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A different approach to absorption coefficient and thickness

Soğurma katsayısı ve kalınlığa farklı bir yaklaşım

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A Different Approach to Absorption Coefficient and Thickness

Highlights

- *Absorption coefficient is calculated with a different method/Soğurma katsayısı farklı bir yöntemle hesaplandı*
- *XRD and Raman analysis is made/XRD ve Raman analizleri yapıldı*
- *SEM and AFM techniques are employed for thickness/Kalınlık için SEM ve AFM teknikleri kullanıldı*

Graphical Abstract

In this study, XRD and Raman analysis is made and absorption coefficient is calculated with a different method. SEM and AFM techniques are employed for determining thickness./Bu çalışmada, XRD ve Raman analizleri yapıldı ve absorpsiyon katsayısı farklı bir yönlemle hesaplandı. SEM ve AFM teknikleri kalınlığı belirlemek için kullanıldı.

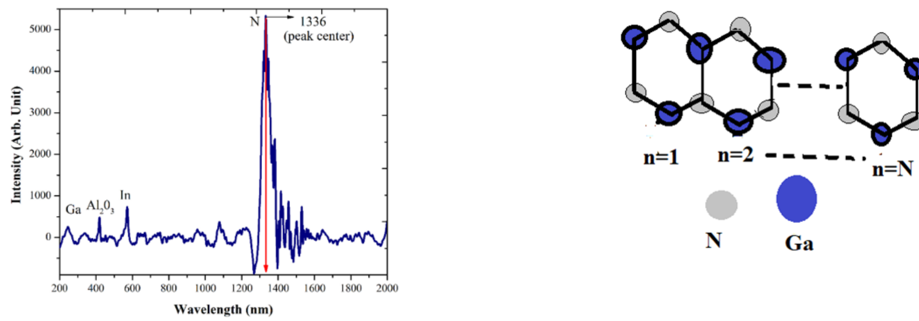

Figure. Raman spectra and number of stacks

Aim

Aim of this study is to calculate absorption coefficient and to determine thickness by using SEM and AFM.

Design & Methodology

In this study, XRD and Raman data are employed for absorption, SEM and AFM techniques are employed for thickness.

Originality

The method for determining absorption coefficient and AFM data are gained and analisied with special softwares.

Findings

Absorption coefficient is determined as 0.3045 and thickness value is determined between 3-4 µm

Conclusion

This study plays a key role for different researchers.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

A Different Approach to Absorption Coefficient and Thickness

Araştırma Makalesi / Research Article

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ABSTRACT

In this study structural and morphological properties of InGaN/GaN/Al_2O_3 structure, grown by Metal Organic Chemical Vapor Deposition (MOCVD) technique, is investigated. Crystal size of GaN in the structure is determined by using X-Ray Diffraction (XRD) techique. By the help of Raman spectra calibration coefficient is gained. This calibration coefficient and Termoelectric figure (ZT) of GaN is used to estimate number of stacks of GaN in the structure. Number of stacks (N) is a structural property and by using it an optical property, absorption coefficient, is determined. Using Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) images total thickness of the sample is determined accurately and they are compared with each other. The sample used in this study is only for an example. The methods used in this study can be applied to different structures if right coefficients can be found. The importance of this study is that it plays a key role for determining structural, optical and morphological features of different samples.

Keywords: InGaN, GaN, XRD, SEM, AFM, raman.

Soğurma Katsayısı ve Kalınlığa Farklı Bir Yaklaşım

ÖZ

Bu çalışmada, metal organic kimyasal buhar biriktirme(MOCVD) yöntemiyle büyütülen InGaN/GaN/Al_2O_3 yapısının yapısal ve morfolojik özellikleri incelendi. GaN'ın kristal boyutu X-ışını kırınımı (XRD) tekniği ile belirlendi. Raman spektrumu kullanılarak kalibrasyon katsayısı belirlendi. Kalibrasyon katsayısı ve termoelektrik figure (ZT) yapıdaki GaN'a ait yığın sayısını tahmin etmek için kullanıldı. Yığın sayısı (N) yapısal bir özelliktir ve onu kullanarak optik bir özellik olan soğurma katsayısı belirlendi. Atomik kuvvet mikroskobisi (AFM) ve tarama elektron mikroskobisi (SEM) kullanılarak numunenin toplam kalınlığı tam olarak belirlendi ve birbiri ile kıyaslandı. Bu çalışmada kullanılan numune sadece bir örnek teşkil eder. Eğer doğru katsayılar bulunabilirse farklı yapılara da uyarlanabilir. Bu çalışmanın önemi, farklı numunelerin optik, yapısal ve morfolojik özelliklerini belirleyebilmek için anahtar rolü oynamasıdır.

Anahtar kelimeler: InGaN, GaN, XRD, SEM, AFM, raman.

1. INTRODUCTION

Semiconductor nitrites such as GaN and InN have an important use area in optoelectronic and electronic technology because of their unique physical properties. Both semiconductor materials have wurtzite crystal structure in termodynamic equilibrium state. These semiconductors have triple compounds such as InGaN. Their forbidden energy band gaps are in 0.7 and 3.4 eV range[1]. This property makes nitrite based semiconductors very essential for producing light emitting diodes (LEDs), laser diodes, solar cells and ultraviolet(UV) photo detectors. III-V group nitrite based semiconductors have wide band gap, high dielectric coefficient and very good thermal conductivity. These properties give opportunity to use them at high power circuits and at high temperature[2].

In this study the sample is grown by using Metal Organic Chemical Vapor Deposition (MOCVD) technique. MOCVD is the name of growth technique in which semiconductor layers are formed by transmission of their gas phase over heated wafer and their chemical reactions involving a dynamic flux[3]. This technique maintains growth of many III-V group materials fast and sensitively. In growth of III-group Nitrite based materials MOCVD technique is preferred more than Molecular Beam Epitaxy (MBE) technique because it has bigger growth rate[4, 5].

Structural properties of materials, for example thickness, have great importance on electronic and optical properties of produced devices. X-ray diffraction (XRD) characterisation is used for determining structural properties of crystals[6]. XRD is a harmless method for determining crystal structure, thickness, components of the material etc. It uses X-ray beam formed in a vacumed tube. The system is called diffractometer because the fundamental of characterisation depends on diffraction of X-rays from crystal lattice[7].

Another way of determining material components is Raman scattering. In this study Raman scattering is used for calculating thickness by means of molecular stacks. Base of Raman scattering is measurement of reflected laser beam with a detector placed in an exclusive

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angle[8]. The difference between incident laser wavelength and reflected laser wavelength from the sample molecule is called Raman shift[9]. In other terms, photons interact with phonons in Raman scattering[10]. Number of GaN stacks are determined by the help of Raman spectra. This number is used with transmission data to calculate thickness. Transmission is percentage of transmitted light intensity and incient light intensity.

In this study Atomic Force microscopy (AFM) and Scanning Electron Microscopy (SEM) are also employed to determine thickness of the sample. Results gained from these last two methods are more valid because direct measurement is possible with these two methods.

2. MATERIAL and METHOD

The schematic diagram of investigated InGaN/GaN structure is shown in Figure 1. The sample is grown on c-(0001) oriented sapphire(Al_2O_3) substrate by MOCVD technique. Trimethylgallium (TMGa), Trimethylindium (TMIn) and amonia (NH_3) are distorted to Ga, In and N respectively. This distortion is made by Aixtron 200/4 HT-S MOCVD reactor. Before epitaxial growth, substrate is annealed at 1100 ºC for 10 minutes in order to remove oxides and other impurities on its surface. GaN buffer layer is grown on the substrate at 1020 ºC with a thickness of 100 nm to reduce lattice mismatch and to prevent possible cracks that can come out with difference in thermal expansion coefficients. After this operation five GaN template layer is grown at 1030 ºC and under 200 mbar pressure to reduce dislocation density. TMGa, TMIn and amonia are transfered with high temperature hydrogen source to grow InGaN quantum well layer and GaN barrier layer. GaN barrier layer prevents dislocations to be transmitted to neighbouring layers. During growth procedure of the sample all the parameters are kept constant in MOCVD system.

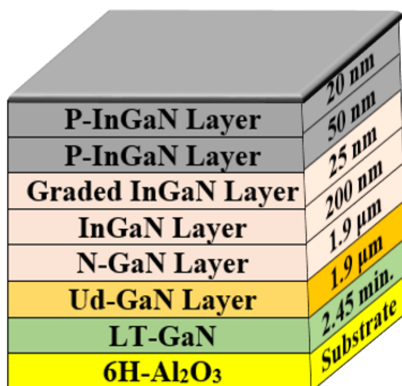

Figure 1. Schematic diagram of InGaN/GaN structure

3. RESULTS &DISCUSSION

XRD data in Figure 2. shows InGaN and GaN peaks. These peaks are gained from w-2θ scan. For the sample chosen, 2θ value for GaN peak is 34.68 degree. According to XRD measurement results crystal size(D) and full width at half maximum(FWHM) value are calculated by the help of a suitable software.

$$D = \frac{k\lambda}{\beta_{(2\theta)}\cos\theta} \tag{1}$$

2θ value is measured with peak center. By using FWHM and θ values crystal size(D) is calculated by equation(1)[11].

In equation(1) D is the crystal size, β is full width at half maximum (FWHM) of the peak, θ is Bragg angle, λ is wavelength of X-ray and k is Bragg coefficient. In this study, k is taken as *0.9* and λ is taken as *0.15405 nm.* As the result of calculation crystal size is found as approximately 15 nm for GaN.

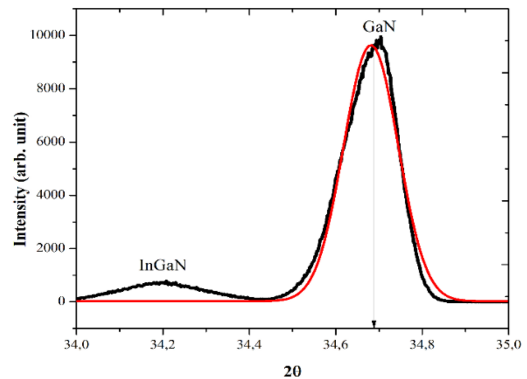

Figure 2. XRD peaks for GaN and InGaN gained from w-2θ scan.

For Raman scattering 785 nm wavelength laser beam is used. By the help of Raman scattering spectra in Figure 3. calibration coefficient can be determined. In Figure 3 shift in peak center of N is used for calculating calibration coefficient. Standart value for N peak center in RRUF database is subtracted from experimental peak center value for N. Calibration coefficient is found as 4.9 cm^{-1}/GPa(S). This result is inserted in equation(2) and number of GaN stacks(N) are found to be used in absorption coefficient calculation by using transmission data.

$$N = \ln\frac{S}{0.15} \tag{2}$$

Here number 0.15 implies ZT of GaN structure. What stack number(N) implies is shown in Figure 4. n are the stack numbers of GaN layer in InGaN/GaN structure. The stack number value gained from equation(2) is approximately 3.5. It may not be an integer because during growth of GaN layer some of the unit hexagonal cell may not be corrected or there may be deformation in some of GaN unit cells near to the surface of the layer. In this study all layers are assumed to be ideal and accepted as they do not contain any defects or impurities.

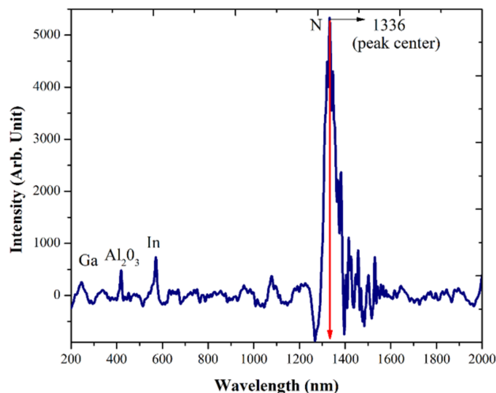

Figure 3. Raman Shifts for InGaN/GaN structure

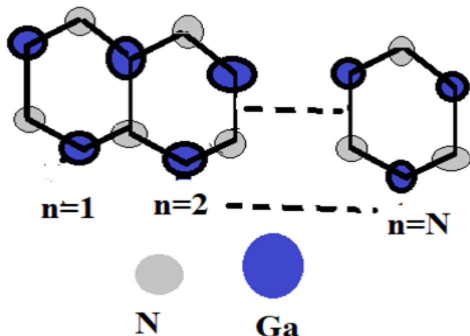

Figure 4. Picture showing stacks of GaN layers in InGaN/GaN structure

By the help of N absorption on GaN layers can be estimated by using equation(3)[12, 13].

$$A = 1 - T = \frac{2N\sigma_0}{1 + n_{GaN}}\sqrt{\frac{\mu_o}{\varepsilon_0}} \tag{3}$$

In equation(3) T is coefficient for transmission, N is number of GaN stacks and n_{GaN} is the refractive index of GaN. μ_o and ε_o are magnetic and dielectric permitivity coefficients respectively. σ_o is the interband conductivity. After calculations A can be written as 0,087N. according to this last equation absorption coefficient is found as 0,3045.

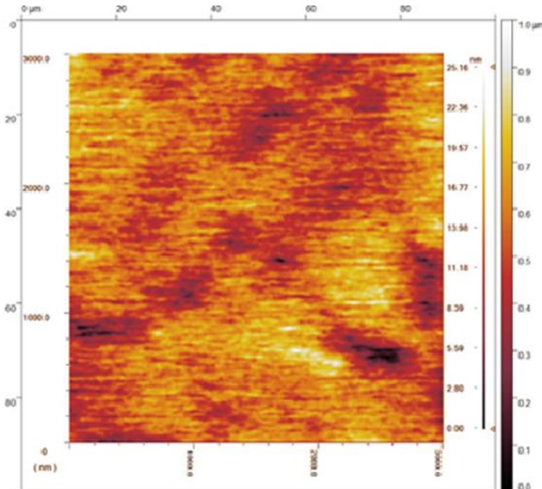

Figure 5. AFM image of sample

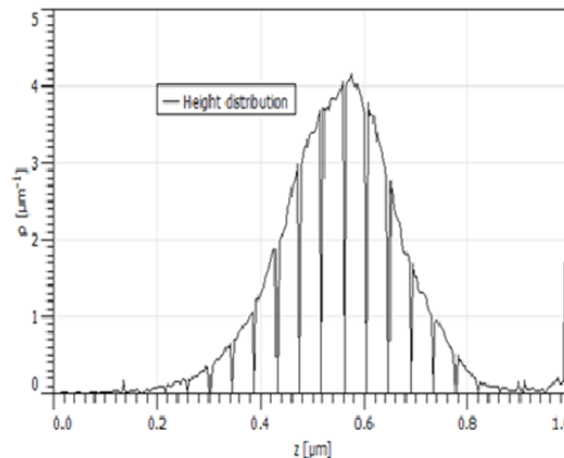

Figure 6. Height distribution along suface

For accurately determining thickness of the samples AFM and SEM images are employed. Surface morphology of InGaN/GaN structure grown on sapphire substrate is investigated by means of AFM technique[14]. 1x1 μm^2 2D image of surface of the sample is given in Figure 5. By the help of a convenient software and using this image thickness of the sample can be determined very sensitively. Plot in Figure 6 shows thickness distribution versus height of 2D plane. As can be seen in Figure 6 thickness distribution (z) is condensed in the range of 0.45-0.65 µm. Also RMS(root mean square) value is gained as 2.97 nm from AFM image. This value implements how rough the surface of the sample is.

SEM images can exactly give the value of thickness because it measures the quantity directly[15]. As shown in Figure 7. Total thickness of the sample is measured as 318µm. This result is in

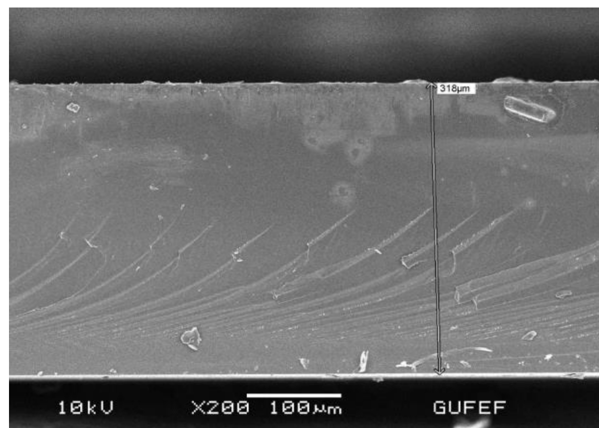

Figure 7. SEM image of cross section of the sample.

good accordance with the determined value from AFM. In Figure 7, 200 times magnified image of cross section of the sample can be seen. The thickness value is gained by the software of the device not by an extra software[16].

4. CONCLUSION

In this study structural, optical and morphological properties of $InGaN/GaN/Al_2O_3$ structure, grown by MOCVD, is investigated by the help of XRD, Raman, AFM and SEM characterisations. In XRD technique Scherrer method is employed to estimate crystal size of GaN layers. Crystal size is determined as 15 nm from Scherrer method. After determining calibration coefficient as 4.9 cm^{-1}/GPa from Raman spectra number of stacks (N) are found around 3.5 by using the related formula. By using N, an optical property, absorption coefficient of GaN layers are determined as 0.3045. Thickness of the sample is estimated from AFM and SEM images. These two images are good at determining thickness accurately because they use direct measurement technique. By using a special software for 2D AFM image thickness distribution of the sample is found in 4.5-6.5 µm range. SEM measurement gave a result of 318 nm for total thickness which is in good accordance with AFM measurement.

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DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Ahmet Kürşat BİLGİLİ: Wrote the manuscript.

Ömer AKPINAR: Performed the experiments and analyse the results.

Süleyman ÖZÇELİK: Maintained technical and device support

Mustafa Kemal ÖZTÜRK: Maintained technical and device support.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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