Question 1

(a) An organic light-emitting diode (OLED) emits a luminous flux of 3600 lumen at a bias of 1.8 V with an associated current density of 500 mA/cm^2. The LED emissive area is 615 mm^2 and the emission spectrum is centred at a wavelength of 440 nm with a full width at half maximum (FWHM) of 40 nm. Calculate the luminous (power) efficiency. **[2]**

(b) Explain which type of material you expect the diode described in part (a) above to incorporate: i) purely fluorescent; ii) purely phosphorescent; or iii) a fluorescent material benefitting from triplet fusion (triplet-triplet annihilation (TTA)) or thermally activated delayed fluorescence (TADF) effects. **[4]**

(c) A yellow emitting OLED incorporates a fluorescent emitter with a photoluminescence quantum yield of 0.6. It is also known that holes are minority carriers at the turn-on bias (i.e., the smallest applied voltage at which electroluminescence is detected), with the electrons' population being six times as large as that of holes.

(i) Calculate the internal quantum efficiency (IQE) of the OLED at turn on, and at the (higher) voltage at which the electron and hole populations become balanced. **[3]**

(ii) Assuming that all triplets can be recycled via TTA (but not by TADF), explain which maximum IQE can be obtained under such a hypothesis. **[4]**

(d) The top of the valence band of a semiconductor is located at 6.5 eV below the vacuum level. Two different anode materials (A, B) are characterised by work functions $\Phi(A)$ = 5.5 eV and $\Phi(B)$ = 7 eV, respectively.

i. State which material is a better hole-injector. **[1]**

ii. Calculate the nominal hole-injection barrier in both cases. Draw a band-diagram (at "flat bands") to explain your answer, also indicating the relevant energy axis for holes. **[2]**

iii. Explain why, in practice, the hole injection barrier may be lower by up to ~0.3 eV with respect to the calculated value. **[1]**

Question 2

a) An OFET was made with a PTCDI-Br2-C18 semiconductor and PMMA as a dielectric (with a dielectric constant of 3.5). The channel length of the device was 25μm and channel width 750μm. Analyse the output and transfer curves of the OFET below.

   a. Which type of semiconductor was used in the device? (n- or p-type)
   b. Extract the values of:
      i. Threshold voltage: 0.82V
      ii. On/off ratio: 10^4
      iii. Pinch-off point
      iv. Leakage current
   c. Calculate the mobility of charges in the semiconductor based on the performance of this device.

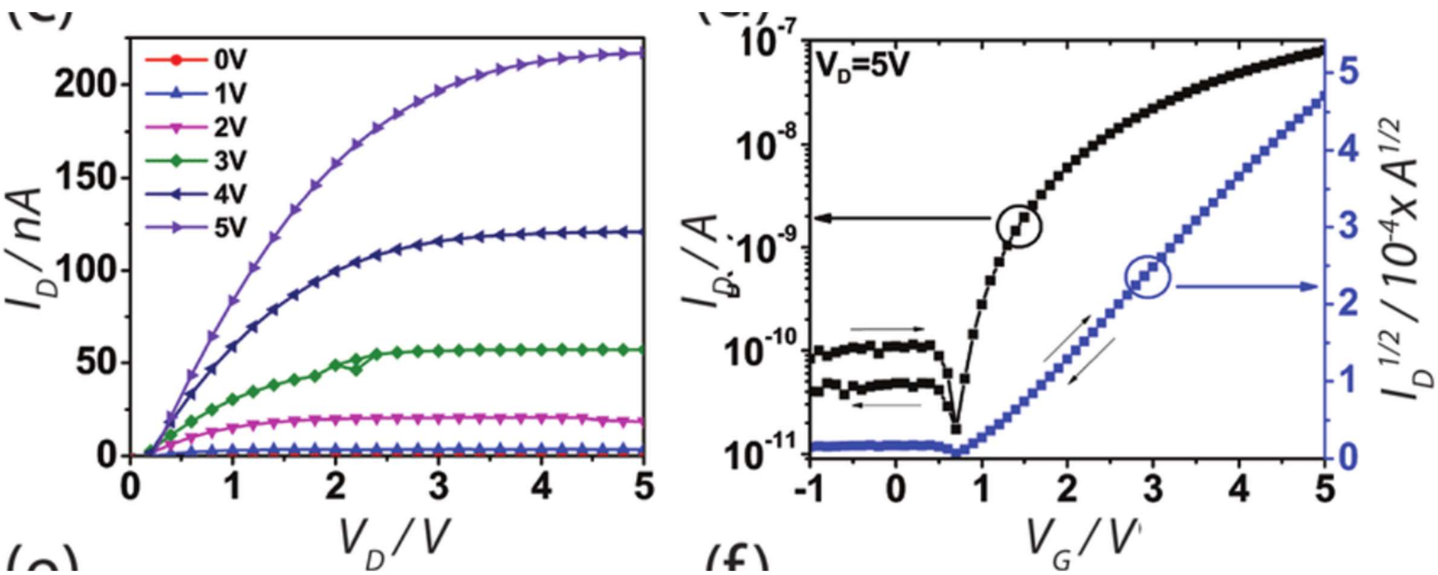

Figure 1. Ouput and transfer characteristics of an OFET. Source: N. V. V. Subbarao et al.: Effect of thickness of bilayer dielectric on PTCDI-Br

b) Analyse the JV curve for an OPV below and answer the following questions:

   a. What is the open-circuit voltage of this device?
   b. What is the short circuit current in the OPV?
   c. Calculate the Fill Factor and comment on the efficiency of this device under AM1.5 conditions and illumination of 100W/m^2.

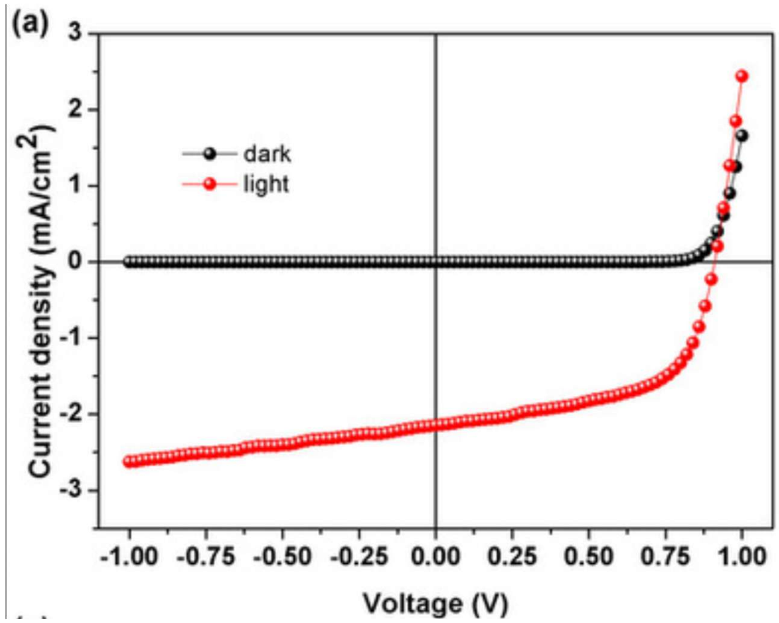

Figure 2. JV curve of an OPV. Source: DOI: 10.1038/srep07787