National Chiao Tung University
College of Photonics

Aligning liquid crystal molecules by nanoparticles

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2012/04/16

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台南校區
光電學院

Outlines

- ➢**Motivation**
- ➢**Liquid Crystal Alignment**
- ➢**Nanoparticle-induced vertical alignment for pretilt control**
- ➢**Pretilt angle controlled by UV treatment**
- ➢**Applications**
- ➢**Conclusion**

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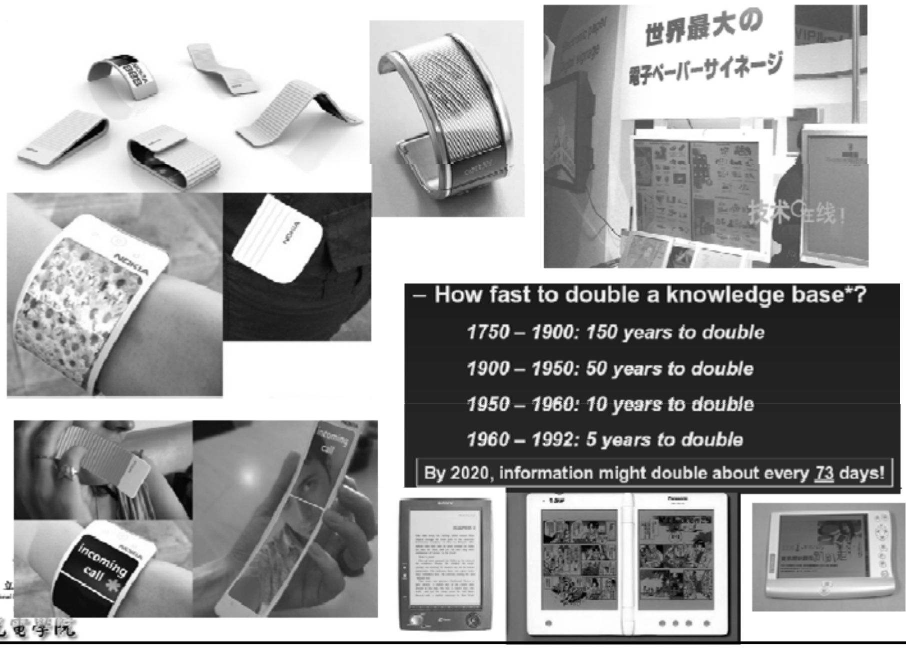
Motivation – Flexible Displays



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台灣LCD面板產業切入點 – 軟性高階 TFT-LCD

適合台灣面板產業切入

Display Devices

Display Options: UTL™ (Ultra-thin and Light-weight) Flexible Display

	E-Paper Display (Electrophoretic)	Active matrix LCD	Active matrix OLED
			
☺	• Ink-on-paper look (B/W) • Product on glass available • Low power consumption • Flexibility	• Full color • High resolution • Can use conventional LCD line	• High flexibility • Full color • Low cost printing process – polymer
☹	• Active matrix driving • Color → CF or colored particles • Slow response time	• Cell gap control • Back light unit • Alignment layer • Handling	• Thin film encapsulation • Handling

SAMSUNG SDI

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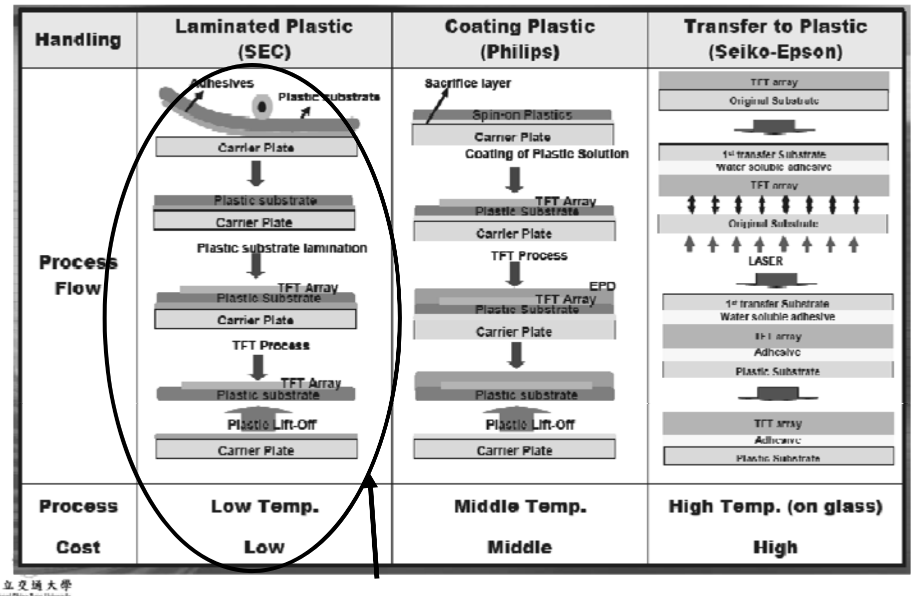
軟性TFT背板製程評估

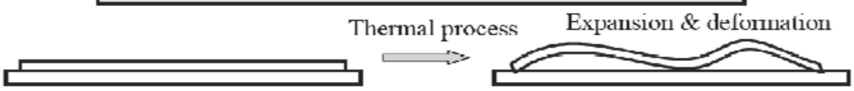


關鍵材料及技術：塑膠與玻璃貼合及剝離

Challenges

High temperature process: TFT, CF, PI baking

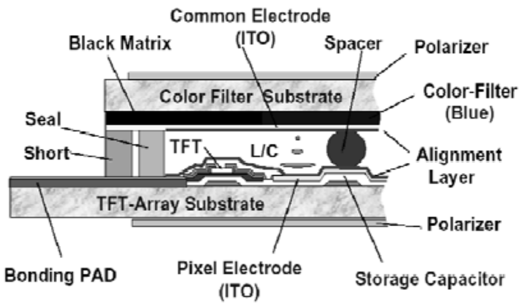
	Total Transmittance (%)	Haze (%)	Retardation (%)	CTE (ppm/°C)	Heat shrinkage (%)
Glass	93	93	1	3.7	0
PC	90	90	1	73	0.01@180°C 2hr

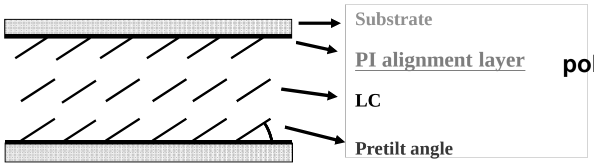


Two approaches:

- **Lower process temperature**
- Increase plastics Tg/ Reduce CTE

LCD Structure





polyimide (聚亞醯胺) 膜

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Approaches for flexible LCDs

Noval structures

- No alignment layer
- No color filter – fast response

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Non-alignment

Isotropic to anisotropic

US 20050062927A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2005/0062927 A1**
Nakamura et al. (43) **Pub. Date: Mar. 24, 2005**

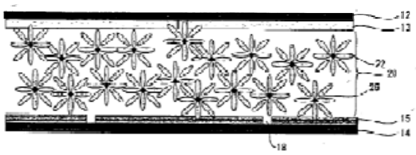
(54) **LIQUID CRYSTAL DISPLAY DEVICE**

(75) Inventors: **Masako Nakamura**, Nara (JP); **Yoshito Hashimoto**, Mie (JP); **Tokihiko Shinomiya**, Nara (JP); **Shigeaki Mizushima**, Nara (JP)

Publication Classification

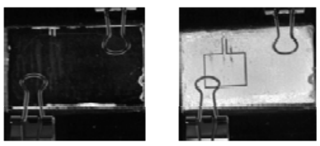
(51) **Int. Cl.**[7] **G02F 1/133**
(52) **U.S. Cl.** **349/170**; 349/167

Sharp's concept

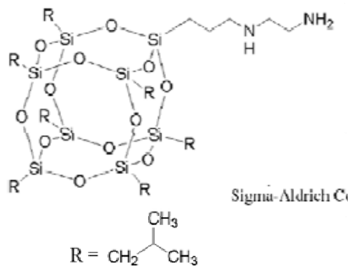


VA-mode without PI alignment layers

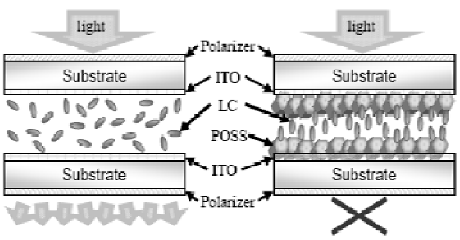
LC+ POSS



0 V   3 V

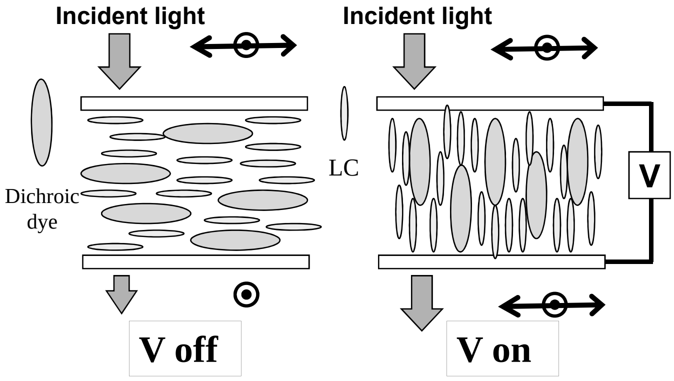


Sigma-Aldrich Corp.



多面體矽氧烷寡聚物(polyhedral oligomeric silsesquioxane，POSS)

Application I: Flexible Guest-Host LCDs



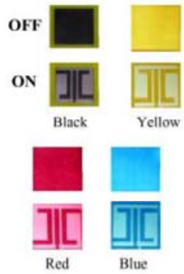
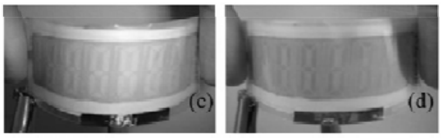


Fig. 3 Different color PDMLC device at 1 inch.



PET substrate
Ball spacer

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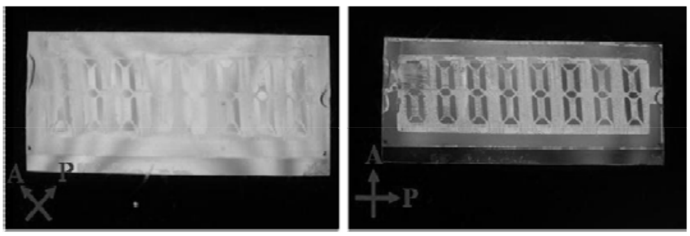
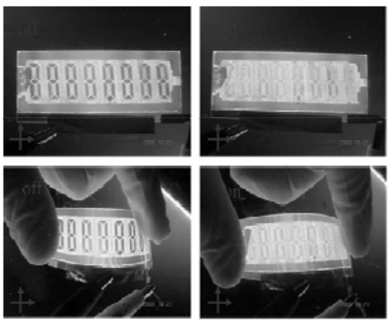
Flexible Homeotropic PET-LCDs





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Voltage-dependent Transmission

Pretilt-control ?

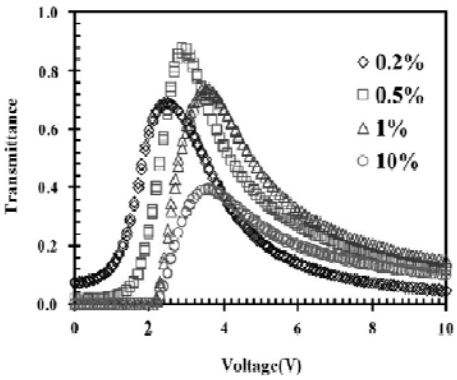

Figure 4. Measured voltage-dependent optical transmission curves of homeotropic LC cells doped with different wt% POSS.

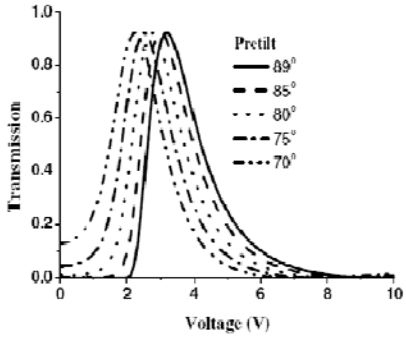

Figure 5. A series of simulated voltage-dependent optical transmission curves with different pretilt angles.

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Outlines

- ➢Pretilt for LCDs and their applications
- ➢Nanoparticle-induced vertical alignment for pretilt control
- ➢Pretilt angle controlled by UV treatment
- ➢Applications
- ➢Conclusion

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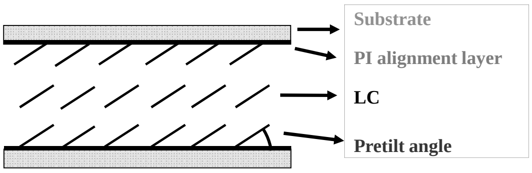
LCD Structure



Pretilt determines all E-O properties:
driving voltage, viewing angle, response time, color

Required pretilt depends on operation modes

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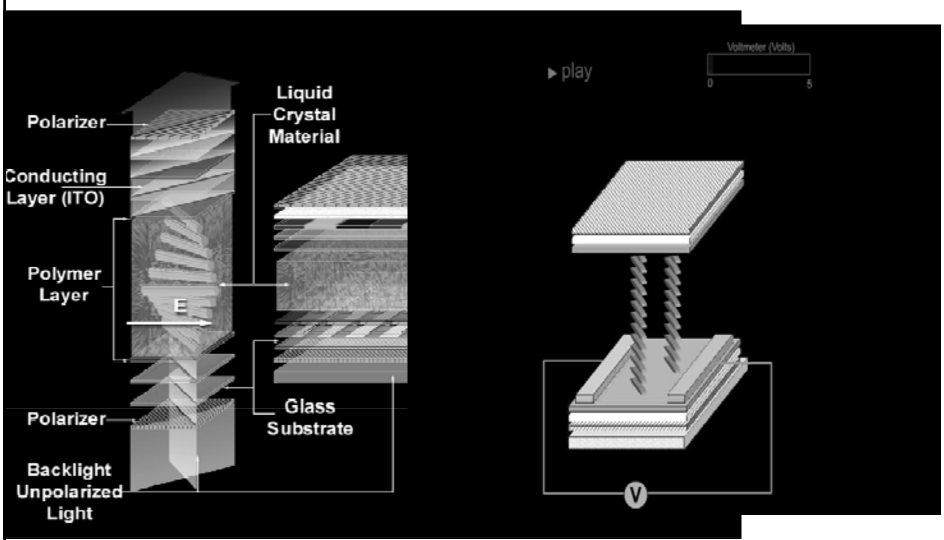
In-Plane Switching



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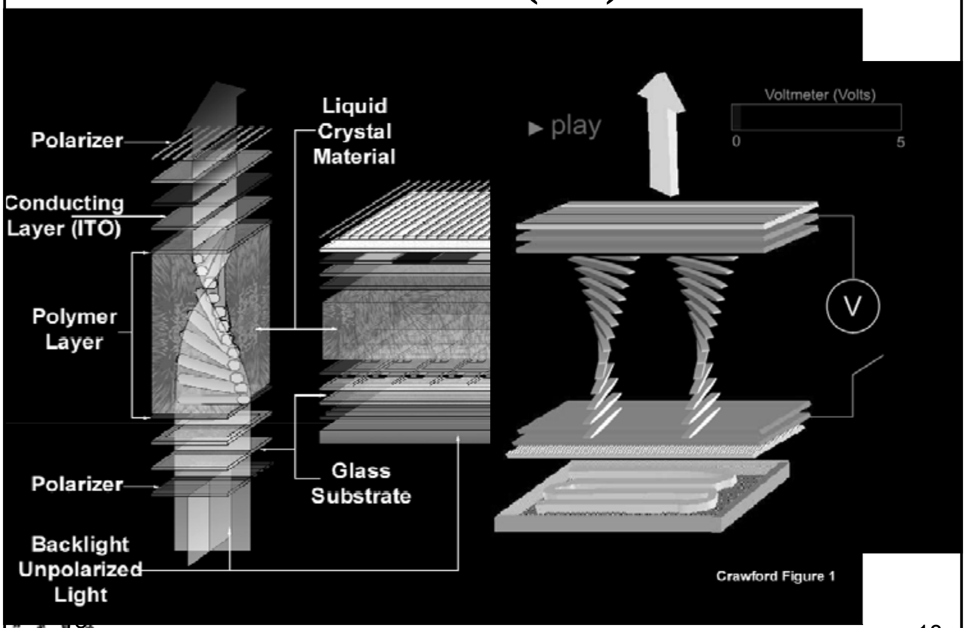
Alignment layers vs. Products

~1°: In-Plane Switching (IPS)
~4°: Twist Nematic (TN)
~7°: Super Twist Nematic
~50°: Bistable bend-splay
~50°: No-bias OCB
~90°: Vertically aligned (VA)

I-pad

Twist-Nematic (TN) LCDs



Alignment layers vs. Products

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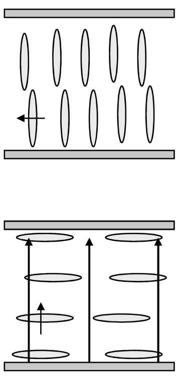
- ~90°: Vertically aligned (VA)

I-pad

Homeotropic (Vertical) Alignment



- ~1°: In-Plane Switching (IPS)
- ~4°: Twist Nematic (TN)
- ~7°: Super Twist Nematic
- ~50°: Bistable bend-splay
- ~50°: No-bias OCB
- ~90°: Vertically aligned (VA)

LCD-TV

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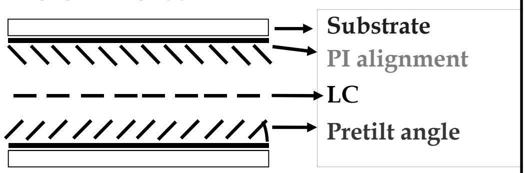
Alignment layers

Commercial homogeneous polyimide low pretilt < 10°

Commercial homeotropic polyimide high pretilt ~ 90°

~1°: In-Plane Switching (IPS)
~4°: Twist Nematic (TN)
~7°: Super Twist Nematic
~50°: Bistable bend-splay
~50°: **No-bias optically-compensated bend (OCB)**
~90°: Vertically aligned (VA)

OCB LC cell



OCB:
Fast response time
Wide viewing angle

Applications of OCB-**LCDs**

Examples:
Power-saving

- **No color filter-** color sequential (field sequential) with RGB backlights

  Color filters Waste ~70% of incident light

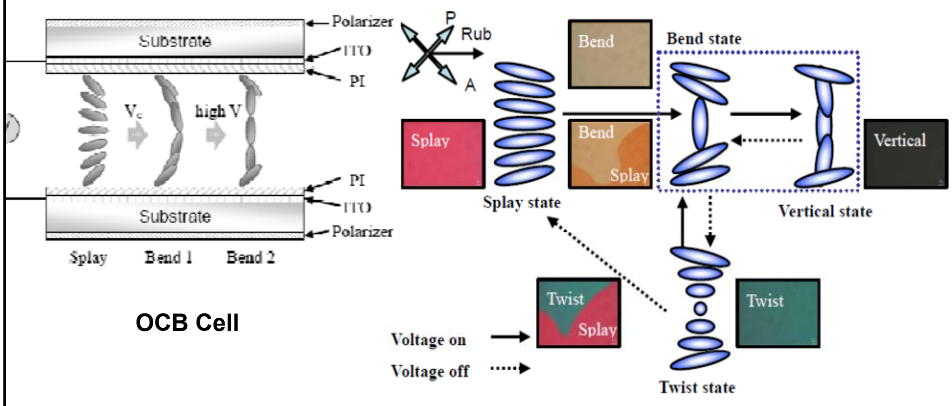
Naked-eyes 3D- Displays

- **Fast active barrier (120 Hz):**
- ✓ full resolution by time-multiplexed and spatial-multiplexed
- ✓ 2D/3D switchable

Optically-Compensated-Bend mode (OCB)

Fast response and wide-viewing angle

OCB is normally operated at bend state



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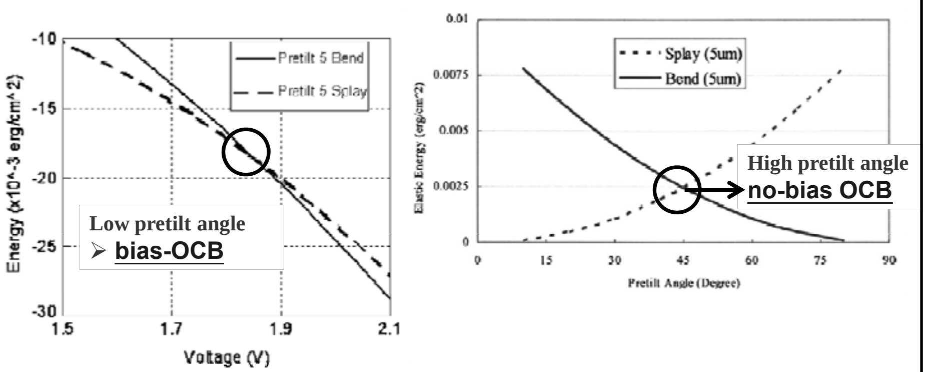
Elastic Deformation Energy of OCB LCDs

$$E = \frac{1}{2}\int_0^d (K_{11}\cos^2\theta + K_{33}\sin^2\theta)\left(\frac{d\theta}{dz}\right)^2 dz,$$

K_{11} and K_{33} are the splay and bend elastic constants.

θ is the tilt angle which is a function of distance



Fion S. Yeung, Y. W. Li, and Hoi-Sing Kwok APPLIED PHYSICS LETTERS **88, 041108 2006**

Fion Sze-Yan Yeung and Hoi-Sing Kwok APPLIED PHYSICS LETTERS **88, 063505 2006**

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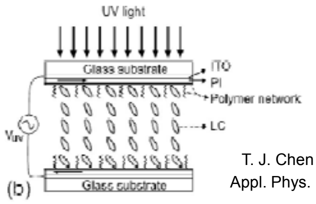
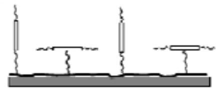
Approaches of tunable pretilt angles

- **SiOx oblique evaporation**
- **Polymer-stabilized alignment**



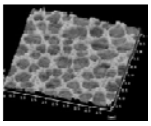
T. J. Chen
Appl. Phys. Lett. 92(9), 091102 (2008).

- **Nanostructured surfaces**
- **Hybrid mixture of two materials**



L. Komitov,
J. Soc. Inf. Disp. 16(9), 919 (2008).

- **Chemical synthesis**
- **Stacked alignment layers**
- **Nanoparticle**



H. S. Kwok
Appl. Phys. Lett. 88(5), 051910 (2006).

- **UV treatment**

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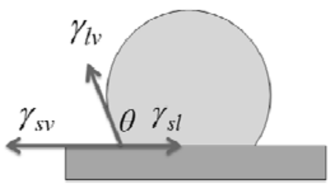
Mechanism of controlling pretilt angles

Friedel-Creagh-Kmetz (FCK) Rule



Contact angle measurement

Homeotropic PIs: low surface energy
Homogeneous PIs: high surface energy

$$\gamma_s < \gamma_{lc} \rightarrow \textit{Homeotropic} \text{ alignment}$$

$$\gamma_s > \gamma_{lc} \rightarrow \textit{Homogeneous} \text{ alignment}$$

γ_s : *surface* energy of a solid film

γ_{lc} : *surface* energy of *LC*

- **Nanoparticle**
- **UV irradiation**

→ **Surface treatment**

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Outlines

- ➢LCD alignment and applications
- ➢Nanoparticle-induced vertical alignment for pretilt control
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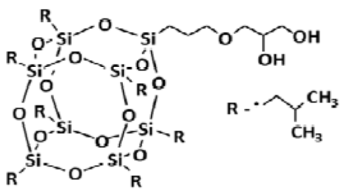
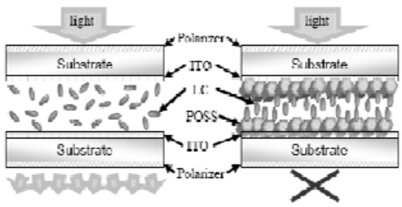
- ➢Conclusion

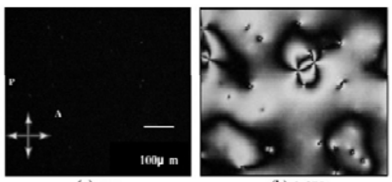
Approaches for Pretilt Control

1. POSS doped in planar LC cells
2. POSS doped in homogeneous PIs





polyhedral oligomeric silsesquioxane (POSS)



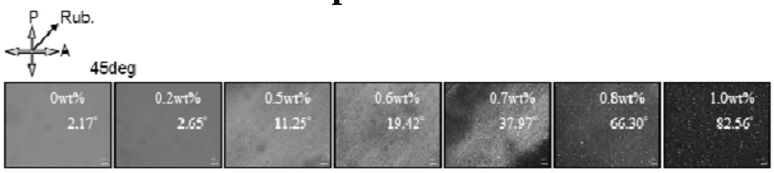
(a) 0V (b) 3.0V

- ➢ **Vertical alignment property**
- ➢ **Surface energy modification by POSS**

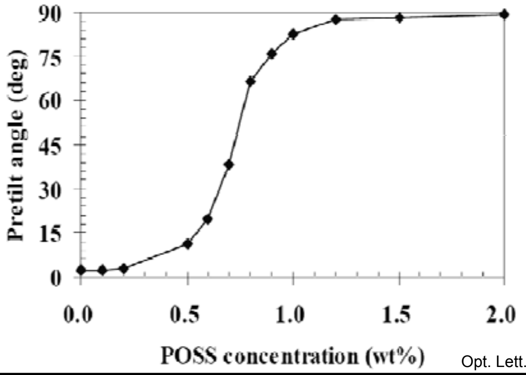
Appl. Phys. Lett. **91(6), 061112 (2007)**

Approach to control pretilt angle

I: LC doped with POSS



Polarizing microscope photographs of an LC cell doped with various POSS concentrations:



Opt. Lett. 34(4), 455–457 (2009).

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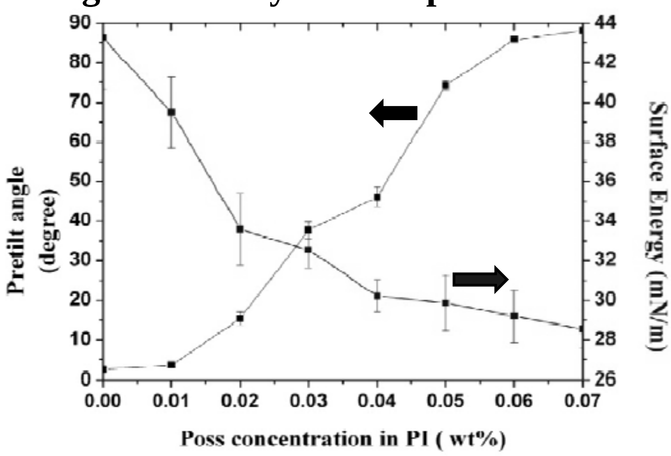
Approach II:

Homogeneous Polyimide doped with POSS



Pretilt angle and surface energy of POSS/PI alignment layers as a function of POSS concentration in PI.

OPTICS EXPRESS, 18, 16508 (2010)

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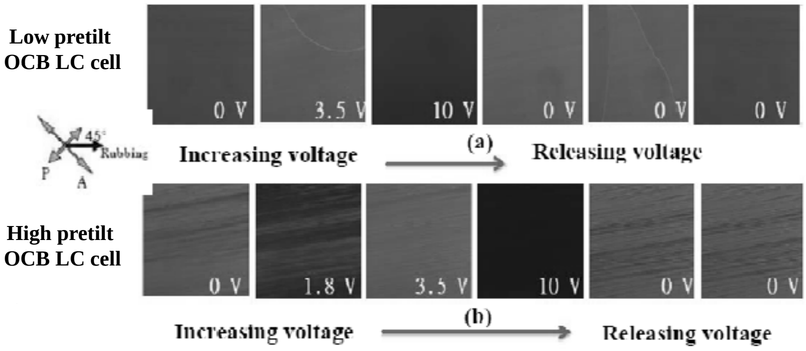
Transitions of OCB LC cells



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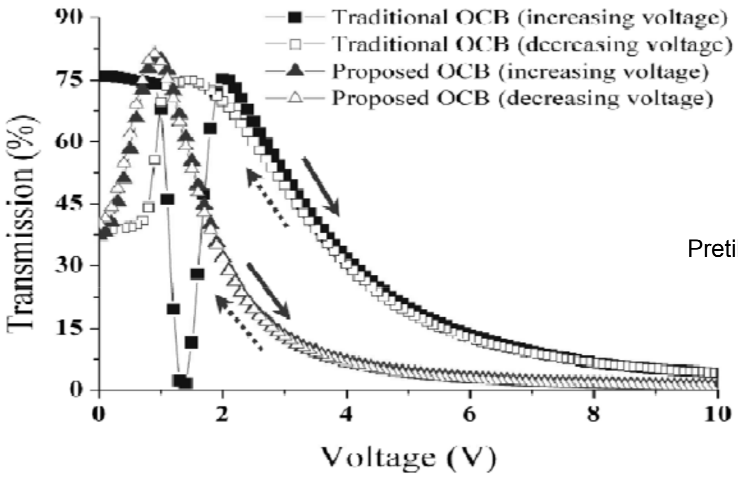
Voltage dependent transmission curves of OCB LCDs

- ➢Traditional OCB LCD: low pretilt
- ➢Proposed OCB LCD: high pretilt



Pretilt ~48°

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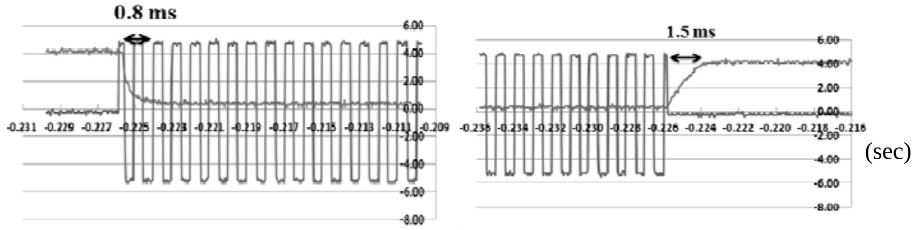
OPTICS EXPRESS, 18, 16508 (2010)

Response time of a no-bias OCB LCD

The typical values:
Cell gap: ~4.5 um
Pretilt angle: ~ 65 °
Driving: 0 V– 5 V



Falling time — Rising time

Total response time: ~ 2.3 ms

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Outlines

- **LCD alignment and applications**
- **Nanoparticle-induced vertical alignment for pretilt control**
- **Pretilt angle controlled by UV treatment**
- **Applications**
- **Conclusion**

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Influence of UV on alignment layers

Photo-decomposition

UV-induced surface modification on homogeneous PI layers
FTIR spectra: bond-breaking reactions for homogeneous PI

5028 J. Appl. Phys. 80 (9), 1 November 1996

We focus on:

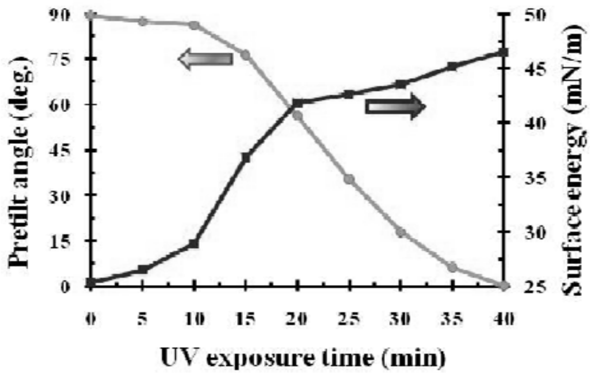
UV-treatment on homeotropic PI layers

Pretilt tuning range: 90° to 0°

LC devices requiring patterned alignment areas.

Influence of UV dosage on PI films

pretilt angle and surface energy



UV intensity: 37 mW/cm²

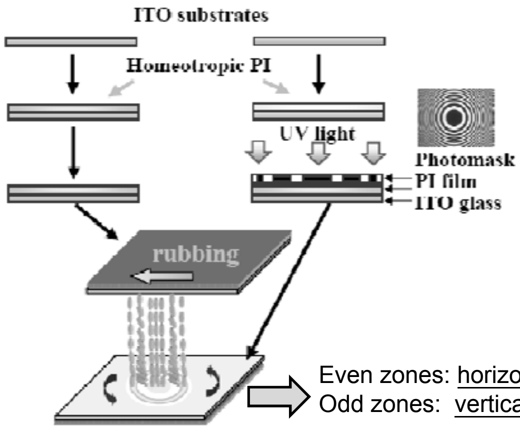
Applications of UV treatment on PI films

Any LC device requires patterned alignment

Applications I: Liquid Crystal Fresnel Lens
Applications II: Liquid Crystal Phase Grating

Applications I: Liquid Crystal Fresnel Lens

Fabrication process



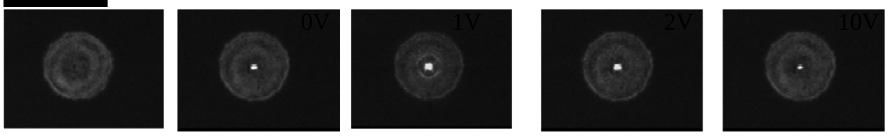
Cell gap: 10 μ m
LC: E7

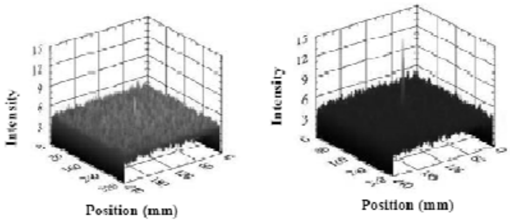
Even zones: horizontally aligned
Odd zones: vertically aligned

Horizontal rubbing: polarization-dependent LCFL
Circular rubbing: polarization-independent LCFL

OPTICS EXPRESS, 18, 26331 (2010)

Focus of Liquid Crystal Fresnel Lens





0 V 1V

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OPTICS EXPRESS, 18, 26325 (2010)

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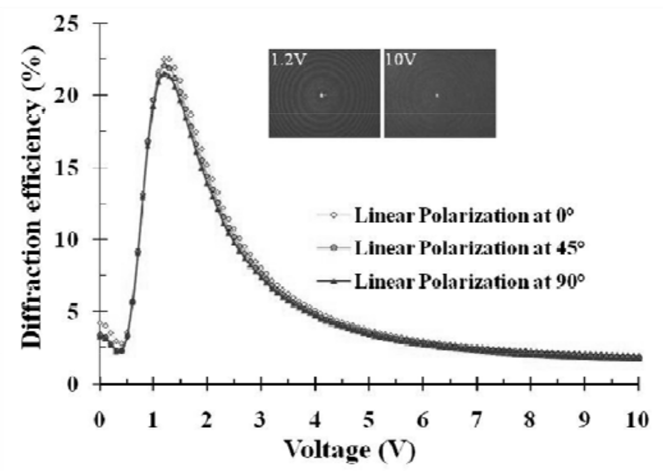
A polarization-independent LC Fresnel lens



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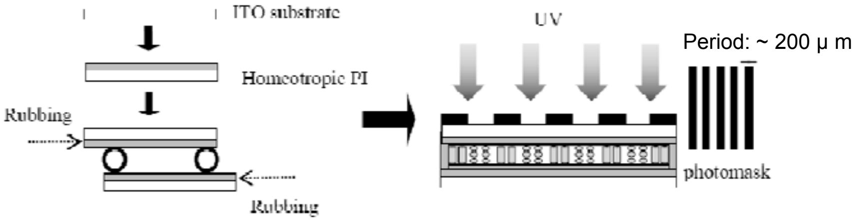
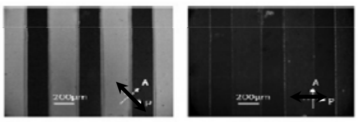
Applications II: Liquid Crystal Phase Grating

Fabrication process



Cell gap: 5.5 μ m
LC: E7



Photos by a crossed polarizing optical microscope.

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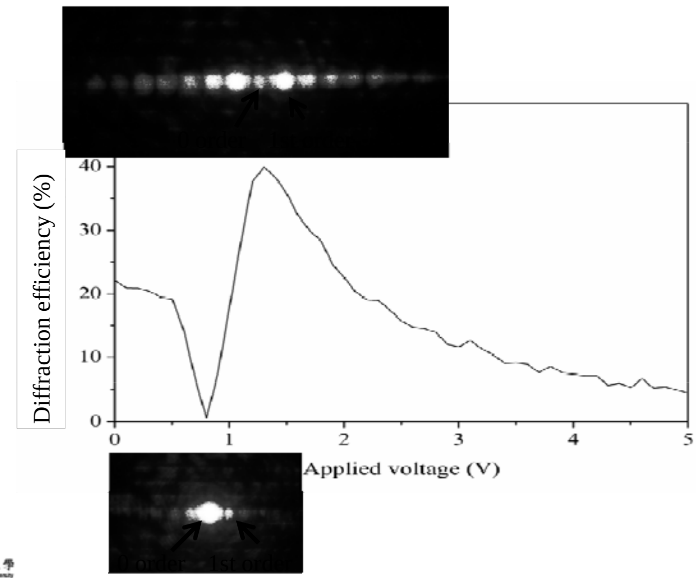
First-order diffraction efficient



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Conclusion and Future work

- POSS nanoparticle and UV irradiation have been applied for controlling pretilt angle of PI films.
- LC devices by these two techniques were demonstrated:
  no-bias OCB LCDs, Fresnel lens, phase grating
- Determine the physical and chemical properties of PI/POSS and UV-treated PI alignment films in the near future.
- Reliability test in the near future:
  thermal aging, voltage holding ratio, etc.

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教學研究空間

奇美樓總樓地面積6,000坪
第一期校地面積8.2公頃

核定招生名額

	光電系統研究所	照明與能源研究所	影像與生醫研究所	碩士在職專班	合計
碩士生	30	30	30	30	120
博士生	10	10	3	0	23

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THANKS FOR YOUR ATTENTION

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