Organic Transistors

By Prasann Viswanathan
190070047

Outline

- Device physics and parameters
- Materials used in fabrication
- Fabrication techniques
- Current applications in industry
- Future plans of work

Device Physics and Parameters

- Carrier Mobility
  - Temperature and Field dependent

$$\mu(T) = \mu_0 \exp\left[-\left(\frac{T_0}{T}\right)^2\right]$$

$$\mu(E) = \mu_0 \exp\left(\beta\sqrt{E}\right)$$

- I-V characteristics in different modes of operation
  - Linear

$$I_D = \frac{W}{L}C_i\mu\left((V_G - V_T)V_D - \frac{V_D^2}{2}\right), \qquad V_G - V_T > V_D$$

  - Saturation

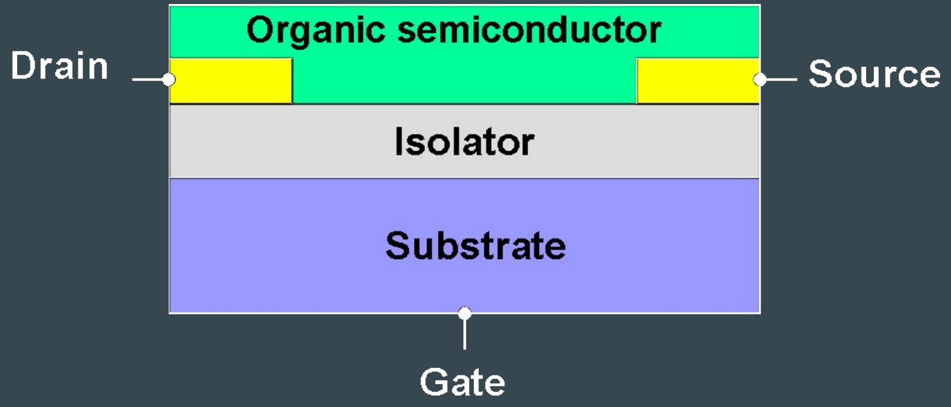
$$I_D = \frac{W}{2L}C_i\mu\left(V_G - V_T\right)^2, \qquad \text{if } V_D > V_G - V_T$$

- On current to Off current ratio
- Threshold voltage

J. Chang, Z. Lin, C. Zhang, and Y. Hao, "Organic Field-Effect Transistor: Device Physics, Materials, and Process", in Different Types of Field-Effect Transistors - Theory and Applications. London, United Kingdom: IntechOpen, 2017

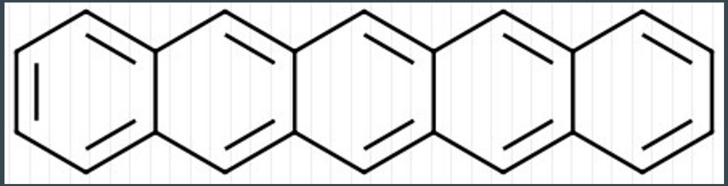
Materials

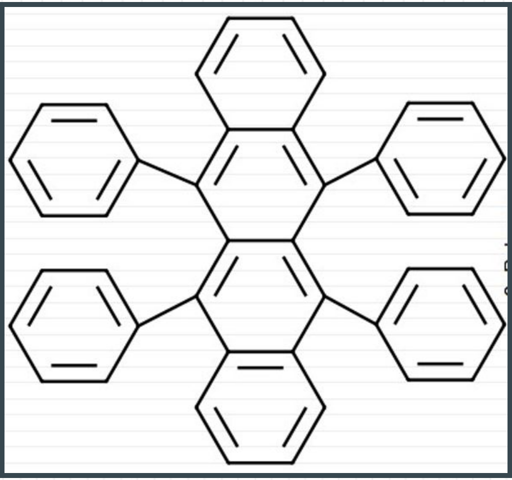
- Substrate
  - Quartz, glass, silicon wafer. Polycarbonate, polyimide
- Electrodes
  - Metals: Gold, palladium, magnesium, aluminium. Non-metal: graphite, 10-CSA doped polyaniline
- Dielectric Layer
  - Ta2O5, Barium zirconate titanate (BZT)
- Semiconducting Layer

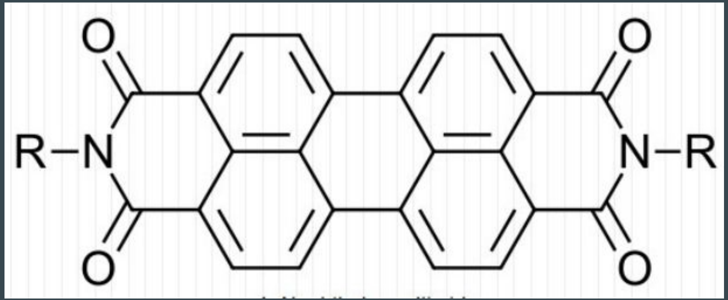


Semiconducting Layer

- Different charge transport nature
- P-type
  - Polycyclic aromatic compounds
  - Pentacene, rubrene
- N-type
  - Scarcer than P-type
  - Lower performance and unstable in ambient conditions
  - Perfluoropentacene, Naphthalene-diimide with cyanides







Chandar Shekar, B., Lee, J. & Rhee, SW. Organic thin film transistors: Materials, processes and devices. *Korean J. Chem. Eng.* 21, 267–285 (2004).

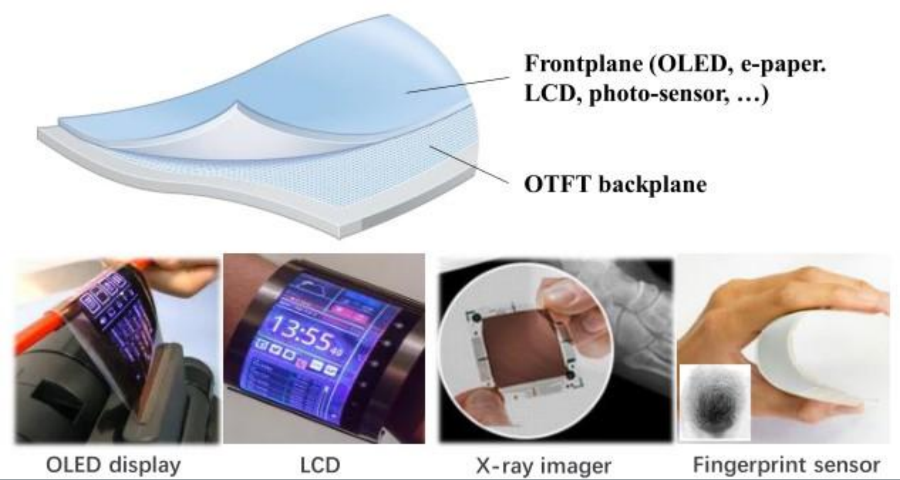
Fabrication Techniques

- Vacuum Evaporation
  - Extremely low pressures
  - Expensive and only for small molecules
- Solution Deposition
  - Cost effective method
  - Material must be soluble or dispersible in medium

Continued

- Thin Film Alignment
  - Alignment provides better mobility
  - Mechanical/ Growing crystals/ Field-induced/ Solution-processed/ Direct deposition
- Patterning
  - Eliminating parasitic leakage and cross talk
  - Different methods

Applications in Industry



- Flexible displays and e-papers
  - iPhone covers with flexible displays
  - Philips with E-Ink demonstrated 85 dpi active-matrix backplane with bend radius 2cm
- Biosensors
  - Mainly voltage transducers
  - Glucose level detection, X-Ray imagery and fingerprint sensing
- Simple logic circuit applications
  - RFID cards, smart cards and disposable sensors

Image by: X. Guo et al., "Current Status and Opportunities of Organic Thin-Film Transistor Technologies," in IEEE Transactions on Electron Devices, vol. 64, no. 5, pp. 1906-1921, May 2017.

Conclusion and Future Improvements

- Lack of material stacks to produce high performance, stable and uniform Organic Transistors
- Lack of standardisation of material, device integration and manufacturing methods
- Trade-offs between large scale, low-cost processing and performance
- Defining focused applications

Thank you!