CHAPTER 7

GENERAL CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

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7.1 General Conclusion

The aim of the thesis as defined in sec. 1.8 of **chapter 1** was

(i) to prepare PbS nanocrystalline films under different conditions,

(ii) to study their properties and

(iii) to suggest possible applications of the appropriate films in optoelectronics.

That is, the thesis is devoted to prepare those films which may find application(s) in optoelectronics.

For preparing the films we used the chemical bath deposition (CBD) method. By changing various deposition parameters, the properties of the films have been studied. The outcome of these studies have been discussed in chapters 3, 4 and 5.

In **chapter 3**, we discussed how the deposition temperature, concentrations of lead acetate (used as source of lead ions) and pH of the bath affected the structural, optical and electrical properties of the films.

(i) It was observed that when films were prepared from 0.4M lead acetate (complexed by 1M TEA) and 1M thiourea at pH=12, no crystalline PbS phase was found below 50^{o}C. Then the crystallite size increased and direct band gap decreased with the increase of deposition temperatures. The maximum crystallite size obtained was 42.67 nm and the least band gap obtained was 1.66 eV. The Urbach energy increased marginally with the increase of deposition temperature. Although the electrical conductivity had been observed to increase with the increase of deposition temperature, its value was very small, the highest being 3.89×10^{-6} $(\Omega cm)^{-1}$.

(ii)When lead acetate solutions of a series of concentrations ranging from 0.5M - 1.2M in step of 0.1M (complexed by 1M TEA) were allowed to react with 1M thiourea at pH=11 and deposition temperature 60ºC, it was found that the best film (considering stoichiometry, crystallinity, optical absorption property and conductivity together) had been developed when the concentration of lead acetate was 0.5M. This film had got the crystallite size of 37.43 nm, direct band gap of 1.4 eV and conductivity of 1.88 x 10^{-3} $(\Omega cm)^{-1}$. The Urbach energy of this film was the least among the films prepared at different concentrations of lead acetate.

(iii)Again it was observed that when PbS nanocrystalline films were prepared with 0.5M lead acetate complexed by 1M TEA and 1M thiourea at 30ºC and at four different pH (8.22, 9.11, 10.7, 12.46), the highest crystallite size (42.37 nm), absorbance and conductivity [5.08 x 10^{-3} $(\Omega cm)^{-1}$] were obtained at pH=12.46. The direct band gap of the film deposited at this value of pH was 1.62 eV. Both the direct band gap and Urbach energy decreased while conductivity increased with the increase of pH.

In **chapter 4**, we discussed the effect of Zn and Fe impurities on the structural and optical properties of PbS nanocrystalline films. We observed that these impurities deteriorate crystallinity of the films, reduced crystallite size, caused lattice expansion, increased transparency and Urbach energy of the films. The undoped film had direct band gap of 1.55 eV. These values for the Zn and Fe doped films were 1.3 and 2.2 eV respectively.

In **chapter 5**, we discussed the effect of triethanolamine (TEA) on the structural, optical and electrical properties of PbS nanocrystalline films prepared by CBD method. TEA is commonly used as complexing agent in CBD process. In the works discussed in chapters 3 and 4, we used TEA to complex the lead ion sources. The most striking conclusion of chapter 5 is that presence of TEA inhibits the current conduction process in the films. Therefore, the conductivities of the films prepared in the bath containing TEA were found very low, the maximum being, 2.3 x 10^{-2} $(\Omega cm)^{-1}$, thereby making these films unsuitable for applications in optoelectronics. On the other hand, the conductivities of the films prepared in the bath containing no TEA were obtained 0.20 $(\Omega cm)^{-1}$ and 0.23 $(\Omega cm)^{-1}$ depending upon whether the lead ion source is lead nitrate or lead acetate. These two films prepared without using any inhibitor like TEA also show very good crystallinity and optical absorption properties in both visible and NIR regions. In **chapter 6**, we discussed the possibility of using these two films as absorber in solar cell.

The facts we acknowledge after all these studies are-

(i) Properties of the films prepared by the chemical bath deposition method are very sensitive to preparative parameters;

(ii) CBD method easily yields nanocrystalline films;

(iii) PbS is a potential semiconductor as far as 'tailoring of band gap' is concerned. In the works described in this thesis, the band gap of PbS could be tuned from 0.8 eV to 2.7 eV where its bulk band gap is 0.41 eV.

7.2 Limitations of the thesis

We believe that the objectives of the thesis have only been partially fulfilled because the following quantities could not be determined-

(i) The type of conductivities of the films suggested as absorbers in solar cell,

(ii) Spectral response of these films

(iii) Conductivities of the doped films,

(iv) Type of conductivities of the doped films.

7.3 Scope for future research

As continuation of the research works discussed in the thesis, following studies can be carried out-

(i) ***Fabrication of PbS thin films without using any inhibitor like TEA, under different preparative conditions and to study their optoelectronic properties***. In this case, lower molarities (~ a few mmol) of the lead and sulfur sources can be considered such that controlled reaction rate can be obtained even without using additional complexing agents like TEA.

(ii) ***Formation of heterojunction of PbS (prepared without using TEA) with other appropriate materials and to determine conversion efficiency.***

(iii) ***Doping of the PbS thin films by different elements in order to examine its suitability as antireflection coating.***