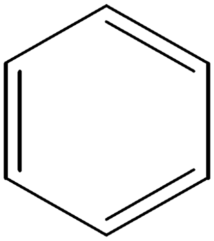
EECS 2077
Semiconductor Devices

18 - OLED & OPV

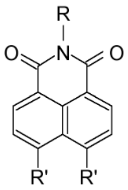
Name:______________________________

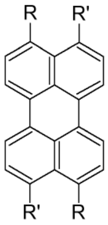
In-Class Problems

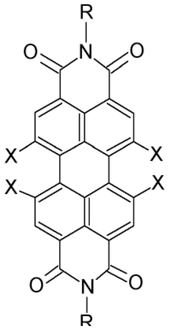
(1) For benzene (shown below), which has conjugated bonding, draw a molecular 'stick and ball' diagram like we had in lecure, and label where you have single bonds (with a '1') and where we have double bonds (with a '2) and ensure that every Carbon has 4 shared covalent bonds to give it 8 total valence electrons.



(2) Three fluorescent dyes are shown below. One is blue, one is green, one is red.







(a) which one of the above molecules is the product shown in the data sheet shown at right?

The biggest one!

(b) obtain two acrylic sheets from Prof. Heikenfeld, one is doped with green fluorescent dye, the other with red fluorescent dye. You will notice that the edges appear to glow more than the large-area surfaces…. WHY?

Hint, this has to do with light out-coupling…

Total internally reflected light emission hits all surfaces, but at the edges the photons/surface-area is the largest ratio!

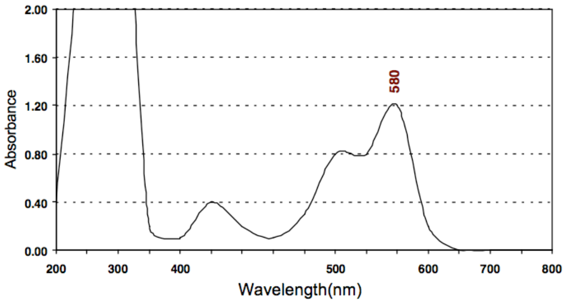
LUMOGEN® F Red 300

0.02% GPPS

Type of Dye		Perylene
Color Index		-----------
Fastness to Weathering (PMMA) *0.02% in PMMA injection-molded plaques of 2 mm thickness Residual fluorescence(%) after 80 days accelerated exposure in Xenotest 1200		>95*
Heat Stability (0.02%)	(PC) (PMMA)	300°C 300°C
Melting Point		>300°
Specific Gravity		1.40 cm^3

Max (nm) Absorption in ethylene dichloride	Max (nm) Absorption in PMMA	Fluorescence (nm) in ethylene dichloride	Max Quantum Yield
578	578	613	0.98

LUMOGEN® F RED 300
Spectral curve run in Acetone



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(c) the acrylic sheet has a refractive index of ~1.5. Calculate the total light outcoupling percentage for the sheet (what is not outcoupled, is trapped inside by total internal reflection!). OLEDs use plastic materials which have similar refractive indices (roughly). You may neglect Fresnel reflection. Equations are in lecture 17 on LEDs….

6 sides, 1/4n^2 per slide or 6/4n^2 = 6/4/1.5^2 = 66.6% of light is outcoupled, the rest is trapped inside.

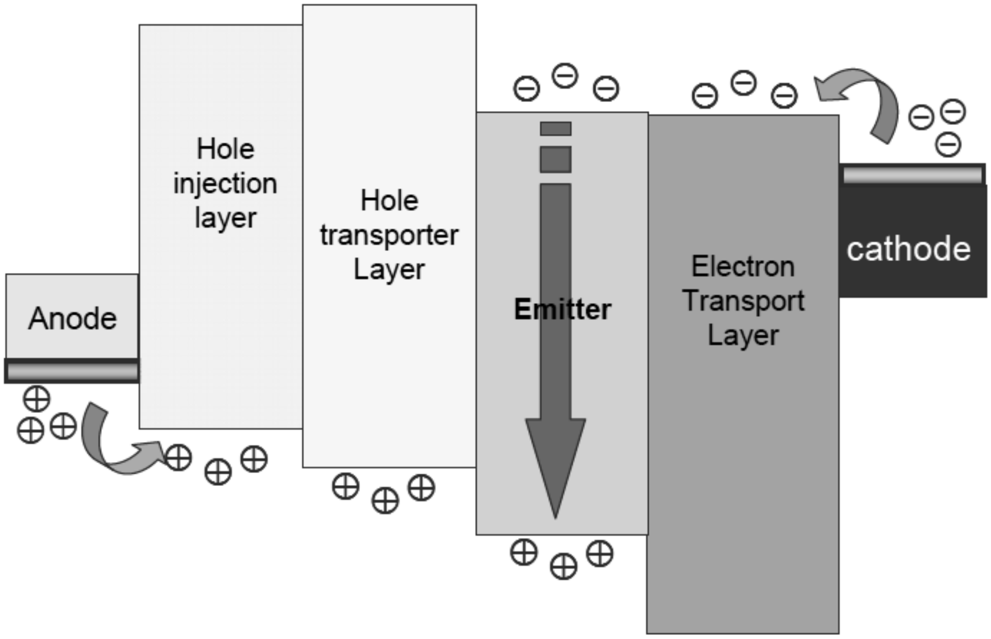
(d) GaP has a refractive index of 3.4. What is its outcoupling? You will see that for inorganic semiconductors, which have higher refractive indices, you need to pay close attention to outcoupling! You may neglect Fresnel reflection again.

6/4/3.4^2 = 13% of light is outcoupled, the rest is trapped inside!

(3) Check all statements below that are true for ORGANIC light emitters and detectors:

_X_ they potentially are lower cost (made of 'plastic', and simple printing/spraying on long rolls of material)
_X_ they are ideal for making thinner, lighter, more flexible/foldable/rollable, and shatterproof devices
_X_ they have lower mobilties and likely will always be inferior to inorganic semiconductors for solar cells, LEDs, etc.
_X_ they degrade faster than inorganic semiconductors and are sensitive to heat, moisture, sunlight fading, etc.

(4) For the more advanced OLED device shown below….



(a) why do we have a hole injection layer? ….. 1 reason

To reduce (step) the barrier for getting holes to the hole transport layer. Think of a barrier to transport of a carrier, probability to get past the barrier is exponentially dependent on height (greater height, exponentially less chance to get past the barrier). Then notice the difference if you break the barrier into small steps (compare e^2+e^2 vs. e^4, big difference!).

(b) why did we add a hole transport layer? …. 2 reasons

To reduce (step) the barrier for getting holes to the emitting layer AND to block electrons from moving past the emitting layer.

(c) why did we add an electron transport layer ? …. 1 reason

To block holes from moving past the emitting layer.

(d) why don't we need an 'electron injection layer'? …. 1 reason

The electron transport layer has a step that is already small enough.

(e) what is the ONE parameter you need for the metals, that you would look up, before you determined if they could inject electrons or holes?

Workfunction!

(f) if the anode is transparent, what type of electrode material do you have to use?

Wide bandgap semiconductor like Indium-Oxide.

(g) if the anode is transparent (e.g. transmits all light >400 nm), then what must the bandgap energy of the material be?

E= 1240/400 = 3.1 eV. ITO meets this requirement, because it has a bandgap energy of ~4.0 eV.
https://en.wikipedia.org/wiki/Indium_tin_oxide

(5) Last question, you create a super high resolution and large OLED display with 9 million pixels. You may assume the display is monochrome (is single color, no RGB sub-pixels which would cause you to require 3X more electrodes).

(a) What is the minimum number of external control electrodes needed if you directly wired your display inputs to each pixel? That means you are not using matrix addressing…

9 million. Yikes! Impossible to do!

(b) What is the minimum number of external control electrodes needed if you use active-matrix transistors to provide input to each pixel?

3000 rows and 3000 columns for 6,000 total…. Because 3E3 x 3E3 is 9E6 which is 90 million. That is roughly THREE orders of magnitude less than those needed for (a).

(c) How many TOTAL number of transistors (thin film transistors) on glass will you need to fabricate to drive the OLED display? Careful, OLEDs are more complex to drive than LCDs….

2 per pixel, or 18 million.

■ *Further Problems (if you have time, finish during class when I can help, or on your own time)*

(6) Lets do some very important review before the final! Circle or underline the right answer!

(a) Exists at 300K for a diode in thermal equilibrium (with no voltage applied to it).

DRIFT DIFFUSION [✓ BOTH] NEITHER

(b) Reduces as you increase doping for a forward biased PN junction.

DRIFT DIFFUSION [✓ BOTH] NEITHER

(c) Is how carriers are transported across the base of a BJT.

DRIFT [✓ DIFFUSION] BOTH NEITHER

(d) Separates photogenerated carriers inside a solar cell so that they can be collected.

[✓ DRIFT] DIFFUSION BOTH NEITHER

(e) Drives the source to drain current in a MOSFET.

[✓ DRIFT] DIFFUSION BOTH NEITHER

(f) How a collector actually 'collects' current in a BJT.

[✓ DRIFT] DIFFUSION BOTH NEITHER

(g) A solar cell with no voltage and no light, drives current flow at thermal equilibrium (think before you answer).

DRIFT DIFFUSION [✓ BOTH] NEITHER

(h) A JFET would have an current-to-current amplification factor of infinity if it were not for this.

[✓ DRIFT] DIFFUSION BOTH NEITHER

(i) What drives current from the emitter to the base in a pnp BJT.

DRIFT [✓ DIFFUSION] BOTH NEITHER

(j) Requires particles that have electrical charge and electric field.

[✓ DRIFT] DIFFUSION BOTH NEITHER

(k) Requires a concentration gradient.

DRIFT [✓ DIFFUSION] BOTH NEITHER

(l) Is personally your favorite type of current.

DRIFT [✓ DIFFUSION] BOTH NEITHER