EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
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1st Mid-Term Exam
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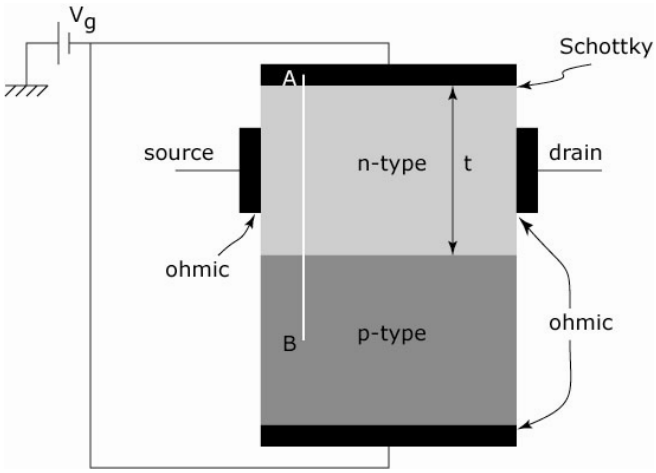
Problem (20 Points): Designing a 'MESJFET'



The figure above shows a device that needs to be analyzed for a certain application. The design part assigned to you will only require your knowledge of metal-semiconductor and p-n junctions. Here's what is required: the device essentially should operate as a transistor. The current flow between the source and drain ohmic contacts has to be modulated by the gate voltage, V_g. Your main task is to find the gate voltage at which no currrent can flow in the n-type layer. The *same* gate voltage is applied to both the metal - n-type semiconductor Schottky junction, as well as the metal – p-type semiconductor ohmic contact (as shown in the figure). Neglect Gummel correction for this problem. The following are given –

1- Semiconductor electron affinity: $q\chi_S$, Intrinsic carrier density: n_i, Dielectric constant: ε_S
2 - Doping densities: N_D & N_A, such that $N_A >> N_D$ (use this to your advantage), and
3 - The thickness of the n-type layer: *t.*
4 - The n-layer is conductive between the source-drain contacts when V_g=0.

a) Find the work function $q\Phi_M$ of the Schottky metal such that the 'built-in' voltage of the Schottky junction is *exactly the same* as the built-in voltage of p-n junction. Choose this to be your metal work function for the rest of the problem.
b) Find the thickness of the conductive region in the n-type layer at zero gate bias. Do so by sketching the charge-field-band diagram along the line A-B for the case when V_g=0, and taking it from there. What can you say about the thickness *t* from given conditions 3 & 4 above?
c) It is specified that the horizontal current between the source-drain contacts should be zero at a certain gate voltage, called the pinch-off voltage. This can happen only if the n-type layer is completely depleted of free carriers. Find the pinch-off gate voltage. Is it positive or negative?
d) Why the strange name – 'MESJFET' (other than the fact that this device has been invented for this exam)?

NOTE:
Sketches, sketches with proper LABELS!! (wherever the situation demands). State your approximations clearly, and use your intuition to cut down on the math.