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# EE566 Solid State Devices

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## Assignment 5

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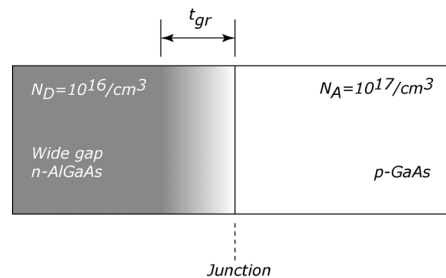
Due: 03/15/2004

### *Heterojunctions and Solar Cells*

#### **Problem 1:** *Heterojunction p-n junction*

Consider the AlGaAs/GaAs graded heterojunction p-n junction shown in Figure 1 at 300K (assume full ionization of dopants). Use the material parameters in Shur for GaAs in this problem for all quantities *except* of course the band gap of AlGaAs (assume  $N_C, N_V$  to be the same for GaAs and AlGaAs). Let the heterojunction be graded from GaAs to  $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$  such that the bandgap difference is  $\Delta E_g = 0.5eV$ . The conduction band offset is  $\Delta E_C = 0.6\Delta E_g$ , i.e., 60% of the total bandgap offset. Assume that the grading is *linear*, and is completed over a thickness  $t_{gr} = 100nm$ .

- 1) *Sketch* the band diagram *without* and then *with* doping. What is the depletion region thickness with doping? Verify your calculation with 1D Poisson.
- 2) What is the built-in voltage for *electrons* across the junction? What is it for *holes*? Are they the same? Verify with 1D Poisson.
- 3) Sketch the band diagram, and minority carrier distribution for a forward bias of 1.0Volt. Label all important quantities.
- 4) Find and sketch the electron and hole currents  $J_n$  and  $J_p$  in the diode. What is the ratio  $J_n / J_p$ ? How does it compare to a GaAs homojunction p-n junction with same doping levels?
- 5) Now suppose the thickness of graded layer was larger than the depletion thickness in the wide-bandgap n-layer. How would it affect the ratio  $J_n / J_p$ ? Give a qualitative answer. This phenomenon will stage a comeback when we study HBTs.



#### **Problem 2:** *Solar Cells (Read Section 5.2 from Shur)*

On a normal sunny day (like in this weekend), the energy carried by sunlight is roughly  $100\text{mW}/\text{cm}^2$ . Assume (somewhat naively) that only 5% of the photons in the sunlight have energy just above the bandgap of GaAs ( $E_g = 1.424eV$ ). My pocket calculator has 4 solar cells of area  $1\text{cm}^2$  each.

- 6) How much total power is absorbed by the cells if they are made of GaAs?
- 7) If the conversion efficiency is 10%, how many electron-hole pairs (EHPs) will it generate in a GaAs layer of thickness  $W = 1\mu\text{m}$ ? What is the generation rate *per*  $\text{cm}^3$  ( $G_L$ ) of these light generated EHPs?
- 8) Suppose the GaAs layer was a p-n junction with the doping densities such that the diffusion lengths are  $L_n = L_p = 0.1\mu\text{m}$ . How much short-circuit *current* will result? (See eq. 5.2.7 of Shur)

Note that this is a rather crude estimate. Real solar cells have *lot more* issues to deal with!