Imprinted Optical Films for Transflective Liquid Crystal Displays

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Outline

- Introduction: Mobile Displays
- Why Transflective LCDs ?
- *Imprinting* Technique for Patterned Retarders
  - *Imprinting* Process
  - LCP Patterned Retarders
- Transflective LCDs with In-cell Retarders
  - TN transflective LCD (*Planar* Alignment)
  - Inverse TN transflective LCD (*Vertical* Alignment)
- Conclusion

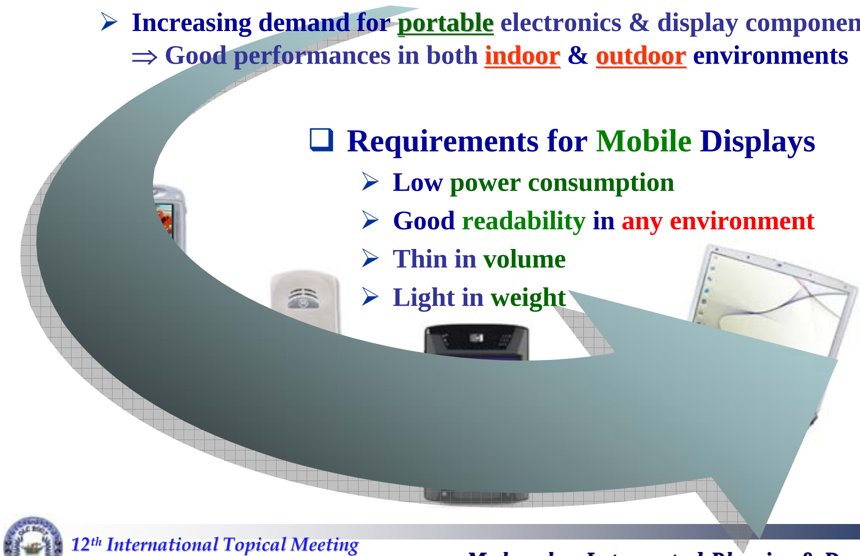
Mobile Displays

❑ **Ubiquitous Era**

- ➢ Increasing demand for <u>portable</u> electronics & display components
  ⇒ Good performances in both <u>indoor</u> & <u>outdoor</u> environments

❑ **Requirements for Mobile Displays**

- ➢ Low power consumption
- ➢ Good readability in any environment
- ➢ Thin in volume
- ➢ Light in weight



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Why Transflective LCDs?

❑ **Outdoor Requirements**

- ➢ High level of *reflectance*
  - White paper ~ 80%
  - Newspaper ~ 50%
  - Visible reflectance ~ 40%
- ➢ High *contrast*
  - White paper ~ 20 : 1
  - Newspaper ~ 7 : 1
- ➢ Full-*color* capability
  - No saturation/blur in color

❑ **Need a New Type of LCD: <u>Transflective !!</u>**

- ➢ Good readability : <u>transmissive</u> type with backlight
- ➢ Low power consumption : <u>reflective</u> type under ambient light

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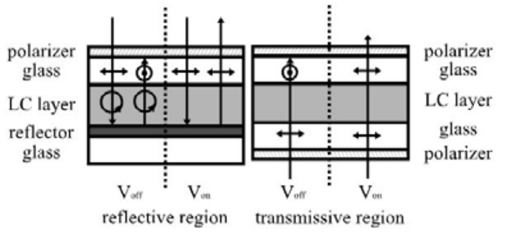
Transflective Configurations

❑ A *Basic* Transflective LCD Structure



❑ Two Main Configurations of Transflective LCDs

- ➢ **Dual cell gap configuration**
  - **Good performances in transmissive and reflective areas**
  - **Difficulty in pixel fabrication**
- ➢ **Single cell gap configuration**
  - **Simple fabrication process of pixel elements**
  - **Optical compensation by a patterned retarder**

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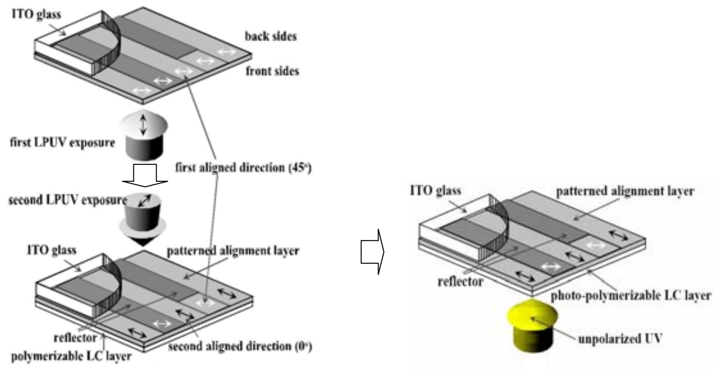
Existing Patterning Process

❑ Photo-alignment of LCP

- ➢ **Resolution of ≥ 2 ㎛**
- ➢ ***Weak anchoring* energy (≈ 10^{-6} J/m^2): *not reliable* at high T's**
- ➢ ***Complex patterning* process: Two LPUV, one UV exposed**



Need a new patterning technology !!

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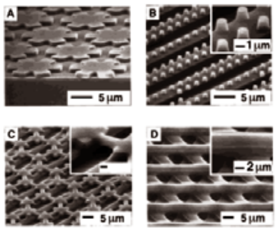
New Patterning Technologies

- **❑ *Soft Lithography* Technologies**
  - ➢ **Non-photolithographic techniques**
    - ***Imprinting* method**
    - **Replica molding (REM)**
    - **Micro-molding in capillaries (MIMIC)**
    - **Solvent-assisted micro-molding (SAMIM)**



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- **❑ Advantages of Soft Litho Technologies**
  - ➢ **Easy & simple process, applicable for flexible substrates**
    - **2D/3D microstructures by a single step process**
    - **Easy patterning of planar/curved surfaces**
    - **Low temperature process**
    - **Cost-effective**

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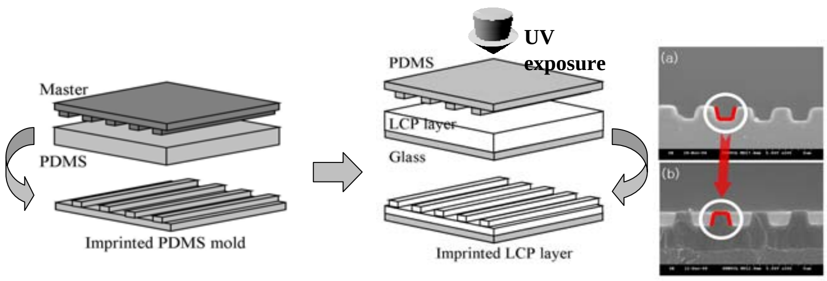
Imprinting Process of LCP

- **❑ Imprinting Process of a LCP patterned retarder**
  - ➢ **Master : UV curable polymer (NOA65, Norland Ltd.) on PET**
  - ➢ **Polymer mold : PDMS on Master**
  - ➢ **LCP material : RMS 03-001 (E. Merck)**



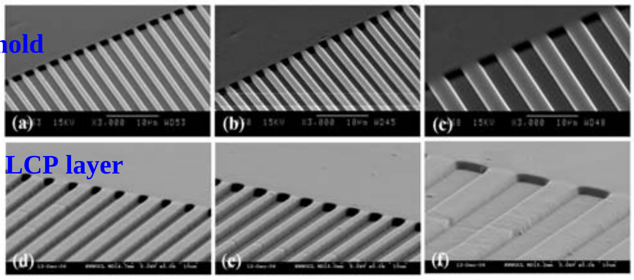
- **Resolution of ≥ 50 nm (typically 200 nm)**
- ***Strong* anchoring energy (≈ 10^{-4} J/m^2): No extra alignment layer (Berreman's elastic description)**

❑ SEM images of *imprinted* LCP layers

- ➢ **Polymer mold having different patterns**
  - **Period from 3um to 8um**

Polymer mold

Imprinted LCP layer

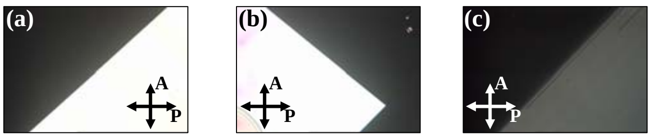


Period:	3um	3um	8um
Ratio :	1:2	1:1	1:1

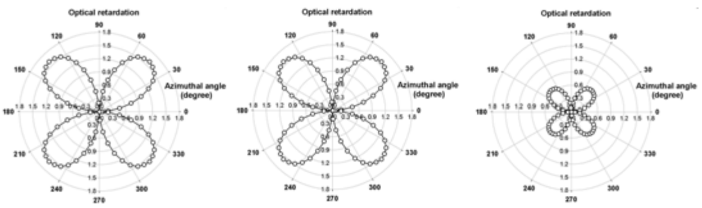
- ➢ **Successful transfer of the patterns onto the LCP layer**

❑ Microscopic Textures of *Imprinted* LCP layers

- ➢ **Imprinted LCP layers with different patterns**



Period(ratio): 3um (1:2) 3um (1:1) 8um (1:1)



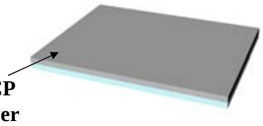
- ➢ **Well-aligned LCP molecules during imprinting (periods ≤ 5μm)**
  - **$2\pi d\Delta n/\lambda \approx 1.57$: QWP**

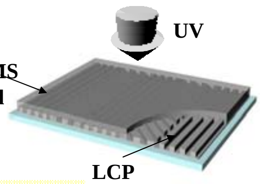
LCP Patterned Retarders

❑ Imprinting of LCP patterned retarder

- LCP material : RMS 03-001C (E. Merck)

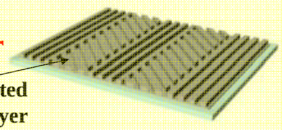
- Spin-coating of LCP @ 2500 RPM for 30sec
- Pre-baking @ 65°C for 10min





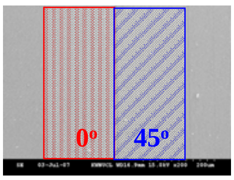
- Imprinting of the LCP layer
- PDMS mold with *different patterns*
- UV exposure @ 40mW for 300sec in N_2

→ **LCP patternd retarder**

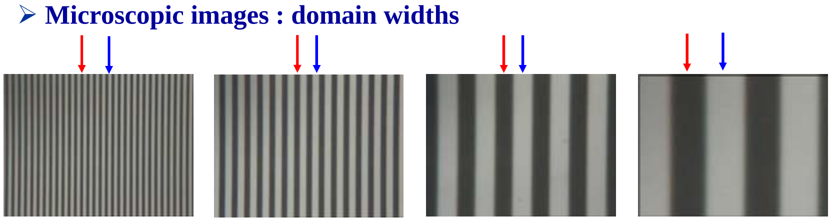


❑ Domain width of *imprinted* LCP layer

- SEM image



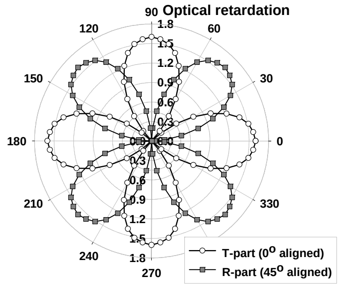
- Microscopic images : domain widths



- **Well-defined periodic domains in *imprinted*, patterned LCP retarder**

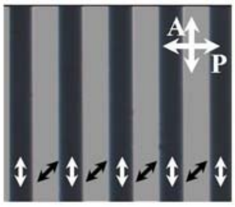
❑ Optical Retardation

- ➢ $2\pi d\Delta n/\lambda = 1.57$ (QWP)
- ➢ Same retardation in both domains



❑ Microscopic Textures

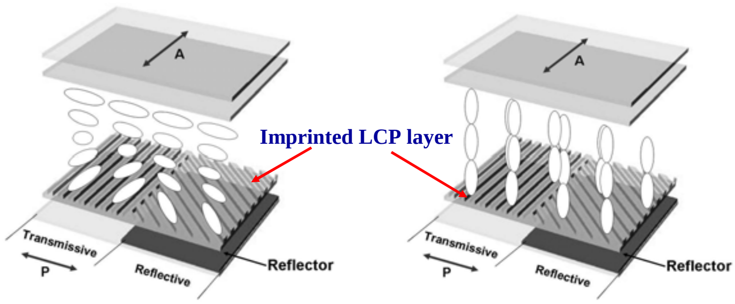
- ➢ 45° domains : QWP for R-areas
- ➢ 0° domains : dummy for T-areas



Transflective LCDs with Retarders

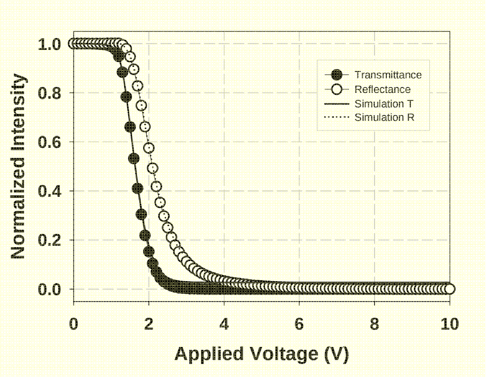
❑ TN Transflective LCD with in-cell patterned retarder

- ➢ Single cell gap & multi LC modes (45°-TN, 90°-TN)
- ➢ Multi-functional *imprinted* LCP layer
  - Self- homogeneous alignment (no alignment layer)
  - In-cell patterned retarder



Bright state (V_{off})   Dark state (V_{on})

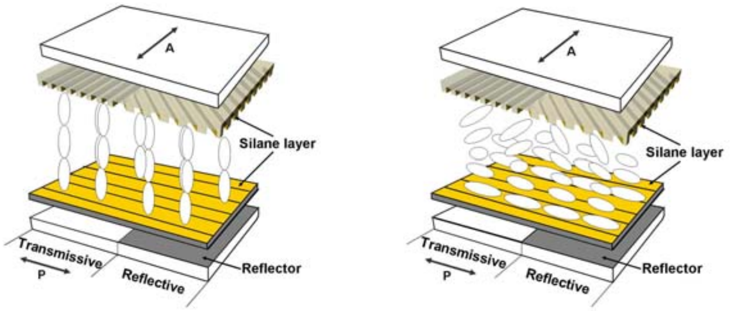
❑ Electro-optic transmission



- ➢ Measured T/R data agree with simulation results
- ➢ In-cell patterned retarder by *imprinting*
  - • No optical parallax and compactness
  - • No extra alignment layer

❑ ITN Transflective LCD with in-cell patterned retarder

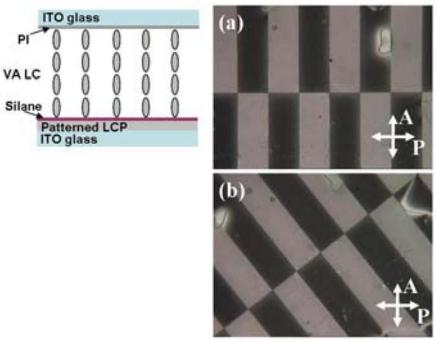
- ➢ Single cell gap & single inverse TN(ITN) LC mode
- ➢ Multi-functional *imprinted* LCP layer
  - • Self-homeotropic alignment (silane treatment)
    - trichloro (1H,1H,2H,2H-perfluorooctyl) silane
  - • In-cell patterned retarder

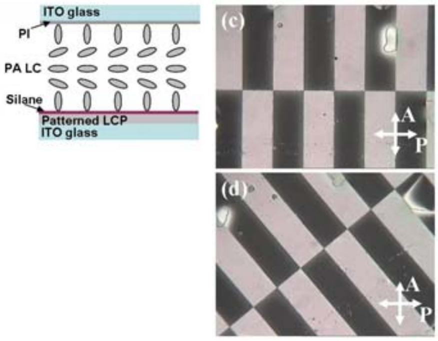


Dark state (V_{off})   Bright state (V_{on})

Microscopic Textures of [*LC* +silane treated *LCP* retarder]

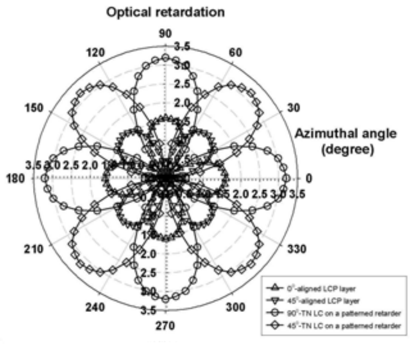
- Voltage 'OFF'
  - Net retardation ("0"+LCP)
    - QWP for 45° for R
    - Dummy for 0° for T
- Voltage 'ON'
  - Net retardation (LC+LCP)
    - HWP for 45° for R
    - Dummy for 0° for T



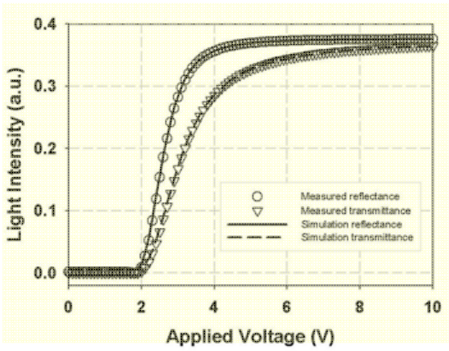


Optical Retardation of [*LC+LCP*]

- Voltage 'OFF'
  - LCP layer (QWP) + LC layer (no retardation)
  - → $2\pi d\Delta n/\lambda = 1.57$ (QWP)
- Voltage 'ON'
  - LCP layer (QWP) + LC layer (QWP)
  - → $2\pi d\Delta n/\lambda = 3.14$ (HWP)



❑ EO transmission of ITN transflective LCD



- ➢ ***High transmittance*** **and** ***high reflectance*** **simultaneously**
- ➢ **Measured T/R data agree well with simulation results**
- ➢ **In-cell patterned retarder by** ***imprinting***
  - **No optical parallax and compactness**

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Conclusion

❑ *Imprinted* optical films based on LCP material

- ➢ **Resolution of ≥ 50 nm**
- ➢ **Strong anchoring energy (≈ 10^{-4} J/m^2)**
- ➢ **Advantages**
  - **Only one-step process**
  - **Easy patterning of LCP retarders**
  - **No extra alignment layer (Berreman's elastic description)**

❑ Transflective LCDs with *in-cell* patterned LCP retarders

- ➢ **In-cell patterned retarder by** ***imprinting***
  - **No optical parallax and compactness**
- ➢ **Multi-functional LCP : retarder & alignment for TRF-TN**
- ➢ **High transmittance and high reflectance for TRF-ITN**

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