ELL231 –Power Semiconductor Devices   Major Exam (100 pts)   May 2015

1. Determine the width of the N-drift region for a planar-gate asymmetric n- channel IGBT structure to obtain a blocking voltage of 600 V if its doping concentration is 1×10^{13} cm^{-3}, assuming that punch-through breakdown voltage conditions are applicable. Given minority carrier lifetime = 1us. High level injection lifetime = 1.5us (**20 pts**)

b) What is the thickness of buffer N+ layer required, assuming it is doped at 1×10^{17} cm^{-3}

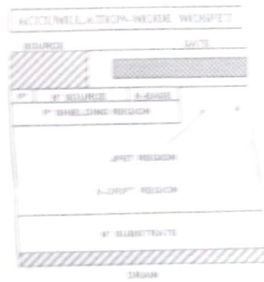
c) What is the blocking voltage in the reverse direction for this device.

d) Determine the base-transport factor, emitter efficiency, and *open-base breakdown voltage of this* transistor in forward direction.

e) What is the ON state voltage drop in the drift region for this IGBT

f) What is the leakage current at 300K when the device is supporting 200V

2. The figure on the right shows a novel accumulation mode MOSFET. For zero gate voltage, channel (base) region is depleted due to the p+ body region adjacent to it. When a gate voltage is applied, an accumulation channel is formed and the FET is turned ON. (**20pts**)



a) Sketch the band diagram across the middle of the channel region for V_g=0V, $V_g = V_t$

b) Sketch the electric field profile

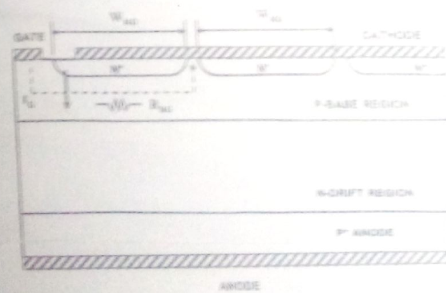
c) Determine the Threshold voltage

3. Consider an $N^+PN^-P^+$ power thyristor structure with uniformly doped N^+ *cathode, P base, N drift, and* P^+ *anode regions*. The N+ cathode region has a doping concentration of *2×10^{19} cm^{-3} and thickness of 10 um*. The P-base region has a doping concentration of 2×10^{17} cm^{3} and thickness of *20um. The N-drift region has a doping concentration of* 5×10^{13} cm^{3} and thickness of 300um. The P+ anode region has a doping concentration of 2×10^{19} cm^{3} and thickness of 50 um. The Shockley–Read–Hall (low- level, high-level, and space-charge generation) lifetime is 10 ns in the N+ cathode and P+ anode regions, 10 us in the P-base and N-drift regions. Ignore band-gap narrowing and Auger recombination. Use an ambipolar diffusion constant Da of 15 cm^2 s^{-1} for the on-state *calculations*. The structure has a linear cell geometry with an emitter width of 0.5 cm and length of 1 cm. (**30pts**)

a) Obtain an upper bound for the blocking voltage capability for the device ?

b) Obtain an upper bound on the gate triggering current

c) For the cathode short geometry shown on the left, determine the width W_{KG} so that forward bias in cathode/base junction is <0.2V at leakage current density of 1 A/cm^2. The width of cathode short is 25um.



d) What is gate trigger current for the device with cathode short (turn on voltage =0.7V)

e) In the ON state of the device, this gate current comes from the regenerative action of the device. Using the two transistor analogy, determine the holding current

f)For the above described device calculate the ON state voltage drop

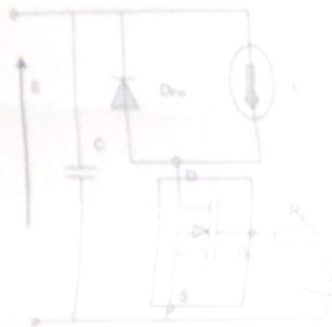
4. Why are wirebonded connections considered problematic when it comes to packaging power devices. Within the framework of TO-220/SO-8 packages describe two strategies for overcoming this problem (**4 pts**)

5. Describe two reasons why hockey puck style packaging is preferred for high power devices (**2pts**)

6. Power IC's utilize large number of planar devices with high blocking voltage capability to be economically viable. For this we need devices which meet the blocking voltage specification without consuming too much area, and good isolation between devices. Describe strategies to achieve this (**3pts**)

7. Describe two advantages, and one disadvantage of trench gate mosfet over VDMOS (**2 pts**)

8. A motor is driven by pulses delivered by a MOSFET. The circuit is shown on the right. (**8 pts**)



a) At what point during the turn on transient does the free-wheeling diode turn OFF.

b) What is the gate voltage at current turn on

c) How long does it take for the transistor to enter linear region

d) How would you minimize switching power loss in MOSFET

9. Empirically the band gap reduction ΔE_g in Si can be expressed as $\Delta E_g = 18.7 \ln(N/(7 \times 10^{17}))$ meV. Compare the emitter injection efficiency at room temperature for emitter dopings of 10^{19} and 10^{20} cm^{-3}. The base doping in both cases is 10^{18} cm−3. Assume that $x_E = x_B$ and $D_E = D_B$ (**5pts**)

The figure below shows three ways of connecting a BJT as a diode. Draw the band diagram of the BJT in all three cases (**6pts**)