CHAPTER 6

POSSIBLE APPLICATIONS OF PREPARED FILMS IN OPTOELECTRONICS: SOME SUGGESTIONS

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Possible Applications of Prepared Films in Optoelectronics: Some Suggestions

Since most of the films discussed in this thesis are highly absorbing, these can be used as solar cell absorbers.

6.1 Principle of solar cell [190]

The solar cell is a p-n junction with the n-region a narrow and heavily doped wide band gap semiconductor. The n-side is called window layer as the illumination is allowed through it. On the other hand, the p-side is thicker and composed of a narrow band gap semiconductor. It is called absorber layer, as it absorbs the radiation transmitted by the window layer to form hole-electron pairs. The depletion region primarily extends into the p-side. Most of the photons are absorbed within the depletion region and the neutral p-side wherein these generate electron-hole pairs (EHPs). The built-in electric field in the depletion region drifts the electrons towards the neutral n-region and holes towards the neutral p-region, developing an open circuit voltage with the p-side at higher potential. On shorting the p-side and the n-side externally, photocurrent can be obtained.

The minority carriers generated within a carrier diffusion length to the depletion region can readily diffuse to the depletion region and get separated, but those photogenerated beyond these diffusion lengths are lost by recombination.

6.2 Prepared Films Applicable as Absorber in Solar Cell

An efficient absorber needs to possess high absorbance and good carrier transfer quality. Low absorption puts a limit to the efficiency of solar cells. For example, Hernández-Borja et.al [123] prepared a CdS/PbS solar cell with efficiency 1.63% and Saikia et.al [154] fabricated another CdS/PbS solar cell with efficiency of 1.668%. Low values of absorbance of the PbS absorber layer were responsible for such low efficiency. Specially the absorber needs to have good absorption in the NIR region as the NIR photons constitute 30% of the full solar spectrum in AM1.5G solar spectra (1000 W/m^2) [100]. The conventional solar absorbers like silicon are unable to absorb this sizable part of solar spectrum. For efficient photon absorption, good oriented crystallinity is required. Again for efficient charge transfer, the absorber should have high conductivity. Considering these requirements and after analyzing structural, optical and electrical properties of the prepared PbS films, we suggest two films **LN0MT** (Film prepared in lead nitrate bath without using triethanolamine) and **LA0MT** (Film prepared in lead acetate bath without using triethanolamine) having the potential of being good absorber in solar cells. The properties of these films were discussed in detail in chapter 5, We reproduce the preparation method, XRD diagram, optical absorption spectra and current-voltage characteristics below.

(i) LN0MT (Film prepared in lead nitrate bath without using triethanolamine)

This film had been prepared in a bath containing 5 ml of 0.5M $Pb(NO_3)_2$ solution the pH of which had been adjusted at 12 by adding 2M NaOH dropwise. Initially, on addition of NaOH,we noticed white precipitate which redissolved on further addition of NaOH. After inserting chemically and ultrasonically cleaned glass substrates vertically, 6 ml of 1 M $SC(NH_2)_2$ solutions were added to it and the total volume was made 100 ml by adding deionized water. After three hours the substrates were taken out of the bath. Uniform grayish black films of thickness 4 μm with good adhesion and coverage on the substrates were obtained.

The XRD pattern of the film (Fig. 6.1) has been compared with the ICDD card no. 78-1900. All the peaks correspond to the fcc structured PbS phase. All standard

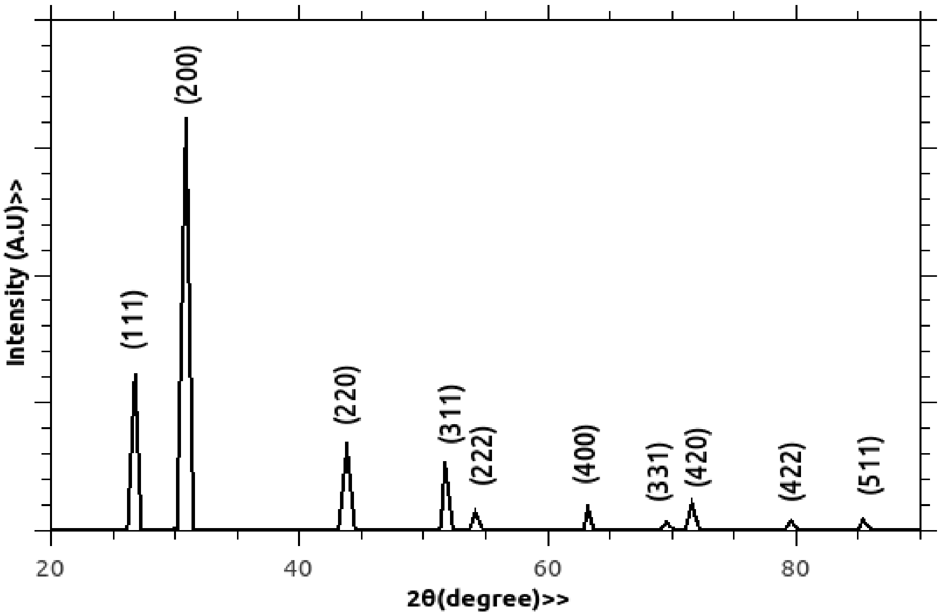

Fig. 6.1: XRD pattern of LN0MT

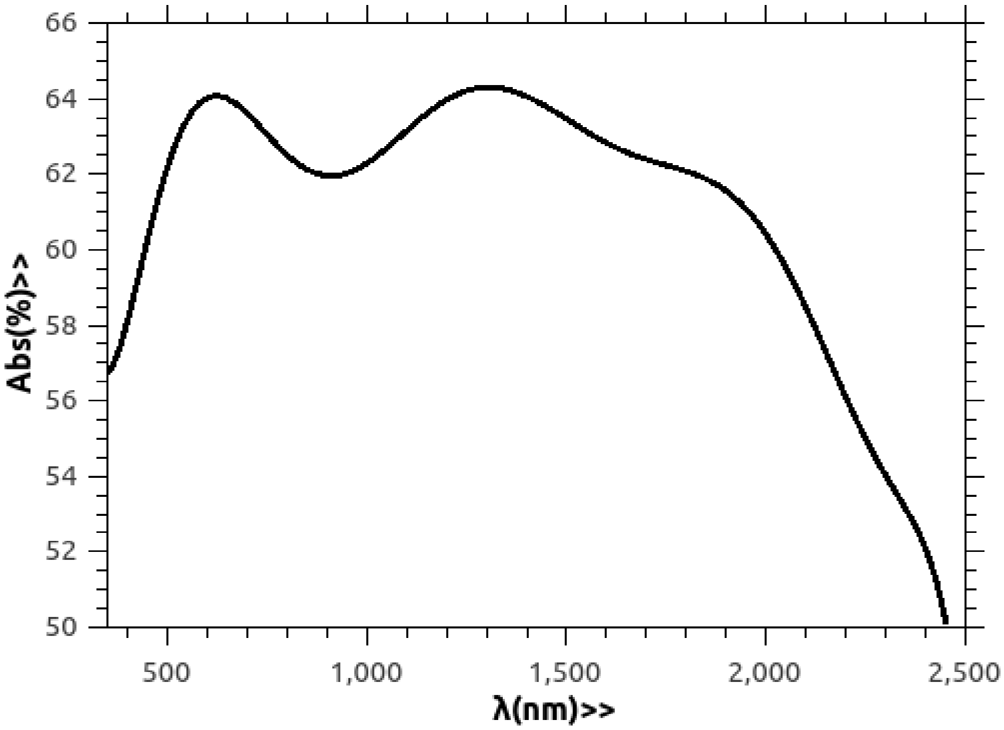

Fig. 6.2: Optical Absorbance of LN0MT at various wavelengths

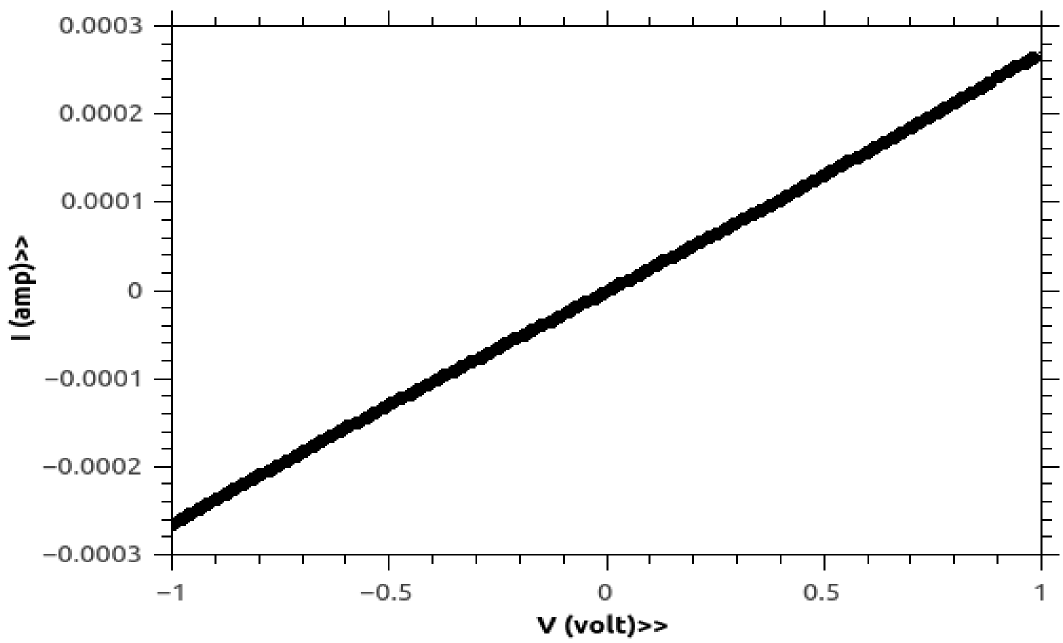

Fig. 6.3: Current- Voltage (I-V) Characteristics of LN0MT film

peaks are evident in the XRD pattern. The lattice constant measured is 5.931 Å which is nearly equal to the standard value. The average crystallite size in [111] and [200] directions comes out as 37.49 nm. The film is highly (200) oriented. The textured co-efficient is 1.87 along (200) plane while it is less than unity along other planes implying that most of the crystallites are oriented along the (200) plane. The Pb:S atomic ratio, as obtained from elemental analysis by EDX, is found 0.8 indicating that the film is Pb deficient and hence p-type [167].

Fig. 6.2 shows the variation of percentage absorbance (calculated from Abs= 100-R-T, where R and T are percentage reflectance and transmittance respectively) with wavelength. From this variation, it is observed that the film is highly absorbing with minimum absorbance of 50%. The most notable fact observed is that the absorbance is almost uniform from 500 to 2000 nm having the absorption co-efficient 10^5 cm^{-1}. This means that the film satisfies the requirement of high NIR absorption. The direct band gap of the film is 0.80 eV.

The current-voltage characteristics (Fig. 6.3) shows linear behaviour over a voltage interval of -1 to +1 V. The conductivity of the film is computed as 0.20 $(\Omega cm)^{-1}$.

(ii) LA0MT (Film prepared in lead acetate bath without using triethanolamine)

This film has been prepared by taking 5 ml of $Pb(CH_3COO)_2.3H_2O$ solution that was added NaOH to make pH become 13. Now after inserting glass slides, 6 ml of $SC(NH_2)_2$ was added slowly. The bath was topped up with deionized water to make a total volume of 100 ml. The deposition was allowed to take place at 29°C for six hours.

The XRD pattern of the film (Fig. 6.4) has been compared with the ICDD card no. 78-1900. All the peaks correspond to the fcc structured PbS phase. All standard peaks are evident in the XRD pattern. The lattice constant measured is 5.925 Å . The average crystallite size comes out as 43 nm and thickness 2 μm. The textured co-efficient is 1.19 along (200) plane while it is nearly equal to 1(1.08) along (111) plane and less than unity along other planes. The Pb:S atomic ratio in the films, as determined from the EDX spectrum is 0.41 confirming the film deficient in Pb.

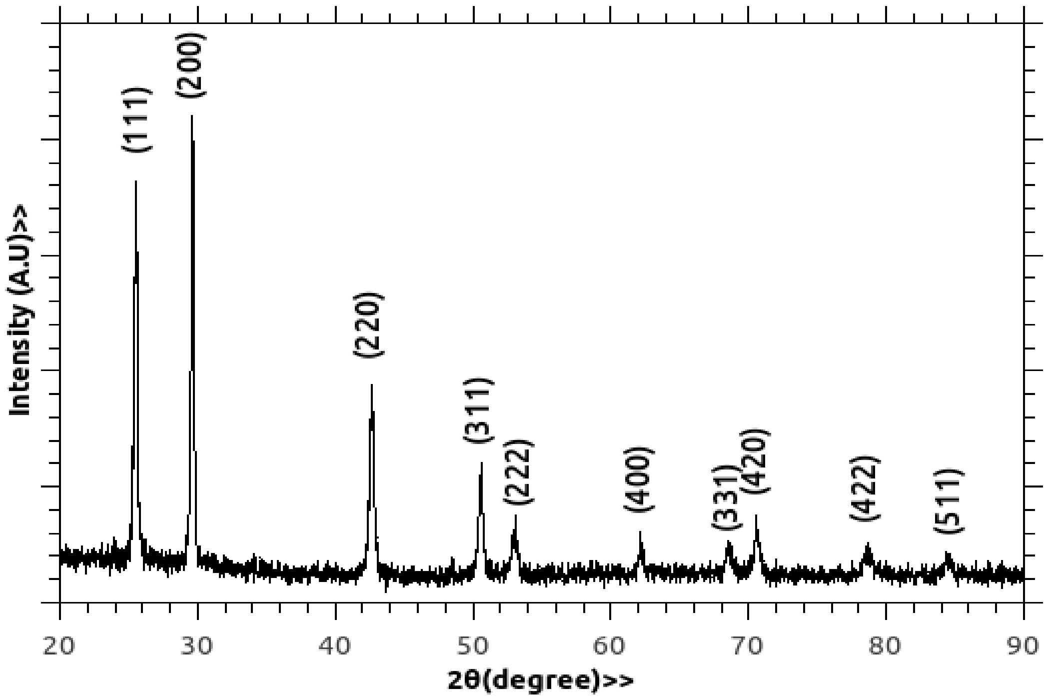

Fig. 6.4: XRD pattern of LA0MT

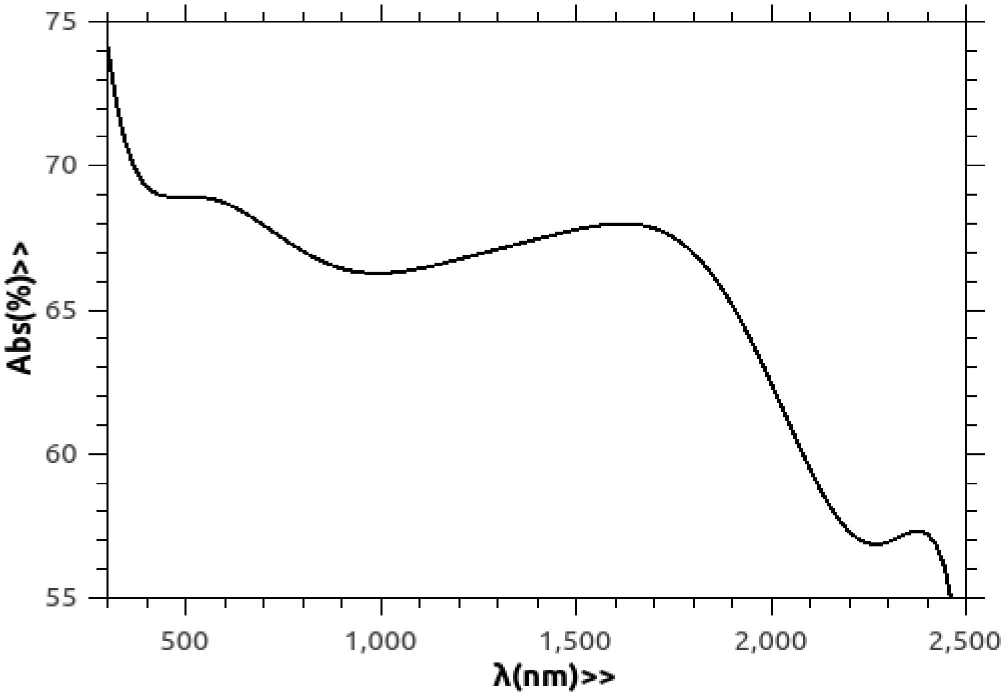

Fig. 6.5: Optical Absorbance of LA0MT at various wavelengths

Fig. 6.5 shows the variation of percentage absorbance (calculated from Abs= 100-R-T, where R and T are percentage reflectance and transmittance respectively) of LA0MT with wavelength. From this variation, it is observed that the film is highly absorbing with minimum absorbance of 55%. The absorbance is almost uniform from 500 to 1750 nm having the absorption co-efficient 10^5 cm^{-1}. That is, like LN0MT, LA0MT is also very good NIR absorber. The direct band gap of the film is 0.80 eV.

Like the previous case, here also the current-voltage characteristics (Fig. 6.6) shows linear behaviour over a voltage interval of -1 to +1 V. The conductivity of the film is computed as 0.23 $(\Omega cm)^{-1}$.

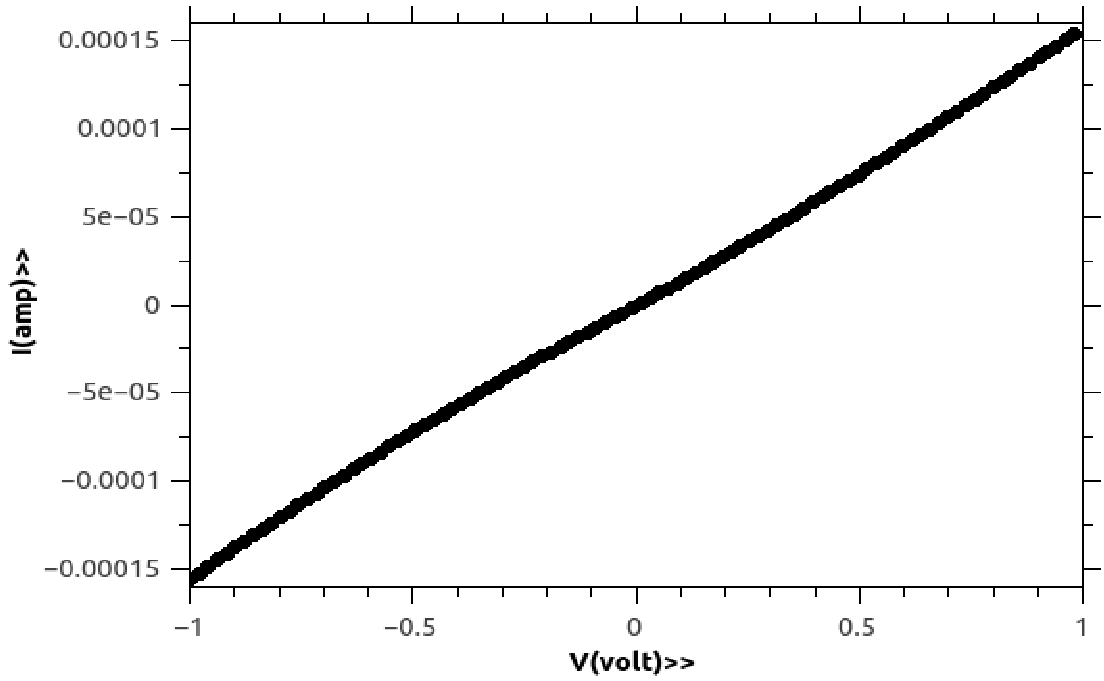

Fig. 6.6: Current- Voltage (I-V) Characteristics of LA0MT film

6.3 Conclusion

The LN0MT and LA0MT films have oriented crystallinity, high absorbance in the visible and NIR region and good conductivity which are the requirements of an efficient absorber in solar cells. That is, these two films have potential to become good absorber. Although the TEA complexed films possess favourable band gaps for solar cell applications, their conductivities are low and hence not suitable for absorption purpose.