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GROWTH AND CHARACTERIZATION OF 4H-SiC BY THERMAL EVAPORATION METHOD

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4H-SiC epitaxial layer was grown on P- type Si (100) substrate by introducing the mixture of Si and C_{60} powder of high purity (99.99%) with weight ratio of 1:1. Source material was evaporated by Mo boat using thermal evaporation method. In this growth, boat was heated by a heater by passing current through 210 A, and increase the temperature of boat up to 1100^0C but keep the temperature of substrate 300^0C fixed. The chamber was evacuated using mechanical and diffusion pump with base pressure $5x10^7$ torr. Different structural and optical characterization techniques were used to characterize the material. XRD of the prepared SiC shows the major phase of SiC was hexagonal as well as the existence of 4H-SiC. The impurities in 4H-SiC epitaxial layers are investigated by PL at low temperature. The 4H-SiC layer was observed at peak of 3.22 eV. Tensor 2700 - FTIR was also performed to confirm the results as predicted by XRD. It shows Si-Si bond peak at 520 cm^{-1} and Si-C bond peak at 750 cm^{-1}. Micro-Raman mapping was also preformed to analyze SiC (LA) mode at 610 cm^{-1} and SiC (TO) mode at 796 cm^{-1} but (TO) mode stress free value of 4H-SiC was observed at 777 cm^{-1}. There are two another peaks also observed at 1300 cm^{-1} and 1600 cm^{-1} corresponding to diamond like carbon and graphitic carbon and these peaks confirm the carbon rich growth of SiC.

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Keywords: P-type Si (100), SiC, Thermal Evaporation Method

1. Introduction

Silicon carbide (SiC) has been known as a semiconductor material with wonderful physical and chemical characteristics. Silicon carbide displays a larger band gap, a higher thermal conductivity, a higher breakdown field, and a higher saturation velocity, compared to usually used silicon. These properties make SiC very stunning for high temperature, high-power and high-frequency electronic devices. Moreover, its positive mechanical properties, for example high elastic modulus and toughness, in blend with its large band gap, make this conductor and outstanding material for electronic devices that can operate at high temperature. Such high-temperature applications contain pressure sensors for internal combustion and jet engines [1]. Also SiC doped with n-type or p-type while diamond cannot. The SiC based Shottky diode and Field Effect Transistors (FETs) could activate under high-temperature, high-voltage, and high-frequency ranges and also have 20 times lesser die size than that of correspondingly rated silicon based devices. Though, SiCs quite immature device fabrication technologies are not yet satisfactorily developed into electronic systems. There have been many methods for the growth of SiC on Si substrate. We achieved growth of 4H-SiC epitaxial layers have been grown on p-type Si

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(100) substrate by thermal evaporation method. In this paper, we study the growth and characterization of 4H-SiC by means of XRD, PL, FTIR and Raman-Spectroscopy. Consequently, the success of technological advances open a new approach for the growth of low cost 4H- SiC based electronic devices.

2. Experimental details

SiC layer was grown on p-type Si (100) substrate by simple evaporation method. The Si substrate was rinsed in methanol, ethanol and deionized (D.I) water and dried by nitrogen gas before loading into chamber. After the cleaning process the substrate was loaded into chamber. The chamber was evacuated using mechanical and diffusion pump with base pressure of $5x10^{-7}$ torr. A mixture of Si and C_{60} powder of high purity (fullerene) having a weight ratio of 1:1 was used as source material and was evaporated by Mo boat. The boat was heated by passing a current with heater. A high current of 210 ampere was used to increase the temperature of boat in the vicinity of 1100^oC. The temperature of substrate was fixed at 300^oC. The distance between substrate and boat was 10 cm and total evaporation time was 3 hours. The structural and optical properties of grown layer was analyzed by, X-Ray diffraction (XRD) with Cuk_α as X-ray source, having wavelength 1.54Å. Photoluminescence spectroscopy (PL) and Raman spectroscopy by Photon system having laser with wavelength 248 nm and Tensor 2700 Fourier Transform Infrared Spectroscopy (FTIR). All measurements were performed at room temperature.

3. Results and discussion

3.1 X-ray diffraction analysis

To determine the polytypes and crystallinity of grown sample, XRD has been performed on it. From the pattern of peak position (θ_B) Full width half maximum (FWHM) represented as B, grain size (t), strain (ε), and dislocation density have been found.

Fig. 1 shows XRD pattern of the grown sample. The structure of 4H-SiC was examined with X-Rays diffractometer by using Cukα radiation with wavelength λ =1.5418 Å .The calculated lattice constant for 4H-SiC epitaxial layer grown on Si (111) is 3.054 Å with 0.8% error due to the presence of strain and the actual value of lattice constant for 4H-SiC epitaxial layer was 3.078 Å has been report in literature [2].

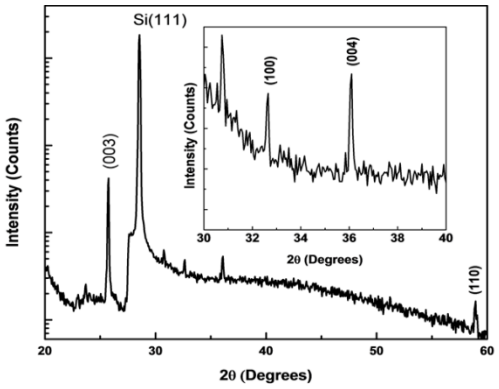

Fig. 1. XRD spectra of 4H-SiC grown on Si (100).

Other peaks at $2\theta = 25.5^o$, $2\theta = 28.5^o$, $2\theta = 30.7^o$, $2\theta = 32.7^o$, $2\theta = 36.1^o$ and $2\theta = 59.0^o$ which attributes to 4H-SiC (003), Si (111), 4H-SiC (100) , 4H-SiC (004), and 4H-SiC (110) respectively, FWHM for 4H-SiC (004) was found 0.68^o reported in literature and this small value of FWHM is in agreement the growing layer was good quality. We observed the diffraction peak for Si (111) plane at $2\theta = 28.4^o$ [3]. The other diffraction peaks for 4H-SiC (100) , 4H-SiC (110),

4H-SiC (003), 4H-SiC (004) planes were observed at 2θ = 32.7°, 2θ = 59°, 2θ = 25.5°, 2θ = 36.1° have been found in the literature [4-6] and it indicates that grown 4H-SiC epitaxial layer is good crystalline structure, which was further confirmed by grain size calculated by Scherer's formula

$$t = 0.94\lambda / B_{(\text{radian or degree})} \times \cos\theta_B \quad (1)$$

The value 2θ = 32.7 ^{0} corresponding to interplanar spacing d_{100} of 0.1425 nm by using Bragg's equation

$$2d\sin\theta = n\lambda \quad (2)$$

The calculated value is 12% less given for 4H-SiC in the joint committee on powder diffraction standards (JCPDS) cards [4]. This is also confirmed the small value of strain and dislocation density is calculated by using formula

$$\varepsilon = B\cos\theta_{B/4} \quad (3)$$

$$\text{Dislocation density} = 1/t^2 \quad (4)$$

The possible reason for this strain is due to 20% lattice mismatch between Si and SiC [7]. The large peak intensity indicates that the removing of native oxides help to increase the crystallinity of SiC [8]. The peak 2θ = 28.5° corresponds to Si substrate [3]. Table enlists angles 2θ, Full width half maximum (B), crystalline size (t), and dislocation density of representative peaks from XRD patterns.

Table. Angles 2θ, Full width half maximum (B), crystalline size (t), and dislocation density of representative peaks from XRD patterns.

Material	2θ (degree)	Plane	B (degree or radians)	t (A^0)	Strain (ε)	Dislocation density (m^{-2})
4H-SiC	25.5°	003	0.70	2.291196	1.57952×10^{-1}	1.90492×10^{19}
4H-SiC	28.5°	111	1.20	1.3726785	2.63645×10^{-1}	5.30716×10^{19}
4H-SiC	32.7°	100	0.79	2.177518	1.66198×10^{-1}	2.10899×10^{19}
4H-SiC	36.1°	004	0.81	2.2118599	1.63362×10^{-1}	2.04402×10^{19}
4H-SiC	59.0°	110	0.88	3.1939386	4.53233×10^{-1}	9.80274×10^{18}

PL was performed to identify the defects present in the samples. The dominating broad peak was observed at 3.22 eV at room temperature indicates the grown 4H-SiC epilayer is of good quality and crystalline structure [9-10]. In these PL spectra, no more peaks were observed as shown in Fig.2 express some impurities present in 4H-SiC due to simple evaporation [11-12].

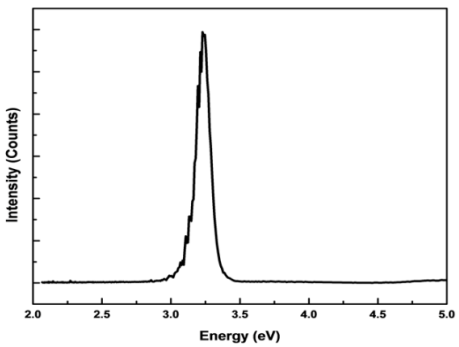

Fig. 2. PL Spectra of 4H-SiC.

3.3. Fourier transform infrared spectroscopy analysis

In this work, We observe Si-C bond at around 750 cm^{-1} and Si- Si vibration bond at 520 cm^{-1} respectively then these two vibration bond showing growing 4H-SiC epilayer of good quality and crystalline structure but peak observed at 795 cm^{-1} not shown in Fig.3 confirmed that the growing epilayer was hexagonal structure [13-15]. FWHM was found from Gaussian fitting and found to be 0.71213^0. This Small value of FWHM indicates good crystallinity confirm the results of XRD.

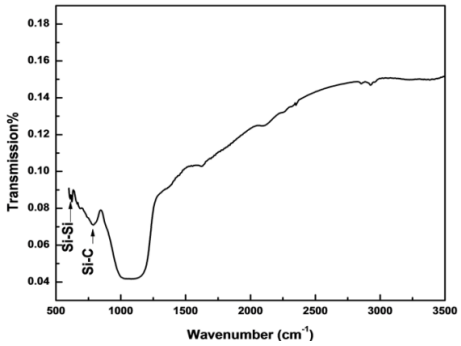

Fig. 3. FTIR of 4H-SiC.

3.4. Raman spectroscopy analysis

The Raman spectrum of epitaxial layer grown at room temperature was observed longitudinal acoustic (LA) phonon mode at 610 cm^{-1}, transverse optical (TO) phonon mode at 796 cm^{-1} and longitudinal optical (LO) phonon mode at 964 cm^{-1} which confirmed that 4H-SiC was a well ordered structure [16-18]. This result further confirmed the 4H-SiC epilayer can be grown successfully with good crystal quality which illustrated in Fig. 4. A typical 4H-SiC Raman signal consist of (TO) and (LO) phonon mode but (TO) Raman shift associated to stress field distribution [19]. The (TO) mode stress free value of 4H-SiC was observed at 777 cm^{-1} [20] and another two peaks were also observed at 1300 $cm^{-1}$and 1600 cm^{-1} corresponding to diamond like carbon and graphitic carbon [21]. These peaks confirmed the growth of SiC.

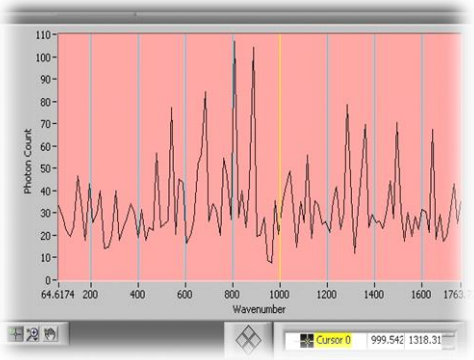

Fig. 4. Raman Spectroscopy of 4H-SiC.

4. Conclusions

The formation of 4H-SiC epitaxial layer was grown on P- type Si (100) substrate was confirmed with XRD, PL, Tensor 2700 FTIR and Raman Spectroscopy. To determine the structural properties of the grown sample XRD is performed. The PL shows that the grown 4C-SiC layer contain some impurities which were observed from their spectra. FTIR was also performed to confirm the results as predicted by XRD. FWHM was found from Gaussian fitting and small

value of FWHM indicates good quality in the grown layer.

Raman spectroscopy is a powerful technique to detect the crystallinity of epitaxial layer. Its peaks are just like finger print confirmation of materials**.** Micro-Raman mapping was performed to analyze the grown layer showing carbon rich growth of SiC. From this study we, concluded that formation of 4H-SiC on Si substrate useful for the fabrication of electronic devices.

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