Exam II

EE 3329 Summer 2003 Dr. Lush

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Instructions
Put your name on Answer sheet (1 point). You can keep the actual exam (suitable for framing). Fill in your ID number with a leading 0.

Note that there are many figures at back of exam. Go ahead and tear off those pages if that is more convenient for you.
1. Which of the following accurately describes the plot in Figure A?
   (a) $pn$ diode in reverse bias
   (b) $pn$ diode in forward bias
   (c) $p^+n$ diode in reverse bias
   (d) $p^+n$ diode in forward bias
   (e) None of the above or not a possible plot

2. Which of the following accurately describes the plot in Figure B?
   (a) $np$ diode in reverse bias
   (b) $np$ diode in forward bias
   (c) $pn$ diode in reverse bias
   (d) $pn$ diode in forward bias
   (e) None of the above or not a possible plot

3. The plot in Figure A is a plot of excess carriers.
   (a) True
   (b) False

4. What is the plot in Figure C representing?
   (a) A $p^+p$ junction
   (b) A $p^+n$ junction
   (c) A $n^+p$ junction
   (d) A $n^+n$ junction
   (e) None of the above

5. Which of the following contributes the most to the value of the total current in an ideal $n^+p$ diode under high forward bias conditions?
   (a) Series resistance.
   (b) Electrons and holes recombining in the space charge region.
   (c) Electrons diffusing over the barrier and into the opposite neutral region.
   (d) Holes diffusing over the barrier and into the opposite neutral region.
   (e) Generation in the space charge region.
6. Looking at the ideal diode equation for a $p^+n$ diode, what happens to the total current for a given voltage if we were to decrease significantly the doping concentration on the n-type side?
   (a) The current would increase significantly.
   (b) The current would decrease significantly.
   (c) The current would increase a little.
   (d) The current would decrease a little.
   (e) The current would stay essentially the same.

7. Looking at the ideal diode equation for a $n^+p$ diode, if $N_D = 10^{18} \text{ cm}^{-3}$ and $N_A = 10^{14} \text{ cm}^{-3}$, what happens to current for a given voltage if $N_D$ were decreased to $N_D = 10^{16} \text{ cm}^{-3}$?
   (a) The current would increase significantly.
   (b) The current would decrease significantly.
   (c) The current would increase a little.
   (d) The current would decrease a little.
   (e) The current would stay essentially the same.

8. Which of the following contributes the most to the total current in a non-ideal $n^+p$ diode under low reverse bias conditions if all the non-ideal current mechanisms could be important for this device?
   (a) Electrons diffusing over the barrier and into the opposite neutral region.
   (b) Holes diffusing over the barrier and into the opposite neutral region.
   (c) Electrons and holes generated in the space charge region.
   (d) Electrons and holes recombining in the space charge region.
   (e) Avalanche breakdown

9. Which of the following contributes significantly to the value of the total current in an $n^+p$ diode under low forward bias conditions if all the non-ideal current mechanisms could be important for this device?
   (a) Series resistance.
   (b) Electrons and holes recombining in the space charge region.
   (c) Electrons diffusing over the barrier and into the opposite neutral region.
   (d) Holes diffusing over the barrier and into the opposite neutral region.
   (e) All contribute at least in some way.

10. Which of the following can we learn to the greatest accuracy about an $n^+p$ diode by making measurements of capacitance versus voltage—and, of course, analyzing the results?
    (a) Doping on the p-type side
    (b) Doping on the n-type side
    (c) Built-in potential ($V_{bi}$)
    (d) All are equally well known
11. The electric field at the metallurgical junction of a \( p^+n \) junction is positive.
   (a) True
   (b) False

12. The electric field at the metallurgical junction of a \( p^+p \) junction is positive.
   (a) True
   (b) False

13. Which plot among those in Figures D accurately represents the charge density for a \( p^+p \) junction?
   (a) (a)
   (b) (b)
   (c) (c)
   (d) (d)
   (e) None of the above

14. Which plot in Figure E accurately represents the charge density for a \( n^+p \) junction?
   (a) (a)
   (b) (b)
   (c) (c)
   (d) (d)
   (e) None of the above

15. What is assumed when the depletion approximation is invoked?
   (a) That \( pm > n_i^2 \)
   (b) That \( p = 0 \) and \( n = 0 \)
   (c) That \( p = p_o \) and \( n = n_o \)
   (d) That \( p = N_A \) and \( n = N_D \)
   (e) None of the above

16. Why do we use the depletion approximation?
   (a) To determine charge density inside a pn junction depletion region
   (b) To determine electric field inside a pn junction depletion region
   (c) To determine potential inside a pn junction depletion region
   (d) To determine whether the doping is non-uniform.
   (e) To determine \( V_{bi} \)
An n+p diode is designed to be a solar cell. Assume that it is an ideal diode in every way except that there is uniform generation throughout, $G_o$. The device is under steady-state conditions.

17. Which carriers do we need to model?
   (a) Holes in the n-type side
   (b) Holes in the p-type side
   (c) Electrons in the n-type side
   (d) Electrons in the p-type side

18. What is the general solution for the minority carriers?
   (a) $\Delta p_n = Ae^{-\frac{x}{\tau_{p,n}}} + Be^{\frac{x}{\tau_{p,n}}} + G_o \tau_{p,n}$
   (b) $\Delta p_n = Ae^{-\frac{x}{\tau_{p,n}}}$
   (c) $\Delta p_n(t) = Ae^{-\frac{t}{\tau_{p,n}}} + G_o \tau_{p,n}$
   (d) $\Delta p_n(t) = Ae^{-\frac{x}{\tau_{p,n}}}$
   (e) None of the above

19. What are the boundary conditions at $x=0$ and $x=\infty$?
   (a) $\Delta p_n(x=0) = 0$; $\Delta p_n(x=\infty) = G_o \tau_{p,n}$
   (b) $\Delta p_n(x=0) = p_{n_o}(e^{\frac{qV_A}{kT}} - 1)$; $\Delta p_n(x=\infty) = G_o \tau_{p,n}$
   (c) $\Delta p_n(x=0) = p_{n_o}(e^{\frac{qV_A}{kT}} - 1)$; $\Delta p_n(x=\infty) = 0$
   (d) $\Delta p_n(x=0) = p_{n_o}$; $\Delta p_n(x=\infty) = 0$
   (e) None of the above

20. What is the exact solution for the minority carrier concentration?
   (a) $\Delta p_n(x) = p_{n_o}(e^{\frac{qV_A}{kT}} - 1)e^{\frac{-x}{\tau_{p,n}}} + G_o \tau_{p,n}$
   (b) $\Delta p_n(x) = p_{n_o}(e^{\frac{qV_A}{kT}} - 1)e^{\frac{-x}{\tau_{p,n}}} - G_o \tau_{p,n}e^{\frac{x}{\tau_{p,n}}}$
   (c) $\Delta p_n(x) = G_o \tau_{p,n}(1 - e^{\frac{-x}{\tau_{p,n}}})$
   (d) $\Delta p_n(x) = p_{n_o}(e^{\frac{qV_A}{kT}} - 1)e^{\frac{-x}{\tau_{p,n}}} + G_o \tau_{p,n}(1 - e^{\frac{x}{\tau_{p,n}}})$
   (e) None of the above

21. Which of the band diagrams (Figures F) represents the situation under $V_{oc}$, open-circuit voltage conditions? (Hint: how much current is there if the device is at $V_{oc}$?)
   (a) (a)
   (b) (b)
   (c) (c)
   (d) (d)
   (e) Not shown
22. Which of the band diagrams (Figures F) represents the situation under $J_{sc}$, short-circuit current conditions? (Hint: what is the voltage if the device is at $J_{sc}$?)
   (a) (a)
   (b) (b)
   (c) (c)
   (d) (d)
   (e) Not shown

23. Which of the band diagrams (Figures F) represents the situation where $V_A > V_{oc}$?
   (a) (a)
   (b) (b)
   (c) (c)
   (d) (d)
   (e) Not shown

24. What is $V_{bi}$ for the diode below (Figure G)? Assume the bandgap of the semiconductor is 1.0 eV.
   (a) 0.0 volt
   (b) 0.25 volt
   (c) 0.5 volt
   (d) 0.75 volt
   (e) None of the above

25. Which of the following (Figure G) accurately describes the device?
   (a) A $p^+n$ junction
   (b) A $pn$ junction
   (c) An $n^+p$ junction
   (d) An $np$ junction
   (e) None of the above

26. Which of the following statements represents Figure H? Assume the device is same as in Figure B.
   (a) A junction with 0.5 volt forward bias.
   (b) A junction with 0.5 volt reverse bias.
   (c) A junction with 0.75 volt forward bias.
   (d) A junction with 0.75 volt reverse bias.
   (e) None of the above

27. All non-idealities we discussed (series resistance, recombination and generation in the space charge region, avalanche breakdown) increase the magnitude of the diode current over an ideal diode.
   (a) True
   (b) False
28. What is $V_{bi}$ for the diode below (Figure I)? Assume the bandgap of the semiconductor is 1.0 eV.
   (a) 0.0 volt 
   (b) 0.25 volt 
   (c) 0.5 volt 
   (d) 0.75 volt 
   (e) None of the above 

29. Which of the following (Figure I) accurately describes the device?
   (a) A $p^+n$ junction 
   (b) A $pn$ junction 
   (c) An $n^+p$ junction 
   (d) An $np$ junction 
   (e) None of the above 

30. Which of the following statements represents Figure J? Assume the device is same as in Figure B.
   (a) A pn junction with 0.5 volt forward bias. 
   (b) A pn junction with 0.5 volt reverse bias. 
   (c) A pn junction with 1.5 volt forward bias. 
   (d) A pn junction with 1.5 volt reverse bias. 
   (e) None of the above 

31. Which of the following statements represents the Figure K?
   (a) A $p^+n$ junction in forward bias 
   (b) A $p^+n$ junction in reverse bias 
   (c) A pn junction in forward bias 
   (d) A pn junction in reverse bias 
   (e) None of the above 

32. Which of the plots in Figures L is a $pn$ diode in reverse bias?
   (a) (a) 
   (b) (b) 
   (c) (c) 
   (d) (d) 
   (e) Not shown 

33. The plots in Figures L are plots of excess carriers.
   (a) True 
   (b) False