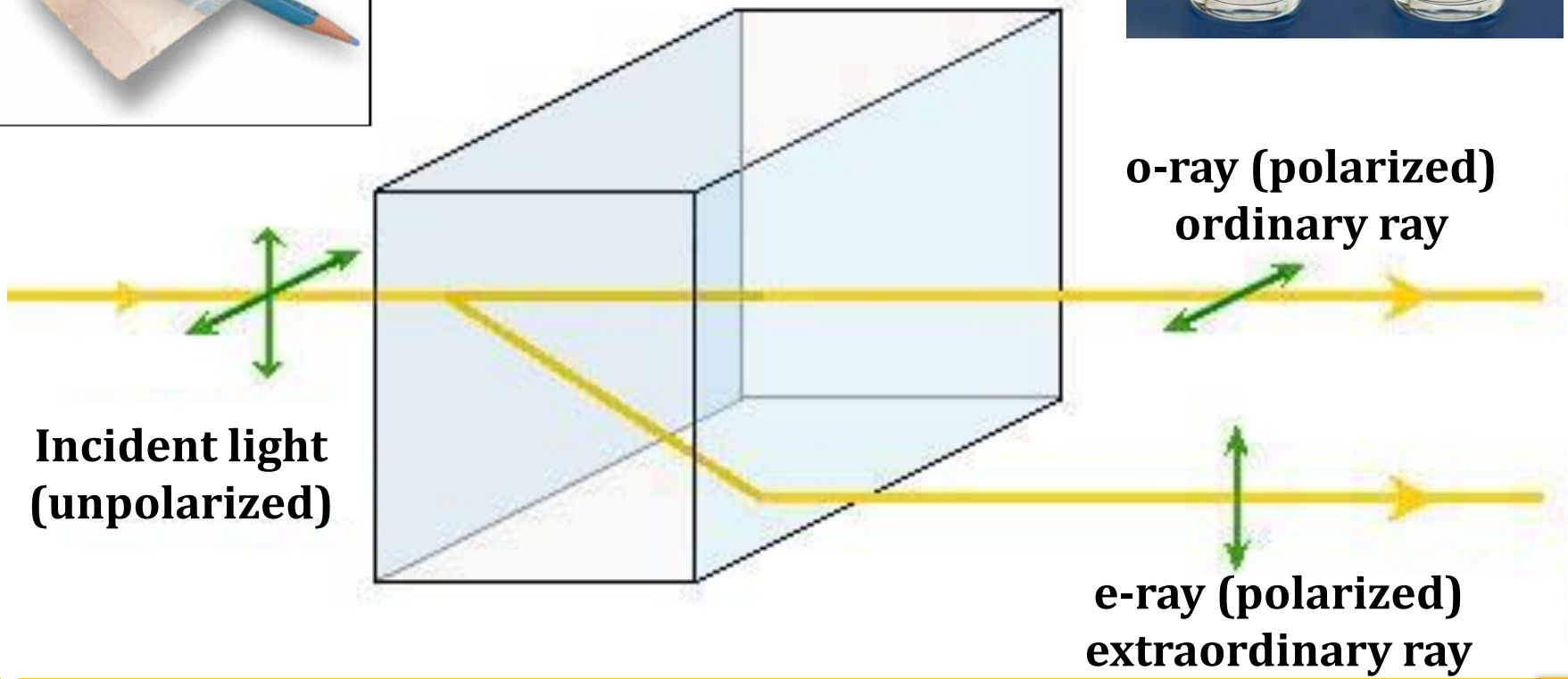
http://cdnet.stpi.org.tw/techroom

Brief introduction to LCs

雙折射 (Birefringence)

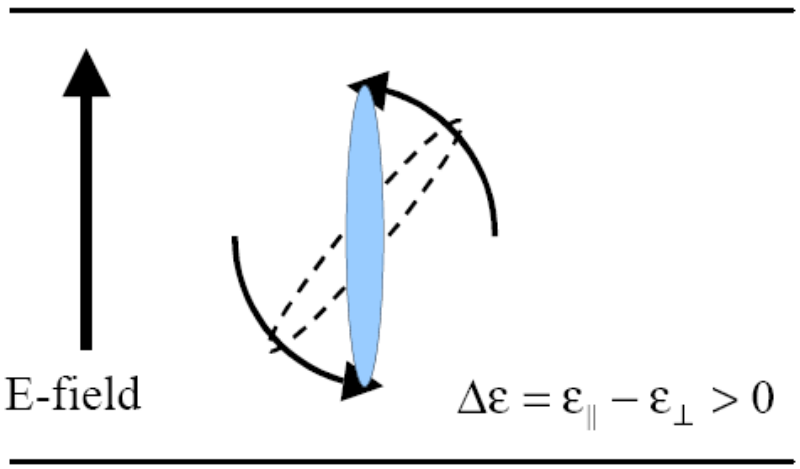


$$\Delta n = n_e - n_o = n_{eff}(V,T,\lambda) - n_o$$

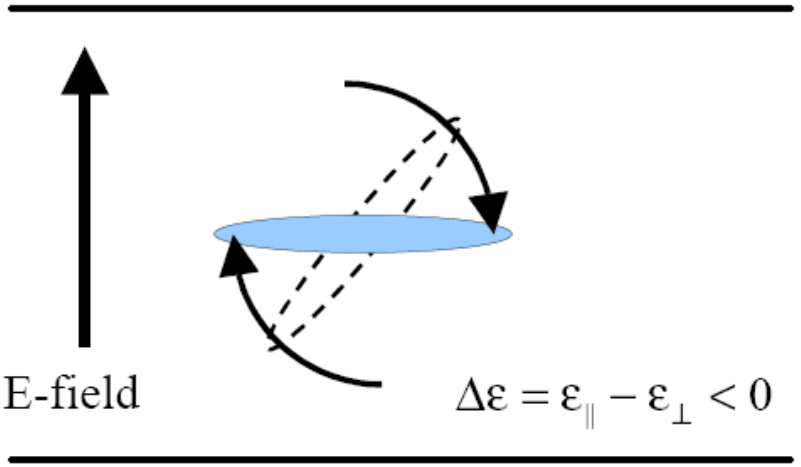


Brief introduction to LCs

Dielectric Anisotropy



Twisted nematics, homogeneous alignment, in-plane-switching, etc.



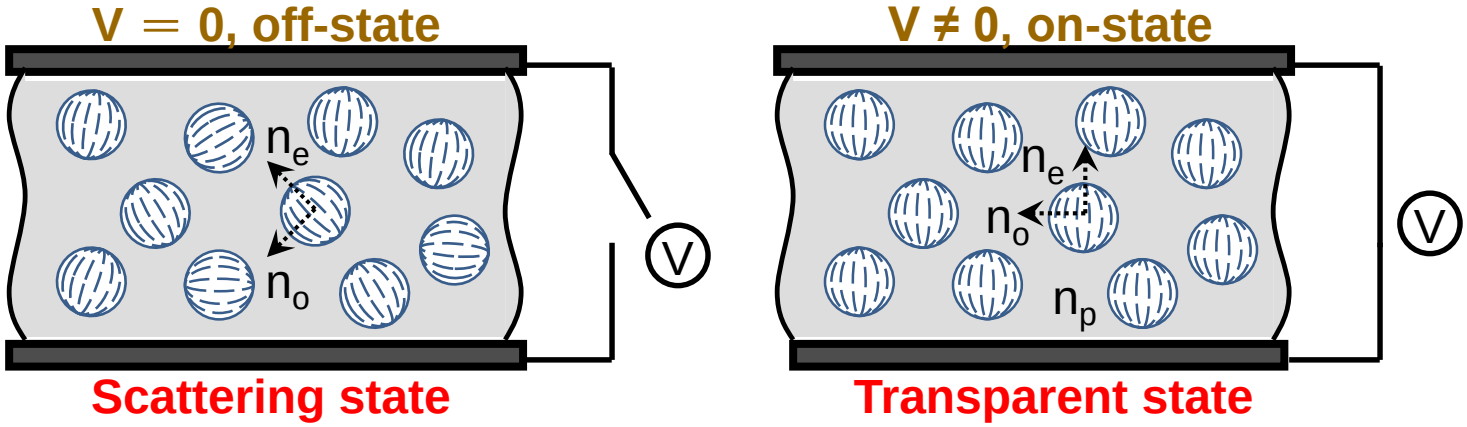
Vertical alignment, dynamic scattering, etc.

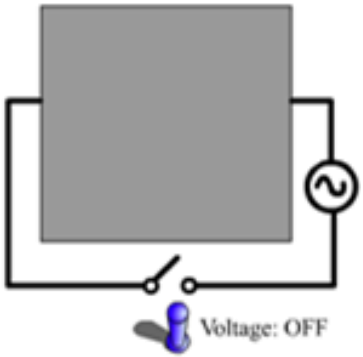
Brief introduction to LCs

Scattering Mode Light Shutters (cell gap, operating voltage)

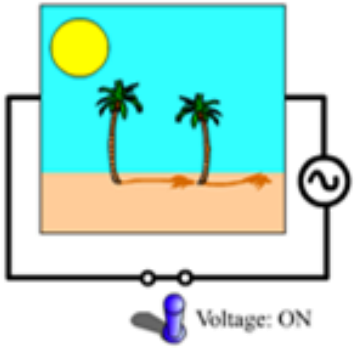
Polymer Dispersed Liquid Crystal (PDLC)

PBT (polymer ball type); LCDT (liquid crystal droplet type);
LCDT (LC droplets dispersed in a continuous polymer matrix)





$n_p \sim n_o \neq n_e$
$\Delta\varepsilon > 0$



Brief introduction to LCs

An application of scattering mode light shutters

Company: Polytronix™ Inc. (USA)

Products: Switchable Privacy Glass

Specification: Driving voltage ~65 V (AC)
Transmission ~75 %
Switching time ~100 ms

Brief introduction to LCs

Brief introduction to LCs

Meeting room

Auto Sunroof

Brief introduction to LCs

V_{ON} V_{OFF}

http://www.stanleyglass.com.tw/

Brief introduction to LCs

LUXGEN 7 CEO

擋風玻璃??!!

http://www.carstuff.com.tw/drive-test/item/847-luxgen-luxgen7-ceo.html

Bistable LCD devices

- Surface Stabilized Ferroelectric LCs (表面穩定鐵電型液晶);
- Chiral Nematic Liquid Crystals: Cholesterics (膽固醇液晶);
- Uniform Lying Helix Textures (均勻橫向螺旋結構);
- Polymer Stabilized Cholesteric Texture (聚合物穩定型膽固醇液晶);
- Bistable Nematic (Bi Nem) LCDs (雙穩態向列型液晶);
- Bistable Smectic A LCDs (雙穩態近晶A型液晶);
- Bistable Twisted-Untwisted Nematic (BTN) LCD 雙穩態扭轉向列型液晶;
- Spontaneous Homeotropic Alignment (自發性垂直配向);
- Gelators: Self-assembling (自組織材料);
- Mesoporous in LCs (中孔洞材料);
- Photo-alignment Technique (光配向技術);
- Photoisomerization Effects (光同素異構化技術);
- Dynamic Fingerprint Chiral Textures (動態手紋結構);
- Electrophoretic Displays (EPD), E-ink (電泳式顯示器);
- Electrowetting Display (EWD) (電濕潤式顯示器).

Boogie Board

2010年開始量產的Boogie Board是一種用於替代傳統書寫的新型電子紙，隨著它的推廣普及，勢必為建設低碳環保的綠色地球做出貢獻。

Boogie Board產品秉承科技，綠色，環保，時尚的理念，能夠適用於任何需要紙張的場合。可以替代五萬張稿紙，一鍵擦除，資訊保密。

一直以來，紙和筆的搭配被看作是書寫資訊最快速和最簡潔的方式，不過隨著時間的流逝，人們已經開始尋找更好的書寫載體。而Boogie Board就能夠實現無紙無筆書寫，用科技延伸著紙張的未來，是傳統和時尚的交融。

該產品最大的亮點就是採用了低功耗的柔性液晶技術，這種液晶屏源自世界上第一條卷對卷(roll to roll) 的LCD生產線。不僅功耗極低，可視角大，不需要偏光片，依靠外界光線就能夠呈現完美的書寫筆跡；極高的書寫精度和靈敏度可以媲 美硬筆書寫的效果， 除了具有在紙上書寫的感覺又區別於傳統的紙張，能夠給你帶來無窮的書寫樂趣。Boogie Board還通過了FCC, CE以及毒性安全認證，證明是一款安全，綠色的產品。可廣泛的用於無紙辦公，商務備忘，家庭留言，文字溝通，輔助學習等領域。

http://www.boogieboard.com.tw/

Boogie Board

[一指清除，輕鬆愛地球。]

Boogie Board
LCD Writing Tablet

1.不需擔心影像消失－鎖住你的清除鍵，防止誤觸! NEW

2.隨身帶著你的觸控筆-內建式筆架，可放置你的觸控筆 NEW

3.用你最喜歡的吊飾妝點你的Boogie Board. NEW

4.超低電子損耗-可更換2 AAAA電池，超過10,000次清除! NEW

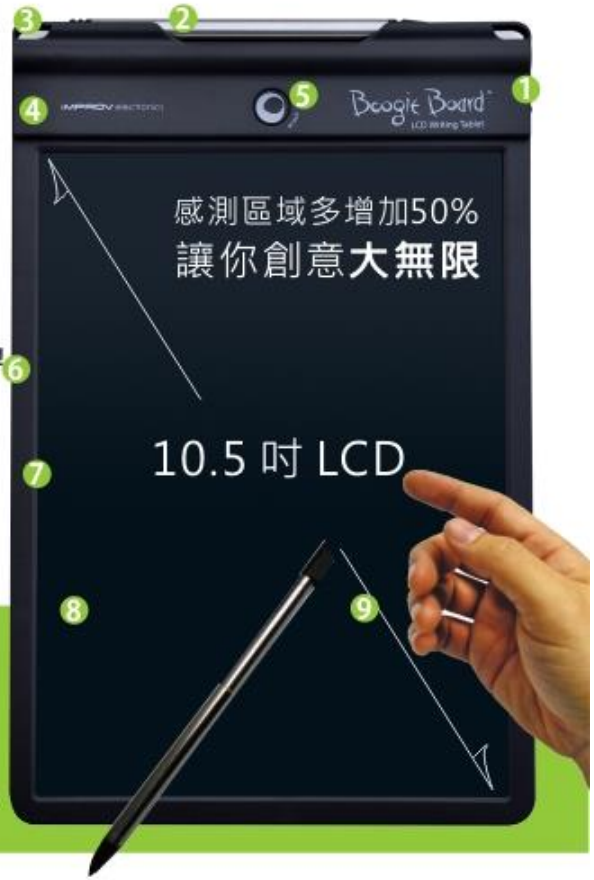
5.Erase一鍵清除，按下erase鍵即可清除影像，輕鬆、方便、省時、酷!

6.低於0.6公分的超薄設計，讓你攜帶方便，無論放在公事包、背包或手提包!

7.外殼及面板使用無毒耐用塑膠材料，耐刮、耐磨、耐摔，讓您安心使用!

8.壓力感測板-可以讓您依照使用筆觸的大小來決定線條的粗細!

9.無論是附贈的不鏽鋼筆或是您的手指，均可在Boogie Board上任意塗鴉!



Boogie Board 10.5吋震撼登場。
環保、便利、新概念書寫。

http://www.boogieboard.com.tw/

Boogie Board

線圈筆記本和便條紙都成為歷史。
現在您無需犧牲書寫手感，就可一頁又一頁的創作數位筆記和圖畫。
Boogie Board Sync 9.7儲存您的影像，並以無線的方式傳輸到您的手機、平板電腦或是透過藍芽傳送到電腦。
而這一切只是個開始。

創作

在Boogie Board Sync上書寫，就像您在筆記本和便條紙上，紀錄課堂筆記或會議議程的感覺一樣。

儲存

只要按個鈕，就可儲存數千張的筆記和草圖到Boogie Board Sync的內部記憶體。

同步與分享

運用電腦和手機應用程式，透過藍芽同步分享到 Evernote、電子郵件和社群媒體。

http://www.boogieboard.com.tw/

Boogie Board

The Original 10.5 eWriter

提供更多的空間讓你記下重要的訊息，解決複雜的程式或是創作你獨特的傑作。

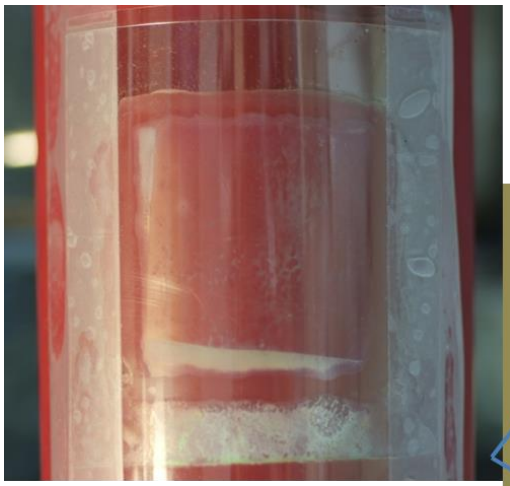
學生也喜歡利用額外的空間來寫作、算術與練習繪畫。

Boogie Board Original 10.5 是Boogie Board系列中最大的尺吋，也是辦公室最佳的小黑板。

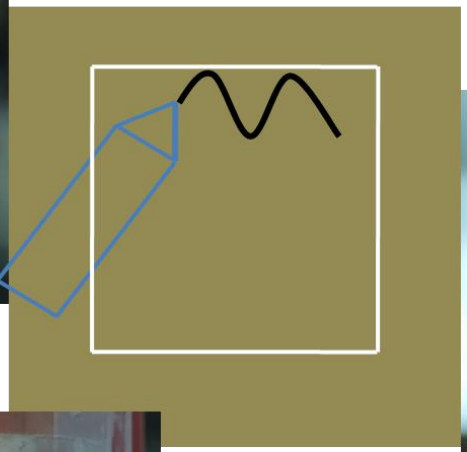
故障率低，沒電時可以換電池，是Boogie Board系列中銷售最久最實用的產品。

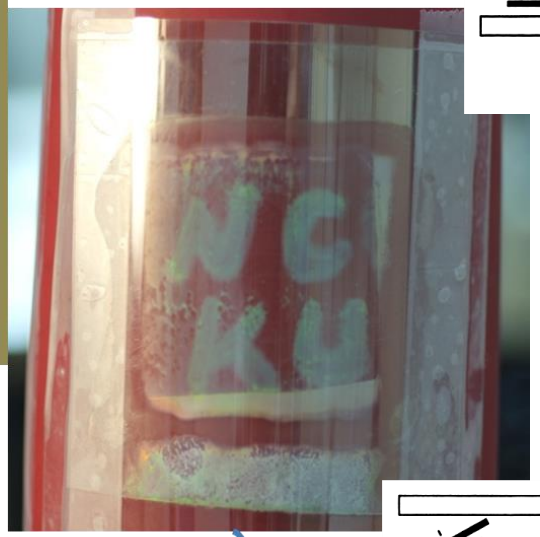
http://www.boogieboard.com.tw/

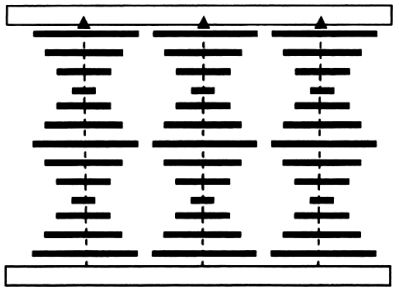
Cholesteric LCs



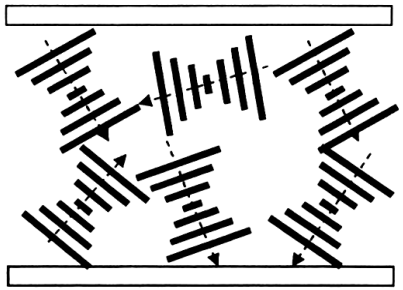
Tablet







planar texture



focal conic texture

Bistable LCD devices -DFCTs

Electrically Switchable and Permanently Stable Dynamic Fingerprint Chiral Textures

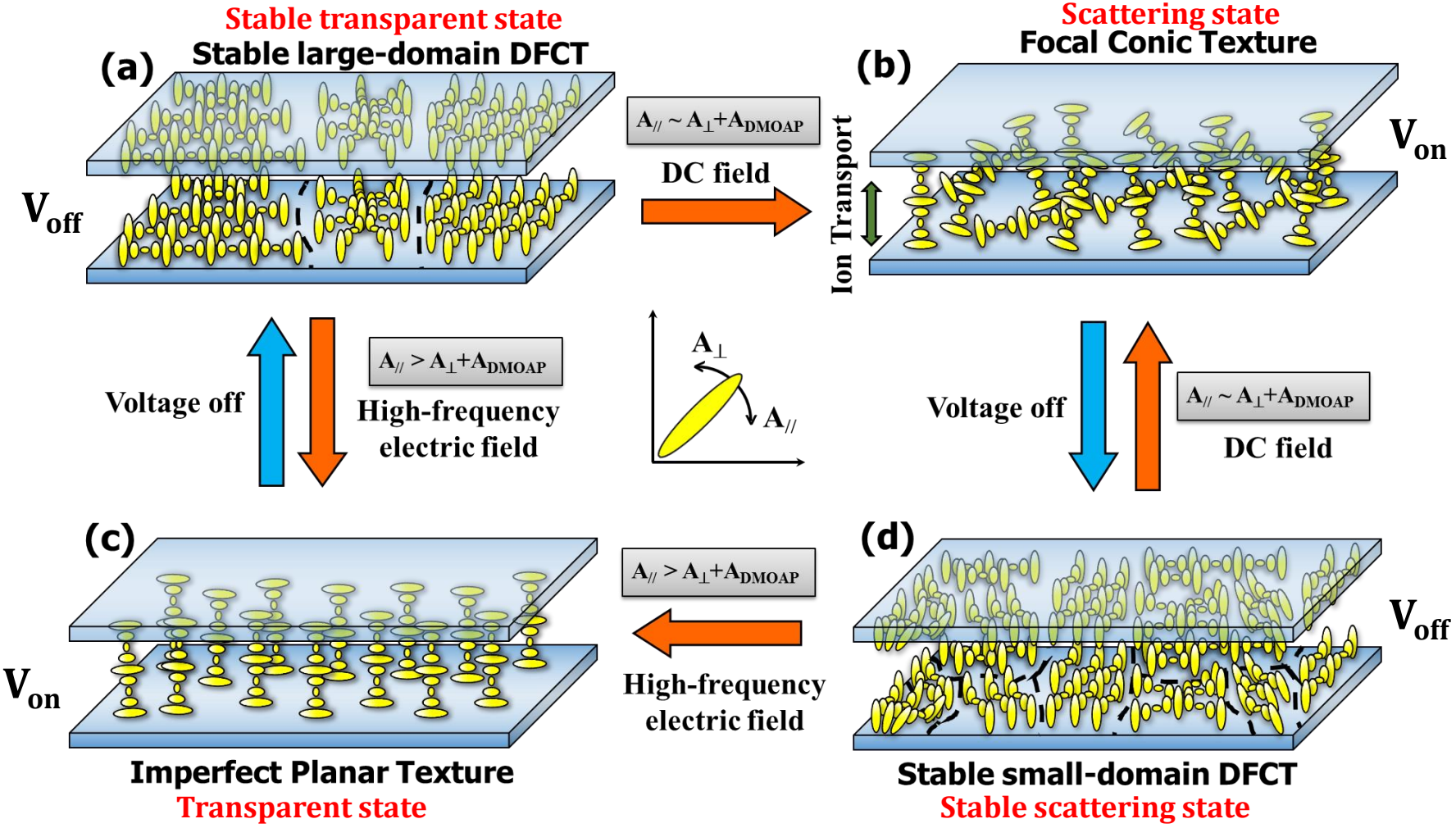
Ko-Ting Cheng*, Po-Yi Lee, Malik M. Qasim, Cheng-Kai Liu, Wen-Fa Cheng, and Timothy D. Wilkinson, "Electrically switchable and permanently stable light scattering modes by dynamic fingerprint chiral textures," ACS Appl. Mater. Interfaces **8**, 10483-10493 (2016/4/1).

鄭恪亭、李柏逸、卡希姆 馬利克 穆罕默德、威爾金森 堤莫西 大衛， "高對比雙穩態散射型液晶光閥" 中華民國專利，發明第**I531839**號 (2016年5月1日)，公開號201631366

日本專利，高コントラスト双安定散乱型液晶ライトバルブ，特願**2015-074791**

Bistable LCD devices -DFCTs

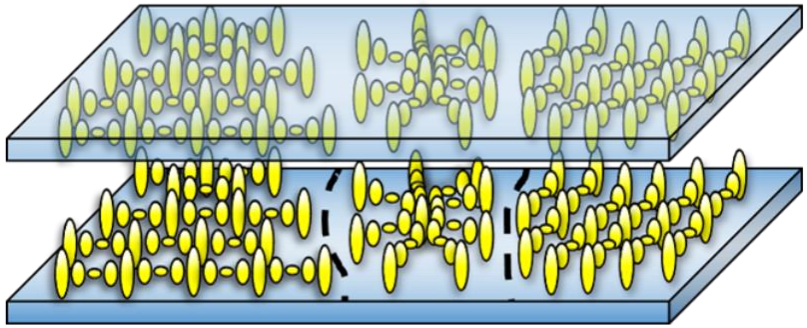
Dynamic Fingerprint Chiral Textures



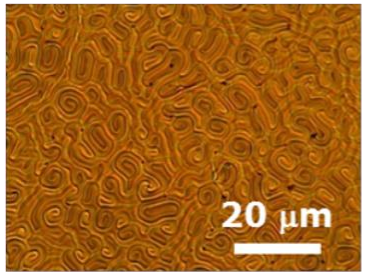
Bistable LCD devices -DFCTs

Dynamic Fingerprint Chiral Textures
Electrically Switchable and Bistable Light Scattering

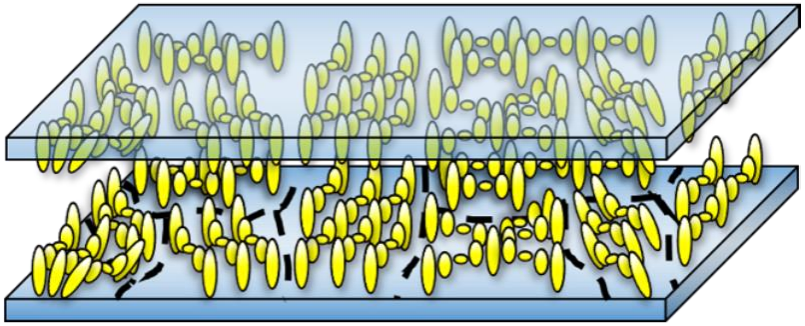
Transparent state



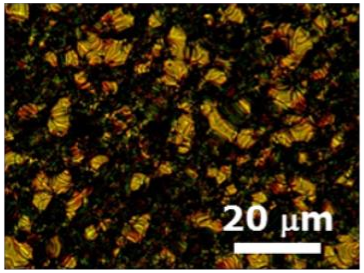
Stable large domains of DFCT



Scattering state

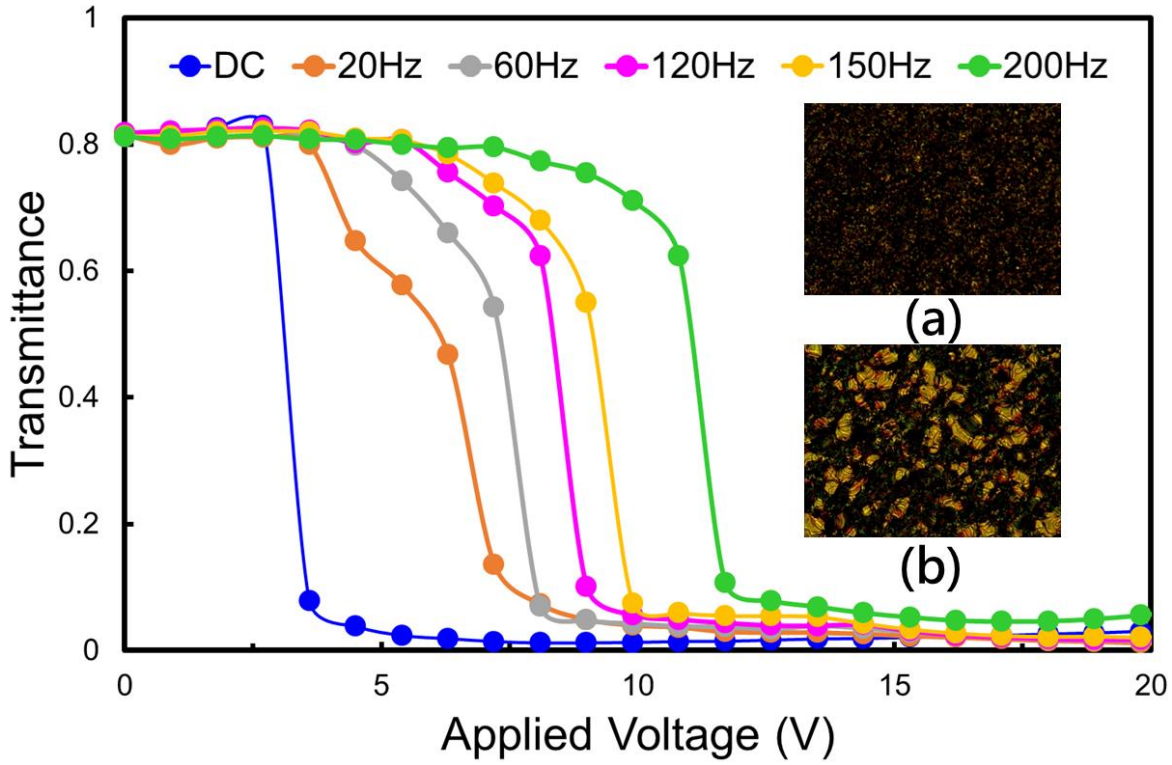


Stable small domains of DFCT



Bistable LCD devices -DFCTs

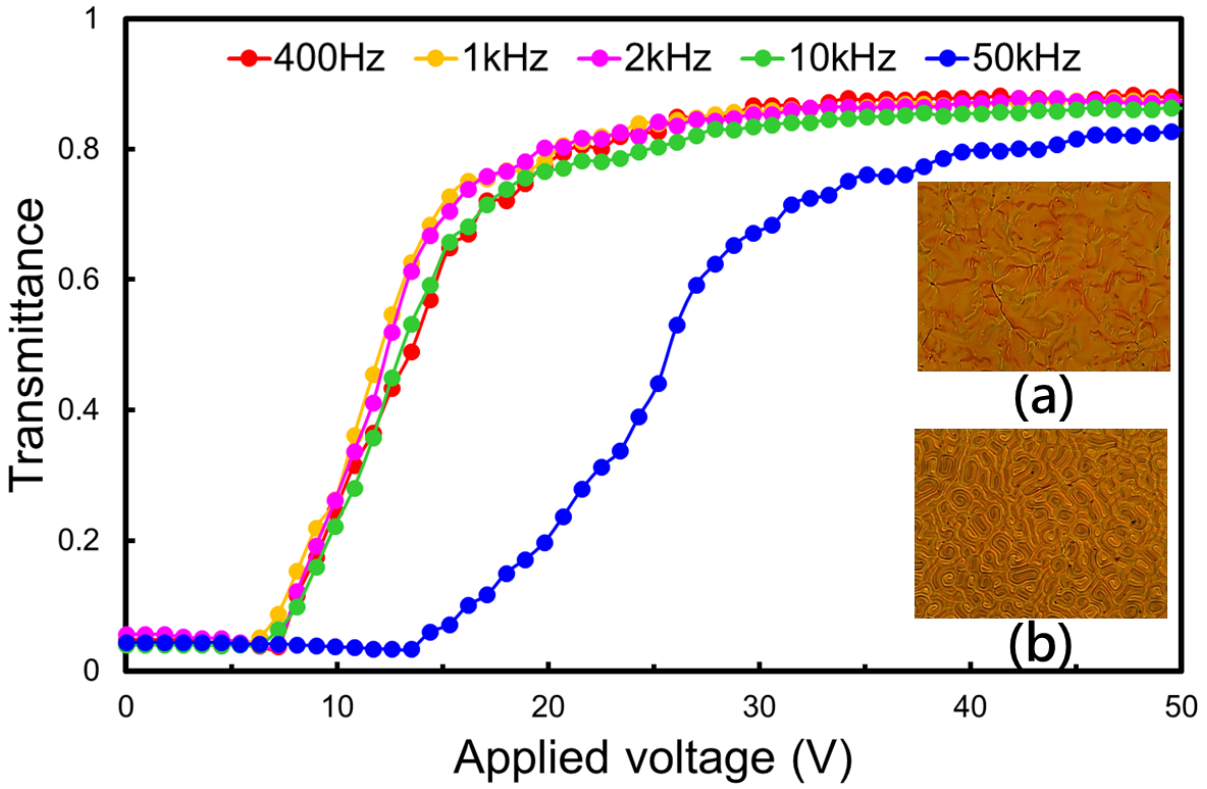
Switching from transparency to scattering



Variations in stable transmittance as functions of the applied voltage with different frequencies of LC light modulators from a transparent state to a scattering state. Insets show the images of the LC light modulator (a) during the application of DC voltage and (b) after the applied DC voltage (14 V) was switched off, as observed under a cross-polarizer polarized optical microscope in a transmissive mode.

Bistable LCD devices -DFCTs

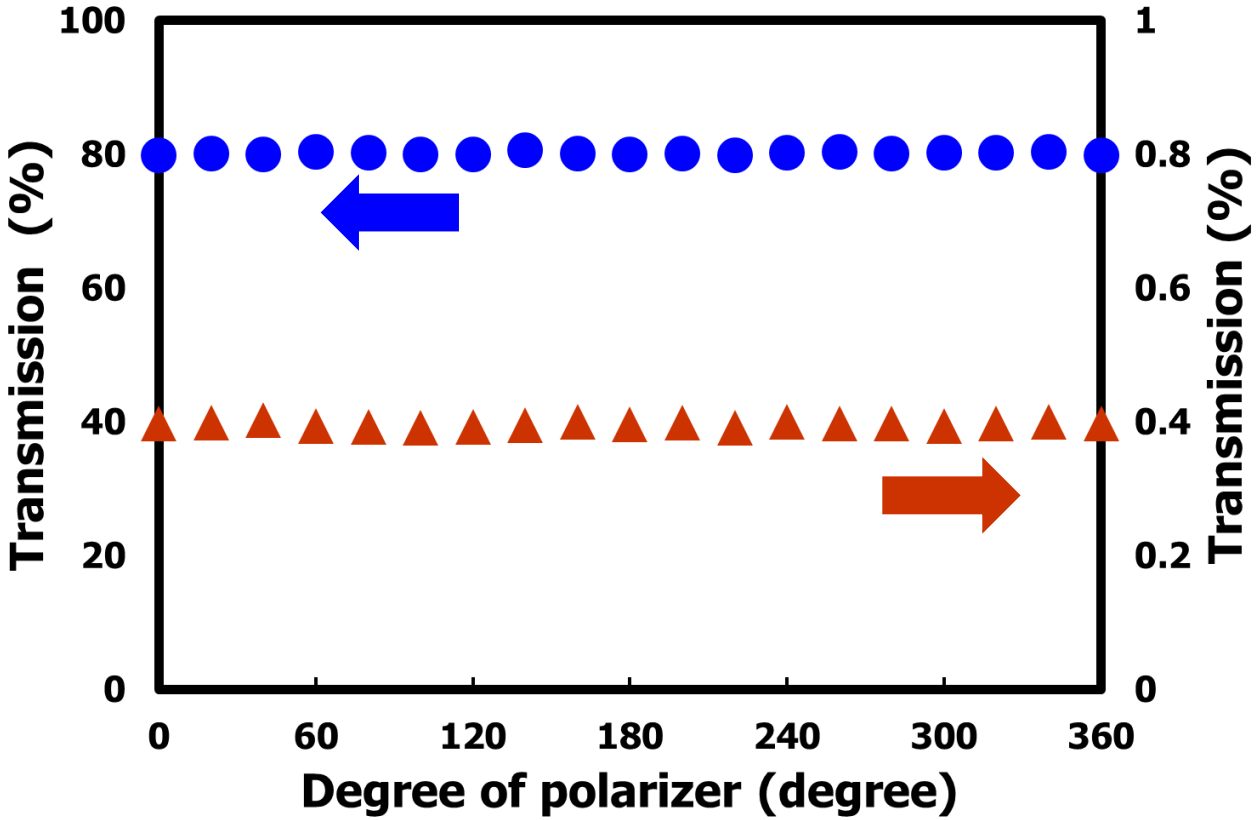
Switching from scattering to transparency



Variations in stable transmittance as functions of the applied voltage with different frequencies of LC light modulators from a scattering state to a transparent state. Insets show the images of the LC light modulator (a) during the application of AC voltage (40 Vpp at 1 kHz) and (b) after the applied AC voltage was switched off, as observed under a cross-polarizer polarized optical microscope in a transmissive mode.

Bistable LCD devices -DFCTs

Polarization-independent light scattering and transparency



Circles and triangles in the figure show the plots of the measured transmission of such a LC light modulator in transparent and scattering states, respectively, as a function of polarization state of incident light.

Bistable LCD devices -DFCTs

Multi-Stable States: Gray-Scale Control

(a) (b) (c)

Photographs of the LC light modulator of (a) a transparent state (transmission ~80%), (b) one gray scale (transmission ~33%), and (c) a scattering state (transmission ~0.5%).

Wide Viewing Angle

Photographs of bistable LC light modulator having transparent large domains of DFCT from different viewing angle of (b) −70˚; (c) 0˚ and (d) 70˚.

Bistable LCD devices -DFCTs

DFCT vs. PDLC

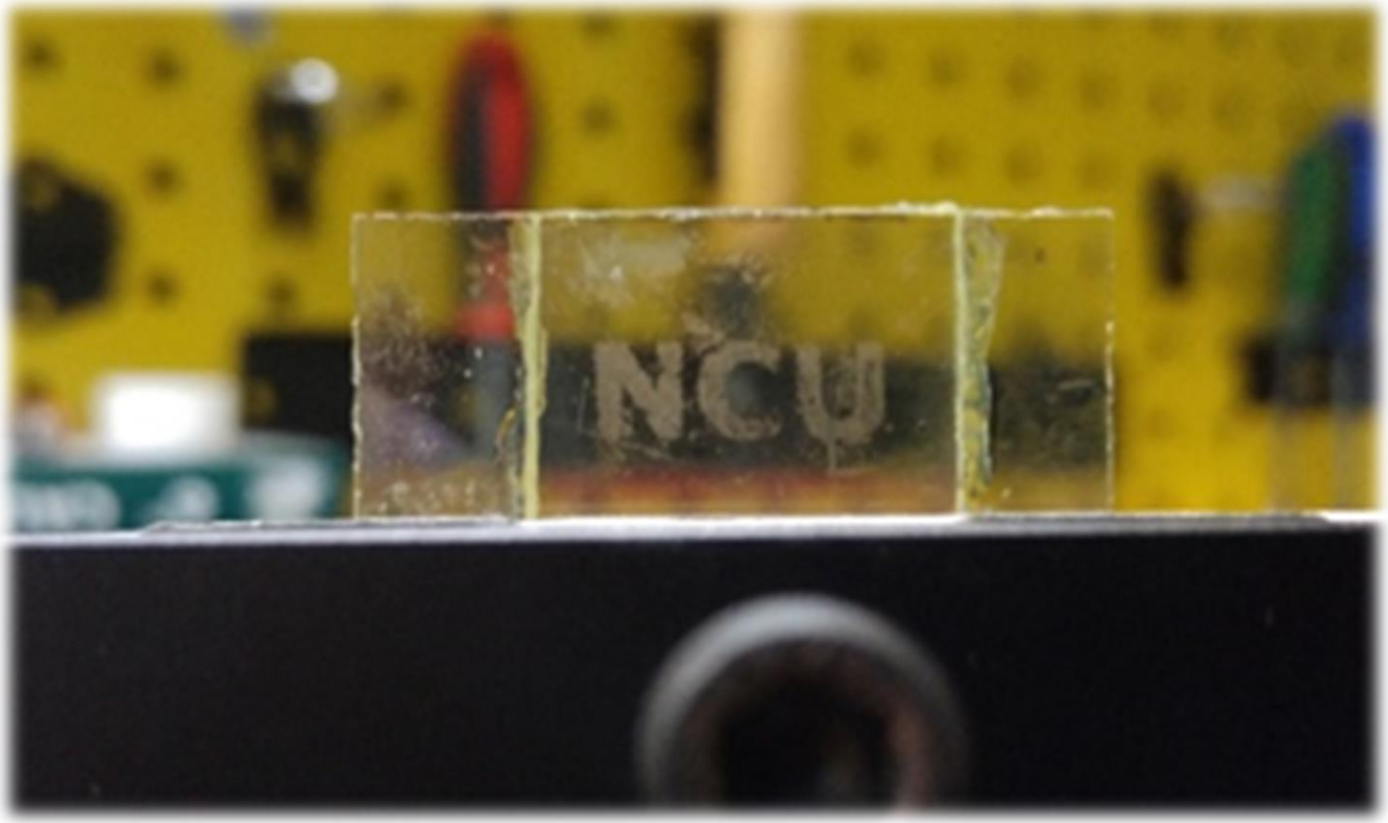
	DFCT	PDLC (InvisiShade)
Bright state	✓ 80%	✓ 70%
Dart state	Scattering (privacy)	Scattering (privacy)
Scattering state	✓✓ (≦ 10%)	✓✓ (≦ 10%)
Response time	✓ (ms)	✓ (ms)
Operation voltage	Δ (15~30 V_{AC})	Δ (30~60 V_{AC})
Viewing angle	✓✓ (wide-viewing angle)	Δ (narrow viewing angle)
V_{off} state	Scattering/Clear	Scattering
Power consumption	0 (bistability)	~7 W/m^2
Price	n/a	Low (~300 USD/m^2)

InvisiShade™ They currently do business in all 50 states and 53 countries in US, and are expanding their markets daily.

http://www.invisishade.com/

Bistable LCD devices -DFCTs

Further improvement: Electro-Opto addressing method

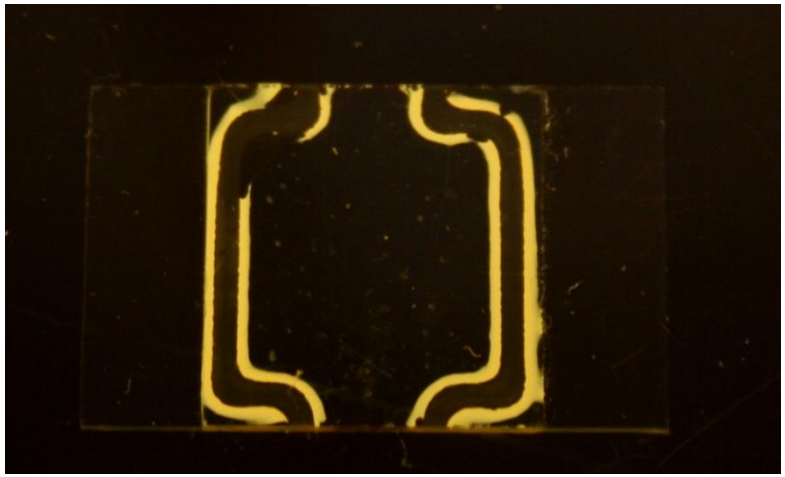


Bistable LCD devices -Others

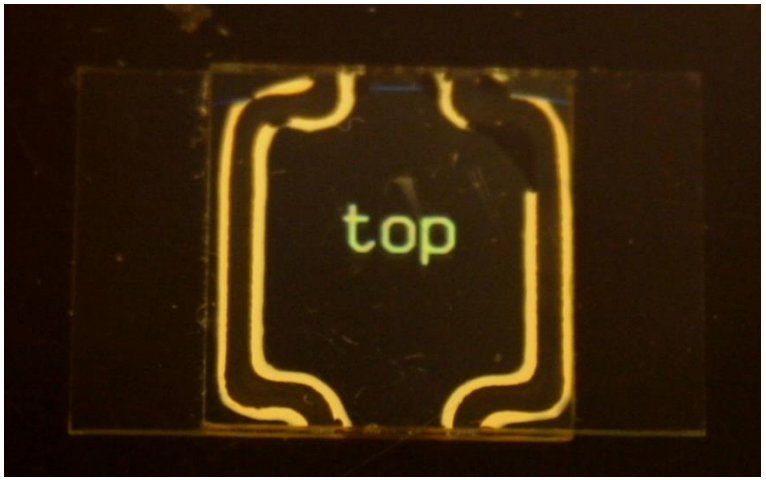
Photo-isomerization

Applications - Optically activated shutters

Dark state between crossed polarizers



After illumination with UV through a mask

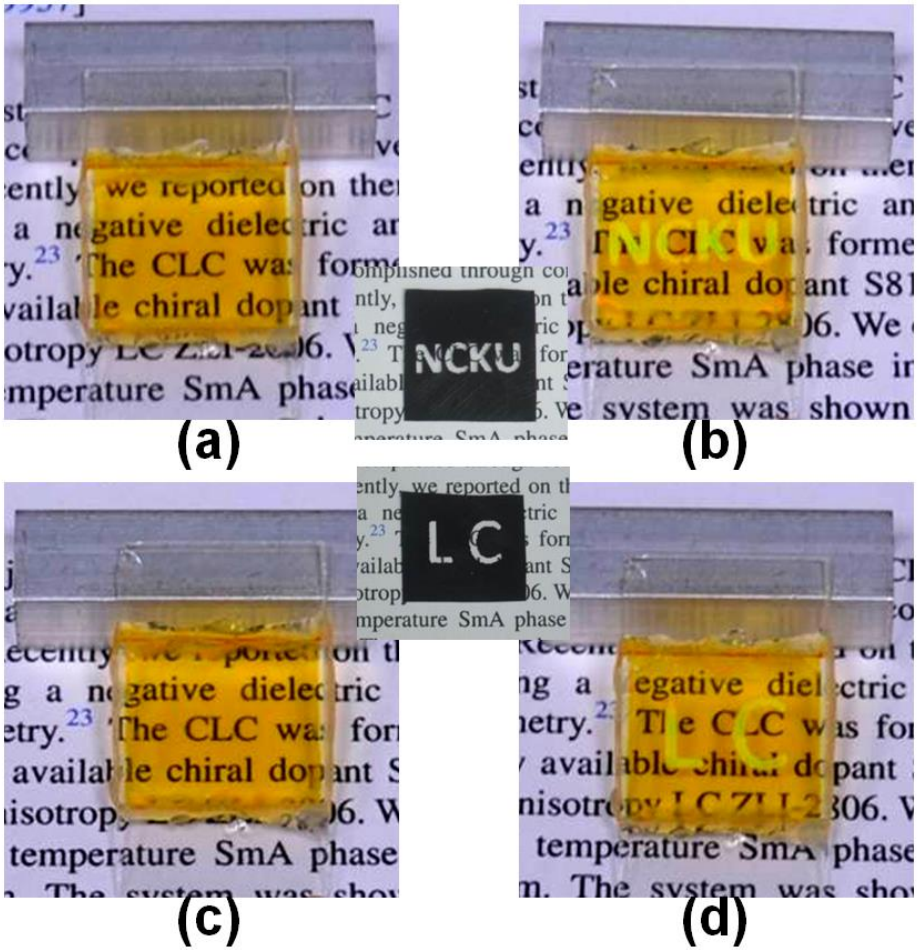


Additionally, the pattern can be optically or thermally erased, and another pattern can be re-addressed optically.

Appl. Phys. Lett. **103**, 101105 (2013).

Bistable LCD devices -Others

Photo-isomerization



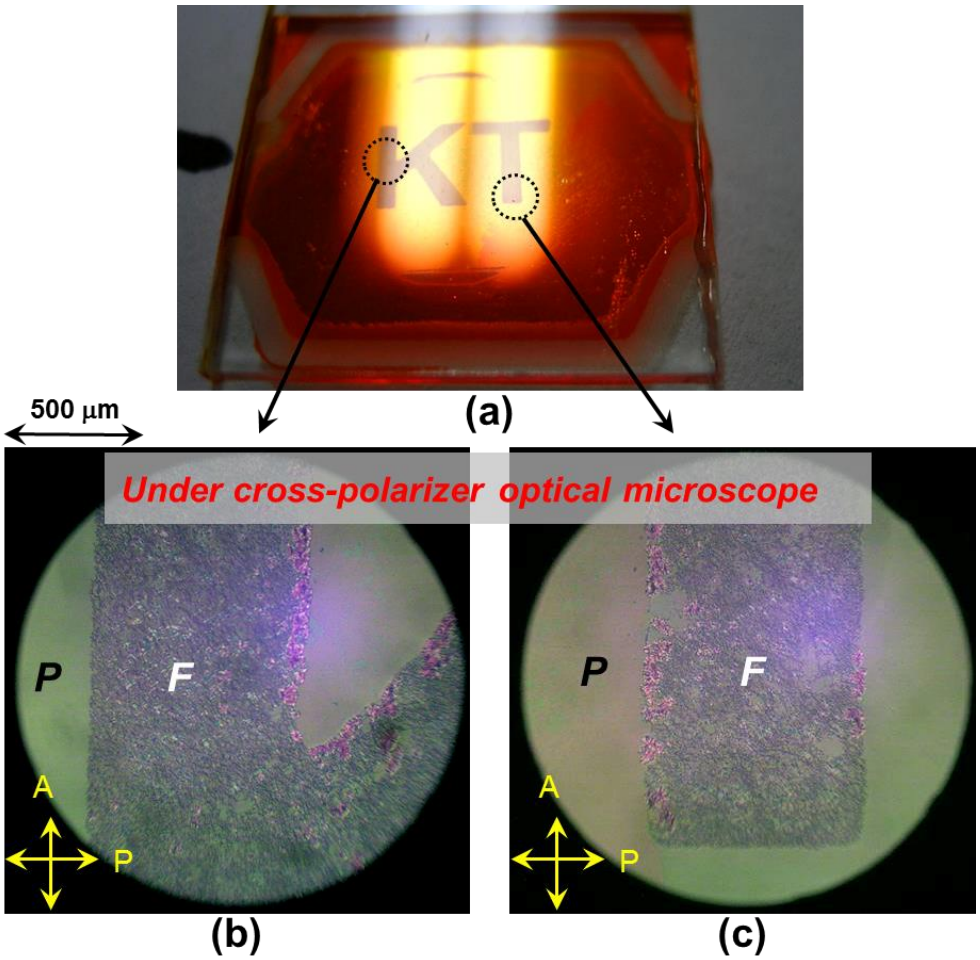
Opt. Express **21**, 21840-21846 (2013).

Bistable LCD devices -Others

Photo-isomerization

Opt. Express **17**, 7088-7094 (2009).

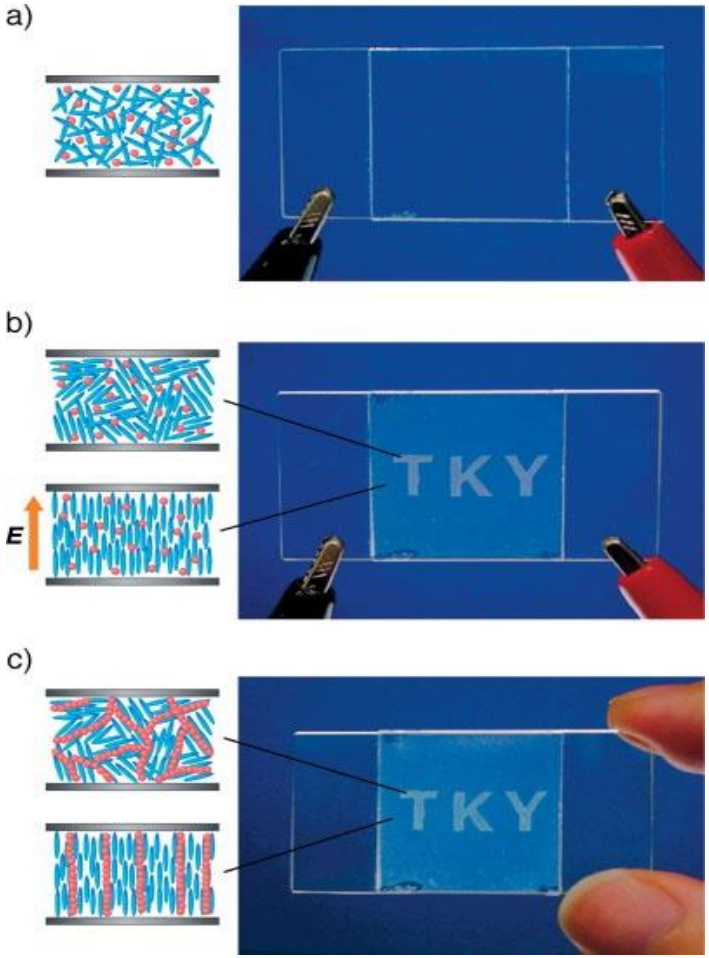
Appl. Optics **50**, 213-217 (2011).



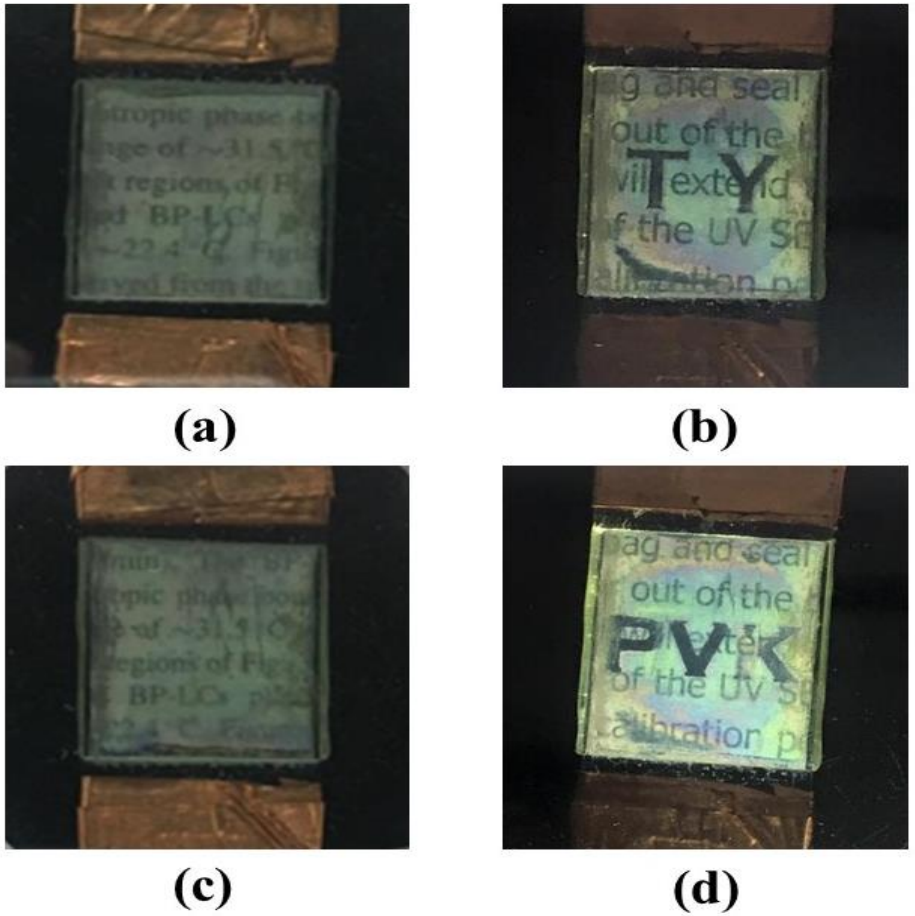
Opt. Commun. **281**, 5133-5139 (2008).

Bistable LCD devices -Others

Gelators: Hydrogen bonds



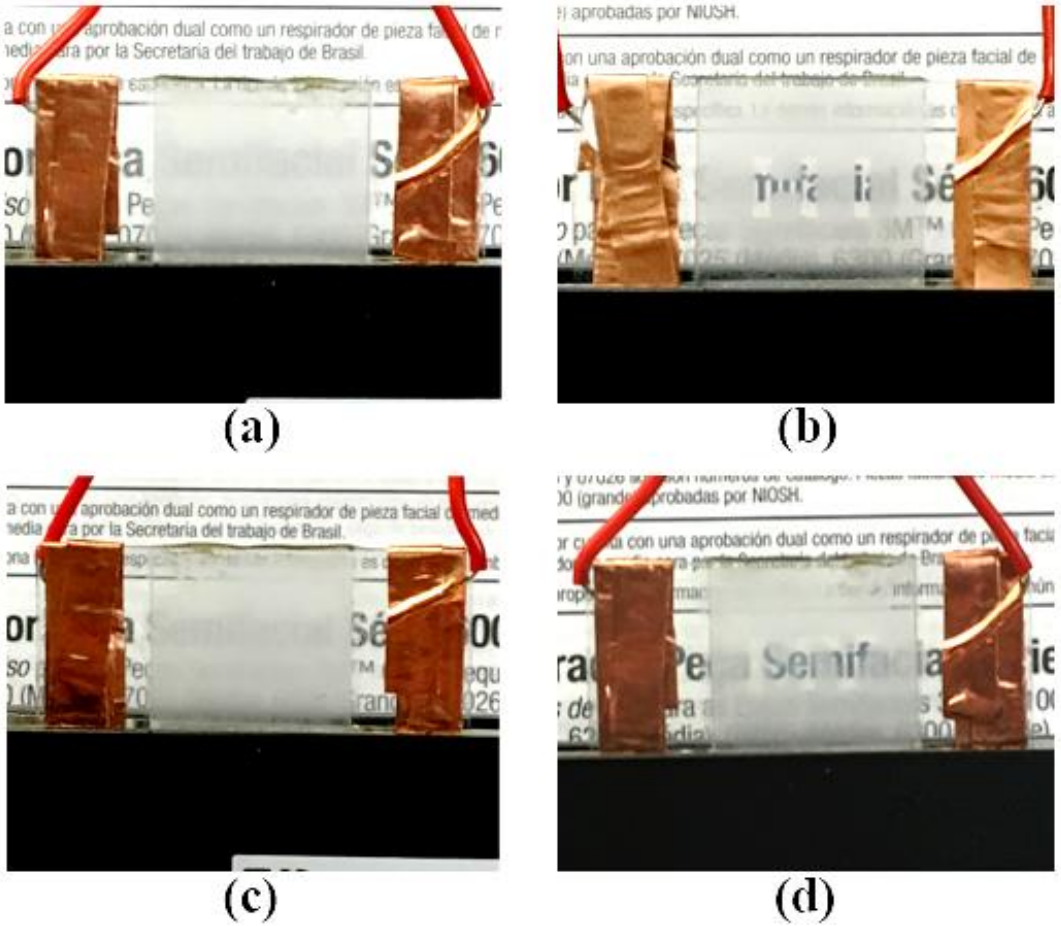
Adv. Mater. **17**(6) 692-696 (2005).



Opt. Express **24**, 23572-23582 (2016).

Bistable LCD devices -Others

Gelators: Hydrogen bonds



Opt. Express **24**, 23572-23582 (2016).

Bistable LCD devices -Others

Cholesterics

Bistable LCD devices -Others

E-ink

在日常生活中，其實有很多大小不一、顏色單一(或不多)、變動不頻繁而又希望盡量不耗電的資訊顯示。這些資訊顯示可以小至標籤；大至廣告招牌，而且許多這類資訊是在戶外顯示的，這些場合便是E-paper最適用之處。元太科技這次推出許多E-ink製成的展品，包括行李箱標籤、貨品標籤與32吋彩色顯示器等。元太也已開發出32,000色的產品，是將四種印刷染料(Pigment)放進同一個像素而製成，這個新產品在SID 2016獲獎，但並未在這次Touch Taiwan展出。另外一項極有特色的是，繼去年推出平面狀的壁飾電子紙之後，這次元太展出了立體兼彩色的版本，更活潑也更有層次感，給人留下強烈的印象。看起來，如果經過適當的設計，電子紙也可以在建築、裝飾或藝術的領域中扮演一個角色。

行李箱標籤 (元太)

http://www.materialsnet.com.tw/

Bistable LCD devices -Others

E-ink

貨品標籤 (元太)

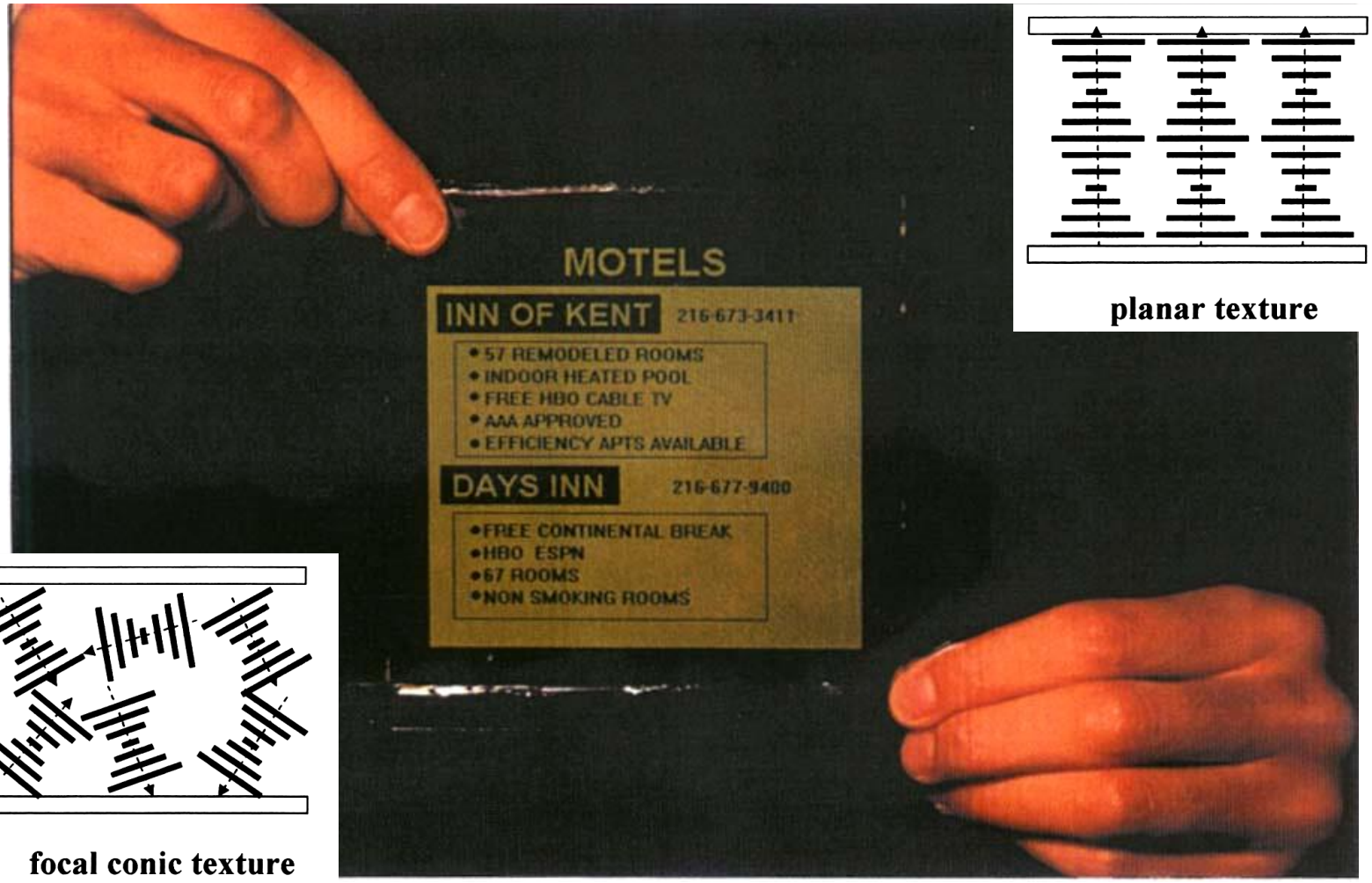
32吋彩色電子紙顯示器(元太)

能改變顏色的電子紙立體壁飾 (元太)

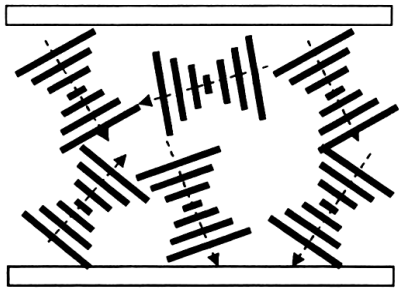
http://www.materialsnet.com.tw/

Bistable LCD devices -Others

Polymer Stabilized Cholesteric Textures

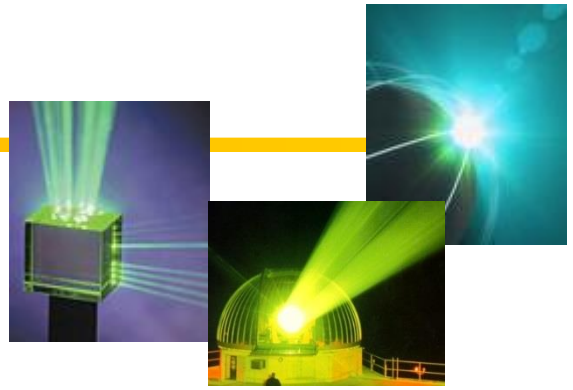


planar texture



focal conic texture

Summary



Still Challenges:

Bistable scattering using DFCT: operating voltage, response time, materials, etc.

Next Challenges:

flexibility, roll to roll process (printing), cuttable devices, etc.

Active attitude: reducing power consumption!!

Passive attitude:

getting more and more energy!!
energy harvesting, energy storage!!

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