CVD로 성장된 다결정 3C-SiC 박막의 라만특성

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Raman Scattering Investigation of Polycrystalline 3C-SiC Thin Films Deposited on SiO_2 by APCVD using HMDS

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Abstract : This paper describes the Raman scattering characteristics of polycrystalline (poly) 3C-SiC films, which were deposited on the thermally oxidized Si(100) substrate by the atmosphere pressure chemical vapor deposition (APCVD) method according to growth temperature. TO and LO phonon modes to 2.0m thick poly 3C-SiC deposited at 1180℃ were measured at 794.4 and 965.7 cm^{-1} respectively. From the intensity ratio of $I_{(LO)}/I_{(TO)}$ 1.0 and the broad full width half maximum (FWHM) of TO modes, itcan be elucidated that the crystallinity of 3C-SiC forms polycrystal instead of disordered crystal and the crystal defect is small. At the interface between 3C-SiC and SiO_2, 1122.6 cm^{-1} related to C-O bonding was measured. Here poly 3C-SiC admixes with nanoparticle graphite with the Raman shifts of D and G bands of C-C bonding 1355.8 and 1596.8 cm^{-1}. Using TO mode of 2.0 m thick poly 3C-SiC, the biaxial stress was calculated as 428 MPa.

Key Words : Raman spectra, poly 3C-SiC, Nanoparticle Graphite, SWNT

1. INTRODUCTION

Silicon carbide (SiC) has characteristics of wide bandgap, high breakdown field, high thermal conductivity, hardness for high-power, high-frequency and high temperature devices. Because of these merits, one has attracted the nano/microelectro-mechanical system (N/MEMS) fabrications for harsh environments such as actuator, biosensor, optoelectronic devices, and FET [1]. However, the interface between SiC and Si in high growth temperature leads to high strain due to the differences of lattice (20%) and thermal expansion coefficients (8%). [2]. So, in order to relieve the defects, a buffer layer has been formed by carbonizing Si surface using propane (C_3H_8) gas [6]. Or, buffer layers as SiO_2, Si_3N_4, and -Al_2O_3 (Sapphire) [3].

In addition, Because of these merits : low growth temperature, small residual stress, low cost, poly 3C-SiC is good for fabrication of harsh environmental N/MEMS, for which its mechanical characteristics are required. Therefore, the paper presents the stress and the lattice disorder of poly 3C-SiC deposited on thermally oxidized Si(100) wafers using Longitudinal optical (LO) and transverse optical (TO) phonon modes of Raman scattering, which is precise and non-destructive to analyze the characteristics of semiconductor materials.

2. EXPERIMENTS

According to growth temperature, poly 3C-SiC was deposited on 800 nm thick SiO_2, which was grown on Si(100) substrate, by APCVD using the Hexamethyldisilane ($Si_2(CH_3)_6$, HMDS purity: 99.99%) as a precursor. HMDS is liquid in the temperature region of 15.7 - 37℃ and its flow rate is adjusted by controlling a carrier gas as Ar through a bubbler. Small amount of H_2 gas is added to enhance the dissociation of HMDS.

In order to deposit 3C-SiC, the optimized growth conditions such as HMDS 8sccm, H_2 100sccm, and Ar 2slm were used The growth temperatures of 0.4μm thick 3C-SiC were 1000, 1100, 1180, and 1200℃, respectively and that of 2.0μm was 1180℃. In order to measure Raman spectrum at Room temperature, Renishaw Ramanscope 1000 with resolution of 1cm^{-1} was employed. The system was equipped with an Ar^+ ion laser (λ = 514.5nm). The spot size of incident laser light was 1.5mm or larger and microscope (20 objective) was used to focus on reflected laser light.

3. RESULTS AND DISCUSSION

Generally, the stress-free 3C-SiC single crystal has two strong phonon modes as longitudinal optical (LO) and transverse optical (TO) phonon modes, whose Raman shifts are 972 cm^{-1} and 796 cm^{-1}, respectively. However, LO and TO phonon modes of poly 3C-SiC are different from these of single 3C-SiC because of crystallinity of 3C-SiC. So, to investigate the mechanical characteristics of poly 3C-SiC deposited on the thermally oxidized Si(100) substrate, since its Raman shifts should be compared with them of free-stress 3C-SiC, the Raman shifts of 3C-SiC on growth temperature were first studied. Fig. 1 shows the polarized Raman spectra to various temperatures. They were measured in backscattering geometry using Ar^+ ion laser with 514.5 nm wavelength. The polarized incident light was vertical to SiC(111) plane and the polarized reflected light was collected in the configuration of $x(zz)\bar{x}$. Here X and Z are parallel and vertical to [111] direction of SiC(111) plane respectively.

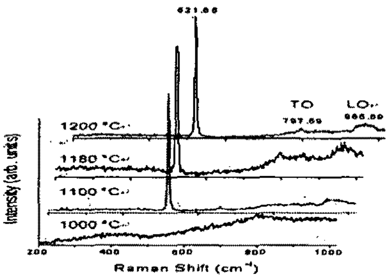

Fig. 1. Raman Shifts to various temperatures. The Raman spectra were measured in the backscattering geometry

$\bar{x}$.

In Fig. 2, another Raman peak 1122.6cm^{-1}, which should be the phonon mode of C-O bonding, appeared. In order to investigate the C-O bonding, when the Raman spectrum of SiO_2/Si was compared with that of Si substrate, there was no different Raman peak. Therefore, the bonding possibilities of 3C-SiC/SiO_2 crystal are Si-Si, Si-C, C-O, and D and G bands of C-C bonding. Additionally, since SiO_2 is amorphous, phonon peak of Si-O bonding may be very weak.

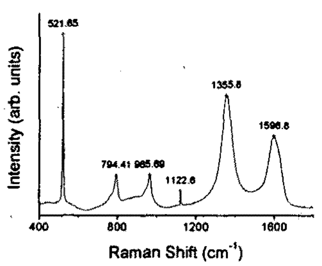

Fig. 2. The Raman spectrum of range 400cm^{-1} and 2000cm^{-1}. Six Raman peaks of poly 3C-SiC deposited at 1180℃ appeared.

4. CONCLUSION

In conclusion, when the Raman spectra of 0.4μm thick 3C-SiC deposited on the thermally oxidized Si(100) substrate were measured according to growth temperature, an activated charcoal not an amorphous 3C-SiC was formed at 1000℃. However, poly 3C-SiC was formed between 1100 C and 1200℃ and its Raman shifts were measured. The Raman peaks related to D and G bands of C-C bonding 1596.8cm^{-1} and 1358.9cm^{-1} should belong to nanoparticle graphite, with which poly 3C-SiC admixed. The Raman peak 1122.6cm^{-1} was measured in 2.0μm thick poly 3C-SiC deposited at 1180℃ and its value should be the phonon mode of C-O bonding. From FWHMs of LO and TO phonon modes, it can be assumed that 3C-SiC grown in 1180℃ is polycrystalline. To obtain physical results such as stress quantitatively, the minimum thickness of 3C-SiC should be at least 2.0μm. It will be able to be applied to MEMS applications for harsh environments.

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