Optoelectronic Materials and Devices

Module 1: Electronic Structure of Materials

Lecture 1: Conductivity of materials, Drude's theory and its failures
Reference: Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976

Questions:

1. Conductivity of semiconductors lies in the range of (a) 10^{-5} to 10^{5} (ohm-m)$^{-1}$; (b) 10^{-18} to 10^{-12} (ohm-m)$^{-1}$; (c) 10^{5} to 10^{8} (ohm-m)$^{-1}$; (d) None of these.
2. Which of these are in the correct order of conductivity? (a) Mica > Si > Cu > Mn ; (b) Mn > Cu > Si > Mica ;(c) Cu > Mn > Si > Mica ;(d) Cu > Mn > Mica > Si.
3. According to Ohm's law: (a) Conductivity is function of electric field ;(b) Conductivity is function of time; (c) Conductivity is function of current density; (d) Conductivity is constant.
4. According to Drude's model, which of the following statement is incorrect? (a) Electrons are free and independent; (b) Motion of electrons is modeled as kinetic theory of gases; (c) Compensating positive ions are immobile; (d) After collision with ions, the velocity of electron is zero.
5. Why was Drude's model successful in quantitatively explaining DC conductivity in metals? (a) Average velocity was underestimated; (b) Effective mass of electron was adjusted; (c) τ (relaxation time) was overestimated; (d) Both A &C.
6. According to Free electron theory (a) All electrons participate in conduction; (b) Only valence electrons participate in conduction; (c) Only electrons close to Fermi surface participate in conduction; (d) Both electrons and holes participate in conduction.
7. What happens when frequency of incident light exceeds plasma frequency of electrons in a metal? (a) Metal becomes insulator; (b) Metal becomes transparent; (c) Metal becomes superconducting; (d) Metal behave like a semiconductor.

Lecture 2 & 3: Free electron theory
Reference: Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976

Questions:

1. What is the wavelength of an electron having energy 3eV? (a) 41 Å;(b) 410 Å ; (c) 4.1 Å; (d) 4100 Å.
2. Integration of electron wave-function and its conjugate over the entire volume V is (a) 1; (b) V; (c) infinity; (d) 0.
3. Calculate average energy of electrons according to free electron theory at T = 0K? (a) $E_f/2$; (b) 0; (c) $3E_f/5$; (d) $2E_f/3$.
4. The **k** vector in free electron theory is related to? (a) electron momentum; (b) electron wave vector; (c) angular momentum; (d) orbital momentum.

5. Which is not true for electrons in a periodic boundary condition (a) continuous k states; (b) discrete k states or quasi-continuous; (c) minimum energy is zero ;(d) there are finite k states possible.
6. Density of states g(E) varies with energy (E) as (a) E^2; (b) $E^{1/2}$; (c) E; (d) It is independent of E.
7. What is the reason for using Born-von Karman boundary condition in free electron theory? (a) To obtain standing wave solution; (b) To obtain travelling wave solution; (c) To represent the periodicity of the lattice; (d) None of these.
8. The shape of Fermi energy surface in free electron theory for a 3-d solid is a (a) cube; (b) ellipsoid; (c) plane; (d) sphere.
9. Why is potential energy of electron is taken as zero in free electron theory? (a) e is free; (b) e is independent; (c) neither A nor B; (d) there is no e-e and e-ion interaction.

Lecture 4: Crystal structure, Reciprocal lattice I

Reference: Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976

Questions:

1. What is a point lattice?
2. What are the symmetry elements underlying a point lattice?
3. Which among these is a primitive lattice (a) FCC; (b) BCC; (c) simple orthorhombic; (d) base centered orthorhombic.
4. What is the reciprocal lattice of an FCC lattice? (a) DC (diamond cubic); (b) FCC; (c) SC; (d) None of these.
5. To describe electronic structure of materials, we use reciprocal lattice because (a) electrons interact with lattice only in reciprocal space; (b) electron energy is expressed in terms of reciprocal lattice vector (**K**); (c) **K** vectors are good vectors for Fourier analysis of electron wave; (d) electrons exist only in reciprocal space

Lecture 5: Reciprocal lattice II, Brillouin zone and Bragg's diffraction condition

References: (a) Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976; (b) Physical Properties of Semiconductors, Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall, 1989

Questions:

1. First Brillouin zone of BCC lattice has same shape as the Wigner-Seitz cell of (a) BCC lattice; (b) FCC lattice; (c) SC lattice; (d) None of these.
2. Show how Bragg's diffraction condition is satisfied at the zone boundaries
3. Are there unique set of reciprocal lattice vectors? Yes or no.

Lecture 6: Electrons in a crystal, Bloch's electron
Reference: Physical Properties of Semiconductors, Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall, 1989

Questions:
1. What is meant by a Bloch's electron? State the result of Bloch's theorem in words.
2. Given a wave vector, how would you use the result of Bloch's theorem to find an equivalent vector in the first Brillouin zone?
3. If you know volume of a crystal, how would you determine how many k-states exists in the first Brillouin zone?

Lecture 7: Free electron band diagrams in an empty lattice
References: (a) Physical Properties of Semiconductors, Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall, 198; (b) Electronic Properties of Materials: An Introduction for Engineers, Rolf E. Hummel, Springer Verlag, 1985.

Questions:

1. Draw a free electron band diagram for BCC material (just as it was done for FCC in the lecture) and compare it with that shown in the lecture. This will be a laborious problem, but will help understand the idea well.

Lecture 8: Effect of periodic potential, Origin of band-gap through Kronig-Penny model
References: (a) Advanced Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 6, Addison Wesley, 1989; (b) Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons 1991

Questions:

1. The potential V_o in Kronig-Penny model is (a) interaction potential between electrons, (b) interaction potential between lattice atoms, (c) effective potential felt by an electron due to atomic cores, (d) applied potential
2. Bandwidth of the energy bands decreases as V_o (a) increases, (b) decreases, (c) goes to zero, (d) none of these
3. In Kronig-Penny model, if V_o=0, electron (a) behaves as a Bloch electron, (b) behaves as a free electron, (c) behaves as a particle in a box, (d) none of the these
4. According to Kronig-Penny model, (a) electrons occupy discrete levels well separated from each other, (b) electrons occupy discrete energy levels within certain allowed energy bands, (c) electrons occupy discrete levels with all energy values allowed, (d) electrons occupy continuous energy levels within allowed energy bands
5. Magnitude of potential barrier in periodic lattice determines the band-gap. Potential barrier becoming very large (V_o --> infinity) results in (a) free electrons, (b) small band gaps, (c) large band gaps, (d) discrete states

Lecture 9: Electron dynamics

References: (a) Advanced Theory of Semiconductor Devices, Karl Hess, Prentice Hall, 1988; (b) Advanced Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 6, Addison Wesley, 1989;

Questions:

1. From a $\mathcal{E}$-k, how would you determine velocity of an electron in a k-state?
2. Rate of change of quantity $\hbar\vec{k}$ is external force applied on an electron. Hence this quantity is called crystal momentum. Prove the first statement.
3. How do you define effective mass of an electron? If $\mathcal{E}$-k diagram is concave upwards, is effective mass positive or negative. Similarly, what is the answer when this diagram is convex upwards?
4. How do you distinguish between a metal and an insulator?
5. How do you distinguish between an insulator and a semiconductor?

Lecture 10: Conduction in relation to band diagrams

References: (a) Advanced Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 6, Addison Wesley, 1989; (b) Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976

Questions:

1. Can band which are empty contribute to conduction?
2. Why do fully filled bands do not contribute to conduction?
3. Where $\mathcal{E}$-k diagram is convex upwards, effective mass of the electrons is negative. What kind of particles we can imagine to be present in those k-states? What would be their charge? How would you justify your answer?
4. Why in semiconductors we say electrons conduct in the conduction band and holes in the valence band?
5. Why is Na in a material form conducting, that is, it behaves like a metal? Why does free electron theory works well for Na metal?
6. Though Be is a metal, it exhibits low conductivity because of (a) low density of states at fermi level, (b) high density of states at fermi level, (c) low effective mass of electrons, (d) low valence
7. Electronic structure of aluminum has (a) partially filled first and second BZ, (b) partially filled second and third BZ, (c) partially filled first and third BZ, (d) completely filled first and second BZ
8. Show that in case of Al, instead of 3 electrons conducting, effectively, it is only one hole that is conducting.
9. The reason for high conductivity in noble metals (mono valent) is due to (a) 1s electron, (b) low effective mass of electrons, (c) participation of 10 d electrons, (d) low relaxation time

Module 2: Electrical Properties of Materials

Lecture 11: Semiconductor E-k diagrams and their material properties
References: (a) Physical Properties of Semiconductors, Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall, 198; (b) Electronic Properties of Materials: An Introduction for Engineers, Rolf E. Hummel, Springer Verlag, 1985.

Questions:
1. What is the crystal lattice of semiconductors Si and GaAs. Draw the crystal structures and observe the similarities and differences.
2. In all the semiconductors examined, where did the maxima of valence band occurred.
3. In GaAs, draw the detailed structure of valence band, observe the curvature of the bands and identify light and heavy hole.
4. Which among the semiconductors examined in the lecture were direct band gap and which were indirect band gap semiconductors.
5. What is the nature of L-valley in conduction band of GaAs.
6. Schematically plot absorption coefficient versus photon energy for Si and GaAs

Lecture 12: Equilibrium carrier statistics in semiconductors: density of states, fermi function and population density in bands
References: Solid State Electronic Device, Ben G. Streetman, Prentice-Hall, N.J. USA, 1980; (b) Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 1, Addison Wesley, 1989

Questions:
1. What does fermi energy in semiconductors indicate? Where is it commonly located in a semiconductor? Are electrons to be found at fermi level? If not, why?
2. Consider a semiconductor with $\mathcal{E}_c$=1.1 eV, $\mathcal{E}_v$ =0, $\mathcal{E}_F$ = 0.7 eV, effective mass of electrons and holes the same as rest mass of electrons and a temperature of 300K. On y-axis plot $\mathcal{E}$ (in eV) with $g_c(\mathcal{E})f(\mathcal{E})$ (that is, the population density) (in $cm^{-3}eV^{-1}$) plotted on x-axis. Observe the energy where the peak lies. How close is it to $\mathcal{E}_c$? Find approximately the area under the curve (if you like, you could do proper integration numerically). Now look at the peak value of $g_c(\mathcal{E})f(\mathcal{E})$. What would be the spread in energy if you approximate the curve by a rectangle of same area as before and a spread in x-direction as peak value of $g_c(\mathcal{E})f(\mathcal{E})$. How small is this spread in energy? Does it prove that electrons are mostly found near the conduction band edge?

Lecture 13: Equilibrium carrier statistics in semiconductors: qualitative examination of carrier densities in conduction and valence bands
References: Solid State Electronic Device, Ben G. Streetman, Prentice-Hall, N.J. USA, 1980; (b) Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 1, Addison Wesley, 1989

Questions:

1. Which among Si, Ge and GaAs has largest density of conduction band?
2. Which among Si, Ge and GaAs has smallest effective mass of electrons? What would be the implication of this fact in device performance.
3. For Si, assume in one case fermi energy to be near conduction band and in another case near the valence band. In both cases, systematically plot the population density to show that more electrons will be available for conduction when fermi energy is near the conduction band.

Lecture 14: Equilibrium carrier statistics in semiconductors: quantitative examination of carrier densities in intrinsic semiconductor

References: Solid State Electronic Device, Ben G. Streetman, Prentice-Hall, N.J. USA, 1980; (b) Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 1, Addison Wesley, 1989

Questions:

1. Distinguish between a degenerate and non-degenerate semiconductor. In which case do the electrons follow Maxwell-Boltzman statistics, that is, when does Fermi-Dirac statistics becomes equivalent to Maxwell-Boltzman statistics.
2. How do you define an intrinsic semiconductor?
3. Is fermi energy exactly in the center of the band gap for an intrinsic semiconductors? If not, why does is deviate?
4. Plot $\log(n_i)$ in cm^{-3} versus band gap (take it in range 0.5-3 eV) at 300K and 500K, using electron mass as rest mass and hole mass as half of rest mass of electrons. Mark Si, GaAs and Ge on the curve. Examine which curve has greater slope.

Lecture 15: Doping in semiconductors

References: Solid State Electronic Device, Ben G. Streetman, Prentice-Hall, N.J. USA, 1980; (b) Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 1, Addison Wesley, 1989

Questions:

1. Name some n- and p-type dopants in Si and GaAs.
2. Why is it that product np is the same, irrespective of whether the semiconductor is intrinsic or extrinsic.
3. Distinguish between shallow and deep levels.
4. What is implied by complete ionization of dopants.
5. If fermi energy in a As and B doped Si is at E_D level, what fraction of each dopant is ionized.

Lecture 16: Equilibrium carrier statistics in semiconductors: complete ionization of dopant levels

References: Solid State Electronic Device, Ben G. Streetman, Prentice-Hall, N.J. USA, 1980; (b) Semiconductor Fundamentals, Robert F. Pierret as part of Modular Series on Solid State Devices Vol. 1, Addison Wesley, 1989

Questions:

1. What is meant by "a compensated" semiconductor
2. A Si sample is doped with $9x10^{16}/cm^3$ donors and $3x10^{16}/cm^3$ acceptors. Assuming complete ionization, find the position of Fermi level with respect to E_i at 300K. Assume $n_i=10^{10}/cm^3$
3. Ge has a band gap of 0.66eV (assume it to be temperature independent). Plot intrinsic electron concentration (on log scale) as a function of 1/T. Use required data from the lectures. If we now dope Ge with $10^{14}cm^{-3}$ n-type dopant, up to what temperature is Ge extrinsic semiconductor? Now together on one plot show carrier concentrations in intrinsic and exhaustion region.
4. Assuming non-degenerate state of GaAs under all conditions in this question, and that its band gap 1.42 eV is independent of temperature, for GaAs doped with [Zn] = $2.1x10^{14}$ cm^{-3} and [Si] = 10^{13} cm^{-3}, determine if the semiconductor is intrinsic or extrinsic (a) at 100K, (b) at 1000K. The effective mass of electrons and holes are: $m_e^* = 0.066m_e$, $m_h^* = 0.52m_e$

Lecture 17: Equilibrium carrier statistics in semiconductors: carrier freeze out

References: Semiconductor Statistics, J. S. Blackmore, Dover Publications, 1987 (Chapter 3)

Questions:

1. Plot log of free carrier concentration vs 1/T for Si when: (a) [B]=$5x10^{16}cm^{-3}$, (b) [B]=$5x10^{16}cm^{-3}$, [P]=10^{14} cm^{-3} and (c) on the graphs for cases a) and b), also plot ionized acceptor concentration $[N_A^-]$. First, draw a band diagram depicting all the energy levels and then answer the questions. MAKE SURE to label the axes and slopes, and the important numerical values on the carrier concentration axis.
2. In the question above, what is the slope of the line in freeze out region for case (a) and (b)? Are they same or different?
3. If the values of dopant concentrations were not given in the first question, describe an experiment that would allow you to determine the dopant concentrations, band gap of the material and the dopant level of the major dopant.

Lecture 18: Semiconductor junctions in band-diagrams

References: Physics of Semiconductor Devices, J. P. Colinge and C. A. Colinge, Kluwer Academic Publishers, 2002

Questions:

1. Draw a band-diagram for a silicon p-n junction when n-Si and p-Si are lightly doped, that is, the fermi energy in both materials is a bit away from the relevant band edge. Then draw the diagram for heavily doped p- and n- Si and observe the differences.
2. Give an example each for straddled, staggered and broken hetero-junction.
3. Draw a band diagram for staggered hetero-junction.

Lecture 19: Linear dielectric behavior

Reference: Fundamentals of Ceramics, M. Barsoum, McGraw-Hill, 1997

Questions:

1. A parallel plate capacitor of plate area 100 cm^2 has the plates separated by 0.5 cm. When 1000 V is applied across the capacitor, calculate the charge on the plates and the electric field within the capacitor. Now insert a dielectric of susceptibility 4 and carry out the same calculations. Observe the differences. How much is the polarization in each case.
2. What are the various mechanisms of polarization that lead to dielectric behavior? Describe their origin.
3. Which polarization mechanisms are likely to operate at a frequency of approximately 10^{11} Hz.
4. Give an example where you would like the dielectric to be lossy.
5. For which polarization mechanism the dielectric susceptibility is a function of temperature?
6. Linear dielectrics have their dielectric constant in the range of (a)1-2 ; (b) 5-10 ; (c) 100-1000; (d) none of the above
7. For a dielectric with no 'ohmic-loss' in an alternating field, the current will lead the voltage by (a) 45 degrees; (b) 90 degrees; (c) the current will lag the voltage by 90 degrees; (d) by an angle 'delta' determined by ratio of complex and real part of dielectric constant

Lecture 20: Non-linear dielectric behavior

Reference: Fundamentals of Ceramics, M. Barsoum, McGraw-Hill, 1997

Questions:

1. Diaphragm of a speaker should be made of a material that exhibits (a) piezoelectricity; (b) ferroelectricity; (c) pyroelectricity; (d) linear dielectric material
2. What is the key requirement on crystal structure for a material to be piezoelectric, pyroelectric or ferroelectric.
3. If a material is ferroelectric, is it necessarily piezoelectric too? Is converse also true?

Module 3: Optoelectronic Device Physics

Lecture 21: Carrier recombination-generation-I: band-to-band transition
Reference: Advanced Semiconductor Fundamentals, Robert F. Pierret , Modular Series on Solid State Devices, Vol. 6, Addison-Wesley, USA, 1989

Questions:
MCQ :
1. GaAs is a/an (a) Direct bandgap semiconductor;(b) Indirect bandgap semiconductor; (c) Elemental semiconductor; (d) Insulator.
2. If you wish to make a solar cell, you will make it with (a) SiO_2; (b) Si; (c) GaN; (d) none of the above.

Short answers :
1. What is generation and recombination of carriers?
2. What is the relationship between thermal generation rate and recombination rate in equilibrium?
3. In equilibrium, product of carrier concentrations in a semiconductor is constant (np = const.). Explain this based on thermal generation and recombination rate.
4. What is the expression for optical generation rate of carriers in a semiconductor? What should be the optimum thickness of a solar cell.
5. How do we generate carriers in a light emitting diode?

Lecture 22: Carrier recombination-generation –II: Other mechanisms
Reference: Advanced Semiconductor Fundamentals, Robert F. Pierret , Modular Series on Solid State Devices, Vol. 6, Addison-Wesley, USA, 1989

Questions:
MCQ :
1. If you wish to make a light emitting diode, you will make it with (a) Si;(b) Ge; (c) GaAs; (d) None of the above.
2. Recombination process/es in optoelectronic devices responsible for emission of light is/are (a) Band-to-band transition; (b) R-G center recombination (deep levels); (c) R-G center recombination (shallow levels); (d) Via excitons; (e) Auger recombination.
3. Mechanisms responsible for creating electron-hole pairs via light (photon) absorption is/are (a) Resonance of various optical oscillators; (b) Band-to-band transition; (c) Via R-G centers; (d) None of the above.

Lecture 23: R-G statistics via R-G centers
Reference: Advanced Semiconductor Fundamentals, Robert F. Pierret , Modular Series on Solid State Devices, Vol. 6, Addison-Wesley, USA, 1989

Questions:

1. What is meant by capture coefficient and emission coefficient for electrons and holes in a semiconductor having R-G centers?

2. What is the difference between equilibrium and steady-state with respect to carrier concentration in a semiconductor?
3. What are the three life-times of carriers discussed in this lecture? Name the associated R-G process for each.
4. If all three R-G processes are operative in a semiconductor, what is the effective life time of carriers for the special case of low-level injection?

Lecture 24: Optoelectronic materials and bandgap engineering

Reference: (1)Semiconductor Optoelectronic devices, Pallab Bhattacharya, Printice-Hall, Inc., Englwood cliff, NJ, 1994.

(2)Light Emitting Diodes, E. Fred Schubert, Cambridge University Press, Cambridge, 2003.

Questions:

MCQ :

1. If you wish to make a light emitting diode, you will make it with (a) Si; (b) Ge; (c) GaAs; (d) None of the above.

Short answers:

2. Suggest a semiconducting material for making red, green and blue LED.
3. Name a semiconducting material having band-gap in infra-red region.
4. What is the uniqueness of III-V semiconductors?
5. What can be done to manipulate the bandgap of a material?

Lecture 25: Optical properties of materials

Reference: Optics (4^{th} Edition), Ajoy Ghatak, Tata Mcgraw-Hill, New Delhi, 2009

Questions:

MCQ :

1. The basic mechanism responsible for optical properties in a dielectric is (a) Orientation polarization; (b) Ionic polarization; (c) Electronic polarization; (d) None of the above.
2. In order to calculate the optical properties of a material, we need dielectric constant around frequency range (a) $\sim 10^9$ Hz; (b) $\sim 10^3$ Hz; (c) $\sim 10^{15}$ Hz; (d) None of the above.
3. Optical properties of a material are (a) Reflectance; (b) Transmittance; (c) n, k; (d) ε', ε".
4. In order to derive the Snell's law, we used the boundary condition (a) Perpendicular component of the E vector is continuous across the boundary; (b) Perpendicular component of the H vector is continuous across the boundary; (c) Tangential component of both E and H vector are continuous across the boundary; (d) None of the above.

Lecture 26: Optical properties of single interfaces: Fresnal reflection coefficients

Reference: Optical properties of thin solid films, O.S. Heavens, Butterworths Publications Ltd., London, 1955

Questions:

1. Fresnal coefficients can be used to calculate R and T at an interface if (a) interface is atomically smooth; (b) interface roughness << wavelength of light; (c) interface roughness has no effect ; (d) None of the above.
2. R and T from a surface depends on (a) Incidence angle; (b) Polarization of light; (c) Wavelength of light; (d) None of the above.
3. Reflectance of parallel and perpendicular polarized light from a surface is same when incidence angle "θ" is (a) 90^o; (b) 0^o; (c) 180^o; (d) 45^o.
4. To reduce the reflectance of a surface, refractive index change should be (a) a step function; (b) gradual; (c) delta function; (d) None of the above.

Lecture 27: Optical Properties of two interfaces: thin film case
Reference: Optical properties of thin solid films, O.S. Heavens, Butterworths Publications Ltd., London, 1955

Questions:

1. Suggest materials for putting an antireflection coating on a silicon solar cell at ~ 500 nm. (Hint: Use the equations for reflectance from a thin film on a substrate. Optical parameters can be obtained from any source.)

Lecture 28: Drift
Reference: Advanced Semiconductor Fundamentals, Robert F. Pierret , Modular Series on Solid State Devices, Vol. 6, Addison-Wesley, USA, 1989

Questions:

1. What is drift action?
2. Is it possible for an intrinsic semiconductor to have higher conductivity than its extrinsic counterpart?
3. How are drift velocity and mobility related?
4. Look up mobilities of carriers (electrons and holes) in GaAs and Si.
5. What are the parameters that effect carrier mobility in a semiconductor?

Lecture 29: Diffusion
Reference: Advanced Semiconductor Fundamentals, Robert F. Pierret , Modular Series on Solid State Devices, Vol. 6, Addison-Wesley, USA, 1989

Questions:

1. What is the expression for diffusion current due to electron and holes in a semiconductor?
2. What is Einstein relationship?

Lecture 30: Continuity Equation

Reference: Advanced Semiconductor Fundamentals, Robert F. Pierret , Modular Series on Solid State Devices, Vol. 6, Addison-Wesley, USA, 1989

Questions:

1. Write down general continuity equation for carriers in a semiconductor.
2. Minority carrier diffusion equations are a special case of continuity equation. What are the assumptions under which minority carrier diffusion equations can be used?

Module 4: Basic Electronic Devices

Lecture 31: Resistor and diode (p-n junction)

Reference: Solid State Electronic Devices, B.G. Streetman, Prentice-Hall, Inc., N.J., USA, 1980

Questions:

1. Why do we use tantulum and not aluminum for making resistors?
2. Draw equilibrium energy band-diagram for a p-n junction.
3. What transport mechanism (drift or diffusion) is responsible for forward current of a p-n junction?
4. In which quadrant of the I-V curve do light emitting diodes operate?
5. In which quadrant of the I-V curve do solar cells operate?

Lecture 32: Fundamentals of p-n junction

Reference: Solid State Electronic Devices, B.G. Streetman, Prentice-Hall, Inc., N.J., USA, 1980

Questions:

1. What is n and p in a n-type semiconductor ? (Assuming complete ionization of only donor dopants)
2. What is the maximum built-in potential that can be generated in a Si p-n junction?
3. What is depletion approximation?
4. Sketch space-charge, electric field and potential in a p-n junction in equilibrium under depletion approximation.
5. Sketch the energy band-diagram of a p-n junction in forward and reverse bias. Use thermal equilibrium as reference.

Lecture 33: Fundamentals of p-n junction contd.

Reference: Solid State Electronic Devices, B.G. Streetman, Prentice-Hall, Inc., N.J., USA, 1980

Questions:

1. Write down the ideal p-n junction diode equation. Explain different parameters used in this equation.
2. Sketch electron and hole current as a function of position in a p-n junction.
3. Is total current constant throughout the device?
4. What are the break-down mechanisms in a p-n junction diode?

Lecture 34: Solar cells

Reference: Physics of Semiconductor Devices, S.M. Sze, A Wile-Interscience publication, Singapore, 1981.

Questions:

1. What is the expression for calculating the efficiency of a solar cell?
2. What are various losses that limit the efficiency of a solar cell?
3. List different generations of solar cells.

Lecture 35: Microelectronics processing
Reference: Fabrication of Microelectronic Devices, Deepak, Vikram Verma, Monica Katiyar, in "Micromanufacturing Processes", edited by V.K. Jain, CRC press (Taylor and Francis) 2012

Questions:

1. What are main thin film deposition processes used in microelectronics fabrication?
2. Name the processes used for changing the dopant concentration in semiconductors.
3. Describe the sub-processes in photolithography.

Lecture 36: MOS capacitor
Reference: Solid State Electronic Devices, B.G. Streetman, Prentice-Hall, Inc., N.J., USA, 1980

Questions:

1. Draw equilibrium energy band diagram for a MOS capacitor when $\phi_m=\phi_s$.
2. Draw accumulation, depletion and inversion situation for MOS device of problem 1.
3. Plot a typical C-V of a MOS capacitor and label accumulation, depletion and inversion region.
4. What are some applications for a MOS capacitor?

Lecture 37: Transistor
Reference: Solid State Electronic Devices, B.G. Streetman, Prentice-Hall, Inc., N.J., USA, 1980

Questions:

1. Describe functioning of a bipolar junction transistor.
2. Describe functioning of a MOSFET transistor.
3. Draw typical output and transfer characteristics of a transistor.

Lecture 38: Organic Electronics
Reference: Physics of Organic Semiconductors, edited by W. Brütting and C. Adachi, Wiley-VCH Verlag & Co. KGaA, Wenheim, Germany,2012

Questions:

1. How are organic semiconductors different from their inorganic counterpart?
2. What is a polaron?
3. Describe an organic diode using energy band diagram.
4. What are some applications of organic electronics?

Lecture 39: Organic Light Emitting Diodes
Reference: Physics of Organic Semiconductors, edited by W. Brütting and C. Adachi, Wiley-VCH Verlag & Co. KGaA, Wenheim, Germany,2012

Questions:

1. What is HOMO and LUMO?
2. What are different factors deciding external efficiency of an OLED?
3. What are singlet and triplet excitons?
4. What is the typical out-coupling efficiency in an OLED (without any optical enhancement)?
5. How do we make white OLED?

Lecture40: Organic Solar Cells and Organics Thin Film Transistors
Reference: Physics of Organic Semiconductors, edited by W. Brütting and C. Adachi, Wiley-VCH Verlag & Co. KGaA, Wenheim, Germany,2012

Questions:

1. What is the difference between Frankel and Wannier-Mott exiton?
2. What is the advantage of bulk-hetrojunction over bilayer organic solar cells?
3. How is thin film transistor different from MOSFET ?
4. How do we get accumulation in an OTFT?
5. How to make n-channel and p-channel OTFT device?