Chapter 5

Summary and Conclusion

Doped and undoped CdO and Cd$_2$SnO$_4$ film were deposited using spray pyrolysis technique and their structural, electrical and optical properties were studied. Spray pyrolysis technique is cost effective and easy to add doping in the film. There are only limited publications available in the literature regarding doped CdO and Cd$_2$SnO$_4$ thin film preparation by spray pyrolysis technique. Therefore, in this thesis work spray pyrolysis technique was used to prepare these films. To understand the effect of irradiation on CdO and Cd$_2$SnO$_4$ films, the films were subjected to SHI irradiation using 120 MeV Ag$^{9+}$ ions for different fluence in the range of $10^{12}$–$10^{13}$ ions/cm$^2$. The results obtained in this work helps to understand the effect of doping and irradiation on CdO and Cd$_2$SnO$_4$ thin films. The (CdO)$_{1-x}$(PbO)$_x$ films were prepared for different $x$ values. The important results discussed in Chapters 2, 3 and 4 are summarized in this chapter.

Doped CdO and mixed (CdO)$_{1-x}$(PbO)$_x$ thin films

1. For Al doped CdO films, a minimum resistivity of $3.4 \times 10^{-4}$ Ω cm with a maximum carrier concentration of $4.12 \times 10^{20}$ cm$^{-1}$ was obtained when the film is doped with 3 wt.% Al. Optical transmittance in the visible region increases (77% for 4wt%) after Al doping. Thus Al doping in CdO films effectively increases the carrier concentration and reduces its resistivity with a reduction in the mobility.

2. Optical band gap of undoped CdO film is 2.36 eV and Indium doping increases the band gap value and reaches a maximum value of 2.72 eV for 6 wt.% due to the Burstein-Moss shift. A minimum resistivity of $4.843 \times 10^{-4}$ Ω cm with maximum carrier concentration of $3.73 \times 10^{20}$ cm$^{-3}$ is achieved at the optimum In-doping concentration of 6wt%. The minimum resistivity with high transmittance of 78% (850 nm) for indium doping concentration of 6 wt.% show that In-doped CdO film can be used as transparent electrode in optoelectronic devices.
3. For mixed thin films of (CdO)$_{1-x}$(PbO)$_{x}$ films, the average visible transmittance in the wavelength ranging 500 – 850 nm varies from 40 to 68 %. The direct optical band gap of the (CdO)$_{1-x}$(PbO)$_{x}$ mixed films varies from 1.96 to 2.69 eV.

**Cd$_2$SnO$_4$ thin films**

4. Cadmium stannate films were deposited on quartz and corning glass. Among them Corning glass results with relatively better film quality and at relatively less temperature. The films were annealed in vacuum to improve the electrical and structural properties. Annealing the cadmium stannate film in vacuum increases the carrier concentration from $7.92 \times 10^{19}$ cm$^{-3}$ to $2.51 \times 10^{20}$ cm$^{-3}$ and decreases the resistivity from $2.66 \times 10^{-3}$ to $9.24 \times 10^{-4}$ Ω cm. Thus, the result shows that the conductivity of the spray deposited cadmium stannate films can be improved by vacuum annealing. The minimum resistivity achieved in the present study is found to be the lowest among the reported values for these films prepared by spray pyrolysis method.

5. A minimum resistivity of $1.76 \times 10^{-3}$ Ω cm and maximum carrier concentration of $9.812 \times 10^{19}$ cm$^{-3}$ is obtained for 1 wt.% In-doped Cd$_2$SnO$_4$ films. The obtained result shows that lower indium doping concentration in the precursor solution has a better doping effect in Cd$_2$SnO$_4$ films.

**Results obtained for SHI irradiated CdO and Cd$_2$SnO$_4$ thin films**

6. SHI irradiation has strong influence on the structural and electrical properties of the films. The CdO films are amorphized when irradiated with the Ag$^{9+}$ ions for the fluence $1 \times 10^{13}$ ions cm$^{-2}$. The decrease in carrier concentration and also increase in resistivity observed by the ion irradiated films are due to the grain boundary scattering. Results show that the swift heavy ion irradiation decreases the surface roughness and carrier concentration and increases the resistivity of the films.
Similarly, Cd$_2$SnO$_4$ films are amorphized after irradiation with the fluence of $1 \times 10^{13}$ ions cm$^{-2}$. A systematic reduction in the optical band gap is observed with increasing ion fluence, which is associated with Ag$^{9+}$ ion induced defects leading to the production of localized states near the band edges and in the energy gap of Cd$_2$SnO$_4$. The resistivity of the film increases with increasing ion fluences. Further, the mobility value decreases with increase in ion fluence and the carrier concentration value slightly increase for higher fluence ($1 \times 10^{13}$ ions/cm$^3$).