CHAPTER–V

SUMMARY AND CONCLUSION

The present work was focused on the preparation and characterization of ZnO, Cu_2O, SnO_2 and Co_3O_4 thin films by chemical bath deposition method. The suitability of these thin films for solar cell application was studied in detail and their summarized results are given below;

ZnO THIN FILM

- ZnO thin film was successfully deposited in glass substrate by chemical bath method using 0.1M zinc acetate, 0.05M EDTA and aqueous NH_3 at the pH of 10.5 and the bath temperature of 80 $^{\circ}$C. The deposition duration 35 min. The Zinc oxide was subjected to calcination at 300 °C for 2 hours and they were characterized by the following studies.
- The effect of various experimental variables such as metal ion concentration, pH, temperature and deposition time on ZnO thin film formation was studied and optimized to get quality thin film
- Film thickness of bath time duration and thickness results were shown as thickness verses temperature graph.
- The phase purity of ZnO thin film was confirmed by XRD studies
- The crystallite size of ZnO thin film was calculated by using Scherrer's formula.
- The morphology and the average particle size of the prepared ZnO thin films were observed by using scanning electron microscope. It clearly showed that the prepared films were exhibited uniform with pinhole free surface. The average particle size of the prepared ZnO thin film was 37.4 nm.

- FTIR study was carried out to know the presence of vibration bands of the metal-oxygen band and other stretching vibrations. The characteristic vibrational peaks were confirmed the formation of ZnO thin films.
- From the hot probe method, it was found that the nature of prepared ZnO thin film is n-type semi-conductor.
- The optical properties were studied using UV-Visible Spectroscopy. From the spectrum it clearly observable that ZnO thin film exhibits the transmittance of 90% with an absorption edge at 370 nm.
- The electrical resistivity of ZnO thin films were predicted by four probe method and it was $3.38 \times 10^{6}\ \Omega\ cm^{-1}$.
- The direct band gap energy was calculated from the absorption spectrum and it was 3.22 eV.

Cu_2O THIN FILM

- Cu_2O thin film was deposited by using 0.02M copper sulphate, 0.02M potassium carbonate and 0.1M potassium sulphite by the Chemical bath deposition method at 90°C and the pH of the bath was 6.7.
- The zinc oxide was subjected to calcination at 350 °C for 2 hours and they were characterized by the following studies;
- The effect of various experimental variables such as metal ion concentration, pH, temperature and deposition time on Cu_2O thin film formation was studied and optimized to get quality thin film.
- Film thickness of Cu_2O was calculated, bath time duration and thickness results were shown as Thickness verses temperature graph.
- The phase purity of Cu_2O thin film was confirmed by XRD studies.

- The crystallite size was calculated using Scherrer's formula.
- The morphology and the average particle size of the prepared Cu_2O thin film were observed by using scanning electron microscope. It clearly showed that the prepared films were exhibited uniform with pinhole free surface. The average particle size of the prepared Cu_2O thin film was 24.9 nm.
- FTIR study was carried out to know the presence of vibration bands of the metal-oxygen band and other stretching vibrations. The characteristic vibrational peaks were confirmed the formation of Cu_2O films.
- From the hot probe method, it was found that the nature of prepared Cu_2O thin film is p-type semi-conductor.
- The optical properties were studied using UV-Visible spectroscopy. From the spectrum, it clearly observed that Cu_2O thin film exhibits the transmittance of 81% with an absorption edge at 400 nm.
- The electrical resistivity of Cu_2O thin film was predicted by four probe method and it was 4.46×10^7 Ω cm^{-1}.
- The direct band gap energy was calculated from the absorption spectrum and it is 2.14 eV.

SnO_2 THIN FILM

- SnO_2 thin film was prepared by using 0.01M stannic chloride, few drops of isopropyl alcohol and aqueous ammonia solution.
- The effect of bath temperature, substrate conduct time, solution pH and metal ion concentration on SnO_2 thin film formation had been observed to get quality thin film.

- Film Thickness was calculated, deposition time duration and thickness results were shown as Thickness verses temperature graph.
- The phase purity of SnO_2 thin films were confirmed by XRD studies.
- The crystallite size was calculated using Scherrer's formula
- The morphology and the average particle size of the prepared SnO_2 thin film were observed by using scanning electron microscope. It clearly showed that the prepared film were exhibited uniform with pinhole free surface. The average particle size of the prepared SnO_2 thin film was 11.65 nm.
- FTIR study was carried out to know the presence of vibration bands of the metal-oxygen band and other stretching vibrations. The characteristic vibrational peaks were confirmed the formation of SnO_2 film.
- From the hot probe method, it was found that the nature of prepared SnO_2 thin film is p-type semi-conductor.
- The optical properties were studied using UV-Visible spectroscopy. From the spectrum it clearly observable that SnO_2 thin film exhibits the transmittance of 78% with an absorption edge at 500 nm.
- The electrical resistivity of SnO_2 thin films were predicted by four probe method and it was 2×10^{-2} Ω cm^{-1}.
- The direct band gap energy was calculated from absorption spectrum and it is 3.42 eV

Co_3O_4 THIN FILM

- Co_3O_4 thin film was deposited in glass substrate by chemical bath method using, 0.1 M cobalt acetate, 0.05 M EDTA and 2 ml of 30% H_2O_2 and aqueous ammonia at 60 °C and the pH of the bath was 6.8. The cobalt oxide was

subjected to calcination at 400 °C for 2 hours and they were characterized by the following studies.

- The effects of various experimental variables such as metal ion concentration, pH, temperature and deposition time on Co_3O_4 thin film formation was studied and optimized to get quality thin film.
- Film thickness of Co_3O_4 was calculated, deposition time duration and thickness results were shown as Thickness verses temperature graph.
- The phase purity of Co_3O_4 thin film was confirmed by XRD studies.
- The crystallite size and was calculated using Scherrer's formula.
- The morphology and the average particle size of the prepared Co_3O_4 film were observed by using scanning electron microscope. It clearly showed that the prepared thin films were exhibited uniform with pinhole free surface. The average particle size of the prepared Co_3O_4 thin film was 18.15 nm.
- FTIR study was carried out to know the presence of vibration bands of the metal-oxygen band and other stretching vibrations. The characteristic vibrational peaks were promising the formation of Co_3O_4 thin film.
- From the hot probe method, it was found that the nature of prepared Co_3O_4 thin film is p-type semi-conductor.
- The optical properties were studied using UV-visible spectroscopy. From the spectrum it clearly observed that Co_3O_4 thin film exhibits the transmittance of 78% with an absorption edge at 360 nm.
- The electrical resistivity of Co_3O_4 thin film was predicted by four probe method and it was $3.1 \times 10^3\ \Omega\ cm^{-1}$.
- The direct band gap energy was calculated from the absorption spectrum and it was 2.07 eV.

A comparative account of various metal oxide thin film parameters is given in Table 5.1. From the above studies, it could be concluded that it is possible to obtain device quality ZnO, Cu_2O, SnO_2 and Co_3O_4 thin films by chemical bath deposition method under optimized conditions.

Table 5.1 A COMPARATIVE ACCOUNT OF METAL OXIDE THIN FILMS PARAMETERS

Thin films/ properties	**ZnO**	**Cu_2O**	**SnO_2**	**Co_3O_4**
Chemical bath Composition	0.01M $Zn(CH_3COO)_2$ 0.05 M EDTA Aqueous NH_3	0.02 M $CuSO_4$ 0.02 M Na_2CO_3 0.01 M Na_2SO_3	0.01M $SnCl_4$ Few drops of Isopropylalcohol Aqueous NH_3	0.01M $Co(CH_3COO)_2$ 0.05 M EDTA Aqueous NH_3
pH	10.5	6.7	6.5	6.8
Temperature	80 °C	90 °C	70 °C	60 °C
Contact time	35 min	30 min	35 min	25 min
Film thickness (μm)	0.54	0.42	0.26	0.38
Unit Cell parameters	Hexagonal Wutzite a =3.312 A° c =5.22 A°	Cubic a =4.271 A°	Tetragonal Rutile a =4.52 A° c =3.063 A°	Cubic Spinel a =8.055 A°
SEM Grain size (nm)	200 - 300	100 - 150	100 -200	100
Crystallite size	37.4 nm	24.9 nm	11.6 nm	18.2 nm
Nature of the thin film	n type	p type	n type	p type
Electrical Resistivity (Ω/cm)	3.38×10^{6}	4.46×10^{7}	2.0×10^{-2}	3.1×10^{3}
Optical studies	Transmittance 90 % Absorption edge at 370 nm	Transmittance 81 % Absorption edge at 400 nm	Transmittance 78 % Absorption edge at 500 nm	Transmittance 78 % Absorption edge at 360 nm
Activation energy, Ea at 30 °C	0.061 eV	0.08 eV	0.07 eV	0.21 eV
Optical energy gap	3.22 eV	2.14 eV	3.42 eV	2.07 eV
Annealing temperature & Time	300 °C 2 hours	350 °C 2 hours	400 °C 2 hours	400 °C 2 hours