Physics 8550 – Physics of Thin Films

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Solution to Assignment #1: Semiconductors

1) a) What is the conductivity of intrinsic HgTe, Si, GaAs and ZnS. b) Why does the conductivity decrease with increasing bandgap? c) What mechanism do you have to change / control its conductivity?

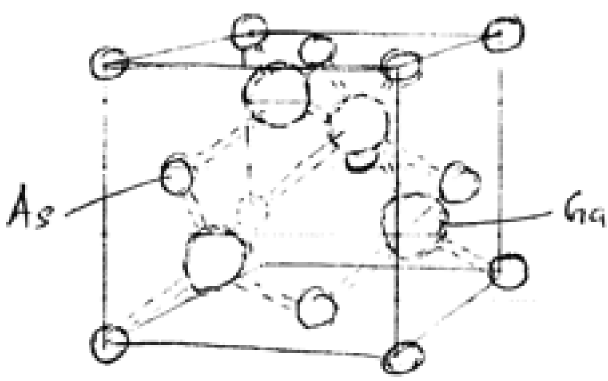
a)

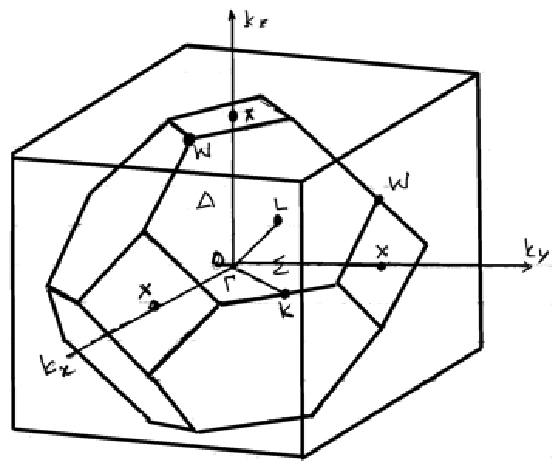
Material	σ	Band Gap (eV)
HgTe	10 to 10^{3}	-0.15 (d)
Si	4.3×10^{-3}	1.11 (i)
GaAs	1×10^{-8}	1.43 (d)
ZnS	1×10^{-10}	3.54

b) The conductivity of a semiconductor decreases with increased band gap energy: see Fermi statistics for transition probability!

c) Can be changed by the mechanism of doping the semiconductor with Donors/acceptors (see shift in Fermi-level and resulting change in transition probabilities).

2) Sketch the zincblende lattice for GaAs and identify the position of the atoms (If all atoms would be the same, what kind of lattice structure would you have?). Construct the Brillouin zone for this zincblende lattice.





3) What do you need the to construct from the Brillouin zone and energy diagram?

From the real-space lattice cell construct the brillioun zone for a crystal structure. Reduce the first Brillouin zone to Wigner-Seitz cell of the reciprocal lattice. Draw energy bands along symmetry line to symmetry points since there you will find the largest joint density of states with the highest probability for electronical and optical transitions.

4) Does a semiconductor need crystal symmetry? Explain and give a few examples for the choice of your answer.

5) Let's assume your semiconductor has two-dimensional (2D) crystal symmetry. a) Give two examples where you have only 2D symmetry. How do you construct you energy band diagram? How do the energy bands evolve in the third dimension?

6) Let's assume you have a group III-V compound semiconductor, say GaAs, and you want to grow on top an epitaxial 2 µm thick GaP layer. What criteria do you have consider to see whether it can be done? Can it be done?

7) Let’s assume you have a group III-V compound semiconductor, say GaAs, and you want to grow on top an epitaxial 2 µm thick ZnS layer. What criteria do you have consider to see whether it can be done? Can it be done?

8) Now lets assume you have a amorphous dielectric, say CaF, and you want to deposit SiO_2 onto it. How do the requirements in 7) change.

9) Name two crystalline semiconductor based device structures that only utilize the materials properties – no layers involved!
For instance: a) nonlinear optical crystals for optical parametric oscillator or second harmonic generation
b)

10) What material properties can be explored in a semiconductor device structures. Name at least 5 different ones and give examples.
a) electrical charge transport (diodes, transistors, ….)
b) EM wave propagation / EM wave diffraction at interfaces
c) Ferromagnetic
d) Superconductivity
e) electron spin transport