NanoElec exam -- Febr, 6th, 2020

Duration: 3 hours. 1 point per question (total = 35 pts)

Answer on Part A and Part B on two separate sheets.

Part A – Molecular electronics & plasmonics

I. Fundamental understanding

Use the figure given in Appendix 1, where the Band diagram of GaAs is drawn.

1. Draw on the diagram the process that occurs when a photon of energy hv is absorbed by the GaAs crystal (you will need to hand over Fig. 1). Explain what happens.
2. Measure the value of the band gap.
3. Is GaAs a direct or an indirect semiconductor?
4. On this diagram, indicate where is the dispersion band of the light hole and that of the heavy holes?

II. Plasmonics

Consider the excitation of SPP on gold film in air, in the Kretschmann configuration at a wavelength of 633 nm.

1. What is the SPP wave and what are its characteristics? (answer in 5 to 10 lines)
2. What is the dispersion relation of the SPP? Make a careful plot of the dispersion curve (qualitative plot). Using this plot indicate what happens when the excitation laser at 633 nm couples to the SPP wave.
3. Explains what is represented in the figure below. Why does the minimum of the reflectivity depend on the wavelength?

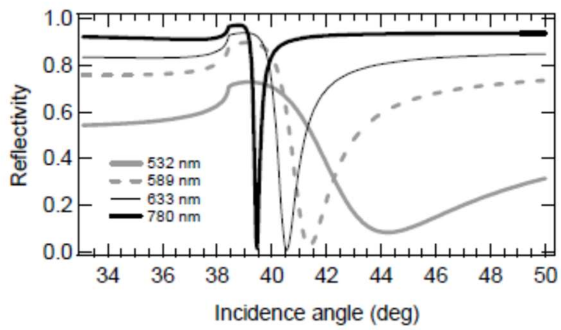


Figure 18. Variation of the SPP extinction curve with the incident wavelength in the case of a 50 nm thick gold layer deposited on a glass prism (n = 1.61) in air. The extinction angle increases with the wavelength: 44.2° (532nm, green light); 41.3° (589nm, orange light); 40.5° (633 nm, red); 39.5° (780 nm far red). More striking is the decrease of width of the resonance when the wavelength increases towards infrared.

4. If you want to use this SPP wave for sensing biomolecular reactions that occur on the gold surface, which one of the wavelengths would you use and why?

III. Problem: the pentacene Organic Field Effect Transistor

The first experimental demonstration of an OFET was published in 1998 by Yin, Gundlach, Neslon and Jackson (IEEE Electron Device Letters 18, 606 ; **1998**): *Stacked Pentacene Layer Organic Thin-Film Transistors with Improved Characteristics*

The pentacene molecule

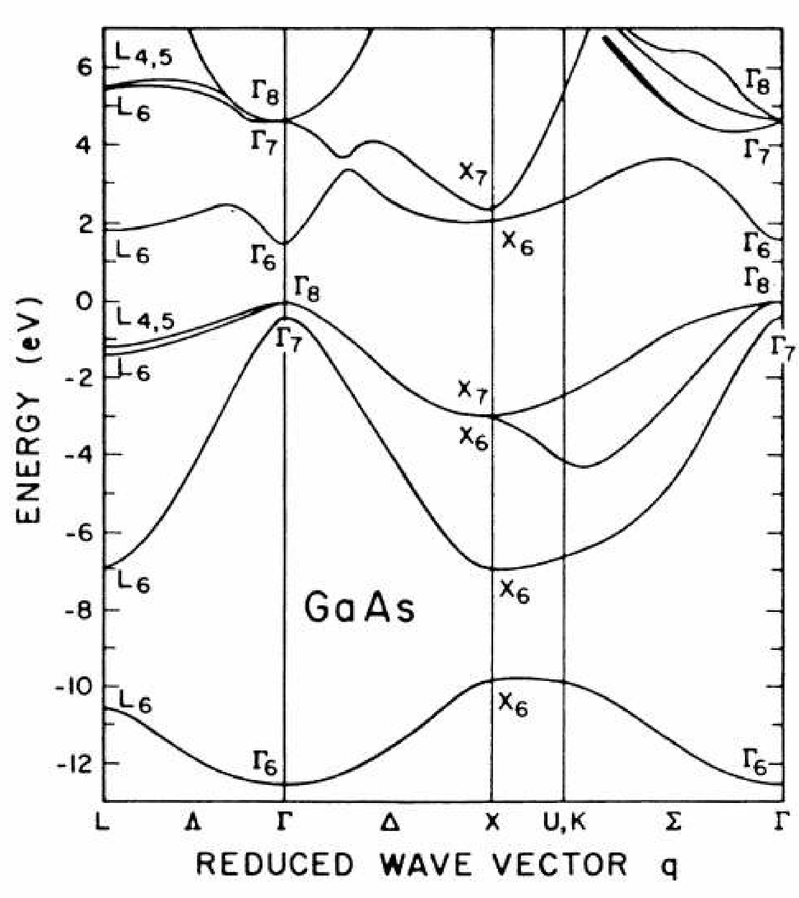
1. Draw the pentacene molecule.
2. Why is it used as a conductive molecule?
3. What is the length of this molecule?
4. From the data provided in **Appendix 2** give the principal electronic properties of the molecule. Give an explanation of the two principal keywords.

Fabrication of an OFET with a pentacene channel

5. Explain the working principal of the OFET. We suppose that electron transport occurs through holes.
   Keywords to be used in the explanation: Drain, Source, Gate. V_{GS}, V_{DS}, I_{DS}. Define the threshold voltage.
6. In the case of the OFET described in the APL authored by Schroeder in 2003 (See **Appendix 3**), draw the band diagram of the junctions Drain-Pentacene-Source.
   For your scheme, use a vertical scale (energy scale) of ~0.5 cm for 1 eV. Take into account the injection barrier mentioned in the beginning of the article. Place a legend on your scheme.
7. Redraw this diagram when V_{DS} =−7 V. We suppose that the gate voltage does not notably influence this diagram.
8. What are the various channel lengths considered for the six OFET of the article? What kind of transport regime, one may expect from such channels?
9. When the gate voltage is set to a negative value, what happens?
10. Explain why this device exhibits Fowler-Nordheim conduction regime when the internal electric field is lower than a critical field E_{crit}.
11. If conduction does not occur through Fowler-Nordheim mechanism, how does it occur?
12. Focus on the OFET where the pentacene layer is 400 nm thick and 40 µm long. Suppose that V_{GS} is set at −3.5 V. Using fig. 2, draw a schematic characteristics of $I_{DS} = f(V_{DS})$ when V_{DS} varies from 0 to −10 V.

APPENDIX 1. Band diagram of GaAs

Exercise I (this scheme should be included in your copy).



APPENDIX 2. Data on Pentacene from Sigma-Aldrich Catalog

Downloaded on 21-nov-2016: https://www.sigmaaldrich.com/

Related Categories	Light-Emitting Dopants and Fluorescent Dyes, Materials Science, Organic Field Effect Transistor (OFET) Materials,Organic and Printed Electronics, Photoluminescent Materials,
assay	**99%**
mp	**372-374 °C (subl.)**
solubility	**organic solvents: slightly soluble (lit)**
Orbital energy	**HOMO 5 eV**
	LUMO 3 eV
OPV Device Performance	**ITO/pentacene/C60/BCP/Al**[1] **• Short-circuit current density (J_{sc}): 15 mA/cm^2** **• Open-circuit voltage (V_{oc}): 0.36 V** **• Fill Factor (FF): 0.5** **• Power Conversion Efficiency (PCE): 2.7 %**
semiconductor properties	**P-type (mobility=0.4-3 cm^2/V·s) (on/off ratio=1E5-1E8)**