Conclusion

The detailed investigation of phase change from amorphous to crystalline transitional effects on structural, electrical and optical properties during the early stages of thin film growth and recrystallization of metal selenium of MₓSe₁₋ₓ (M=In, Ga, Sb) (x=0.4, 0.5, 0.6, 0.7) alloys with change in metal concentration have been investigated. Glassy alloys were prepared by the melt quenching technique. Thin films of these alloys have been prepared by thermal evaporation technique. X-ray diffraction measurements were done using PANalytical X'Pert PRO diffractometer in 2θ range 10° to 60°. The normal incidence transmission spectra of MSe thin films have been measured by Monochromator spectrograph [SOLAR TII, MS 2004], recorded at different temperatures, varying from 100-400K in steps of 10±2K in the wavelength range 400-1100 nm. The electrical conductivity (dark and photoconductivity) measurements have been done in vacuum (2x10⁻³ mbar) at different temperatures. Time of flight (TOF) measurements have been done in these samples. Diodes and solar cells have been fabricated using chalcogenide semiconductors InₓSe₁₋ₓ (x = 0.4, 0.5, 0.6), GaₓSe₁₋ₓ (x = 0.4, 0.5, 0.6, 0.7) and SbₓSe₁₋ₓ (x = 0.4, 0.5, 0.6, 0.7) and their characteristics have also been measured.

We have also got amorphous-to-crystalline phase transition in thin films as we increase the metal concentration to selenium, after a certain value. In case of InₓSe₁₋ₓ (at x=0.6) it will become crystalline, and this has also been confirmed by XRD. No such phase transformation occurs in the case of GaₓSe₁₋ₓ and SbₓSe₁₋ₓ when we increase the concentration from 0.4< x < 0.7. Phase transition have been achieved by annealing of these thin films at high temperatures. We have annealed a-GaₓSe₃ and a-SbₓSe₃ at 453K for 30 min under vacuum due to which these will become crystalline. Crystalline-to-crystalline phase transition for c-In₃Se₂ thin films has been done by annealing at high temperature (T=393 K) for 30 min under vacuum.

The temperature dependence of the optical energy gaps in the range of temperature 100-400K, were fitted with four equations beginning with linear, non linear, Varshni and Bose Einstein equations. The results have been best fitted with the Varshni equation. We have found that the energy gap decreases with the increase in metal percentage in these thin films and an increase in energy gap with the decrease of temperature. When metal concentration increases from (40 at. %) to (60 at. %) in
Se content, this lead to decrease in the optical band gap ($E_g$), refractive index ($n$), energy of the effective dispersion oscillator ($E_0$) and oscillator strength ($E_d$). Change in the optical energy gap with metal concentration is due to change in the bonded atoms network linked with each other. When we increase the concentration in $M_xSe_{1-x}$, Se-Se and Se-M bonds change to Se-M and M-M islands.

DC conductivity measurements of $M_xSe_{1-x}$ ($M=$In, Ga, Sb) ($x=0.4$, $0.5$, $0.6$, $0.7$) thin films have been measured by computer controlled Keithley 6517A electrometer. The current (A) is recorded at different temperatures varying from (100 to 400K) in steps of 10K. We have found three activation energies for $In_xSe_{1-x}$ and two activation energies for $Ga_xSe_{1-x}$ and $Sb_xSe_{1-x}$. Electrical parameters like activation energy ($E_a$), carrier concentration ($n$ or $p$), conductivity ($\sigma$) and Hall mobility ($\mu$), density of localized states at the Fermi level ($N(E_f)$), hopping distance ($R$) and hopping energy ($W$) for MSe thin films have been calculated and all these parameters change with change in metal concentration. The incorporation of metal atoms in Se matrix leads to an increase in the electrical conductivity and carrier concentration.

We have measured the photoconductivity of all the thin films alloys of $M_xSe_{1-x}$ ($M=$In, Ga, Sb and $x=0.4$, $0.5$ and $0.6$). We observed that all thin films have photoconductivity action except for $x=0.6$. The photoconductivity is higher for thin films in which percentage of Se is 40% than 50%. The thin film was illuminated using the second harmonic double frequency KTP crystal (532 nm) of a Nd:YAG laser pulse 1064 nm with 10 ns pulse durations. All samples are p-type as is investigated by Hall measurements. We have calculated signal data parameters like rise time ($t_r$), transit time ($t_t$), life time ($t_l$) and fall time ($t_f$). We have measured mobility from TOF measurements for all these samples. It implies that when we increase the metal concentration, the transit time increases and leads to decrease in mobility for $In_xSe_{1-x}$ and $Ga_xSe_{1-x}$ but increase in mobility in the case of $Sb_xSe_{1-x}$ thin films.

We have made few diodes and solar cells of the samples $M_xSe_{1-x}$ ($x=0.4$, $0.5$, $0.6$, $0.7$ where $M=$In, Ga, Sb). Current –Voltage parameters like built-in voltage ($V_b$), forward resistance ($R_f$), ideal factor ($n$), saturation current ($I_0$), breakdown current ($I_{bd}$) and breakdown voltage ($V_{bd}$) of p-n junction diodes have been calculated. The I-V characteristics of the solar cell, open-circuit voltage ($V_{OC}$), short-circuit current ($I_{SC}$), maximum power ($P_{max}$), fill factor (FF) and efficiency ($\eta$) have also been investigated.