Liquid Crystal Displays
-a Technological Revolution

Avtar S Matharu

am537@york.ac.uk
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Contents

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   LCDs everywhere, market dominance, TN Display type, definitions, economic factors.

2. Cell assembly
   Backlighting: clarity, luminance.

3. Manufacturing
   Minimising costs, panel size, filling, thinning.

[4. See examples of liquid crystals: both display and non-display]
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LCDs - everywhere
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- market penetration

Data source: Norman Bardsley, DisplaySearch
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LCDs versus CRTs

**Benefits:**
- Flat panel
- Lightweight
- Low power
- Do not emit harmful radiation

**LC requirements (problems):**
- Wide operating range, -40°C to +50°C
- Chemical, physical and electro-chemical stability
- Wide viewing angle, contrast, brightness
- Low viscosity
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- Not just LCDs
‘A Technological Revolution’ - what are liquid crystals?

Conventional wisdom – 3 states:

- **Gas**
  - Total disorder; much empty space; particles have complete freedom of motion; particles far apart.

- **Liquid**
  - Disorder; particles or clusters of particles are free to move relative to each other; particles close together.

- **Crystalline solid**
  - Ordered arrangement; particles are essentially in fixed positions; particles close together.

A FOURTH STATE!

“Liquid crystals are materials that exhibit an intermediate state of matter that exists between the crystalline and isotropic liquid states”
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Twisted Nematic Display

- Front polariser
- Front glass substrate
- ITO layer
- Alignment layer
- Nematic Liquid crystal
- Alignment layer
- ITO layer
- Rear glass substrate
- Rear polariser
- Backlight
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Twisted Nematic Display

ON STATE
(DARK)

OFF STATE
(BRIGHT)

0 V

V
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New - IPS and VAN

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Display Construction

- ANTI GLARE
- LC CELL
  - Polarizer
  - Image Layer
  - Polarizer
  - Diffuser
- COLLIMATION
  - DBEF
  - BEF
- LIGHT SOURCE
  - BEF
  - Diffuser
  - Light guide plane
  - Reflector
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Economic considerations

- CLARITY
- POWER
- PORTABILITY
- MATERIALS
- MACHINERY
- PROCESS TIME

COST
‘cut-throat business’
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Backlighting types

- LCD cell
- Clear Plastic lightguide
- Point sources emitting sideways into light guide
- Reflective surface
- LCD cell
- Reflective surface
- Line sources
Total Internal Reflection

Dots for extracting light from light guide

Cold Cathode fluorescent lamp (CCFL)

White reflector

Light guide

CCFT Lamp

ESR

3M Enhanced Specular Reflector is a 98.5%, non-metallic specular (mirror-like) reflector
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Brightness Enhancement Films

Total Internal Reflection

Diffusely recycled

70°

Refractive - Usable refracted rays are increased 40% - 70%

Low percentage lost

Re-enter next prism

Diffuse Illumination

Diffuse Illumination
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Backlighting - integrated

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Backlighting losses

Backlight
100% of light

Display with active pixel areas
<100% of light available passes through pixel areas
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Backlighting losses

Actual size of active pixel area (overlap of upper and lower electrodes)

Actual size of pixel to pixel gap

Aperture% = active pixel area / actual pixel area

Aperture of typical (pixellated) passive LCD = 90 - 95%

Aperture of typical AM TFT LCD ~ 35 - 65%
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Polariser losses

Commercial grade \(\sim < 48\%\) transmission

Extended grade \(\sim < 40-45\%\) transmission
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Colour Filter losses

Monochrome display
White = 100% $L_{BL}$

Colour display
White = 33% $L_{int}$
Mother glass preparation

- Glass substrates coated with Indium Tin Oxide (ITO). Resistivity in the range of 10 – 125 Ohm sq.
- Substrate thickness ranges from 0.3 to 1.1 mm.
- Soda lime or Borosilicate

Generation 1 = 320 x 400
Gen 2 = 370 x 470
Gen 2.5 = 400 x 500
Gen 3 = 550 x 650
Gen 3.25 = 620 x 750
Gen 3.5 = 650 x 830
Gen 4 = 730 x 920
Gen 5 = 1100 x 1250
Gen 6 (2003) = 1500 x 1800
Gen 7 (2004) = 1800 x 2100
Gen 8 (2006) = 2160 x 2460 (0.7 mm thick!!)
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Putting it together

Pre-cleaning

- Use detergent and ultrasonic baths to remove oil and particles on the substrate surface

Mother glass
Preparation

Pre-Cleaning
ITO Patterning

- **Photo-resist coating**
- Coat a photo-resist layer on the substrate surface
- Thickness of PR at ~1.2 um
- Offset printer spin-coat techniques used

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ITO Patterning

- **Photolithography**
- The UV exposure time depends on the resolution, usually at around 10 to 20 sec.
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Putting it together

**ITO Etching**
- Etch the ITO pattern by using strong acid
- Control bath temperature to control the etching rate
- The etching time depends on the ITO layer thickness
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- Polyimide alignment layer
- PI offset printed coating or spin coated
- Coat the patterned or coated PI layer on the mother glass
- Cure under high temperature for around 3 hours

Mother glass
Preparing

Pre-Cleaning

Photo Resist Coating

UV Exposure

Developing

ITO Etching

Final cleaning

PI offset coating
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Maximising yield - coatings

Spin coating

No tooling = cheap process

Offset lithographic printing

Tooling required
more expensive process
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**Buffing (Rubbing)**

- Determine the buffing direction of display which determines the LC twist angle
- Rub the PI layer using Wool, Nylon or Rayon
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Putting it together

Perimeter seal, conductive dot screen printing, spacer filling

- Mother glass Preparing
- Pre-Cleaning
- Photo Resist Coating
- UV Exposure
- Developing
- ITO Etching
- Final cleaning
  - Spacer spraying
  - Main seal screen printing
  - Buffing
  - PI offset coating
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Maximising yield - sealants

Spin process

Off set litho print process

Epoxy seal rests on dielectric = low strength, poor reliability, low lifetime but CHEAP

Epoxy seal on glass or metal = high strength, good reliability, long lifetime but MORE EXPENSIVE
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Putting it together

- Coupleing and Vac pack
- Sealed
- Plastic Bag
- Mother glass Preparing
- Pre-Cleaning
- Photo Resist Coating
- UV Exposure
- Developing
- ITO Etching
- Final cleaning
- Vacuum pack
- Coupling
- Spacer spraying
- Main seal screen printing
- Buffing
- PI offset coating
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Maximising yield - filling

Full Size Substrate → LC Drop → VAC, Alignment
ATM, Press UV Curing → Alignment & Press → Cutting

30 inch Panel 5 MINS!


30 inch Panel 5 DAYS!
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Maximising yield - glass

25% more per panel

x4 rows

x5 rows
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Maximising yield - Electronics

Wire on Array and Chip on Glass Technology
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Maximising yield

- Glass weight
- Spacer Technology
- Rubbing direction and alignment layers
- Backlight optimisation
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