TECHNISCHE UNIVERSITÄT DRESDEN

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Workshop with Specialists from PFOE / Infinite Project

Introduction to Organic Electronics

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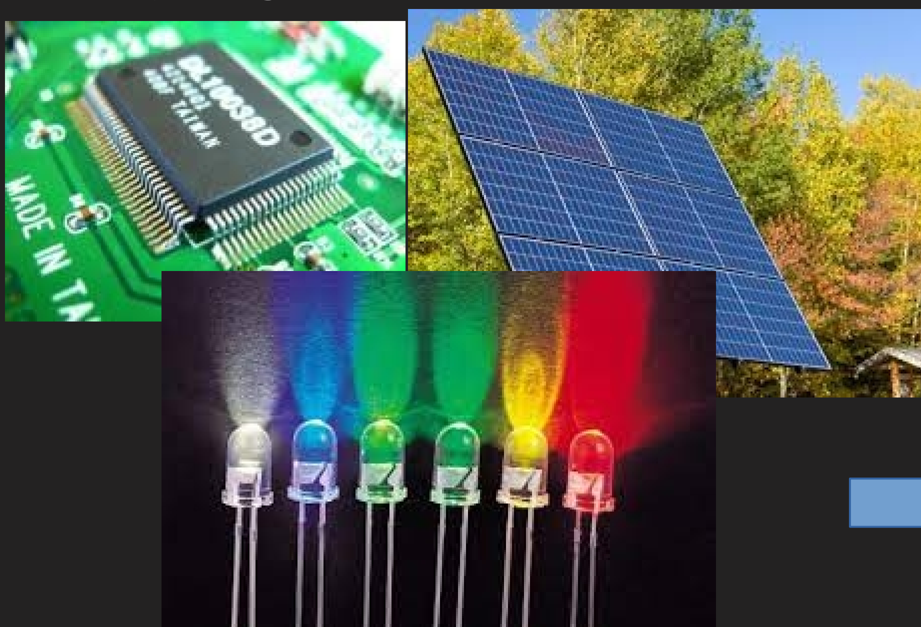
From Silicon (inorganic) to Organic Electronics

Traditional Electronics

(inorganic: Si, GaAs, GaN)



Organic Electronics

(molecular semiconductors)

Incredibily large & well-established market

- process temperatue ~ 1000°C
- unsustainable & expensive processes
- non-ideal material choices (e.g., Si solar cell)

Emerging market (OLED is already established)

- process temperatue < 200°C
- Low CO2-Footprint materials & processes (e.g. printing)
- light-weight and flexible products

- **Organic light-emitting diodes (OLEDs) →**
  from a lab curiosity to a leading display technology
  - Brilliant colors/ High contrast
  - Energy efficient
  - Flexible displays

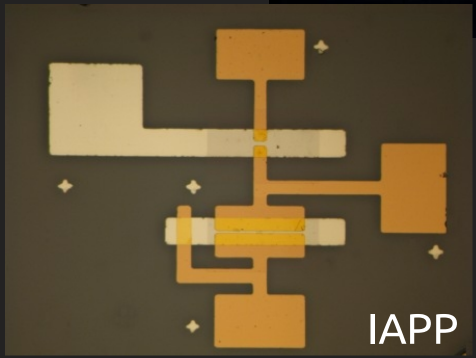
LG Display

- **Organic solar cells (OSCs) →**
  a new vision for photovoltaics
  - Large area roll-to-roll production
  - Light-weight & flexible modules
  - Improving efficiency

Heliatek

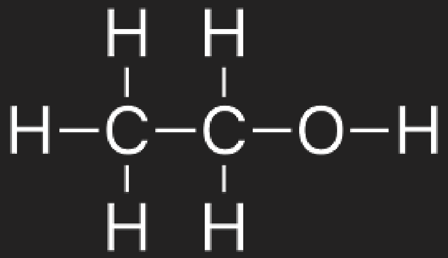
Heliatek

- **Organic electronics → Enabling flexible electronics !**
  - Smart labels, RFID tags, sensor arrays,….
  - Light-weight & flexible
  - Cost effective
  - Applications in bioelectronics, sensing, and implantable systems



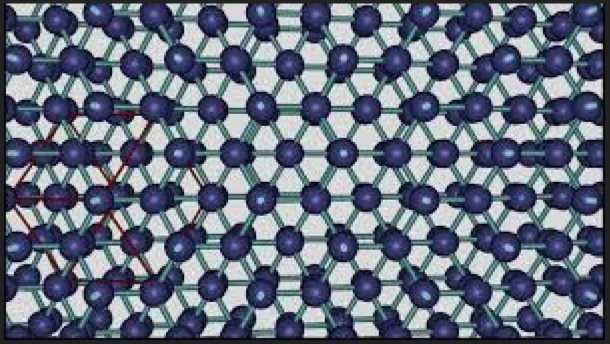
Organic Semiconductors

- Molecular Properties



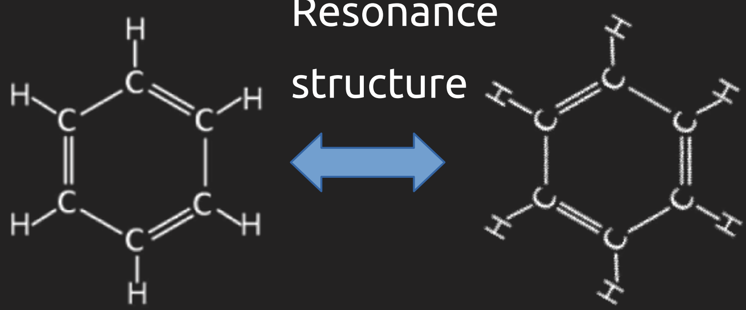
Organic Molecule (linear molecules)

- all atoms at a defined position
but no free charges (all are used for bonds) → **no conductor**



Silicon crystal

- all atoms at a defined position
with free charge carriers moving around



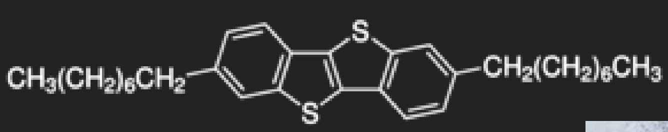
Organic Molecule (conjugated molecules)

- all atoms at a defined position
but charges are interchangable
→ **conductor**

Organic Semiconductors

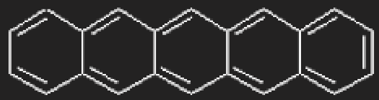
- **Molecular Properties**
  - **Carbon-based molecules (organic molecules) with conjugated π-electron system**
  - **Semiconducting properties due to energy gap (1…3 eV) between frontier orbitals**
  - **Weakly bound van-der-Waals crystals/ poly-crystalline thin-films**

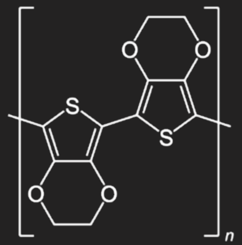
Hole transport - p-type



C_8-BTBT

μ > 10 $cm^2/(Vs)$





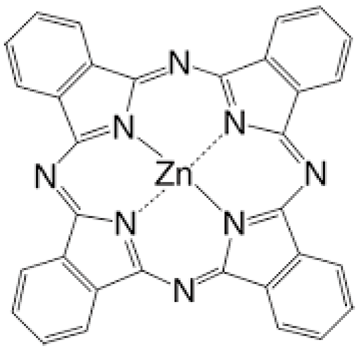
Electron transport - n-type

C_{60}

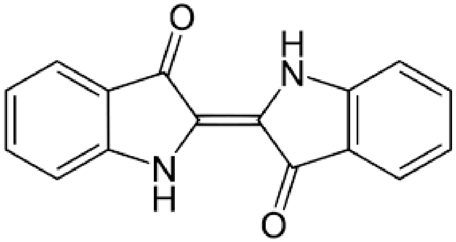
μ > 1 $cm^2/(Vs)$

Organic Semiconductors – Famous Examples

DPP



ZnPc

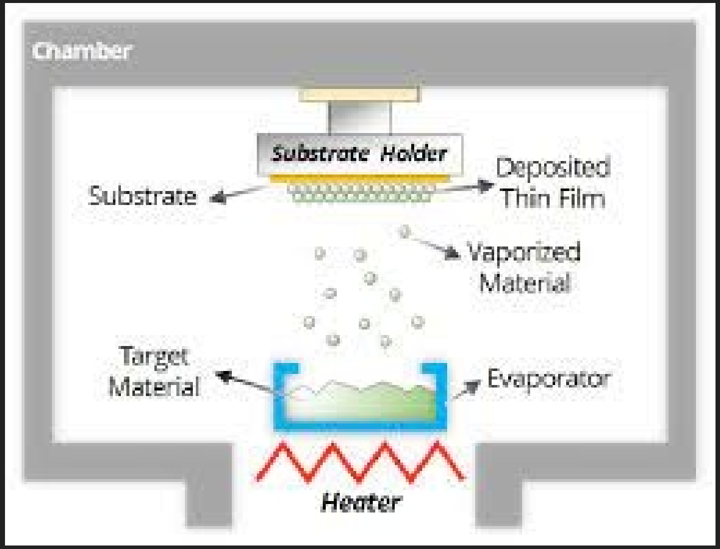


Indigo

Organic Semiconductors

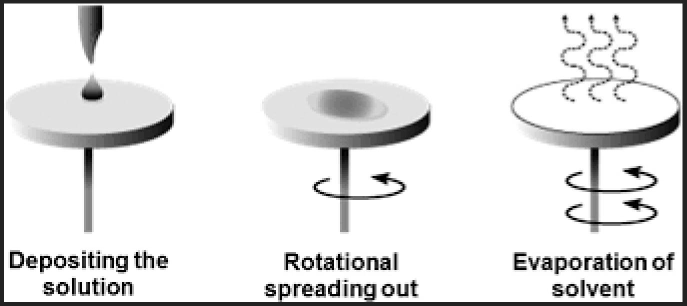
- **Processing**
  - **Organic Semiconductors can be deposited in vacuum (ideal for small molecules) or from solution (spin-coating, ink-jet printing, etc.... ideal for polymers)**

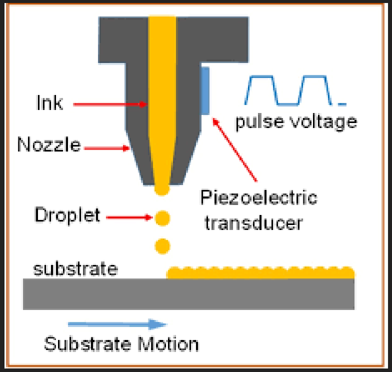
UHV Thermal Vapor Deposition



- **Powder heated to ~100...300°C at <10^{-6}mbar, condensates on substrate, nm precise control of thickness → used for AMOLED phones**

Deposition from Solution

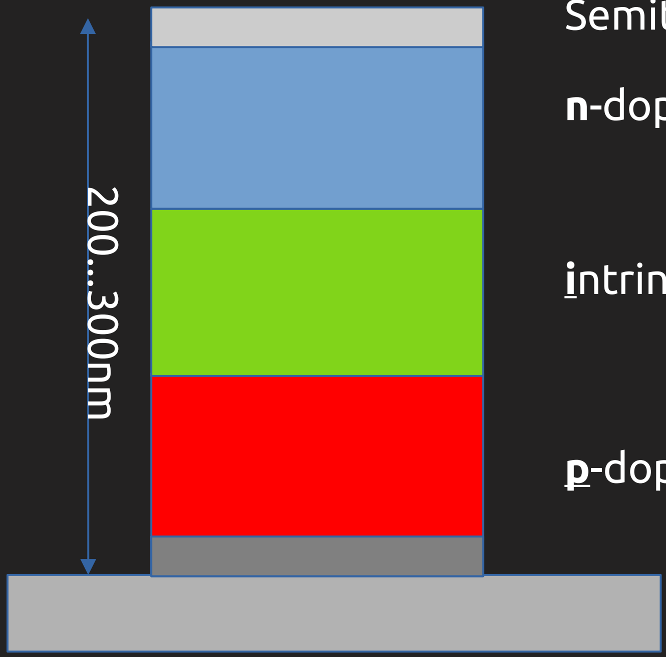




- **Many types of printing techniques, ideal for large-area and high-throughput production**

Making an OLED

- **Processing**
  - **OLEDs, Solar cells and Photodectors follow a simple p i n – diode design**
  - **Doping of layers can be achieved by additives = preferred transport of positive or negative charges**



Semitransparent metal electrode (e.g., 17nm of Ag)

n-doped layer = prefers to transport negative charges

intrinsic layer = prefers to transport pos. & negative charges

p-doped layer = prefers to transport positive charges

Reflective metal electrode (e.g., 100nm of Ag or Al)

Substrate (e.g. a foil)

Making an OLED

- **Processing**
  - **OLEDs, Solar cells and Photodectors follow a simple p i n – diode design**
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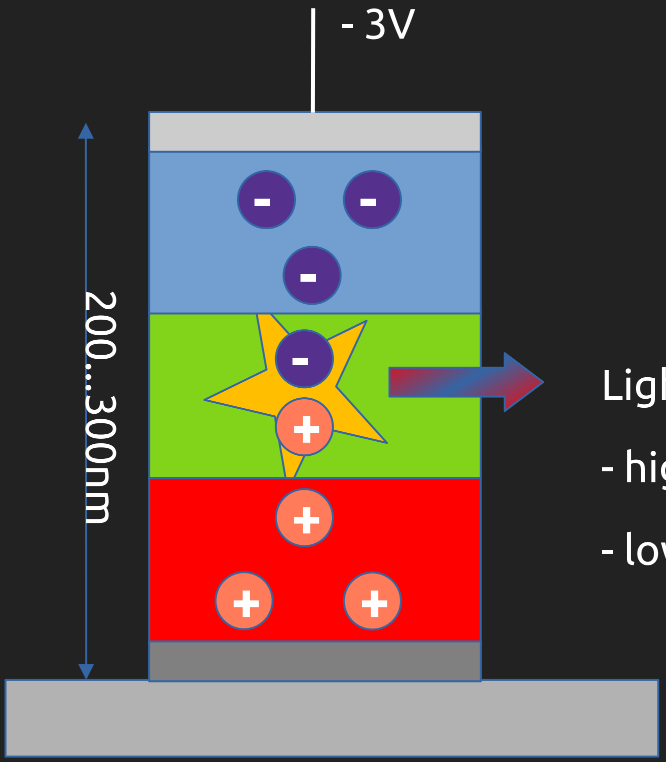


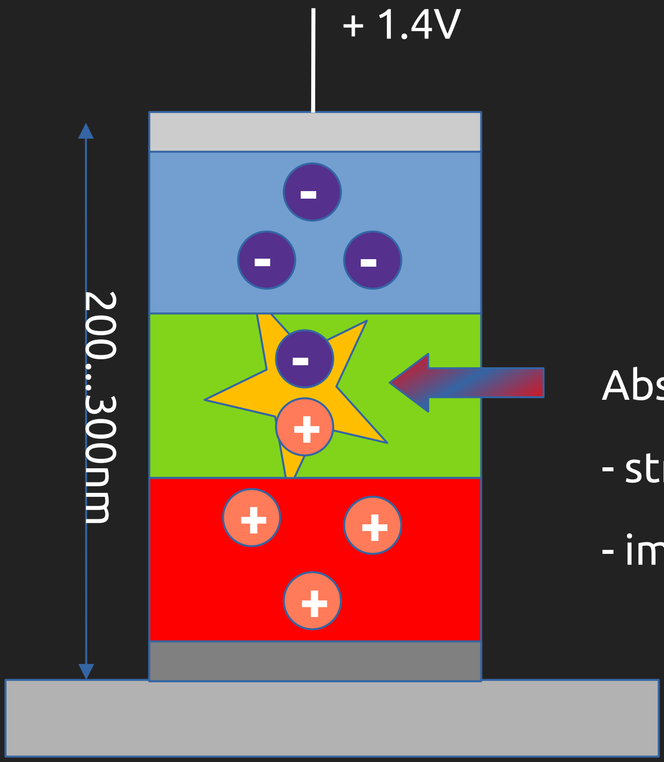
Light emission depending on the properties of the specific molecule

- high quantum efficiency to due efficient recombination

- low driving voltage <3V

Switching to Solar Cell

- **Processing**
  - **OLEDs, Solar cells and Photodectors follow a simple p i n – diode design**
  - **Doping of layers can be achieved by additives = preferred transport of positive or negative charges**



Absorption of light depending on the properties of the specific molecule

- strong absorption (~20nm are usually enough)

- improving efficiency (record cells are close to 20%)