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# UNIVERSITI SAINS MALAYSIA

First Semester Examination  
Academic Session 2008/2009

November 2008

## **EBB 525/3 - Electronics Materials & Optical Devices**

Duration : 3 hours

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Please ensure that this examination paper contains FIVE printed pages before you begin the examination.

This paper contains SEVEN questions.

**Instructions:** Answer **FIVE** questions. If a candidate answers more than five questions only the first five questions in the answer sheet will be graded.

Answer to any question must start on a new page.

All questions must be answered in English.

1. [a] Briefly explain the following terms:
  - (i) electronic materials
  - (ii) Moore's law

(40 marks)
  
- [b] SiO<sub>2</sub>-based gate oxide is replacing by alternative materials. What are the requirements of these materials to be considered as an alternative gate oxide?

(60 marks)
  
2. [a] Explain the different between a direct tunneling process and Fowler-Nordheim tunneling process through a dielectric.

(30 marks)
  
- [b] Explain the main characteristics required for a low dielectric constant (k) material to be employed in a deep-submicron CMOS structure.

(30 marks)
  
- [c] Explain some of the important issues in high dielectric-constant (k) gate stack materials in deep-submicron CMOS structure.

(40 marks)
  
3. [a] Briefly explain four (4) types of charge conduction mechanisms through a dielectric.

(40 marks)
  
- [b] Discuss in detail why low dielectric constant (k) material is used as Inter-level Dielectric (ILD) in a deep-submicron CMOS structure.

(60 marks)

4. [a] Explain the challenges of using high dielectric constant material as an alternative gate oxide in a deep-submicron CMOS structure.  
(50 marks)
- [b] How does a dielectric mirror differ from a regular mirror? Why regular mirror is not suitable for semiconductor lasers development.  
(25 marks)
- [c] How exactly do semiconductor lasers operate differently from light-emitting diodes (LEDs)?  
(25 marks)
5. As we know, there are many promising achievement on the research and applications of III-V compound semiconductor. For example, LED traffic light uses InGaN/AlGaN, AlInGaP and AlGaAs compounds to generated blue-green, yellow and red lights, respectively.
- (a) Explain the reason why energy gaps of  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  and  $\text{In}_x\text{Ga}_{1-x}\text{N}$  alloys are dependent on their compositions.  
(30 marks)
- (b) Explain why direct bandgap semiconductors are preferred instead of indirect bandgap semiconductors for LED applications.  
(20 marks)
- (c) Explain light emission mechanism of a GaN p-n junction LED, as shown in Figure 1. (A sketch might help)  
(50 marks)

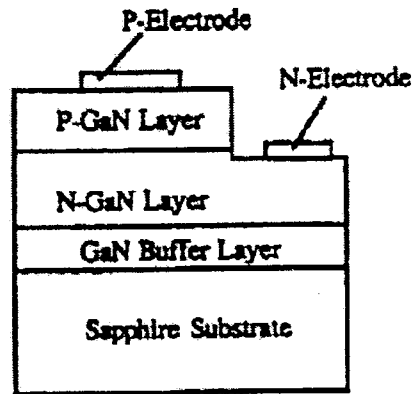


Figure 1 - The structure of the GaN pn junction LEDs.

6. [a] Suppose you are an engineer and assigned to build (i) blue and (ii) green LEDs, using  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  or  $\text{In}_x\text{Ga}_{1-x}\text{N}$  alloys. Calculate possible compositions for each material. Assume that  $h\nu = E_g$  and use the data given in Figures 2. (Please don't use band gap data from other references!).

(60 marks)

- [b] Why does a double heterostructure LED (DH-LED) device perform more efficient if compared to a conventional p-n junction LED?

(40 marks)

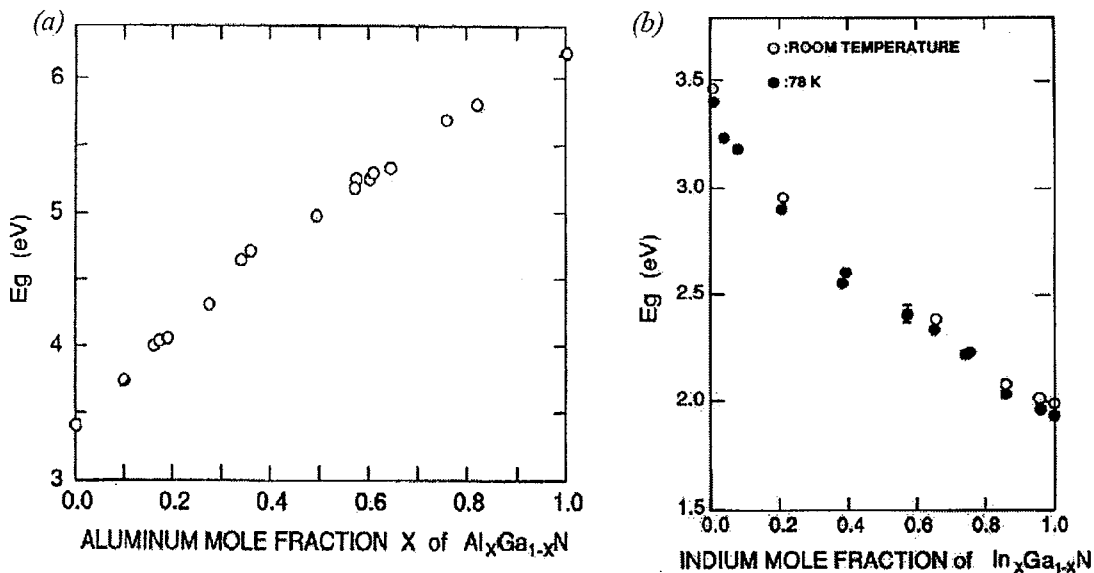


Figure 2 - Composition dependence of the direct energy gap  $E_g$  of (a)  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  alloys, and (b)  $\text{In}_x\text{Ga}_{1-x}\text{N}$  alloys.

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7. [a] There are three (3) types of solar cell materials (monocrystalline, polycrystalline and amorphous). Explain what are the advantages and weakness of these materials.

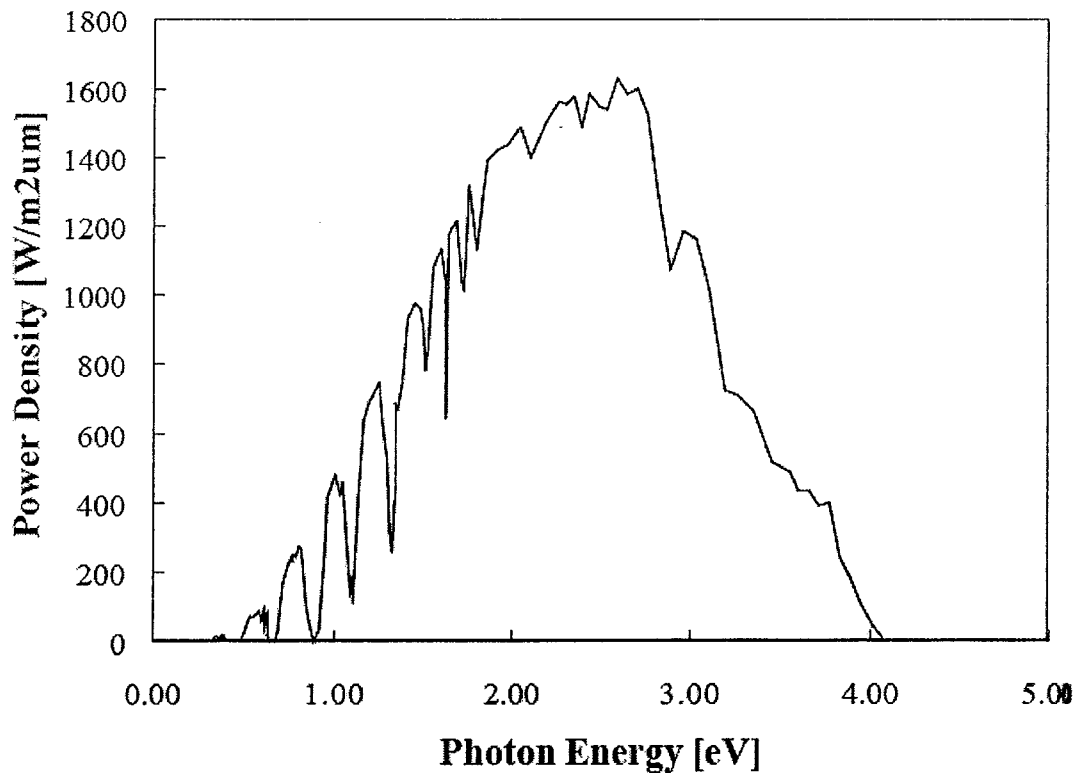
(30 marks)

- [b] Solar spectrum irradiance at air mass 1 (AM1) is shown in Figure 3. Based on the band gap value of given materials, choose and explain a very promising material for solar energy conversion application: Ge = 0.78 eV, Si = 1.17 eV, InP = 1.35 eV, GaAs = 1.42 eV, GaP = 3.30 eV, ZnO = 3.40 eV, and ZnS = 3.6 eV.

(40 marks)

- [c] How does a solar photovoltaic plant produce energy?

(30 marks)



**Figure 3 - Solar spectrum irradiance**  
(power per unit area and unit wavelength) at air mass 1 (AM1).

