CHAPTER 9

Conclusions

In this research, transparent conducting films from In_2O_3 and ZnO groups were fabricated by ultrasonic spray pyrolysis for solar cell applications. The contribution of this thesis has been focused on the optical and electrical properties of these films. The project results can be divided in to five categories.

In the first part, the effects of Sn doping on In_2O_3 films were investigated. The starting solution of the prepared films was 0.025 M of $InCl_3$with Sn doping in the range of 0-9 at.%. All films showed cubic structure of In_2O_3 while the morphology of undoped In_2O_3 films was irregular shape and changed to cubical shape with additional Sn concentration to 5 at.%. Moreover, all films showed high transmittance more than 80% and the band gap of these films decreased with increasing Sn concentration. The conductivity of films was improved by Sn doping. However, the minimum resistivity was presented in 5 at.% Sn doping condition. This behavior may be due to the solubility limited of Sn^{4+} into In_2O_3 lattice.

The second part, the ITO/metal/ITO multilayer films were fabricated for improving the electrical properties of ITO films. The In_2O_3 film doped with 5 at.% Sn doping was chosen as ITO layer and Au metal was employed for intermediated layer of multilayer films via the sputtering technique with thickness in the range of 0-20 nm. Both single layer and multilayer films were identified as cubic structure of In_2O_3. While, the average grain size and transmittance of films decreased with increasing Au intermediate layer thickness. The addition of Au layer enhanced the conductivity but reduced the transmittance of multilayer films. The figure of merit of film was used to indicate the best condition of films in this part. The ITO multilayer with 10 nm of Au layer had the maximum figure of merit or it has condition was the best performance of multilayer film among other samples.

The effect Mg doping on band gap of the ZnO films has been investigated in third part. The starting solution of the prepared films was 0.2 M of $Zn(CH_3OO)_2 \cdot 2H_2O$ with Mg doping in the range of 0-9 at.% . All films showed hexagonal wurtize structure of ZnO while the morphology of all undoped ZnO films were irregular shape and changed to hexagonal shape with addition Mg concentration. In addition, all films showed highest transmittance of more than 80%. A shift of absorption edge in transmittance spectra of the prepared films occurred with addition Mg doping. These shift behavior has significant effect on the increase of band gap in ZnO films. The 9 at.% Mg doped ZnO film deposited on glass substrate heated at 400°C showed the highest band gap of 3.364 eV. While Mg^{2+} ions have not changed conductivity in ZnO films due to the partial substitution of Zn^{2+} ion by the same valence Mg^{2+} ion.

In the fourth part, Mg doped ZnO film was synthesized from lower concentration of 0.02 M of $Zn(CH_3OO)_2 \cdot 2H_2O$ with Mg doping in the range of 0-20 at.%. All films showed hexagonal wurtizte structure of ZnO and the morphology of all films are spherical shape. In addition, all films showed transmittance of more than 85%. A shift of absorption edge in transmittance spectra of the prepared films occurred with addition Mg doping. The maximum of wide band gap was 3.550 eV at 20 at.% Mg doping. While Mg^{2+} ions have not changed conductivity in ZnO films due to the partial substitution of Zn^{2+} ion by the same valence Mg^{2+} ion.

In final part, effect of In on electrical properties of Mg doped ZnO films were investigated. The starting solution of the prepared films were fixed 0.02 M of $Zn(CH_3OO)_2 \cdot 2H_2O$ and 20 at.% Mg with In doping in the range of 0-9 at.%. All films showed hexagonal wurtize structure of ZnO film the morphology of all films are spherical shape. Moreover, all films showed high transmittance more than 80% and the band gap of these films decreased with addition of In doping. While the electrical properties of Mg doped ZnO films improved by In doping. However, the minimum resistivity was presented in 4 at.% In doping. This behavior could be resulted from the solubility limits of In^{3+} into ZnO lattice. The wide band gap of these conditions could be achieved at 3.403 eV, this range was suitable for application in solar cell.