

# **C3A - Display Technology**

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# Lecture Course Content

1. Introduction to displays and LCDs
2. LC materials/physical properties/switching principles
3. Theory (switching mechanisms/optics)
4. Twisted Nematic LCD/passive addressing
5. Supertwisted Nematic LCD/TFTs
6. Advanced LCDs
7. Optical films for LCDs
8. Other displays

# Purpose of a Display

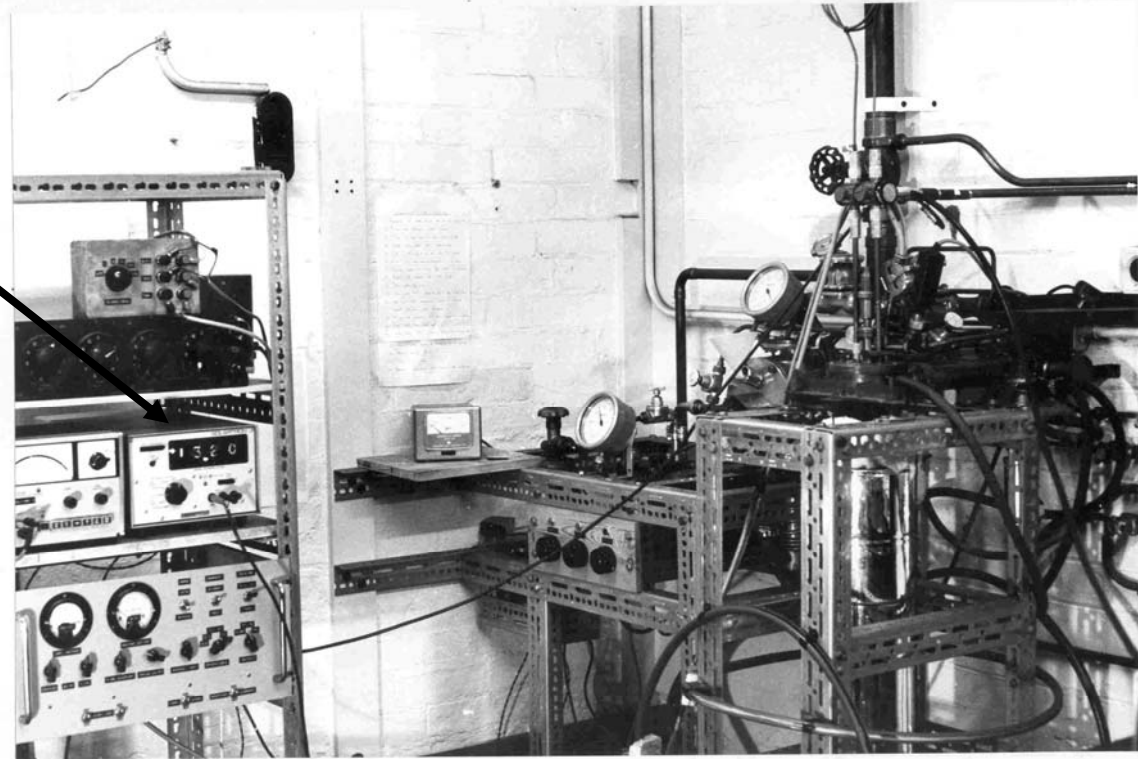
- To convert electrical information into visual information for benefit of operator/viewer
- Examples
  - Battery charge indicator
  - MP3 player
  - Calculator
  - Mobile phone
  - Computer monitor
  - TV screen

# History of Displays

- Years around 1970 were a watershed
  - Before ~1970 is ancient history
    - Lamps
      - Incandescent lamps
      - Gas-discharge lamps
    - Cathode Ray Tubes (CRTs)
    - Light Emitting Diodes (LEDs)
  - After ~1970 saw start of modern displays
    - Two key driving forces from solid state electronics
      - Flat panels
      - Low power/low voltage

# Gas-discharge Lamp - 1970

Voltmeter using  
Nixie tubes



# Nixie Tube

- Gas discharge tube introduced in 1920s
- Multiple cathodes shaped of characters (eg 0 to 9)
- Filled with neon + mercury and/or argon
- Cold cathode (no heating)
- Gas glows red-orange with
  - ~ 100 Volts DC
  - Few mA

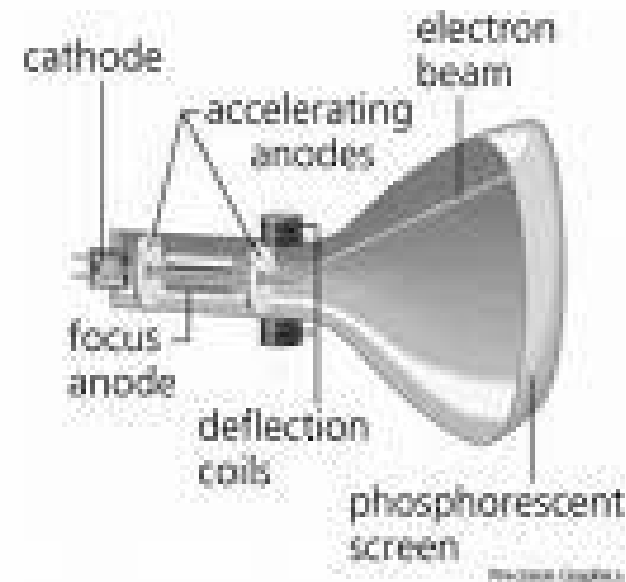


## Dekatron



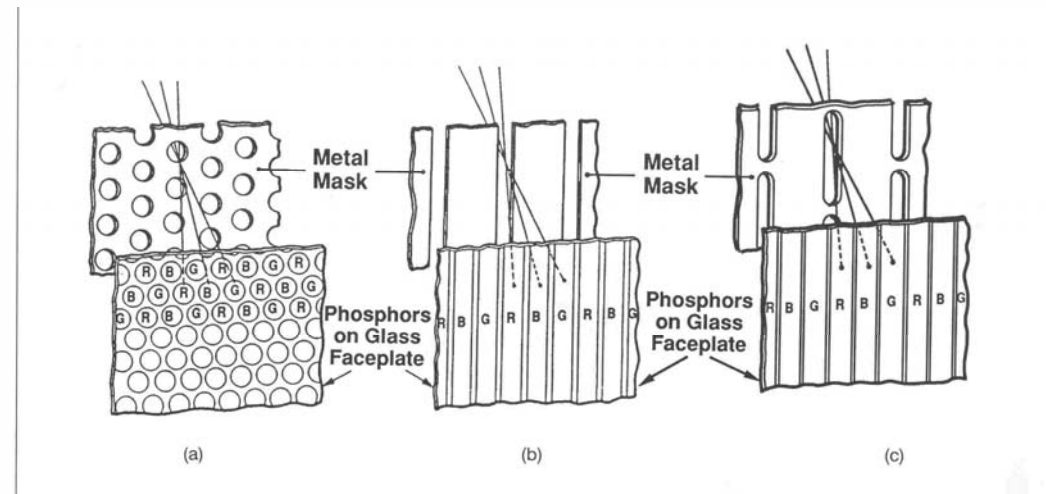
# Cathode Ray Tube (CRT)

- Invented in 1897 by Braun (and J J Thompson)
- Commercial product by 1922
- Source of electrons
  - Hot cathode
- Accelerated by anode
- Focused by coil
- Deflected by coils
- Phosphor screen



# Colour - Shadow Mask Tube

- 3 electron guns and 3 phosphors (RGB)
- Correct electron beam to correct phosphor



- Achieved using shadow mask
- Several types



# Use of CRTs

- Widespread use in
  - TVs
  - Computer monitors
  - Oscilloscopes
  - Radar sets
  - etc
- Dominant till recently
- High voltage (up to 30kV) and 50W for 21" colour CRT
- Large vacuum envelope  $\Rightarrow$  bulky and heavy

# Light Emitting Diodes (LEDs)

- p-n junction can emit light with photon energy of band gap
- Colour depends on semiconductor material
- Low voltage (1.5-3V)
- Reasonably low current (10s mA)
- Efficient source of light
- Long life



# Use of LEDs

- ~1970 as a display device before LCDs
  - Portable devices
  - Short battery life
- Since 1970
  - Indicator lamps
  - Source of light
- Recently re-emerged as displays using organic semiconductors

# 1970 - Display Requirements

- Two clear requirements driven by:
  - Emergence of integrated circuits
  - Desire for portable equipment
- Flat panel displays
  - Space
  - Weight
- Battery driven equipment
  - Low voltage
  - Low power

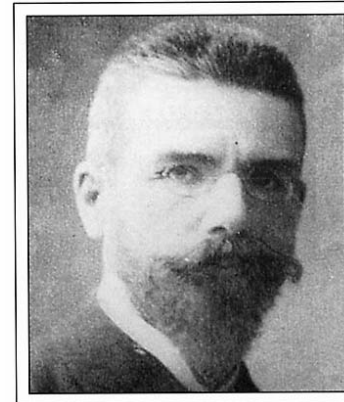
# 1970 - New Display Technologies

- Existing display technologies
  - CRT
    - Large
    - High voltage, large power
  - Nixie tubes
    - Lack of flexibility
    - High voltage
- Liquid Crystal Displays
  - Considerable promise
    - Flat panel display
    - Low voltage, low power
  - But considerable number of problems

# Introduction to Liquid Crystals

- Centenaries

- LC discovery (1888)



- First commercial LC material (1904)



# LCDs - Progress

- 1973
  - Original LCD calculator
  - Electro-hydrodynamic mode
    - Interesting science
    - Poor performance
    - Soon obsolete
- 2007
  - Billions of LCDs made
  - Worth 10sB£
  - 46" HD TV at Dixons



# First Generation of LCDs

- 1970: lack of suitable
  - LC device
  - LC material
- 1971: Twisted Nematic LCD invented
- 1972: First stable room temperature LC material
- 1975-1980: Widespread adoption of LC watches and calculators



# Second Generation of LCDs

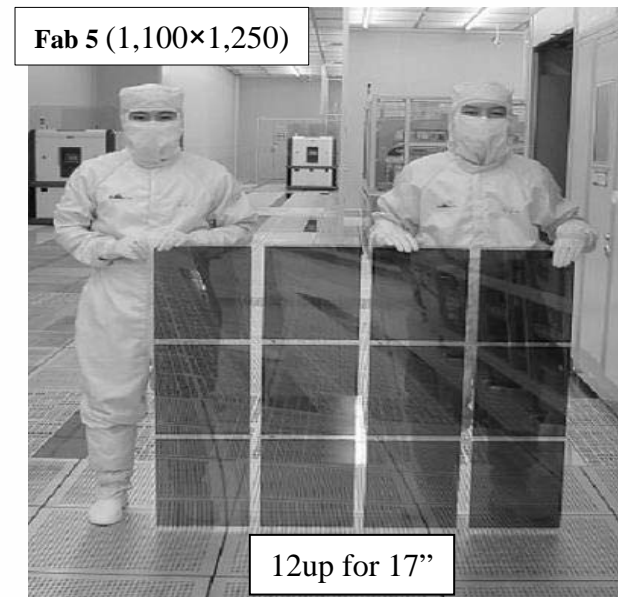
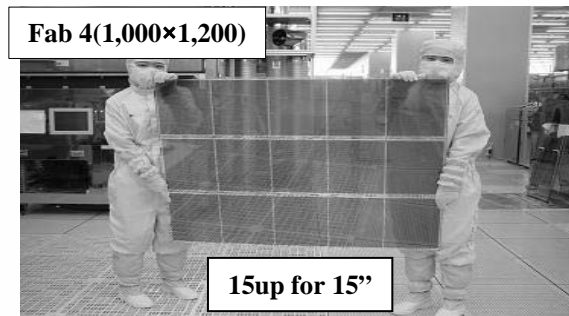
- 1980: lack of high information content LCD for
  - Computer monitors
  - TVs
  - Range of domestic, automotive and office equipment
  - (Mobile phone)
- 1980: amorphous silicon TFTs (Dundee Un.)
- 1982: Supertwisted Nematic (STN) LCD (MoD)

# Third Generation of LCDs

- 1990: lack of high contrast ratio, fast switching for TV
- 1995: two 'old' LCDs revisited, both with TFTs
  - In-plane-switching (IPS)
  - Vertically aligned nematic (VAN)
- TV market split now between these two technologies

# Substrate Size

- Evolution of size



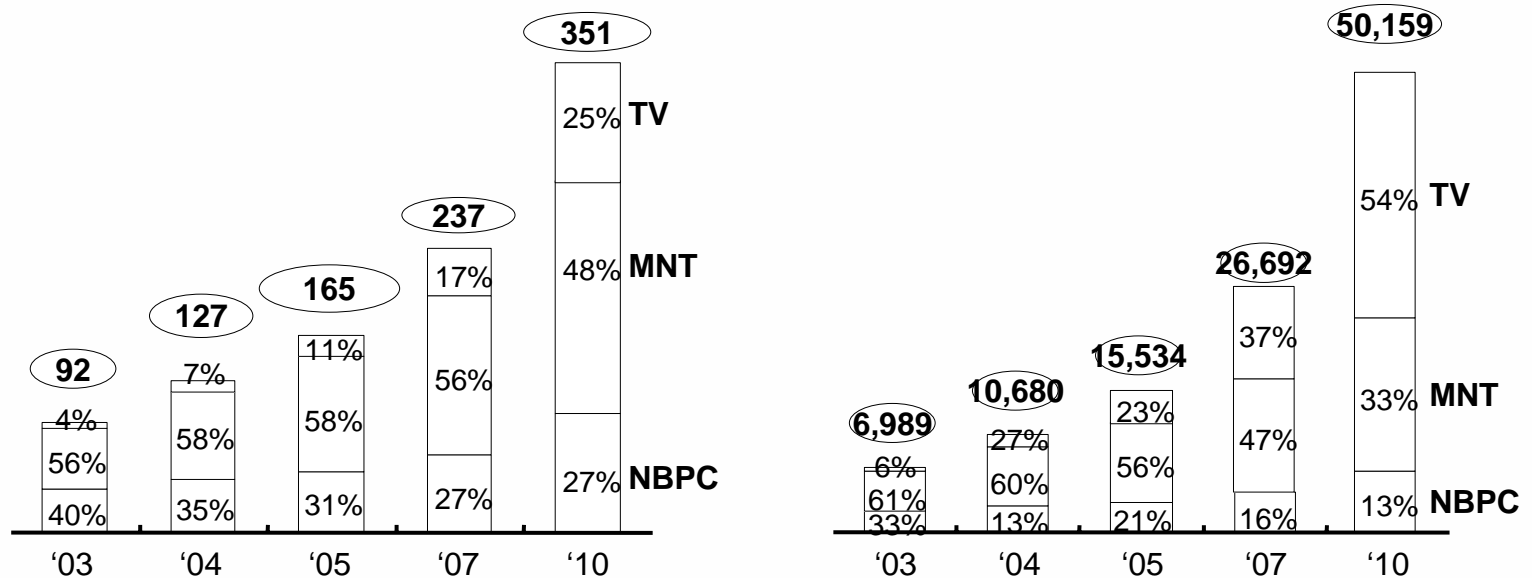
- Now generation 8: > 2m x 2m

# LCD Market

(Ignores small/medium size displays)

Units (M)

Area (1000m<sup>2</sup>)



# Liquid Crystal Life Before Displays

- 1888: LC phase discovered (identified)
- 1905
  - Alignment on surfaces
  - Twisted nematic optics
- 1935
  - Alignment in fields
  - Field re-alignment of aligned layers
- 1955
  - Application of continuum mechanics to LCs
- 1965
  - Chemical principles for forming LC phases

# Next Lecture

- LC materials
  - Various LC phases
  - Range of chemical structures
- Physical properties
  - Spontaneous ordering present
  - Anisotropic properties
    - Refractive indices
    - Dielectric constants
    - Viscosities
- Switching principles
  - Surface alignment
  - Field alignment
  - Competition between the two