Optical Properties of GaN Thin Flim

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Abstract

GaN thin films were deposited by thermal evaporation onto glass substrates at substrate temperature of 403 K and a thickness of 385 nm . GaN films have amorphous structure as shown in X-ray diffraction pattern . From absorbance data within the range (200-900) nm direct optical energy gap was calculated . Also the others optical parameters like transmittance T, reflectance R , refractive index n , extinction coefficient k , real dielectric constant $\in_1$, and imaginary dielectric constant $\in_2$ were determined . GaN films have good absorbance and minimum transmittance in the region of the visible light .

Keywords

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الخصائص البصرية لأغشية GaN الرقيقة

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الخلاصة :

رسبت أغشية GaN الرقيقة على قواعد زجاجية بدرجة حرارة قاعدة 403 K وسمك 385 nm . أظهر نموذج حيود الاشعة السينية التركيب العشوائي لمركب GaN . حسبت فجوة الطاقة البصرية المباشرة من قيم الامتصاصية ضمن المدى (200-900) nm . كذلك حسبت العوامل البصرية الاخرى مثل معامل الانكسار R , النفاذية T , مغامل الخمود k , ثابت العزل الحقيقي $\in_1$, ثابت العزل الخيالي $\in_2$. وجد ان أغشيته تمتلك امتصاصية عالية واقل نفاذية في منطقة الضوء المرئي .

Introduction

The Gallium Nitride (GaN) is a binary compound of the III–V group of the periodic table and is commonly used in LEDs and high-frequency devices. The GaN compound has a direct-band gap of wurtzite crystal structure . Its sensitivity to ionizing radiation is low, making it a suitable material for solar cells[1,2]. GaN compound which was used in transistor devices can operate at high temperatures and higher voltages when compared with GaAs transistors. The absorption of radiation which leads to electronic transitions [3,4,5] between conduction band and valence band is described by the equation

$$\alpha h\upsilon = A^*(h\upsilon - Eg)^r \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where A^* is constant , α is the absorption coefficient , $h\upsilon$ is the incident photon energy , and r is constant which takes the values (1/2, 3/2 , 2, 3) depending on the material and the type of optical transition whether it is direct or indirect . The theory of the optical absorption gives the relationship between the absorption coefficient α and the photon energy $h\upsilon$ for direct allowed transition

$$\alpha = (h\upsilon - E_g)^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

We have

□□□□□□□□□□□□ $\alpha = 2.303\ (A/t)$ …….(3)

where A is the absorbance and t is the thickness .

The reflectance (R) can be found by the relationship:

$R+T+A=1$ ……...(4)

where T is the transmittance . For normal reflectance [8,9] , we have

$n = (1-R^{1/2})/(1+R^{1/2})$ ……....(5)

The extinction coefficient is related to the absorption coefficient α by the relation

$k = \alpha\lambda / 4\pi$ ……..(6)

where λ is the incident photon wavelength . The real and imaginary parts of dielectric constant ($\varepsilon_1$and ε_2 respectively) can be calculated as follows

□□□□□□□□□□□□□ $\varepsilon_r = (n^2 - k^2)$ …….(7)

$\varepsilon_i = \sqrt{(2nk)}$ …..…….(8)

Experimental Part

GaN thin films were evaporated by thermal evaporation process from a resistively heated boat onto glass substrates at substrate temperature 403 K and were simultaneously exposed to a beam of nitrogen gas during evaporation. Thin films have 385 nm thickness and rate of deposition of (1.1 nm /sec). Spectrophotometer, type Shimadzu and UV-Visible Recorder Spectrophotometer UV-160, was used to measure the absorbance and transmittance of the film in the range (200-900) nm . X-ray diffraction technique of Source (Cukα) of wavelength (1.54) A^o was used to know the structure of GaN films.

Results and Discussions

The X-ray diffraction pattern of GaN compound as a thin film have amorphous structure as shown in figure (1) .

The absorbance spectrum for GaN thin films is shown in Fig. (2). From this figure the maximum absorption peak located at the wavelength 329 nm.

The optical transmittance spectra for GaN thin film is shown in Fig (3) where the minimum transmittance peak located at the wavelength 329 nm and very minimum transmittance at the extreme of the region of the visible light and near infrared region [6,7] .

The absorption Coefficient α was determined from the region of high absorption at the fundamental absorption edge of the film by using equation (3) .

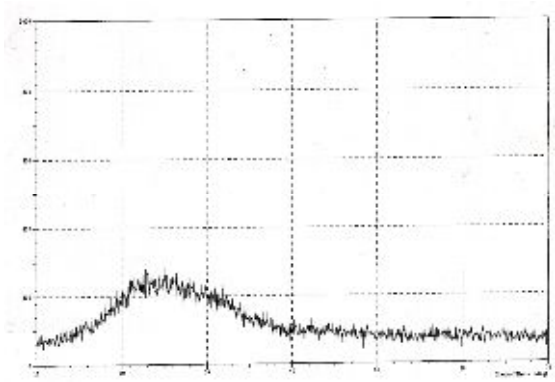
Equation (2) gives the band gap E_g from the straight portion of $(\alpha h\upsilon)^2$ versus $h\upsilon$ plot which is equal to 2.4 eV as illustrate in Fig (4).

Fig. (5) shows the optical reflectance spectra of GaN thin film which was found by using equation (4). From the figure thin films have high reflectance in the middle region of the visible light as compared with transmittance.

The optical constants like refractive index n, extinction coefficient k , the real ε_{1r} and imaginary ε_{2i} parts of dielectric constant for GaN films were calculated . From equation (5) the refractive index was calculated and its variation as a function of wavelength was shown in Fig.(6) . Films have high refractive index in the Ultra Violet region of radiation and minimum value at 329 nm of wavelength due to high absorption. So these films consider good materials for solar cell devices.

The extinction coefficient was calculated from equation (6). Figure (7) shows its variation as a function of wavelength for GaN thin films. It is observed from this figure that the extinction coefficient increases with the increase of the wavelength and it have high values in the near infrared region [7].

Real and imaginary dielectric constants were calculated using equations (7) and (8) respectively. Figures (8&9) show their variation as a function of wavelength respectively. It is observed from the figures that its behavior follow the reflectance as mentioned before. The behavior of the imaginary dielectric constants follow behavior of the extinction coefficient as mentioned before.



2θ

Fig. 1 X-Ray diffraction of GaN thin films

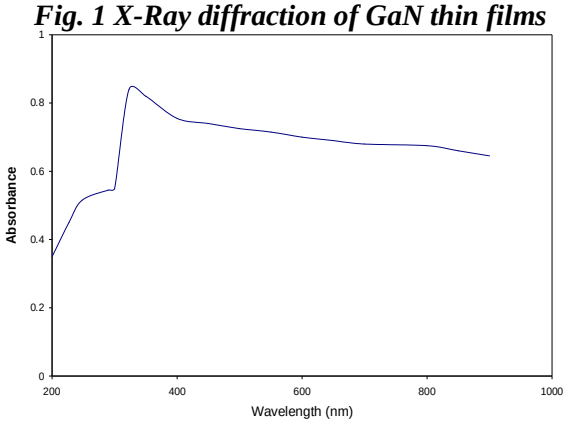


Fig. (2) The optical absorbance of GaN thin films

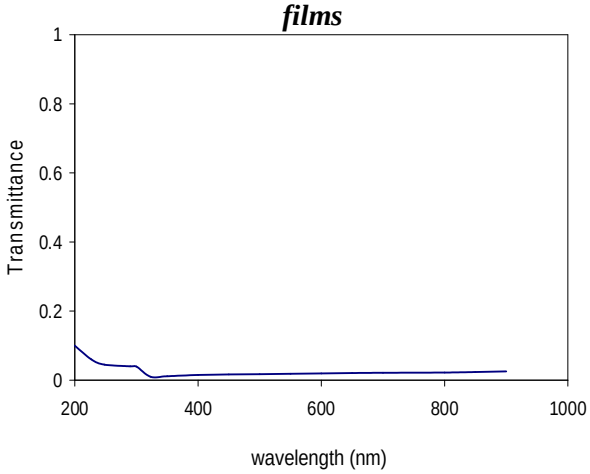


Fig. (3) Transmittance spectrum of GaN films

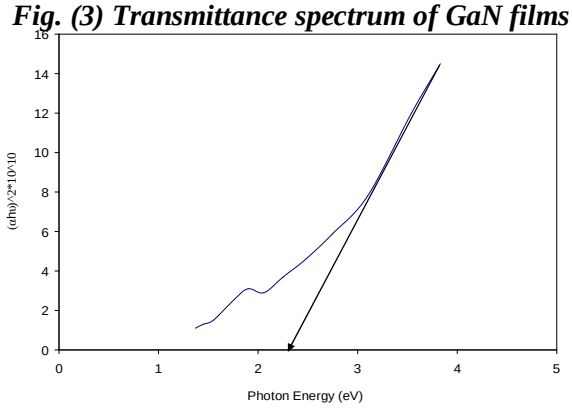


Fig. (4) A plot of $(\alpha h \upsilon)^2$ versus $h\upsilon$ for GaN thin films

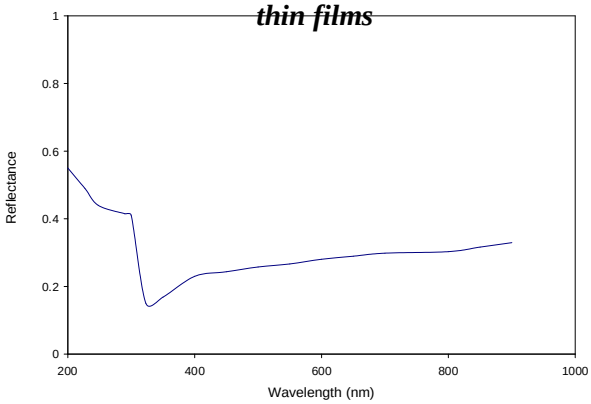


Fig . (5) Reflectance spectra for GaN thin films

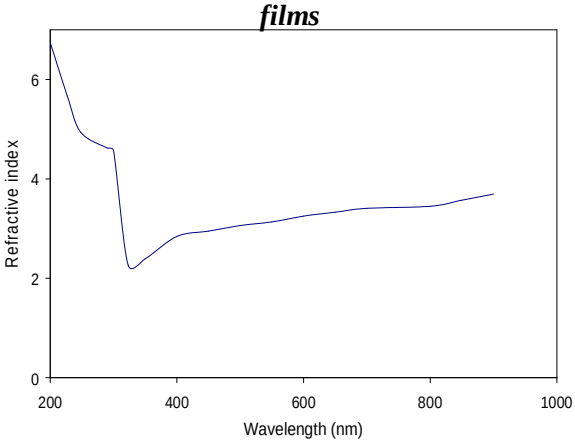


Fig . (6) Refractive index for GaN thin films

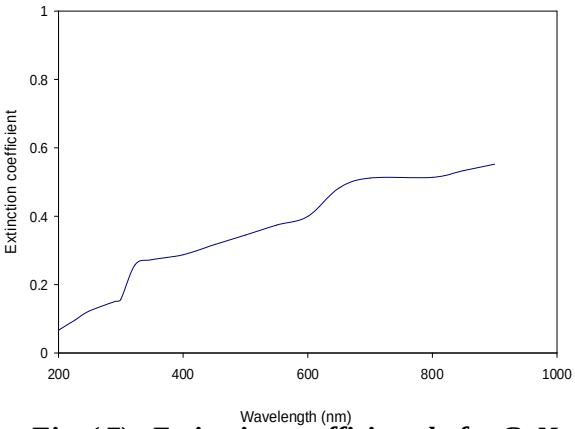


Fig .(7) . Extinction coefficient k for GaN thin film

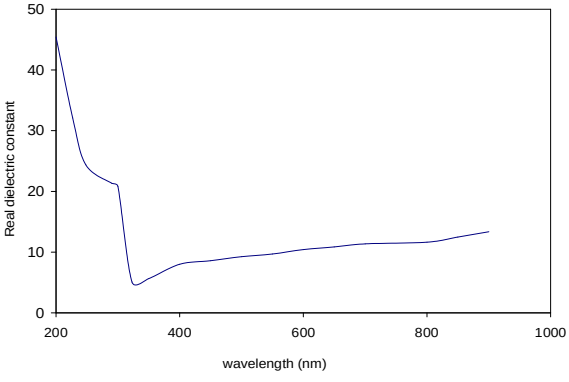


Fig .(□8) Real dielectric constant for GaN thin films

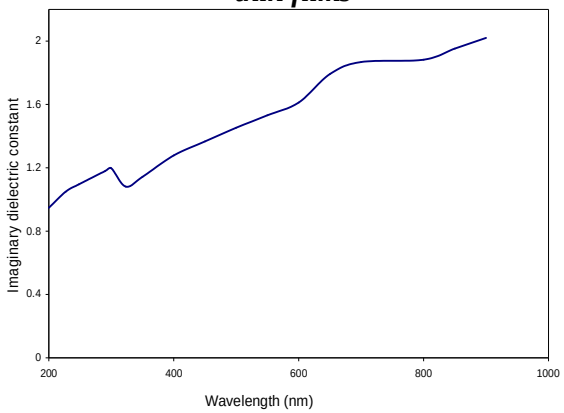


Fig .(9) Imaginary dielectric constant ε_i for GaN thin films

Conclusion

GaN thin films which have a thickness of 385 nm were deposited by thermal evaporation onto glass substrates at substrate temperature 403 K. GaN thin films have amorphous structure and have direct energy gap (2.4) eV . Films have good absorption at the extreme of visible region Also films have high reflectance in the ultra-violet region and minimum peak at 329 nm . High values for the extinction coefficient in the near infrared region.

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