EE566 Solid State Devices

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Assignment 3
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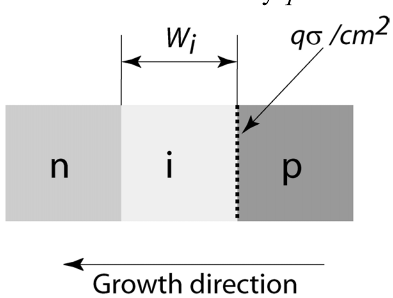
p-n Junctions and C-V measurements – the good, the bad, and the ugly

(Practice) Consider a p-n junction made of GaAs at T=300K. Let the doping densities be $N_A=10^{17}/\text{cm}^3$ and $N_D=10^{16}/\text{cm}^3$. For all material constants, learn to look them up in tables. For example, see Shur, Appendix 8, Page 625.

a) *Sketch* the charge-field-band diagrams under the depletion approximation. Label it with the *calculated* values of all important quantities such as x_n, x_p, W, F_{max}, V_{bi}, etc. Use natural units like *nm* for lengths, *V/cm* for fields, and *Volts* for potential. Your sketch should be roughly *to scale*. Which side is the depletion region large? Remember this property of the ratio of depletion region thickness in p-n junctions. How does the maximum electric field in the depletion region compare with the breakdown voltage of GaAs? What is the capacitance of the depletion region?

b) Use 1-D Poisson to simulate the junction, and *plot* the charge-field-band diagram *neatly*. Compare the values you calculated from part a) and explain the critical differences invoking the Gummel correction.

And now for the fun part! Here is a real-life problem in dealing with junctions, especially if you are a great device engineer at the hands of a not-so-great crystal grower (they are known to be a strange lot!). Suppose you asked the grower to grow you a GaAs *p-i-n* junction. Since the grower was paranoid that zinc, the acceptor dopant, might diffuse into the *i*-layer, he dropped the temperature after the p-layer, and waited for all the excess zinc to be pumped away before doing on to grow the *i*-layer (thickness W_i), followed by the *n*-layer. When he gave the sample to you, you performed a *C-V* measurement and found that the depletion capacitance is the same as the normal p-n junction, i.e., as if there was NO *i*-layer at all! The reason is that while he was waiting for the zinc to be pumped away, oxygen, a donor, incorporated in the crystal and formed a sheet of density $q\sigma/cm^2$ at the *p-i* interface (see Figure below).



c) Derive an algebraic relation between the doping densities N_D, N_A, $q\sigma$, and W_i which will explain the capacitance. To do this, you *have* to sketch the charge, field, and band diagram. Assume $N_D=N_A$ for simplicity. Neglect Gummel correction.

d) Next, calculate a numerical value of W_i. Assume $N_D=N_A=10^{17}/cm^3$, and $q\sigma=5\text{x}10^{11}/cm^2$.