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INVESTIGATING THE OPTICAL STUDY OF ELECTRODEAPOSITED GASE THIN FILM AT DIFFERENT TEMPERATURES

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ABSTRACT: *The GaSe thin films have been obtained by cathodic electrodeposition technique onto the fluorine tin oxide (FTO) glass substrates from aqueous acidic solutions at various temperatures of 323^{0}K, 333^{0}K, 343^{0}K, and 3530K. UV-VIS spectrophotometer was used to measure the optical absorption of GaSe thin film at their temperature variations. The optical study illustrated that the direct energy band gap of 3.0 eV, 3.0 eV, 2.8 eV, and 4.0 eV were appraised for electrodeposited GaSe thin film layers at different temperatures of 323 ^{0}K, 333 ^{0}K, 343 ^{0}K and 353 ^{0}K respectively. The thickness of the thin film layers increases along with the increase of electrodeposited temperature.*

KEY WORDS*:* GaSe, electrodeposition technique, temperature, optical study.

INTRODUCTION

GaSe is one of the metal selenide of a group III-VI thin film compound semiconductors and a metal chalcogenide which has developed a great scientific interest in opto- electronics applications and photovoltaic devices. It has been seen as an alternative to group II-IV nanomaterials. The thin film has a unique GaSe has a direct bandgap of ~2.10 eV and an indirect bandgap of ~3.0 eV which makes it useful inoptoelectronic appliances, such as photodetectors. The bandgap permits capable photo current device as well as main decrease of the dark current, which leads to higher sensitivity. Recently, tunable graphene contacts on GaSe have been exploited in construction of a FET where the contacts, instead of the channel, were subjected to the field modulation.

Gallium selenide has been deposited through various means which include molecular beam epitaxy(Tse & Yu, 2016), Bridgman method (Ni et al., 2013), [4], chemical vapour deposition (CVD) (Paranthaman et al., 2015) , thermal evaporation (Peng et al., 2007)[7] among which Electrodeposition has not been utilized. Electrodeposition is the process of depositing metals or compound semiconductors on a conducting substrate by passing an electric current through an ionic electrolyte in which metal or semiconductor ions are inherent.

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Electrodeposition method has caught a unique interest in modern years because it does not call for weighty equipment, it can produce films (especially large area thin films) expertly and regulate the composition without difficulty and equally importantly. The electrodeposition can work at room temperature or comparatively low temperatures, making it a technique that is compatible with flexible substrates and therefore a highly welcomed technique for producing flexible electronics (Saha et al., 2020). in addition, the electrodeposition method offers the advantage over other methods in particular in the production of thin films that include multiple elements, for example, ternary or quaternary chalcogenides, visible to the usefulness and flexibility of the method in composition control through tailoring the electrolytes. In this research work, Electrodeposition technique was used to deposit gallium selenide.

EXPERIMENTAL PROCEDURE

GaSe compound semiconductor was deposited on Fluorine doped Tin Oxide (FTO) substrate from an aqueous electrolytic bath comprising of 0.3 M of $Ga_2(SO_4)_2$ (Anhydrous) and 0.003 M of SeO_2. The two compounds were made to dissolve in a 500 ml glass beaker having 400 ml of de-ionized water. The solution pH reads 2.5 and with continuous stirring, addition of methane sulfonic acid lowers the pH of GaSe from 2.5 to 1.18 the deposition was uniform, dark in colour and precise on the substrate. The deposition took place for 30 minutes and the cathodic voltage of -500 mV at 100 µA was used for the deposition. The deposition was done at different temperatures of 323^0K, 333^0K, 343^0K, and 353^0K For each time of deposition at different temperatures, the current rate of flowing was resolute for every one minute of deposition.

RESULT AND DISCUSSION

Determining the thickness of electrodeposited GaSe thin film layers at different temperature

The thin film thickness is significant since it affects device act mainly in thin film solar cells. In addition, it aids in the formative of the window or absorber layer in thin film solar cells. The thickness in this research work was determined by calculation and this was attained through Faradays law of electrolysis. Faradays law of electrolysis in determining the thickness of a thin film is exemplified using Equation 1.

$$T = \frac{JtM}{n\rho F} \qquad 1$$

Where T, is the thin film thickness , *J* as the current density , *t* is the deposition time, *M* is the molecular weight of the thin film, *n* is the number of electrons transferred in the deposition of 1mole of the thin film, ρ is the density of the compound and F represents the Faraday constant (96485 C/Mol.). In this researched work, the thickness of GaSe layers was determined for each deposition temperature of 323^0K, 333^0K, 343^0K and 353^0K. The deposition time is 900 s Figure 1 shows the variation of thickness with deposition temperatur

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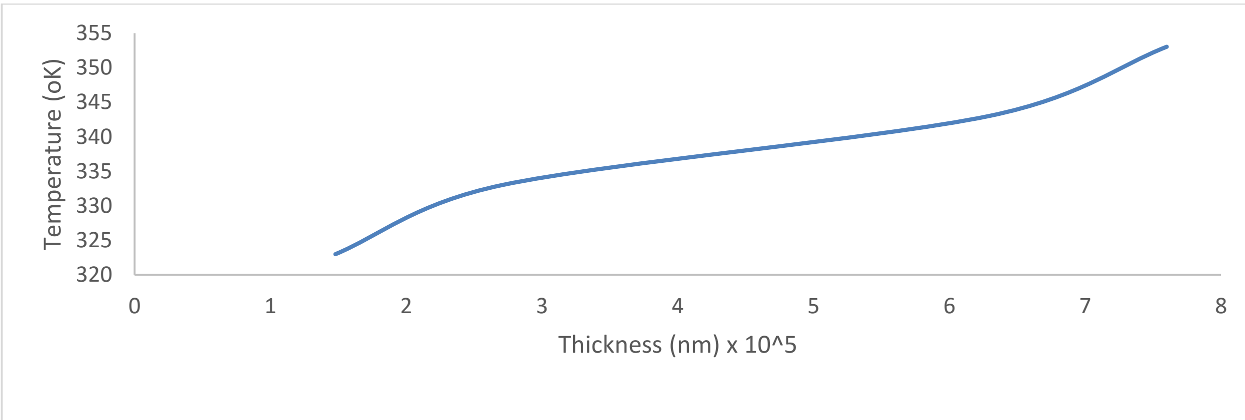

Figure1: The variation of Temperature deposition with the thickness (nm).

From Figure 1, the thickness of the compound layers increases with the increase in temperature. The temperature increase result to decrease in the number of electrons transferred in the deposition which still affirms the Faradays law.

Optical Absorption Study

The absorbance (A) is the division of radiation absorbed from the radiation that strikes the surface of the material (Tse & Yu, 2016). during this work, UV-VIS spectrophotometer was used to measure the optical absorption of GaSe thin film at their temperature variations. Figure 2 shows the optical absorption spectra for the thin film layers. They were carried out within the wavelength range of 300 nm to 900 nm.

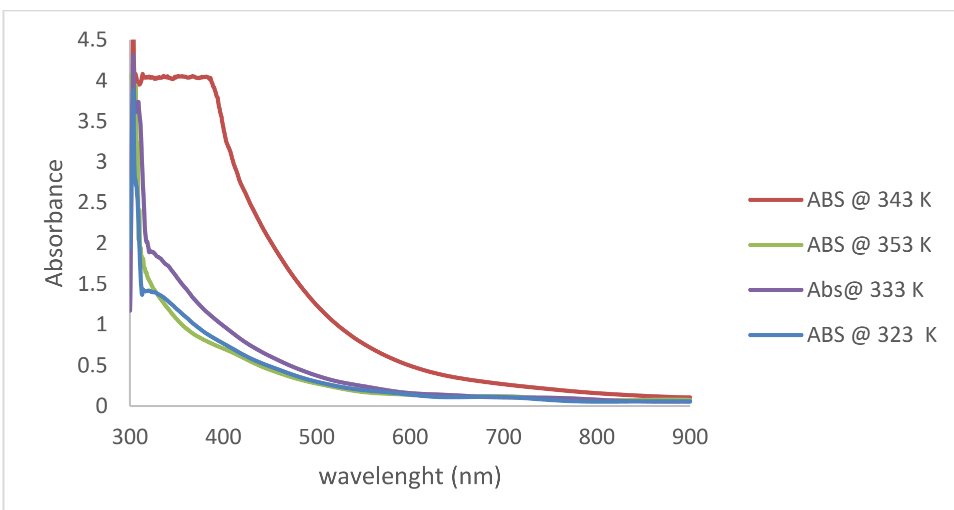

Figure 2: Graph of absorbance against wavelength at electrodeposited temperature of 323 ^{0}K,333 ^{0}K,343 ^{0}K and 353 ^{0}K

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As demonstrated from the graph, the increase in wavelength, effect to the pace at which the absorbance started to be absorbed. The Electrodeposited GaSe thin film layers of temperature 323 ^{0}K to 353 ^{0}K had their highest and lowest absorption in the Ultraviolet and infrared region respectively (< 400 nm – 900 nm).A decline in the absorption of photons was observed from the visible to the infrared region. This submits the fact that band-to-band optical changes arise in the high photon energy region, whereas, the changes between the valence band and the conduction band happen in the lower energy region This experimental result agrees with the work published by (Gujar et al., 2008) GaSe thin films have high absorbance in the UV region.

The energy band gap (E_g) study of GaSe thin film layers

E_g is the energy required for electron to jump from valence band into the conduction band. Establishing the energy band gap is by varying the graphical illustration of square of absorption coefficient $(\alpha h\nu)^2$ against photon energy ($h\nu$). This is done by using Tauc's plot in Equation 2 (Thirumoorthy & Murali, 2019) .

$$(\alpha h\nu) = \beta (h\nu - E_g)^{1/n} \qquad 2$$

Where α is the absorption coefficient, h the planks constant, ν the frequency of light, β the band tailing parameter, E_g the band gap, and n in the equation above is ½ for direct band gap while it is 2 for indirect band gap (Raut et al., 2017). Thus for direct band gap, squaring Equation 2 becomes;

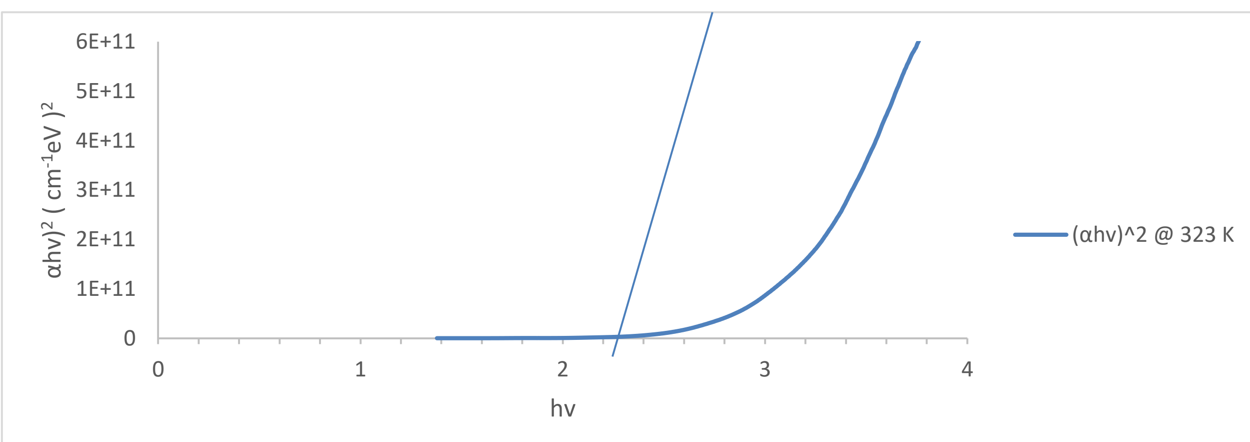
$$(\alpha h\nu)^2 = \beta^2(h\nu - Eg) \qquad 3$$

Making $(\alpha h\nu)^2 = 0$,

$$h\nu = Eg \qquad 4$$

This mean that E_g can be decided by extrapolating the straight-line portion of the absorption curve by drawing a gradient with highest value to the photon energy axis where $(\alpha h\nu)^2$ equals zero.

This is illustrated in Figure 3(a-d)



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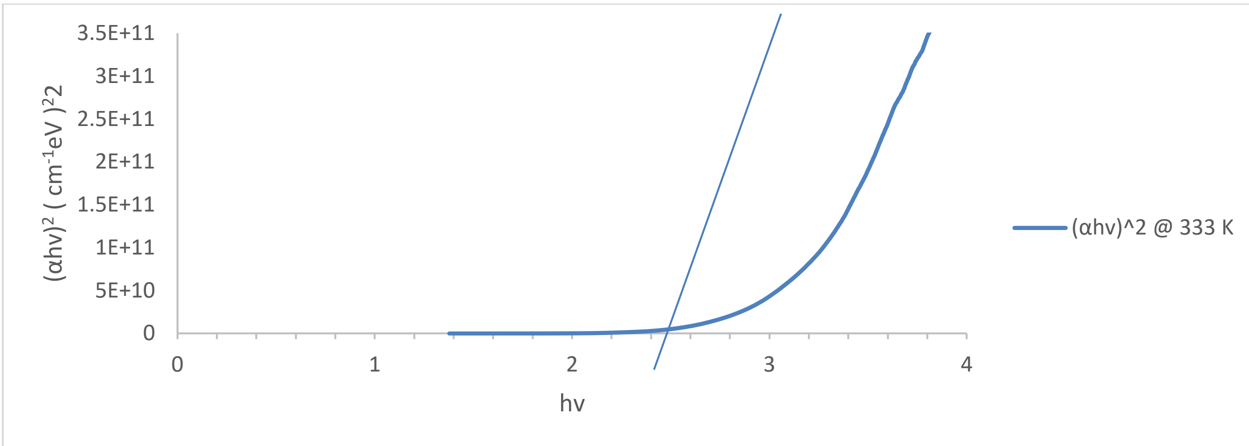
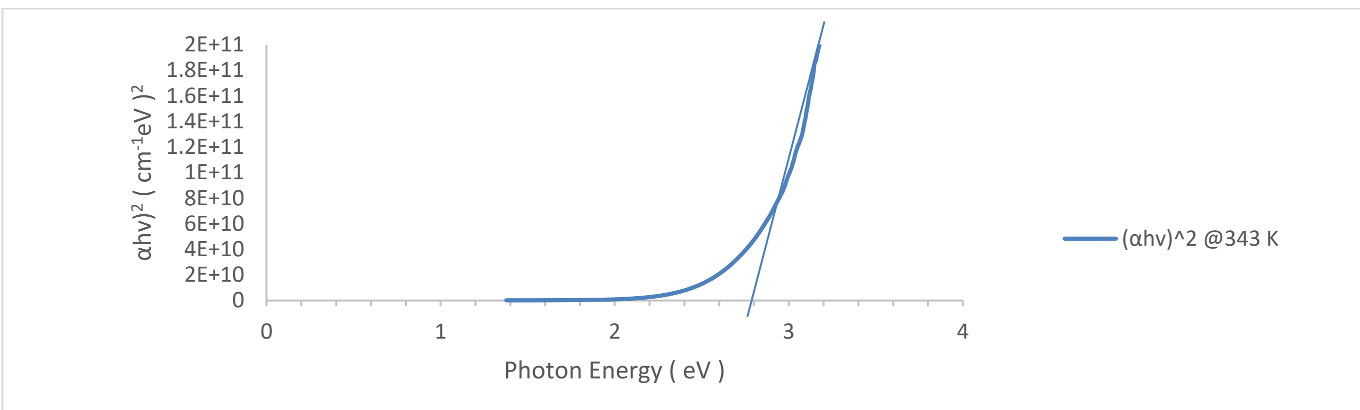
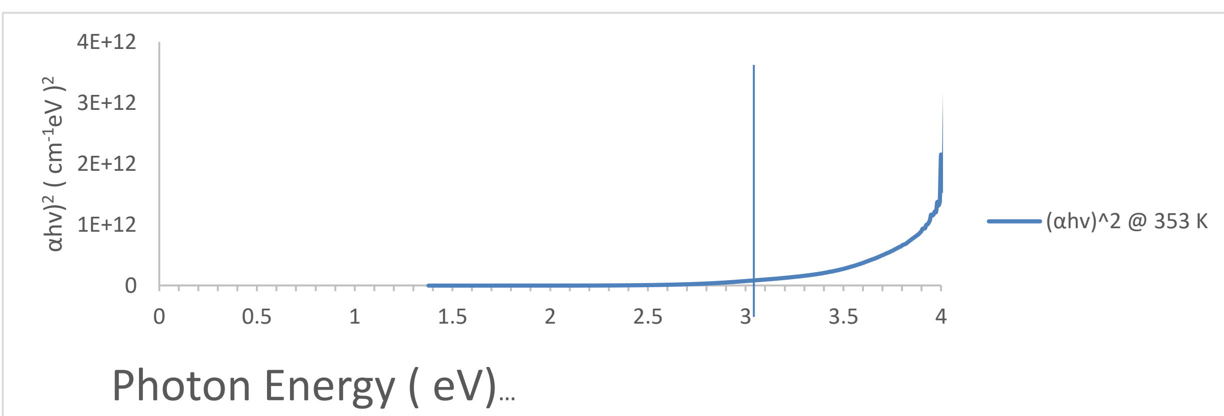


(a) (b)





(c) (d)

Figure 3 (a-d): The variation of $(\alpha h\nu)^2$ against photon energy at electrodeposited temperature of 323 ^{0}K,333 ^{0}K,343 ^{0}K and 353 ^{0}K

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As demonstrated in Figure 3(a-d), the direct energy band gap of 3.0 eV, 3.0 eV, 2.8 eV, and 4.0 eV were appraised for electrodeposited GaSe thin film layers at different temperatures of 323 ^{0}K, 333 ^{0}K, 343 ^{0}K and 353 ^{0}K respectively. It was observed from the result that the deposition at 323 ^{0}K and 333 ^{0}K possess the same band gap and the electrodeposition at temperatures of 323 ^{0}K, 333 ^{0}K, 343 ^{0}K lies in the range of band gap of GaSe thin films (Arora, 2021; Tse & Yu, 2016). The band gap of 2.8 eV correspond to the one of Gujar et al., 2008 with band gap of 2.85 eV. GaSe thin film layer experienced highest band gap at highest temperature of 353 ^{0}K.

Optical Transmittance Study

The transmittance of GaSe thin film layers were obtained by using UV-VIS spectrophotometer. Figure 4. illustrates the optical transmittance spectrum for electrodeposited GaSe thin film layers at different temperatures of 323 ^{0}K, 333 ^{0}K, 343 ^{0}K and 353 ^{0}K As shown in Figure 4, the thin film layers started transmitting within the ultraviolet region ($\lambda < 400$nm) and increases with increase in the wavelength up to infrared region ($\lambda > 700$ nm). The GaSe thin films attained high transmission peaks in the infrared region. This makes GaSe thin film as a semiconductor, a suitable material to use as high-power infrared sensor.

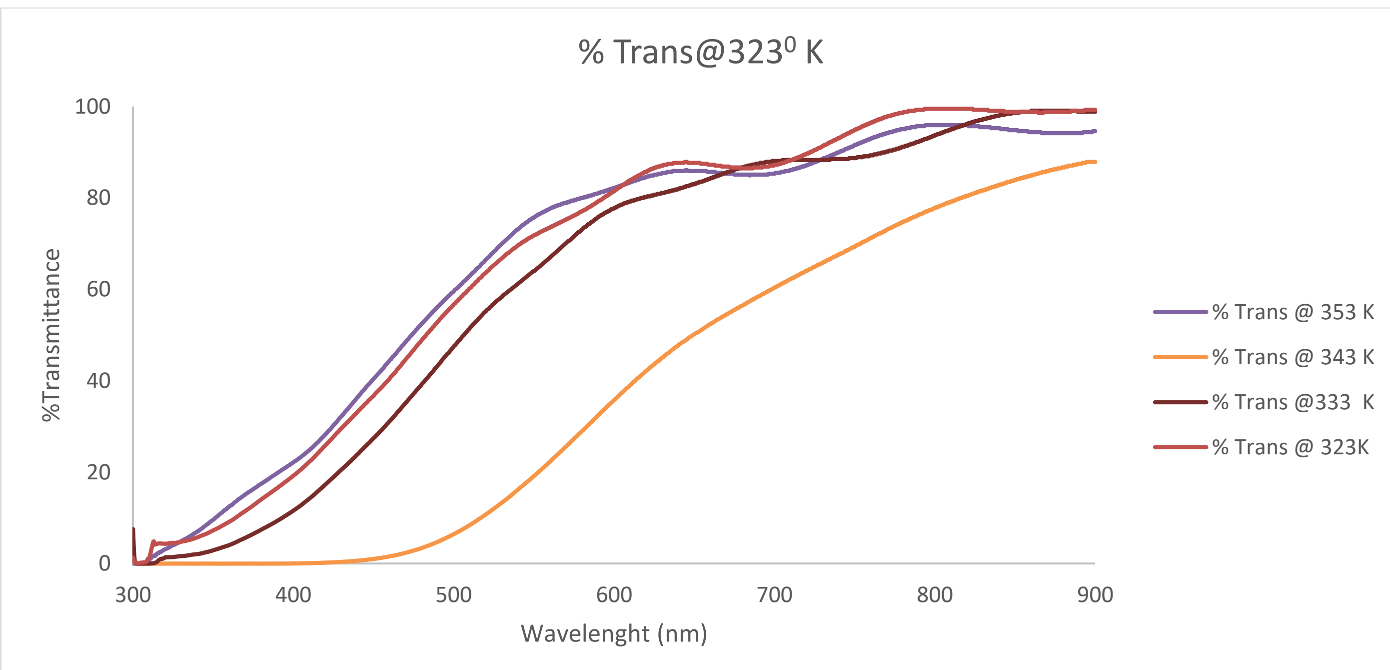

Figure 4.: The optical transmittance spectrum for electrodeposited GaSe thin film layers at temperature 323 ^{0}K, 333 ^{0}K, 343 ^{0}K and 353 ^{0}K.

The table 1, shows the optical variables attained from electrodeposited GaSe thin films at their various different deposited temperatures which effects the optical properties of a semiconductor materials. The optical variables summarized in table 1 at each corresponding deposited temperatures are; the average refractive index (n_{avg}), average absorption coefficient (α_{avg}), average extinction coefficient (k_{avg}), average total dielectrics (E_T)

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which is the addition of both real and imaginary dielectrics, average optical conductivity (σ_{avg}) , average absorbance (A_{avg}), average transmittance (T_{avg}) and average reflectance (R_{avg})

Table 1; the optical variables obtained from electrodeposited GaSe thin films of different deposited temperatures

Deposited Temperature	n_{avg}	α_{avg} **(nm^{-1})**	k_{avg}	E_T	$\sigma_{avg} \times 10^{14}$	A_{avg}	T_{avg}	R_{avg}
323 ^{0}K	1.781	0.005	0.159	3.820	1.311	0.375	0.560	0.065
333 ^{0}K	1.856	0.004	0.117	3.903	0.748	0.488	0.511	0.001
343 ^{0}K	2.196	0.004	0.149	5.158	0.518	0.414	0.574	0.012
353 ^{0}K	1.862	0.005	0.161	4.049	1.373	0.378	0.619	0.003

As per gotten in Table 1, for GaSe thin film layer, there is an increases in refractive index and total dielectrics as the deposition temperature increases from 323 ^{0}K to 343 ^{0}K and then experience a rapid decrease at 353 ^{0}K. In the absorption coefficient, Extinction coefficient and optical conductivity, of the optical variables obtained affirms that the thin film as a good semiconductor and a good absorber layer (Chander & Dhaka, 2017). The summation of the average absorbance (A), transmittance (T), and reflectance (R), in the table approves the law of conservation of energy which is equal to one as seen in the table at their various electrodeposited temperature range. The average absorbance gotten confirms that high absorbance value observed will make the films suitable as photo absorbers in solar cell fabrication (Nwofe et al., n.d.). The reflectance of electrodeposited GaSe thin film layers at their various growth temperature gives an average reflectance of zero (0) which expresses that the thin films will be a good substance for anti-reflective coatings as a result of no energy loss due to reflection (Chander & Dhaka, 2015).

CONCLUSION

This study demonstrated the effect of temperature variation on electrodeposited GaSe thin films. It was affirmed that at each deposited temperature variation, GaSe possess a high quality of good absorber layer, a lovely photo sensor and a good anti-reflective coatings. The band gap obtained was in the range of electrodeposited GaSe thin film semiconductor.

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