EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
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Assignment 3
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Due: 02/11/2008

Reading: Chapter 3 & 4 of the Textbook (Muller/Kamins/Chan: MKC). For material constants & parameters, Table 1.3 page 52 of MKC should work. For materials not listed in this table, go to - http://www.ioffe.rssi.ru/SVA/NSM/.

Problem 1*
MKC Problem 3.11.

Problem 2
We saw in class that the I-V characteristics of rectifying Schottky junctions can be calculated in 2 ways – one by heuristic arguments, and the second by Schottky's drift-diffusion theory. The third method is based on thermionic emission theory, and was first used by the celebrated physicist Hans Bethe in 1943. His result for a Schottky-diode of barrier height $q\Phi_B$ is $J = J_0[\exp(qV_a / kT) - 1]$ (the same as by other methods!), where $J_0 = A^* T^2 \exp(-q\Phi_B / kT)$, and

$$A^* = \frac{4\pi q m^* k_B^2}{h^3} \approx 120\left(\frac{m^*}{m_0}\right)\frac{A}{cm^2 K}$$

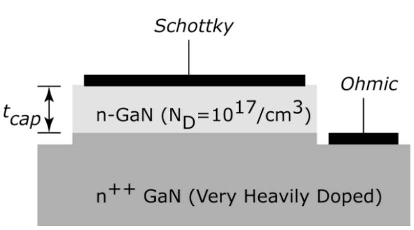
is the effective Richardson's constant and m^* is the el. effective mass. You will now verify this result.

a) Derive this result assuming that the current is ENTIRELY due to thermionic-emission. You might need to read up a semiconductor devices textbook other thab MKC for doing that.

Answer the following *qualitatively* with help of sketches -

b) The derivation holds for *both* a Schottky and a Mott-diode – why?
c) What would happen to the current-voltage characteristic of the Schottky diodes if I shine light with photon energy larger than semiconductor bandgap?

Problem 3



The GaN structure shown was grown epitaxially, but due to the carelessness of the grower, the thickness of the cap layer t_{cap} was not recorded. After growth, a Schottky-diode was formed by etching and metal evaporation steps, by depositing Nickel ($q\Phi_B$=1eV) on the cap layer, and an ohmic contact on the heavily doped layer under it. From your knowledge of device physics, you will find the thickness of the cap layer, t_{cap}. You have to figure out where to draw charge-field-band diagrams in the way.

a) What is the depletion thickness x_{depl} with *no applied bias* for a Nickel- (very long n-GaN) Schottky diode with doping N_D=10^{17}/cm^3? What is the electric field at the surface of the semiconductor of the long Schottky diode? Is it larger or smaller than the breakdown field for GaN F_{BR}?
b) The careless grower had performed a capacitance-voltage measurement on the structure shown above. He tells you that the capacitance *did not change appreciably* as he increased the reverse bias on the Schottky diode. However, he forgot to note down the *value* of the (constant)

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* Remember to use proper units and label every figure/plot. Turn in your answers worked out neatly. Please attach this question sheet to your solution when you turn it in.

capacitance! Using his information, what can be inferred about t_{cap} in relation to x_{depl} calculated in part (a)? If he had recorded the capacitance, could you have found t_{cap}?

c) You take matters into your own hands, and measure the current-voltage characteristic of the Schottky diode. You observe that the diode has a sharp and well-defined breakdown at a reverse bias of $|V_R|$=38.4 Volts. Find t_{cap}.

Problem 4

MKC Problem 3.12.

Problem 5

MKC Problem 3.17.

In general, make sure you are comfortable with the chapter-end problems of MKC Chapters 3 & 4.