







micrographs of NiS/ZnS bilayer thin films annealed at 500°C and it is observed as hexagonal structure. Chemical compositions of the constituents' in the coatings, obtained from EDAX spectra for the NiS/ZnS bilayer thinfilm annealed at 400°C and 500°C are shown in FIG 3 (a) and 3 (b). The other elements Ca, Al, Mg and Si that are not expected to be in the deposited films may be resulted from the glass substrates [10].

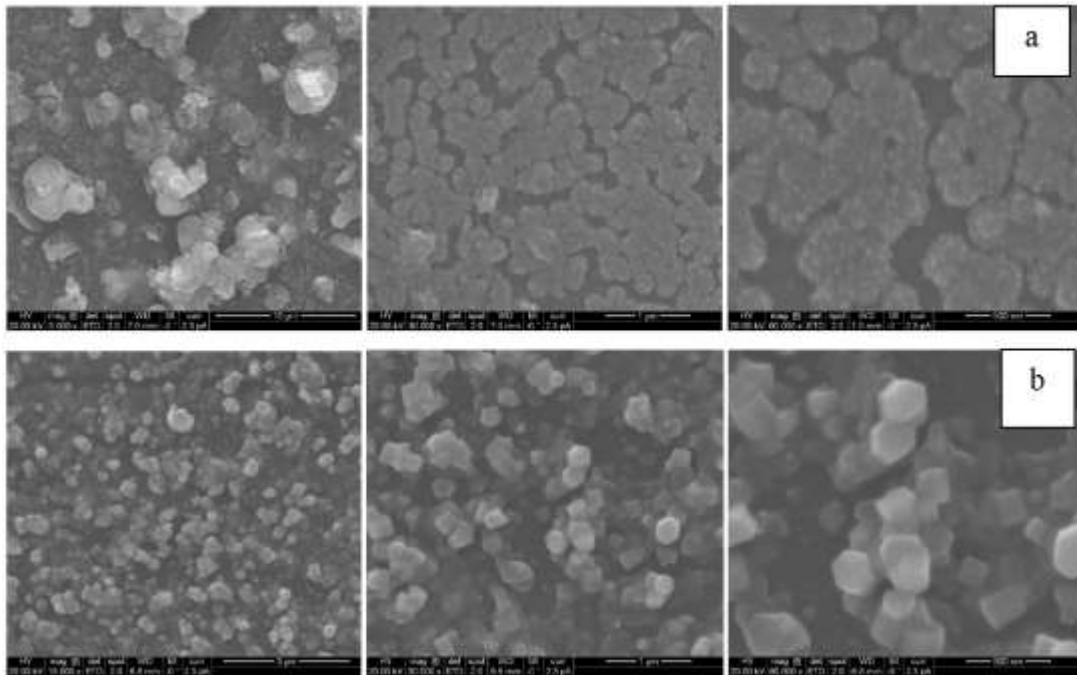


FIG 2. (a) to (b) SEM image of NiS/ ZnS bilayer annealed at 400°C and 500 °C

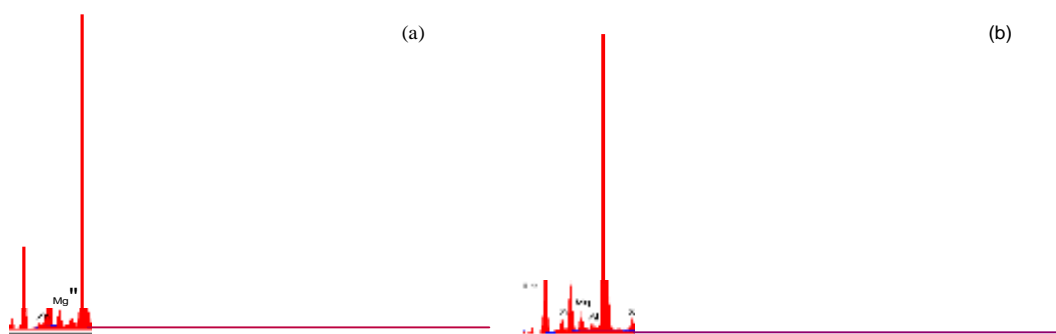


FIG 3 (a), (b) EDAX images of NiS/ ZnS bilayer annealed at 400°C and 500 °C

The optical properties of NiS/ZnS bilayer were determined from absorption measurement in the range 300nm to 1000nm. From the spectra, it is observed that, the absorption is higher below 300nm and lower in the range of 400nm to 900nm.

The optical transmission spectrum of the NiS/ZnS bilayer thinfilms annealed at 400°C and 500°C shows good transmission (>60) for wavelengths larger than 500 nm FIG 4, which is one of the prerequisites' for opto-electronics devices, especially for solar cell window layers. The band gap energy ( $E_g$ ) and the parameters such as refractive-index ( $n$ ), dielectric constant ( $\epsilon$ ), optical conductivity ( $\sigma_o$ ) and electrical conductivity ( $\sigma_e$ ) were determined by various equations based on UV- absorption spectrum.

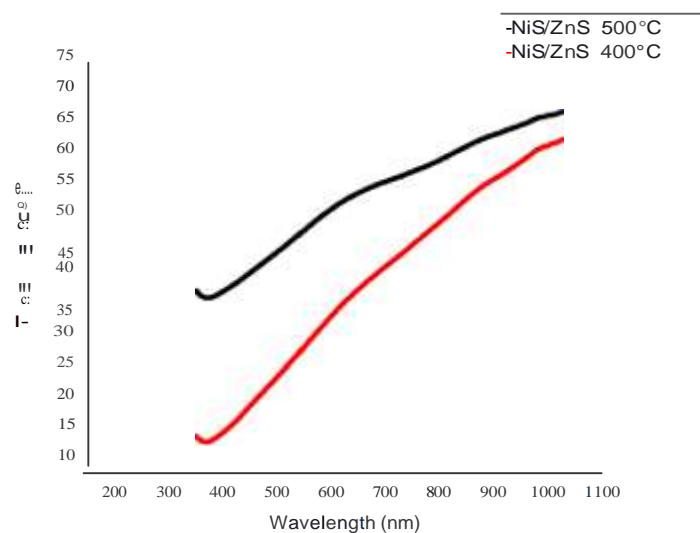


FIG 4 Plot of Transmittance % Versus Wavelength for NiS/ZnS bilayer annealed at 400 °C and 500 °C

Absorption coefficient  $a$  associated with the strong absorption region of the film was calculated from transmittance ( $T$ ) using the relation,

$$\text{Absorption coefficient } a = \frac{2.303}{d} \ln \left( \frac{I_0}{I} \right) = \ln \left( \frac{1}{T} \right) \times 10^6 \text{ m}^{-1} \quad [11]$$

The band gap was determined from the intersection of straight portion of  $a^2$  versus eV graph which is shown in FIG 5 for NiS/ZnS bilayer thin film. The observed band gap value of the thin films annealed at 400 °C and 500 °C are 1eV and 1.45 eV respectively.

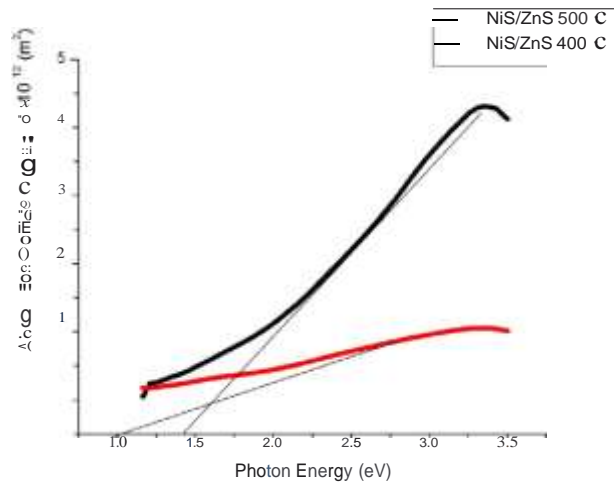


FIG 5 Plot of square of absorption Coefficient  $a^2$  Versus Photon energy for NiS/ZnS bilayer annealed at 400 °C and 500 °C

The coefficient of absorption  $a$  is also related to extinction coefficient  $K$  by,

$$\text{Extinction coefficient } K = \frac{a_{il}}{4T} \quad [12]$$

FIG 6 portrays a plot of extinction coefficient versus photon energy. The extinction coefficient for NiS/ZnS, is observed that there is a gradual increase from 1eV to 3eV and found a sudden decrease from 3eV to 5eV.

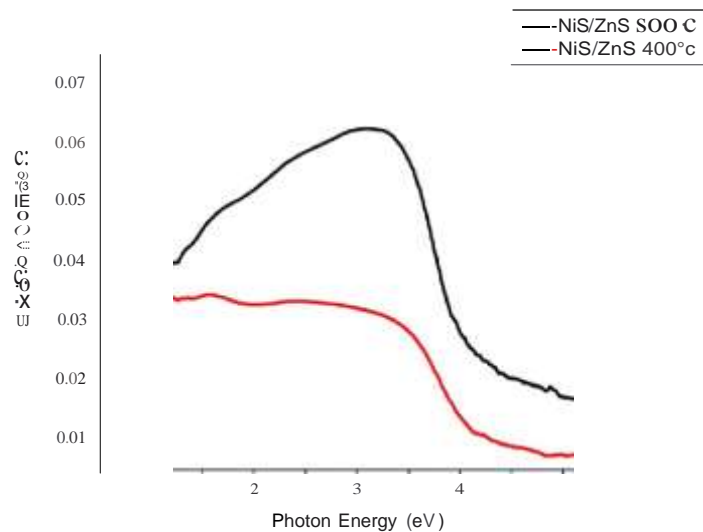


FIG 6 Plot of Extinction Coefficient Versus Photon energy for NiS/ZnS bilayer annealed at 400°C and 500°C

The refractive index of film is calculated using Modified envelope method [13].

Refractive index

$$n = \left[ N + (N^2 - n_0^2 n_1^2) \frac{1}{2T} \right]$$

$$\text{Where } N = \frac{n_0^2 + n_1^2}{2} + \frac{2n_0 n_1 (T_{max} - T_{min})}{T_{max} + T_{min}}$$

$n_0$  is the refractive index of air,  $n_1$  is the refractive index of the substrate,  $T_{max}$  and  $T_{min}$  are the maximum and minimum transmittances respectively for a particular wavelength.

The variation of refractive index ( $n$ ) with wavelength for the as deposited thin films is shown in FIG 7. The high refractive index of 0.7 to 0.1 for wavelength range 200nm to 400nm and increases to 0.8 for values wavelength range 390nm to 1000nm, which shows variation in the refractive index values. The bilayer of NiS/ZnS with the values of low refractive index which could be useful in applications of antireflection coatings. [14].

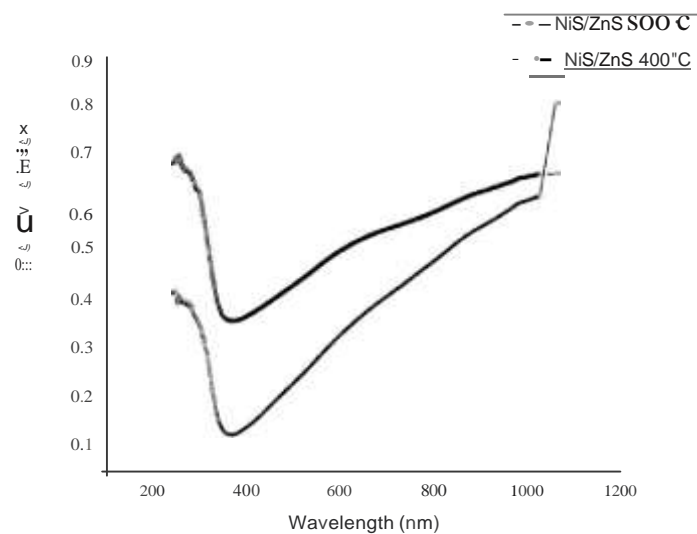


FIG 7 Plot of Refractive Index Versus Wavelength for NiS/ZnS bilayer annealed at 400 °C and 500 °C

The optical conductivity is given by

$$\text{Optical conductivity } \sigma_j = \frac{anc}{4\pi T}$$

The electrical conductivity  $\sigma_{ie}$  is given by the expression [15]

Electrical conductivity  $(\sigma = \frac{ze^2 n \tau}{a})$

The complex dielectric constant

$$\epsilon_r = \epsilon_r' + i\epsilon_r''$$

where  $\epsilon_r' = n^2 - K^2, \epsilon_r'' = 2nK$  [16, 17]

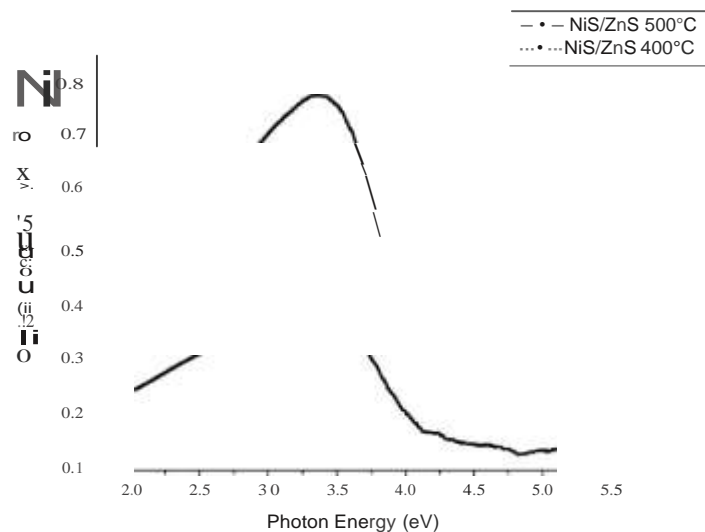


FIG 8 Plot of Optical Conductivity Versus Photon energy for NiS/ZnS bilayer annealed at 400 °C and 500°C

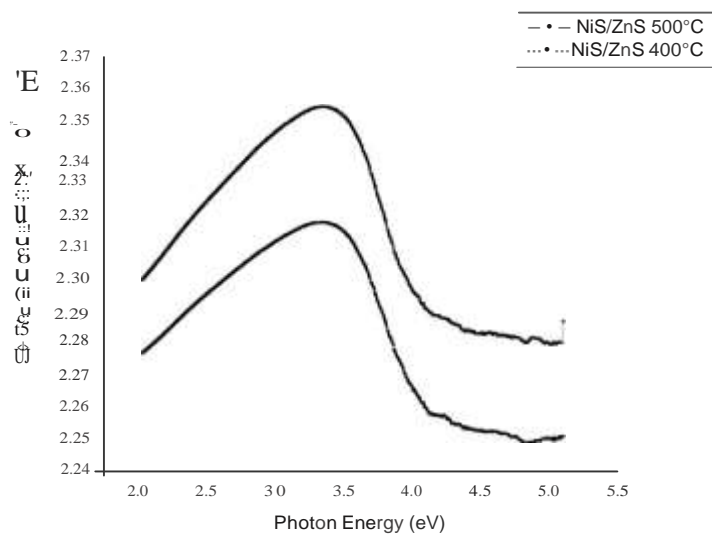


FIG 9 Plot of Electrical Conductivity Versus Photon energy for NiS/ZnS bilayer annealed at 400 °C and 500 °C



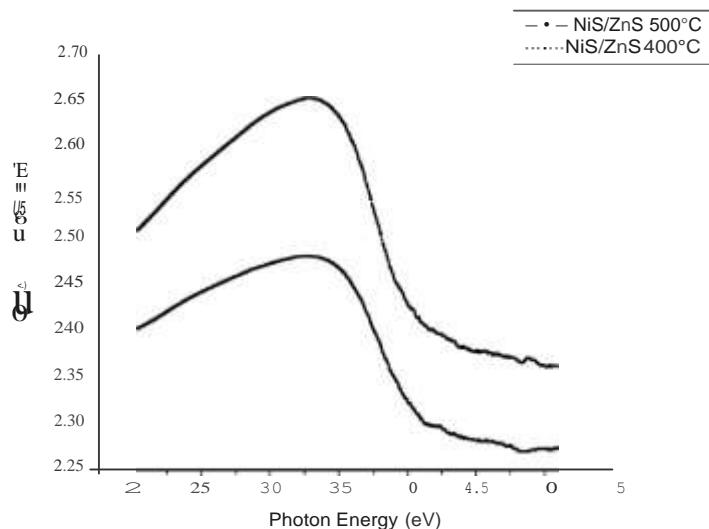


FIG 10 Plot of Dielectric constant Versus Photon energy for NiS/ZnS bilayer annealed at 400 °C and 500°C

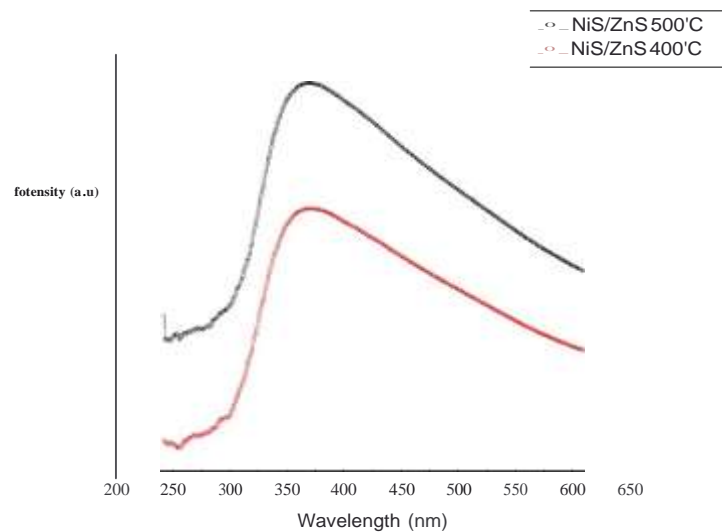
The optical conductivity  $\sigma_0$  against photon energy, electrical conductivity  $C_{ie}$  against photon energy and dielectric constant versus photon energy for NiS/ZnS are shown in FIG 8,9 and 10 respectively. The nature of the curve of optical, electrical conductivity and dielectric constant has a gradual increase upto 3.5eV and a sudden decrease from 3.5eV to 5.0eV and the observed values are tabulated in Table I.

NiS/ZnS	At 2.00 (eV)		At 3.50 (eV)		At 5.00 (eV)	
	400 °C	500 °C	400 °C	500 °C	400 °C	500 °C
Optical Conductivity ( $\sigma_0 \times 10^{13} \text{ s}^{-1}$ )	0.25	0.4	0.35	0.8	0.1	0.3
Electrical Conductivity ( $\sigma_{ie} \times 10^7 \text{ s/m}$ )	2.27	2.30	2.30	2.36	2.25	2.29
Dielectric constant (Ee)	2.40	2.51	2.45	2.65	2.25	2.40

TABLE 1 Optical conductivity, Electrical conductivity and Dielectric constant of the Samples

Photoluminescence (PL) spectra of NiS/ZnS bilayer thin films excited with a 320 nm Xe lamp source at room temperature are presented in FIG 11. A dominant emission peak centred at 3.75eV (330 nm) and 3.87eV (320 nm) respectively. This shows strong ultraviolet (UV)

peak is attributed to the recombination of free excitons through exciton-exciton collision process [18]. The strongest peak is comparatively broad and gives near blue emission bands. The intensity of photoluminescence decreases significantly with increasing temperature.



**FIG 11** Photoluminescence spectra of NiS/ ZnS bilayer annealed at 400°C and 500 °C

## CONCLUSION

NiS/ZnS bilayer thinfilms were successfully deposited on glass substrates by CBD technique. The as deposited films possess the wurtzite hexagonal structure and show very good crystalline quality. The atomic composition is confirmed by EDAX spectrum. The photoluminescence spectra of NiS/ZnS bilayer thin films exhibit a strong UV excitonic peak. The band gap energy of bilayer thinfilms were found to be 1eV and 1.45eV respectively.

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