OLED display

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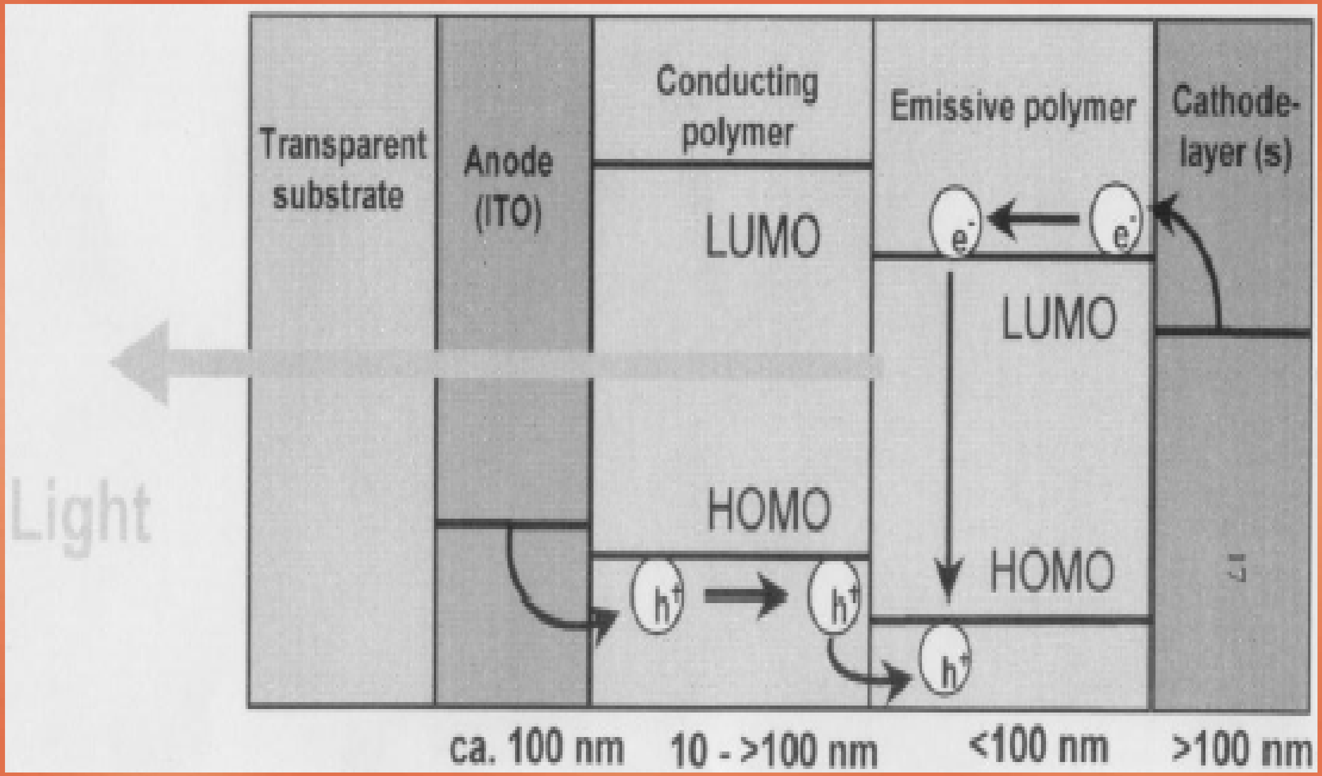
Outline

- OLED basics
- OLED display
- A novel method of fabrication of flexible OLED display

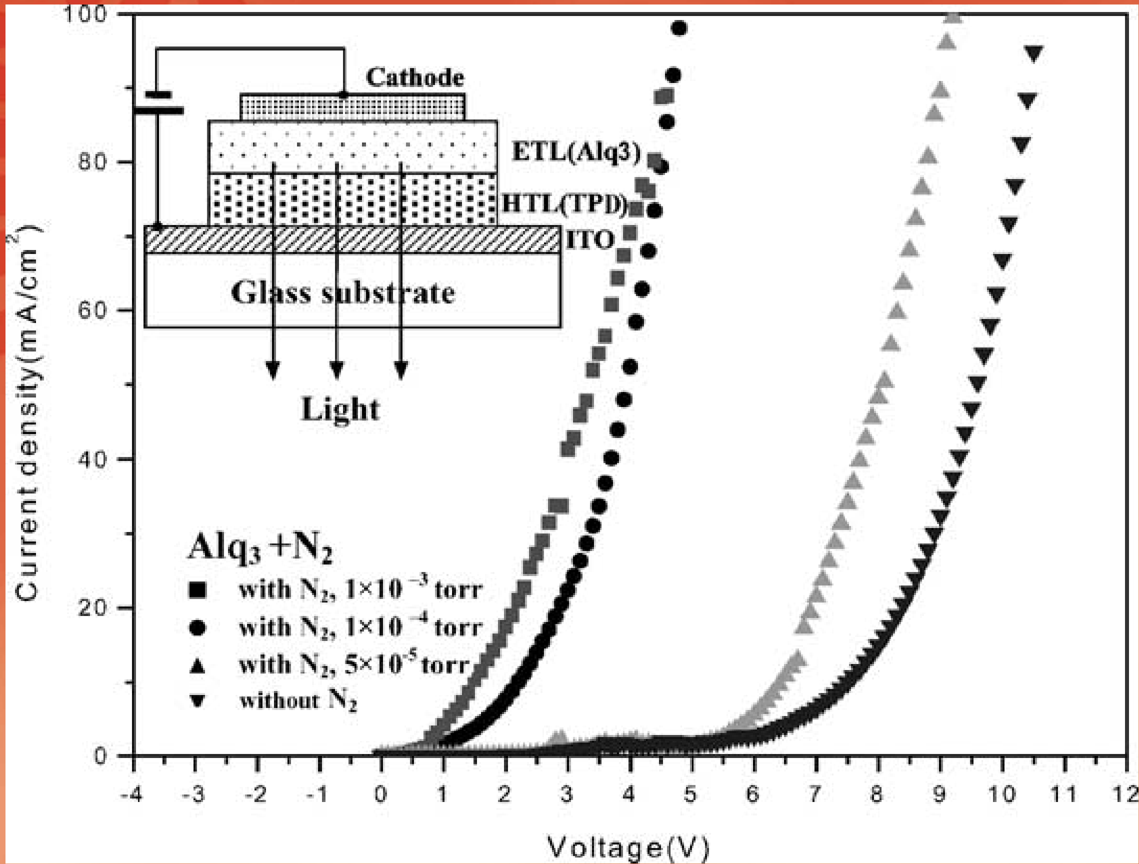
Potentials of OLED

- Suitable for thin, lightweight, printable displays
- Broad color range
- Good contrast
- High resolution(<5 μm pixel size)
- Fast switching (1-10 μs)
- Wide viewing angle
- Low cost of materials

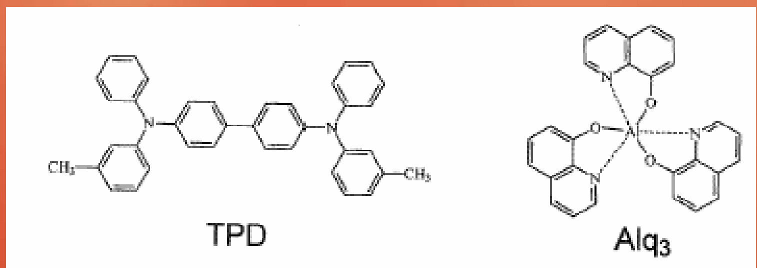
Energy level diagram of OLED



- Electrons injected from the cathode (Ca, Al, Ba, etc.)
- Holes injected from the anode (Indium/tin oxide, PANi, PEDOT)
- Transport and radiative recombination of electron hole pairs at the emissive polymer



The J-V curves of bi-layer OLEDs with Alq_3 evaporated under different N_2 ambient pressure. The insert presents schematic structure diagram of OLEDs. [2]

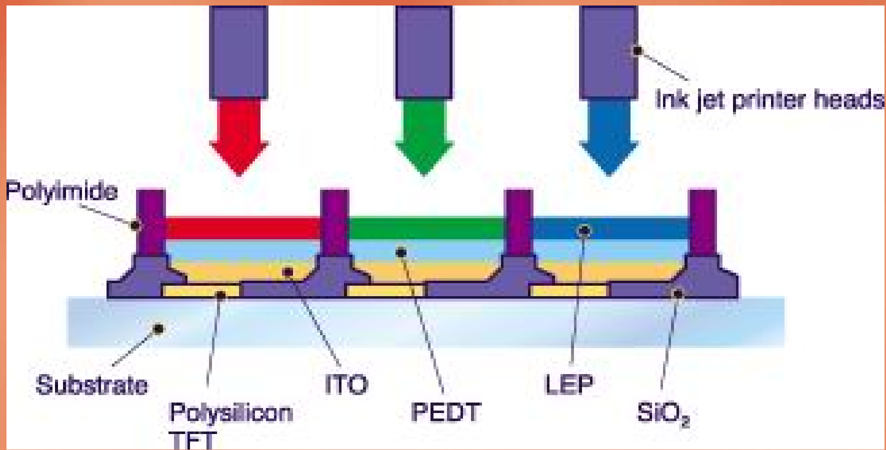


- A threshold voltage must be achieved to overcome the barriers to inject charges into the organic materials
- N_2 molecules doped during the evaporation of Alq_3 cause the expansion of the traps states below the LUMO thus lowering the injection barrier for electrons

OLED types

- Small-molecular OLED
  - Made by vacuum evaporating small molecules to the substrate similar to that used in semiconductor manufacturing
  - Well proven on fabrication of up to about 15 inches in diameter (shadow mask)
  - Crystallization due to low glass transition temperature shortens lifetime and reliability
- Polymer OLED
  - Made by depositing the polymer materials on substrates through an inkjet printing process or other solution processing methods under ambient conditions
  - Fabrication of large screen sizes
  - Oxidation of carbon-carbon bonds between the aromatic rings reduce the conjugation length of the polymer

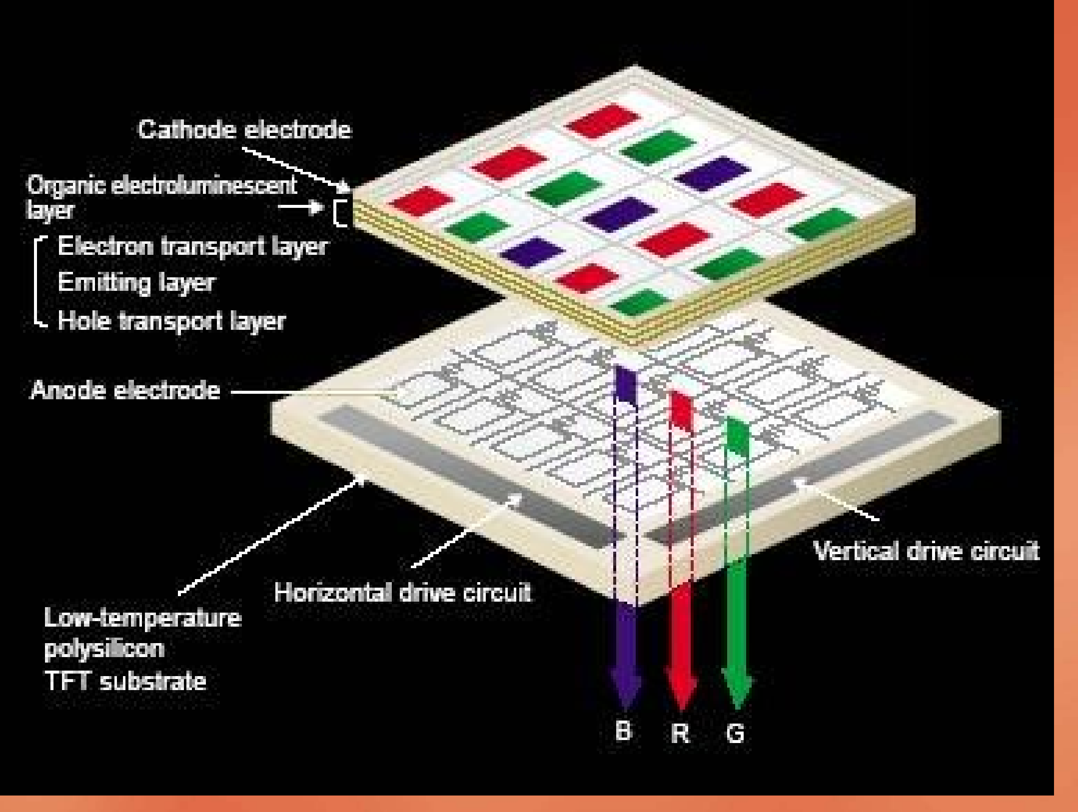
Inkjet printing



Ref. 3

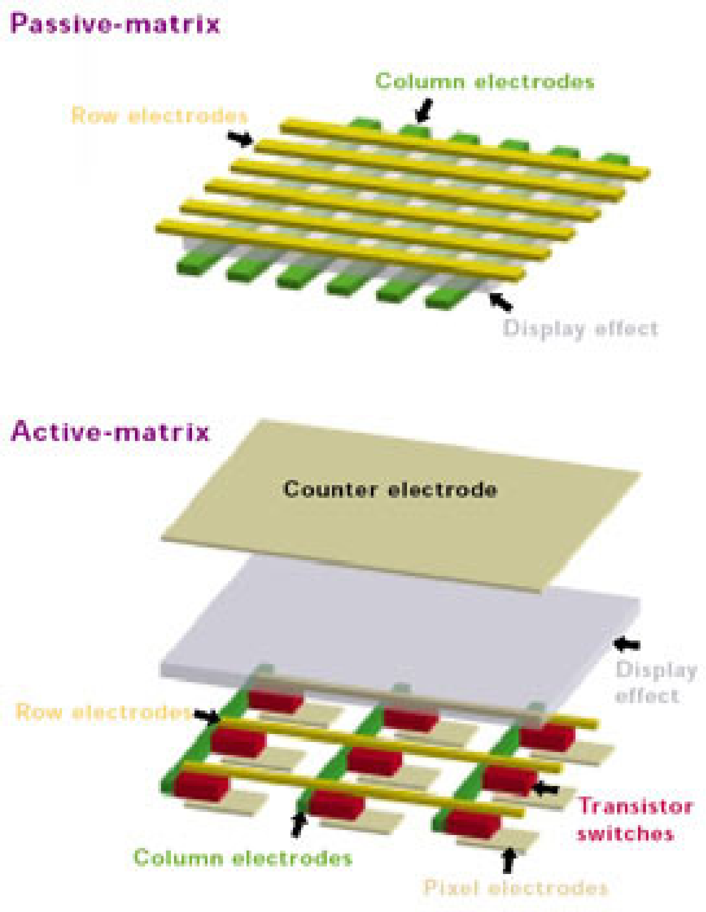
- Advantage: high-resolution, low cost, materials saving
- selectively deposit many layers in a display simultaneously
- Surface properties of the substrate affect the uniformity of the film thickness
- Problems: layer shift and dimentional changes from the PLED drying and evaporation process

OLED display



First active-matrix full-color display by Sanyo in 1999

Challenges and shortcomings I



- Addressing schemes
  - Huge driving currents are needed to achieve adequate average brightness in Passive Matrix addressing displays. Such large currents cause problems such as large drive voltages leading to increased power dissipation, excess flicker, and shortened lifetimes.
  - Active Matrix addressing can be used to overcome such problems

Challenges and shortcomings II

- Brightness and Lifetime Requirements
  - State of art OLED brightness and lifetime: 100 nits and 40,000 hours (50% initial luminance)
  - High brightness level require the display driving voltage levels to be increased which trades off expected lifetime. For most OLED materials, the relationship between driving voltage level and lifetime is nearly linear.
- Moisture sensitivity
  - Over time, moisture can react with the organic layers and cause degradation and defects in an OLED display
  - Sealing techniques
  - Inserting desiccants

Applications

- Current main commercial applications
  - Mobile phone screen (Samsung/NEC, Motorola, LG)
  - Car radio
  - Digital camera (Kodak)
  - Car stereo (Pioneer, TDK, Kenwood)
  - Razor (Philips)
- Future
  - Flexible displays
  - Replacing incandescent and fluorescent light bulbs
    - Currently power efficiency equivalent to incandescent light bulb while a factor of five less than that of fluorescent lighting

Flexible display

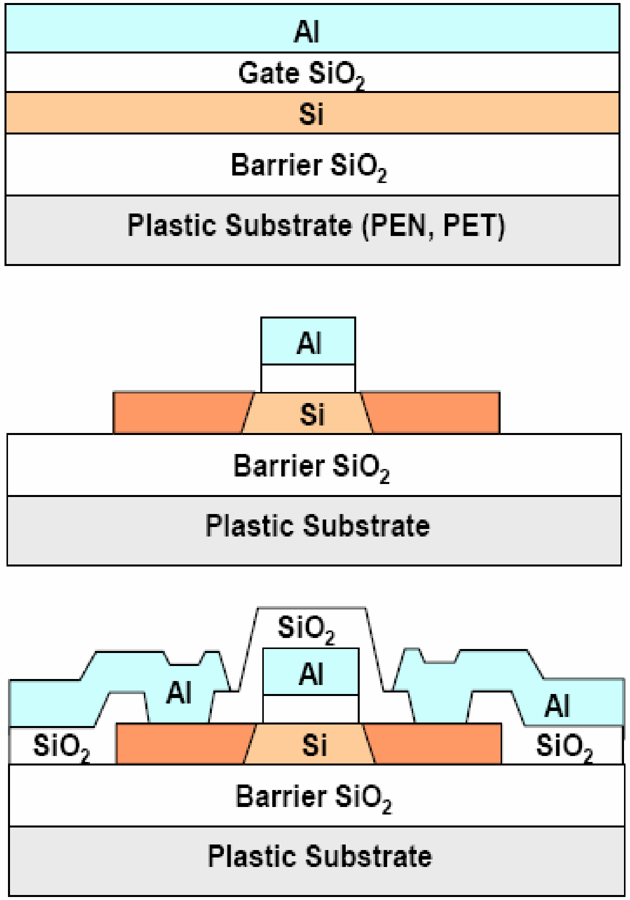
- Flexible substrate requirements
  - Transparent
  - Robustness
  - Low cost
  - Stability
    - Low coefficient of thermal expansion
    - Low moisture absorption
    - Resistant to chemicals & solvents
- Processing temperatures limited by :
  - Deformation temperature of material layers
    - For common plastic materials, <300 ºC

Top-gate TFT process flow [4]

1. deposit barrier oxide
2. deposit a-Si
3. crystallize a-Si (laser)
4. deposit gate oxide
5. deposit gate electrode

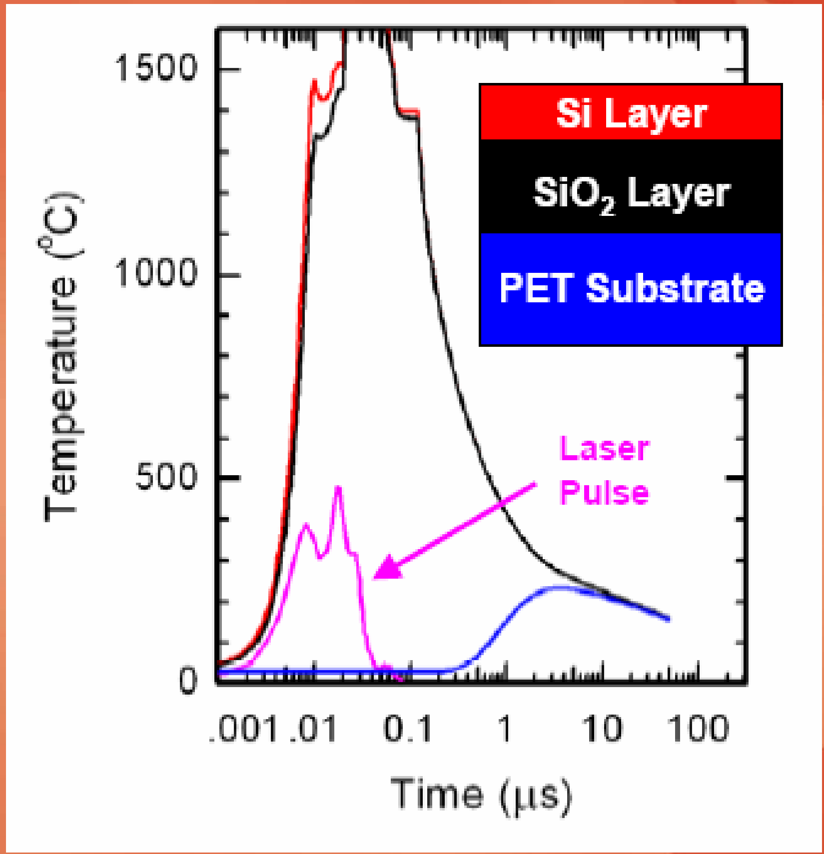
6. pattern gate (2µm min. features)
7. dope source/drain (laser)
8. pattern Si device regions

9. deposit contact isolation oxide
10. pattern and etch contact holes
11. deposit and pattern metal



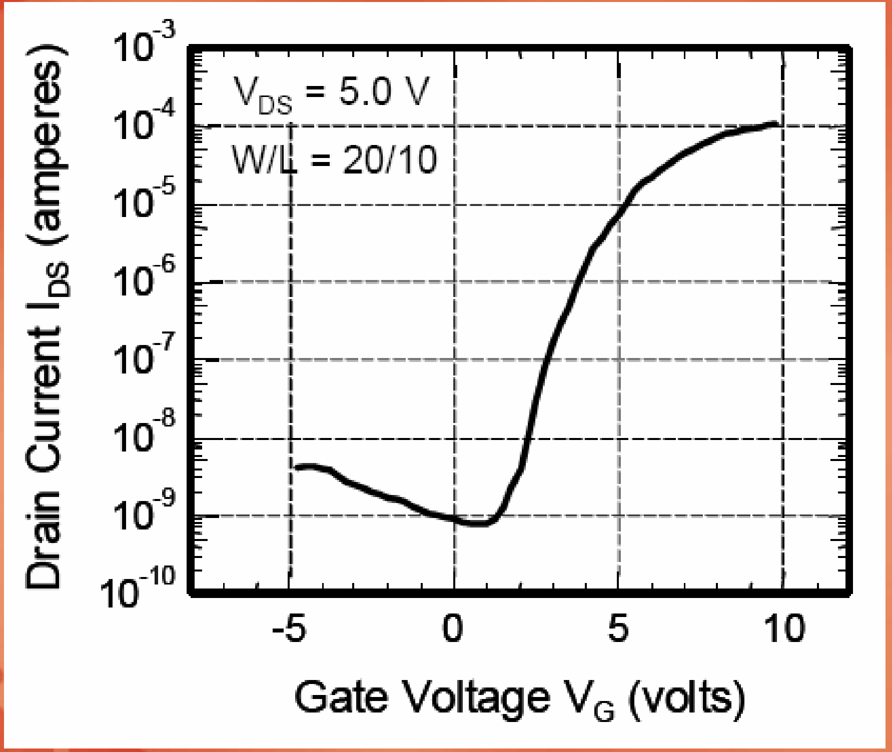
- 4-inch PET (Polyester), PEN (Polyethylenenapthalate) substrates
- Poly-Si formation by pulsed laser crystallization
- Low temperature (<100 ^{o}C) gate oxide (~100 nm) formation
- Dopant activation by pulsed laser annealing the dopant layer

- Pulsed Laser Crystallization (PLC)
  - PLC converts a-Si film (90 nm) to poly-Si via ultrafast melting and solidification.
  - SiO_2 buffer layer prevent the heat to be transferred to the substrate
  - Plastic kept below 250 ºC, cools rapidly



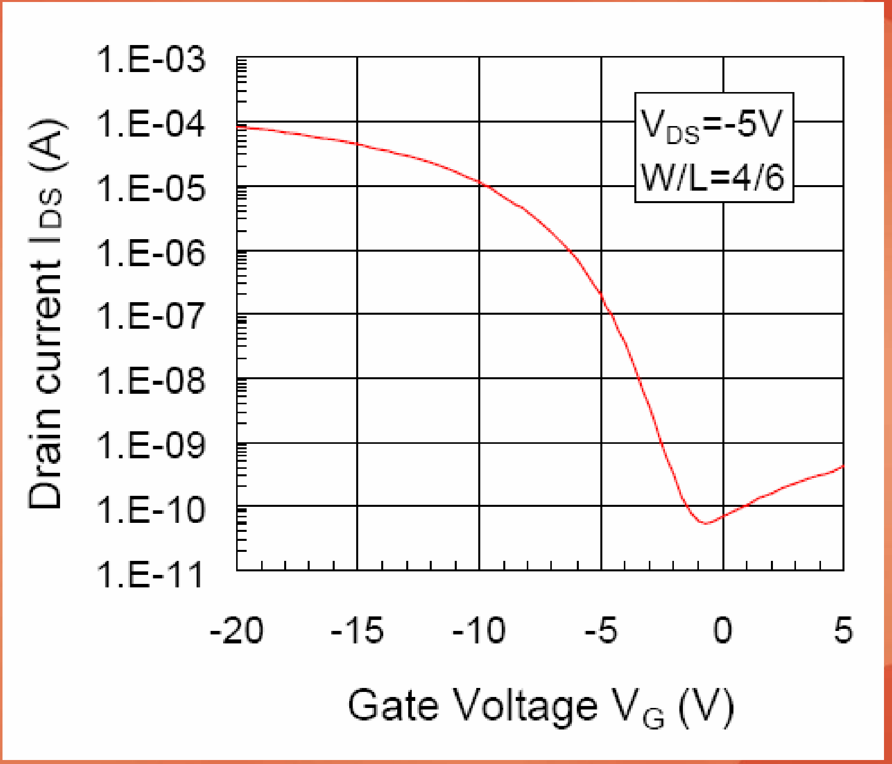
TFT results [4]

NMOS



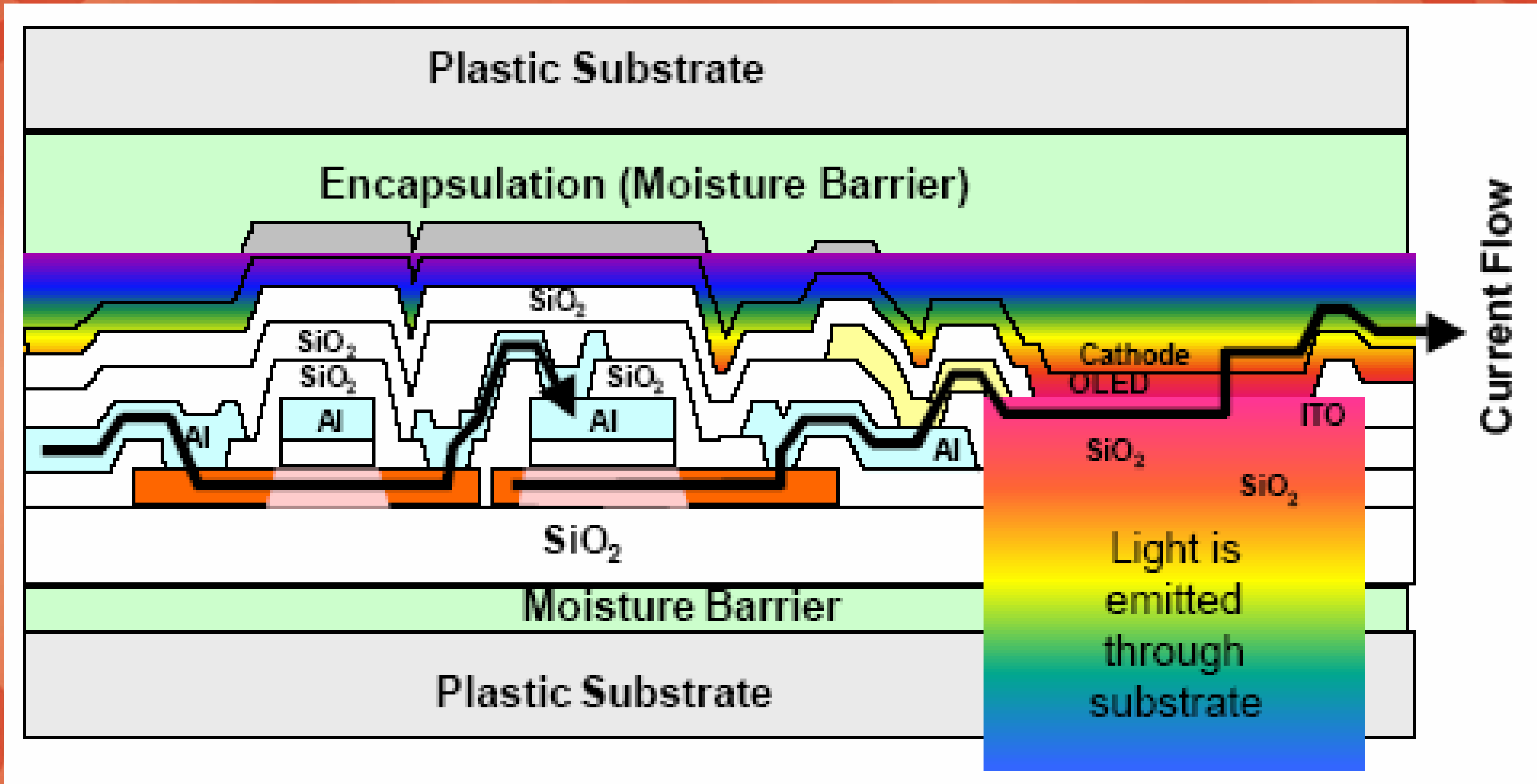
Mobility ~250 cm^2/V-s
Threshold voltage ~ 5 V

PMOS

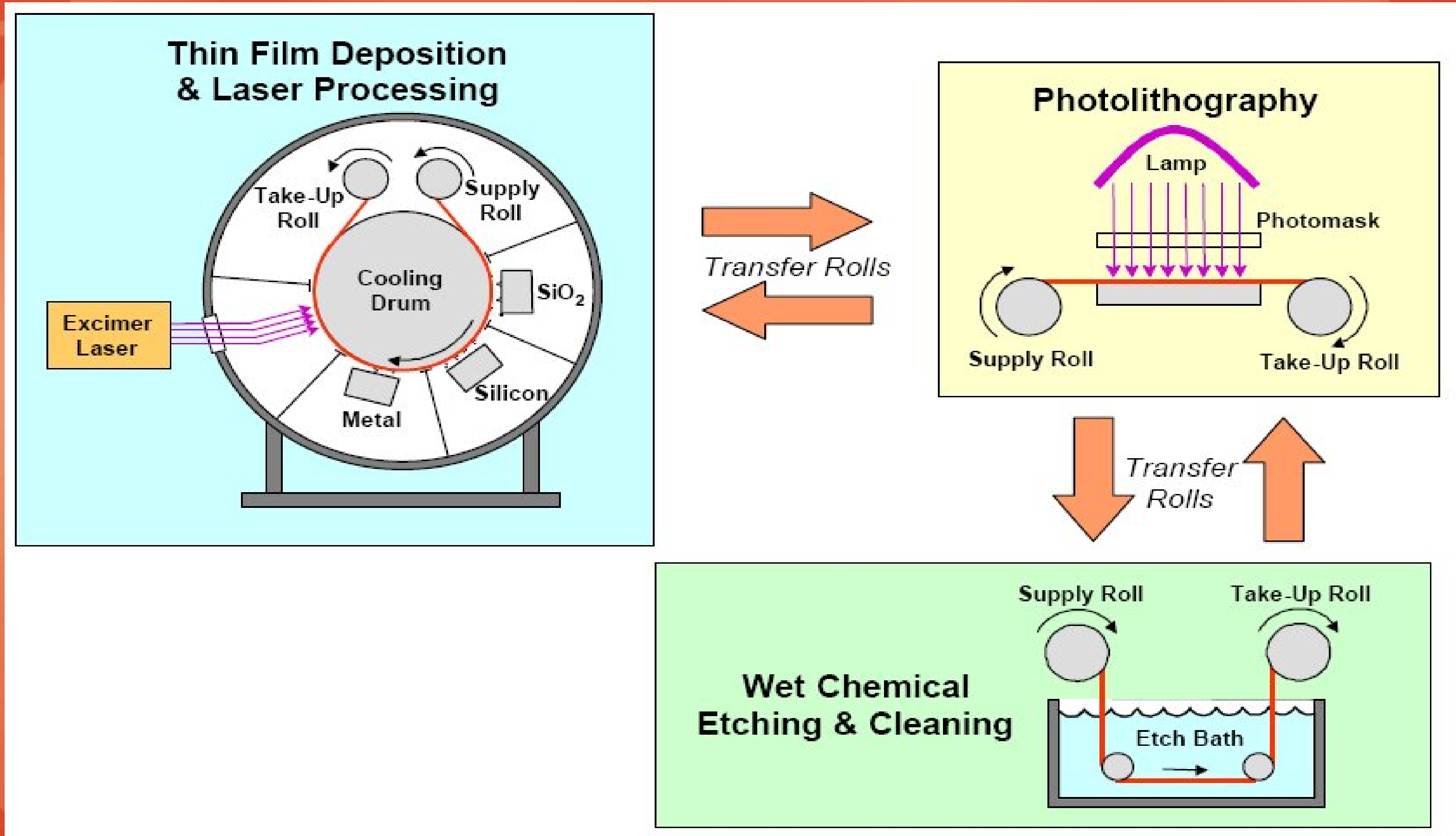


Mobility ~65 cm^2/V-s
Threshold voltage ~ -4.8 V

OLED integration [4]



Fabrication challenges [4]



- Evaluate damage to plastic & thin films
- Defects generation during thin film deposition

References

- 1. S. M. Kelly, “*Flat Panel Displays*”, p. 141, 2000
- 2. W.J. Lee, Y.K. Fang, Hsin-Che Chiang, S.F. Ting, S.F. Chen, W.R. Chang, C.Y. Lin, T.Y. Lin, W.D. Wang, S.C. Hou, Jyh-Jier Ho, Solid-State Electronics 47 (2003) 927–929
- 3. Clark W. Crawford, “*Organic Light Emitting Diodes Have Bright Future in Flat Panel Displays*”, Technology Commercialization Alliance, 2003
- 4. Daniel T., Teruo S., Sunder R., Patrick M. S., Paul G. C., and Paul W., “*Active Matrix OLED Display Backplanes on Flexible Substrates”, FlexICs, Inc.,2002*