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Engineering Physics

Term Test 1 Assignment:

1) Metallic iron changes from BCC to FCC form at 910°C. At this temperature the atomic radii of the iron atom in the two structures are 0.1258 nm and 0.1292 nm respectively. Calculate the volume change in percentage during the structural change. Also, calculate the percentage change in density.

Solution: Given: $r_{BCC} = 0.1258$ nm

$r_{FCC} = 0.1292$ nm

Now, we know that

$$a_{BCC} = \frac{4}{\sqrt{3}} r_{BCC} = \frac{4}{\sqrt{3}} \times 0.1258 = 0.2905 \text{ nm}$$

$$a_{FCC} = 2\sqrt{2}\, r_{FCC} = 2\sqrt{2} \times 0.1292 = 0.3654 \text{ nm}$$

Now,

$$\text{Percentage change in volume} = \left(\frac{V_{FCC} - V_{BCC}}{V_{BCC}}\right) \times 100$$

$$= \left(\frac{a^3_{FCC} - a^3_{BCC}}{a^3_{BCC}}\right) \times 100$$

$$= \left[\frac{(0.3654)^3 - (0.2905)^3}{(0.2905)^3}\right] \times 100$$

$$= 0.990065 \times 100$$

$\therefore$ Percentage change in volume = 99.0065 %.

Now,

$$\rho_{FCC} = \frac{Z_{FCC} \times M}{N_a \times a^3_{FCC}} \quad , \quad \rho_{BCC} = \frac{Z_{BCC} \times M}{N_a \times a^3_{BCC}}$$

$$= \frac{4M}{N_a \times a^3_{FCC}} \qquad = \frac{2M}{a^3_{BCC} \times N_a}$$

$\therefore$ Percentage change in density $= \left(\frac{\rho_{FCC} - \rho_{BCC}}{\rho_{BCC}}\right) \times 100$

$$= \frac{\frac{\cancel{2M}}{\cancel{N_a}}\left(\frac{2}{a^3_{FCC}} - \frac{1}{a^3_{BCC}}\right)}{\frac{\cancel{2M}}{\cancel{N_a} \times a^3_{BCC}}} \times 100$$

$$= a^3_{BCC}\left(\frac{2}{a^3_{FCC}} - \frac{1}{a^3_{BCC}}\right) \times 100$$

$$= \left[2\left(\frac{a_{BCC}}{a_{FCC}}\right)^3 - 1\right] \times 100$$

$$= \left[2\left(\frac{0.2905}{0.3654}\right)^3 - 1\right] \times 100$$

$$= 0.00499 \times 100$$

Percentage change in density $= 0.499\%$

$\therefore$ Percentage change in volume is 99.0065% and Percentage change in the density is 0.499%.

2) Monochromatic x-Rays of wavelength 1Å incident on a crystal and are diffracted. The glancing angles for (100), (110) and (111) planes were found to be 16.13', 23.13' and 28.76'. Indentify the crystal structure and find its lattice constant. Hence, find the atomic weight of crystal, given the density is 8.96 g/cc.

Solution: Let the glancing angles for (100), (110) and (111) planes be θ_1, θ_2 and θ_3 respectively.

$\therefore \theta_1 = 16.13'$, $\theta_2 = 23.13'$, $\theta_3 = 28.76'$

Now,

Let d_{100}, d_{110} and d_{111} be the interplanar spacing for (100), (110) and (111) planes respectively.

$\therefore$ According to Bragg's equation,

$$2d_{100}\sin\theta_1 = \lambda, \quad 2d_{110}\sin\theta_2 = \lambda, \quad 2d_{111}\sin\theta_3 = \lambda$$

$\therefore$ We have

$$d_{100} : d_{110} : d_{111} = \frac{1}{\sin\theta_1} : \frac{1}{\sin\theta_2} : \frac{1}{\sin\theta_3}$$

$$= \frac{1}{\sin(16.13')} : \frac{1}{\sin(23.13')} : \frac{1}{\sin(28.76')}$$

$$= 3.599 : 2.546 : 2.078$$

$$= 1 : 0.707 : 0.577$$

$$d_{100} : d_{110} : d_{111} = 1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{3}}$$

We know that, For simple cubic lattice

$$d_{100} : d_{110} : d_{111} = 1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{3}}$$

$\therefore$ The given crystal structure is simple cubic structure.

Now,

$$2 d_{100} \sin\theta_1 = \lambda$$

$$\therefore d_{100} = \frac{\lambda}{2\sin\theta_1} = \frac{1}{2 \times \sin(16.13^\circ)} = \frac{3.599}{2} = 1.7995 \text{ Å}$$

$$\therefore d_{100} = \frac{a}{\sqrt{h^2+k^2+l^2}} = \frac{a}{\sqrt{1+0+0}}$$

$$\therefore d_{100} = a = 1.7995 \text{ Å}$$

$\therefore$ Lattice constant or edge length is 1.7995 Å

Now we know that, $\rho = \frac{ZM}{a^3 N_a}$

$$\therefore 8.96 = \frac{1 \times M}{(1.7995)^3 \times 6.022 \times 10^{23} \times 10^{-24}}$$

$$\therefore M = 8.96 \times 35.091 \times 10^{-1}$$

$$\therefore M = 31.442 \text{ g}$$

$\therefore$ The atomic weight of the given crystal is 31.442 g

3) The fermi energy level for copper is 6.25 eV. Determine the temperature at which there is a 1% probability that an energy state 0.30 eV below the fermi energy level will not contain an electron.

Solution. Given: $E_F = 6.25\,eV$

$E_f - E = 0.30\,eV$

$\therefore E - E_f = -0.30\,eV$

P(not containing an electron) = 1%

$\therefore$ P(containing an electron) = 99% = 0.99

Now,

$$P(\text{containing an electron}) = \frac{1}{1 + e^{\left(\frac{E-E_f}{kT}\right)}}$$

$$\therefore 0.99 = \frac{1}{1 + e^{\left(\frac{-0.30\,eV}{kT}\right)}}$$

$$\therefore 0.99\left[1 + e^{\left(\frac{-0.30\,eV}{kT}\right)}\right] = 1$$

$$\therefore 1 + e^{\left[\frac{-0.30 \times 1.6 \times 10^{-19}}{kT}\right]} = 1.01$$

$$\therefore e^{\left[\frac{-3476.6}{T}\right]} = 0.01$$

Taking ln on both sides,

$$\therefore \frac{-3476.6}{T} = \ln(10^{-2})$$

$$\therefore \frac{\cancel{-}3476.6}{T} = \cancel{-}2 \ln 10$$

$\therefore T = \dfrac{3476.6}{2 \ln 10}$

$\therefore T = 756.93\ K$

$\therefore$ The required temperature is 756.93 K

4) An impurity of 0.01 ppm is added to Si. The semiconductor has a resistivity 0.25 ohm/m at 300 K. Calculate the hole concenteration and its mobility. Also, comment on the result. Atomic weight of Si = 28.1, density of Si = $2.4 \times 10^3\ kg/m^3$.

<u>Solution</u> $\rho = 0.25$ ohm/m , $M = 28.1$, density $= 2.4 \times 10^3\ kg/m^3$

$\therefore$ Number of Si atoms $/m^3 = 6.022 \times 10^{23} \times \dfrac{\text{density}}{M}$

$= 6.022 \times 10^{23} \times \dfrac{2.4 \times 10^3}{28.1 \times 10^{-3}}$

$= 0.51433 \times 10^{29}$

$= 5.143 \times 10^{28}$ atoms $/m^3$

Now,

Impurity of 0.01 ppm implies that is 1 impure atom for every 10^8 atoms of Si

$\therefore$ Number of impure atoms $/m^3 = \frac{5.143 \times 10^{28}}{10^8} = 5.143 \times 10^{20}$ atoms$/m^3$

Now,

each impurity introduces one hole.

$\therefore$ number of holes $/m^3 = \boxed{n_h = 5.143 \times 10^{20} \text{ holes}/m^3}$

$\therefore$ mobility of holes $= \mu_p = \frac{1}{\rho n_h e}$

$$\therefore \mu_p = \frac{1}{0.25 \times 5.143 \times 10^{20} \times 1.6 \times 10^{-19}}$$

$$\therefore \mu_p = 0.0486 \ m^2/V\text{-}s$$

$\therefore$ Concentration of holes is 5.143×10^{20} holes$/m^3$ and Mobility of holes is $0.0486 \ m^2/V\text{-}s$

Comment $\rightarrow$ On addition of trivalent impurity, the mobility of Si remains the same but the concentration of holes increases and it behaves as a p-type semiconductor.

5) The Hall coefficient of certain silicon is found to be $-7.35 \times 10^{-5}\ m^3/C$ from 100 to 400 K. Determine the nature of the semiconductor. If the conductivity was found to be $200/\Omega m$, calculate the density and mobility of the charge carrier.

Solution: Given: $R_H = -7.35 \times 10^{-5}\ m^3/C$, $\sigma = 200/\Omega m$

The negative sign of the Hall coefficient indicates that the nature of the semi-conductor is n-type.

$\therefore$ density of electrons $= n_e = \dfrac{1}{R_H e} = \dfrac{1}{7.35 \times 10^{-5} \times 1.6 \times 10^{-19}}$

$\therefore n_e = 8.5034 \times 10^{22}$ electrons$/m^3$

Now,

mobility of electrons $= \mu_e = \dfrac{\sigma}{n_e e} = \dfrac{200}{8.5034 \times 10^{22} \times 1.6 \times 10^{-19}}$

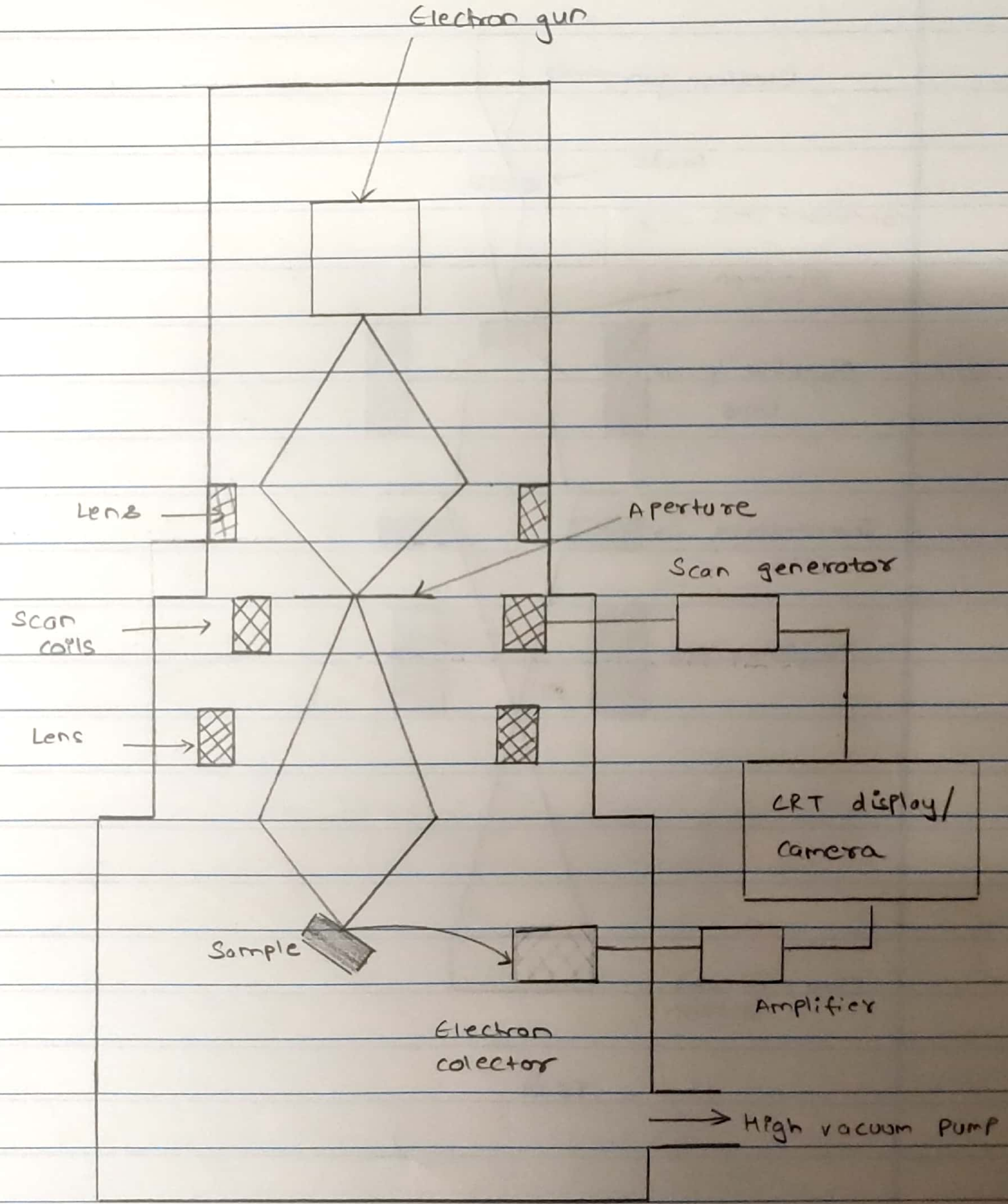
$\therefore \mu_e = 14.700 \times 10^{-3}\ m^2/V\text{-}s$

$\therefore$ Nature : n-type semiconductor.

density of charge carriers $= 8.5034 \times 10^{22}$ electrons$/m^3$

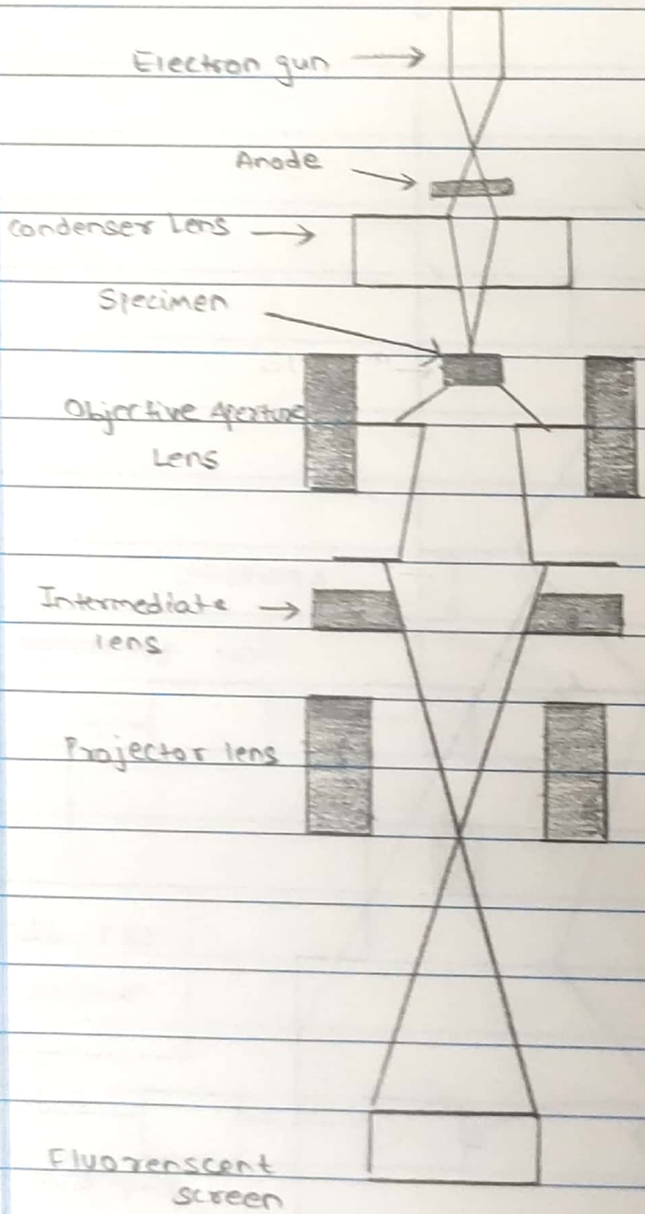
Mobility of charge carriers $= 14.700 \times 10^{-3}\ m^2/V\text{-}s$

6) Draw a neat labelled diagram of SEM



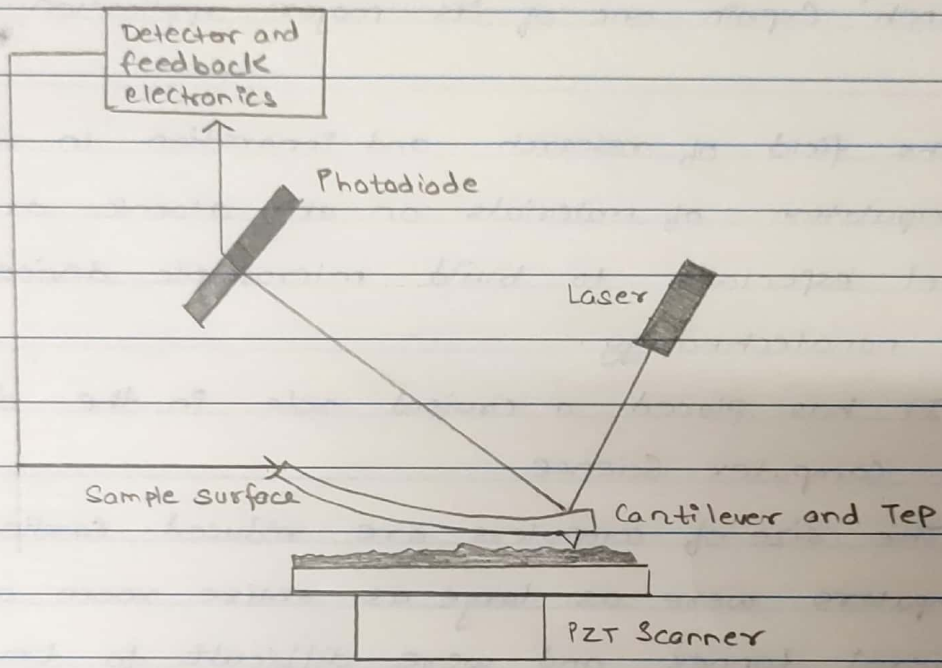
SEM

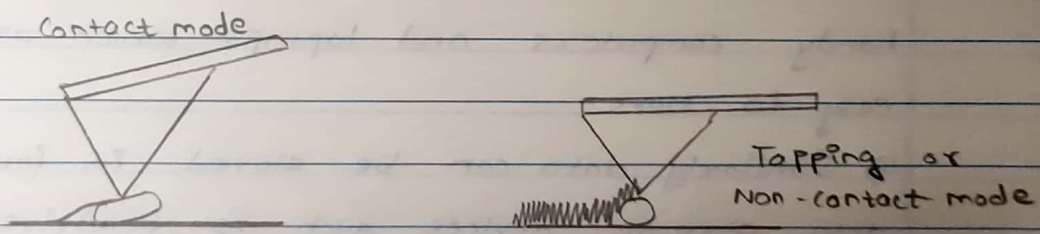
7) Draw a neat labelled diagram of TEM.



TEM

8) Draw a neat labelled diagram of AFM





AFM

9) How is nanotechnology connected to your core engineering branch? Explain one of its major application in your field.

Ans i) The field of research and innovation in which the manipulation of materials on an atomic or molecular level especially to build microscopic devices is known as nanotechnology.

2) It has placed a cruisal role in the development of Computer Science.

3) The size of computers are reduced. Earlier the computers were as large as entire room and weighed several tonnes and were difficult to travel with or to move. But now we can use small and handy computers and laptops which are portable and easy to move.

4) Similarly data can be stored in few inches small data storage devices such as pendrives, memory cards, hard drives, etc.

5) Data transmission is revolutionized by nanotechnology, computer processes large amount of data in just few seconds.

6) All this is possible today because of the development of the nanoscience and nanotechnology.

10) Describe in brief the future scope of Nanotechnology related to your core engineering branch.

Ans. 1) To keep pace with the constant miniaturisation of computer chips, transistor size must be reduced.
2) Unfortunately, size of silicon cannot be reduced below 5nm.
3) So, carbonnanotubes are being developed to overcome the above limitations.
4) Further, data managements developments and advancement are also taking place.
5) Nanotechnology could play a part in the evolution of integrated circuits (IC's) capable of increasing storage capacity and processing power.
6) Nanotechnology is a way of shaping a bright and an advanced future in the field of computer engineering where computing will be way more efficient than it is today.