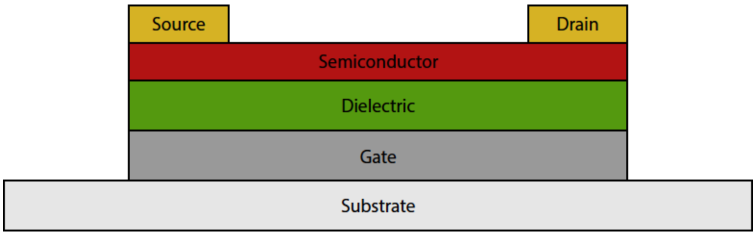
School of Engineering
Institute of Materials
Laboratory of Macromolecular
and Organic Materials

Organic Electronic Materials 2025 Exercise 8 (submit on 01.06.2025)

Solutions

1. What is the function of a transistor and in which applications can thin film transistors (TFTs) be found? Draw a schematic illustration of a bottom gate, top contact OTFT. Name all the parts and give examples of possible constituent materials.

   Function: electronic switch or amplifier
   Applications: backplane of displays, RFID tags



Materials: Substrate: glass, plastic foil, paper, Si/SiO2
Gate, Source, Drain: all kinds of metals, ITO, PEDOT:PSS, graphene, CNTs
Semiconductor: P3HT, BTBT, PBIs….
Dielectric: metal oxides, insulating polymers (e.g. PMMA), SAMs

2. Describe the working principle of an organic thin film transistor. Illustrate your answer with both the charges evolution on OFET drawings and the output characteristics at the different working regimes, in the case of a p-type top gate, bottom contact OFET.

   Applying of a gate voltage induces an electrical field in the semiconductor, which leads to accumulation of free charge carriers in the semiconductor at the interface to the dielectric. The amount of charge carriers depends on the applied field (that means on the applied voltage and the dielectric thickness and permittivity). Upon applying a voltage at the drain electrode, these charge carriers can be moved between source and drain, i.e. a current can flow. The amount of current that flows can be controlled via the applied electrical field (voltage) according to $\sigma = n*\mu*e$.

   The expected drawings are 3 similar drawings to the ones on the slides titled "response of an OFET in the … regime" simply readapted to the case of p-type top gate, bottom contact

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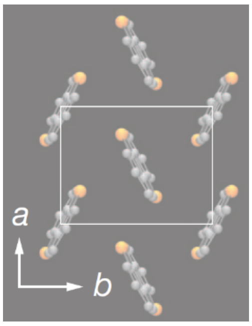
asked here, which will not affect the curves since a p-type material is already considered in the class but only the device's shape.

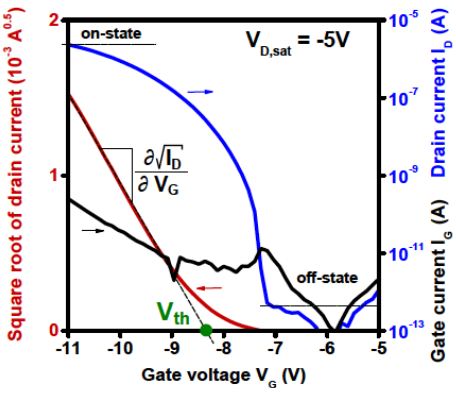
3. A typical value for the number of accumulated charge carriers in an OTFT in the on-state is 10^{13} cm^{-2}. What is the percentage of charged molecules in an OTFT based on a single layer of C_8-BTBT, with herringbone packing (image on the right) and crystal lattice parameters of a=5.9 Å and b=7.9 Å?



Molecules per area in BTBT-layer:
$N = 2/(a*b) = 2/(5.9\ Å * 7.9\ Å) = 2/(5.9 * 10^{-8}\ cm * 7.9 * 10^{-8}\ cm) =$
$= 4.3\ 10^{14}\ cm^2$

consequently, one out of 43 molecules carries a charge
-> 2.3 % of the molecules are charged

4. Draw a transfer curve for a typical n-type TFT. Which parameters can be extracted from the transfer curve (and $\sqrt{I_D}$ vs V_G curve) and how?



On/off-ratio, Vth, the slope of sqrt(I_D) vs. V_G with which the mobility can be extracted

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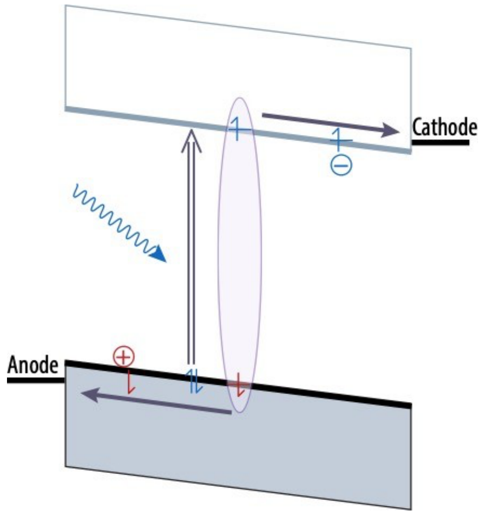
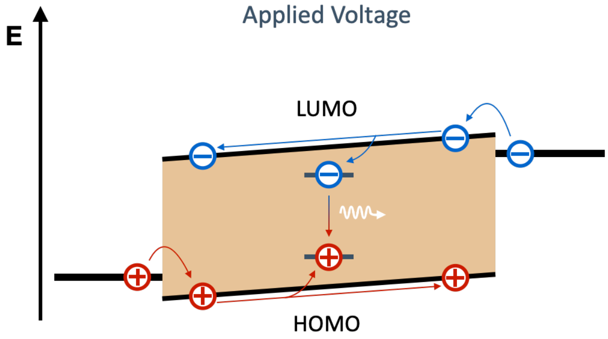
5. The working principles of OVP and OLED are opposite. Explain this affirmation with the help of schemes of charges evolution on energy diagrams, in the simple case of devices with a mono active layer between the two electrodes.

   OVP convert light to current while OLED convert current to light

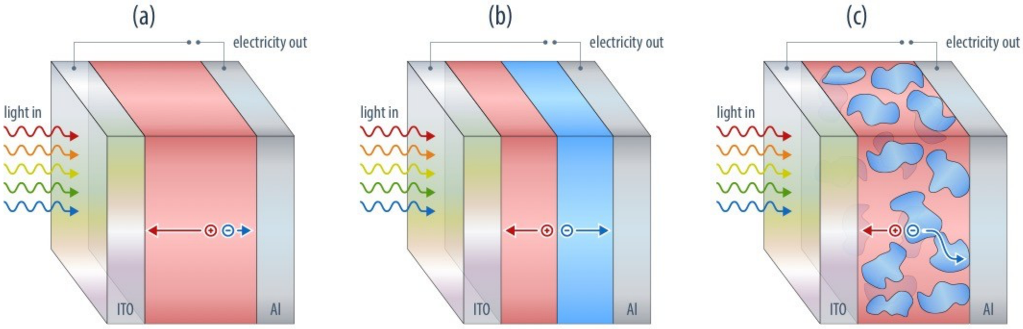
   OVP:



   OLED:



6. Explain why bulk heterojunction OPVs are more efficient than single layer or bilayer OPVs. Draw their structure. What is the exciton diffusion length and why is it important for the device efficiency?



(a) Single layer, (b) bilayer, (c) bulk heterojunction

The exciton diffusion length is the average distance an exciton can travel within the organic semiconductor before it recombines. Typical exciton diffusion length in organic semiconductors is approx. 10 nm. It is important for device efficiency because each exciton must separate into an electron and hole to generate a current, and charge separation should occur before the exciton travels this distance.

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