Problem Sheet 1 - Organic Semiconductors

Submission deadline: 1pm on 7th February 2025

Fundamental constants and formulae can be found in the Exam Summary Sheet (available on Moodle).

Problem 1: General physics

a) Organic semiconductors offer advantages such as flexibility and biocompatibility but are slower than silicon. Propose a specific application where these advantages outweigh the disadvantages, and justify your choice. [2]

b) A polymer chain with alternating single and double bonds has a conjugation length of 10 monomers. How does increasing the conjugation length affect the bandgap of the material? Provide a brief explanation with reference to HOMO and LUMO levels. [2]

c) Describe how the presence of polarons in an organic semiconductor affects its optical properties. [2]

Problem 2: OLEDs

a) Discuss the importance of luminance for OLED performance. [2]

b) Assuming that singlet and triplet excitons have the same formation probability, say what is the maximum value of the electroluminescence quantum efficiency in an OLED as a fraction of the photoluminescence quantum efficiency. Assume that radiative transitions are strictly dipole allowed. Explain your reasoning. [3]

c) Briefly explain aggregation quenching. [1]

d) Suggest how the addition of long alkyl chains in a semiconducting polymer affects charge mobility, PL efficiency and spectrum of emitted light. Consider a HT structure (minimised steric hindrance). [3]

Problem 3: OPVs

a) Explain the meaning of the so-called "AM1.5 condition" for the measurement of the efficiency of solar cells. [2]

b) What is the maximum theoretical efficiency of a single junction solar cell? List and briefly describe 3 factors that limit it. [2]

c) A photovoltaic device made from an organic semiconductor absorbs photons with an energy of 2 eV. If the external quantum efficiency (EQE) is 60%, calculate the number of electron-hole pairs generated per second when the device is illuminated with a light intensity of 100 mW/cm^2. Assume 100% absorption for simplicity. [2]

d) A solar cell is illuminated with a power of 30 mW of monochromatic light at a wavelength at which the current-voltage characteristic features a fill factor $FF = 0.5$, a short circuit current $I_{SC} = 3$ mA, and an open circuit voltage $V_{OC} = 1.2$ V.

(a) Calculate the efficiency of the cell under these conditions. [1]

(b) Explain briefly whether or not the result found is plausible for a state-of-the-art organic solar cell. [1]

Problem 4: OFETs

a) Explain the meaning of the Förster radius as deduced from the mathematical expression below.

$$k_{ET} = \tau_0^{-1} \times (\frac{R_F}{R})^6$$

[1]

b) Based on the equation in a), calculate a symbolic expression of the donor-acceptor distance at which the energy transfer rate is half the “experimental” radiative decay rate (i.e. not the intrinsic one). [2]

c) Calculate this distance for a donor acceptor system for which the Förster radius is 4.5 nm. [2]

d) Comment your result and say if it is in agreement with your expectations, and why. [2]