

# Characteristics of polycrystalline 3C-SiC thin films grown on Si wafers for harsh environment microdevices

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## Abstract

This paper presents the growth conditions and characteristics of polycrystalline (poly) 3C-SiC thin films for applications related to harsh environments. The growth of the poly 3C-SiC thin film on the oxidized Si wafer was carried out by (atmospheric pressure chemical vapor deposition) APCVD using hexamethyldisilane (HMDS,  $\text{Si}_2(\text{CH}_3)_6$ ) precursor. To obtain an optimized growth condition, we have performed depositions under various conditions that temperature adjusted from 1000 to 1200 °C, the HMDS flow rate changed from 5 to 9 sccm, and carrier gas (Ar) kept up 500 sccm. Each sample was analyzed by XRD (X-ray diffraction), XPS (X-ray photoelectron spectroscopy) and GDS (glow discharge spectrometer). SEM (scanning electron microscope) was utilized to determine layer density, voids and dislocations of the cross-section. From the results of experiment, we have obtained that temperature and HMDS flow rates of the optimized polycrystalline 3C-SiC thin films growth condition were 1100 °C and 8 sccm, respectively.

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*Keywords:* Carbides; SiC; Grown growth; Gas phase reaction

## 1. Introduction

In recent years, many electronic and mechanical micro-devices that can apply to high temperature and corrosive environments have particularly demanded by fields involved in automotive, aerospace, ships, nuclear power instrumentation, satellites, space exploration and geothermal wells [1]. Therefore, many researchers have concentrated on development of small, light and fast microdevices. Silicon carbide (SiC), among semiconductor materials, is a suitable material for these applications because it has many merits, which are wide bandgap energy, high-power, -voltage, -frequency, -temperature, -thermal conductivity, -break down field and -saturation velocity properties [2,3]. Thus, the polycrystalline (poly) 3C-SiC thin film is very useful to fabricate extreme environment micro-sensors and -actuators applied to vehicle, RF, bio, space and environment fields. The 3C-SiC is classified into single and poly types by crystal directions. Since the growth temperature of the single 3C-SiC is higher than that of the poly 3C-SiC, the single crystalline 3C-SiC has the problems which are residual

stress, cracks and lattice mismatching of interfacial Si/SiC caused by high growth temperature and different thermal expansion coefficients. These problems are serious factors to microdevices fabrication and other technology applications [4]. However, since the growth temperature of poly is lower than that of single crystal, these problems can reduce.

In general, one may use, chemical vapor deposition (CVD) to grow heteroepitaxial SiC thin films with two precursors such as  $\text{SiH}_4$  (or  $\text{SiHCl}_3$ ) and  $\text{C}_3\text{H}_8$ . However, it is difficult to control Si and C ratio and silane gas explosive nature, flammability and toxicity. To overcome these serious problems, a single organo-silane precursor such as tetramethyldisilane (TMS,  $\text{Si}(\text{CH}_3)_4$ ) or hexamethyldisilane (HMDS,  $\text{Si}_2(\text{CH}_3)_6$ ) gas has been used to grow 3C-SiC thin films for safety, ease of handling, low growth temperature and accurate stoichiometry recently.

In this work, heteroepitaxial polycrystalline 3C-SiC thin films grown on the oxidized Si wafers with the single precursor HMDS. Then, the grown 3C-SiC films were analyzed by XRD (X-ray diffraction), GDS (glow discharge spectrometer), XPS (X-ray photoelectron spectroscopy). Finally, the layer density, voids and dislocations of the cross-section of the deposited 3C-SiC films were also evaluated by SEM (scanning electron microscope).

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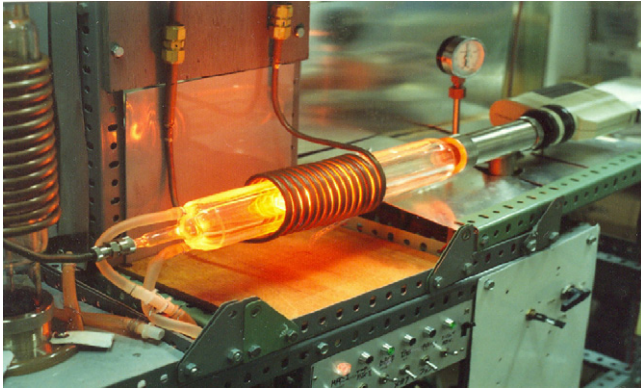


Fig. 1. The reactor tube image of APCVD for the deposition of poly 3C-SiC thin film.

## 2. Experimental procedure

Fig. 1 shows the schematic diagram of APCVD used in this work. The oxide Si substrate is horizontally parallel to gas flow of the center of the reactor tube. For cleaning the reactor tube, Ar purging cycle was performed three times. The graphite susceptor heated by high frequency and ramping up the time (from room temperature to growth temperature) was less than 2 min. The HMDS flow rate was kept up 7 sccm and growth temperature was varied from 1000 to 1200 °C to find an optimal growth temperature. After the optimal growth temperature was defined, the HMDS flow rate was changed from 5 to 9 sccm to investigate the effect of flow rate on SiC film density. Various conditions employed to investigate the effect of growth temperature on the film compositions, bonding structure and crystallinity of 3C-SiC thin film.

XRD patterns were recorded using X'pert APD operated in  $\theta$ - $2\theta$  geometry to determine the crystal structure of the deposited SiC films. Wavenumber has chosen 400–1000  $\text{cm}^{-1}$  range to avoid the Si-O ( $1100 \text{ cm}^{-1}$ ) bonding peak float. Crystallinity of the polycrystalline 3C-SiC was characterized by XRD measurements. XPS used to determine the chemical nature and elemental compositions of the deposit films. The XPS analyses were performed using ESCALAB 250 XPS spectrometer. Surface and cross-section observed by SEM (Jeol

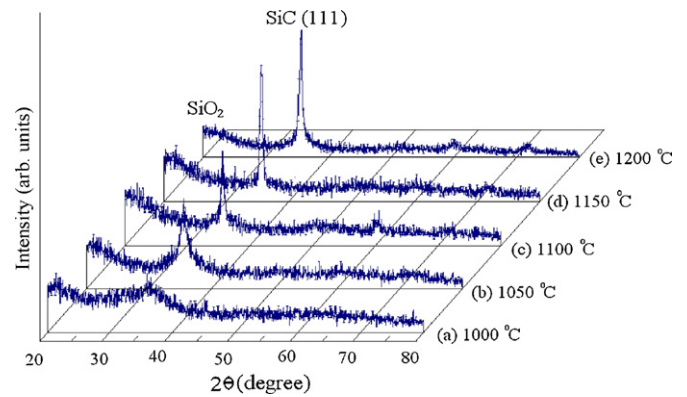


Fig. 2. The XRD spectra of the poly 3C-SiC thin films grown on the oxidized Si substrate according to temperature.

JSM-820). GDS investigates the depth profiling for component analysis by thickness change.

## 3. Results and discussion

Fig. 2 shows the crystallinities of the polycrystalline 3C-SiC deposited on the oxidized Si substrates. By scattering effect of crystal structure, the polycrystalline 3C-SiC and the Si peaks were corresponding to  $2\theta = 36^\circ$  and  $69^\circ$ , respectively. In this figure, the Si peak corresponding to  $2\theta = 69^\circ$  was removed for reducing the errors caused by the difference of the intensity peaks. The SiC (1 1 1) peak was observed at  $2\theta = 35.6^\circ$ . This result was consistent with previously reported data [5]. This peak shows the polycrystalline SiC (1 1 1) thin films were heteroepitaxially grown on the oxidized Si (1 0 0) substrate with the single HMDS precursor. By increasing growth temperature, shape and intensity of peaks were sharper and higher, respectively. These results clearly indicated that the SiC crystal structure had improved as increasing temperature.

Fig. 3(a) and (b) shows the SEM images of the crystalline 3C-SiC grown at 1100 °C, in which the HMDS flow rate was 5 and 8 sccm, respectively. The HMDS flow rate was adjusted for confiding in 3C-SiC film quality. In Fig. 3(a), there are some voids in polycrystalline 3C-SiC film, but not appears in Fig. 3(b). These results may be considered that 5 sccm flow rate

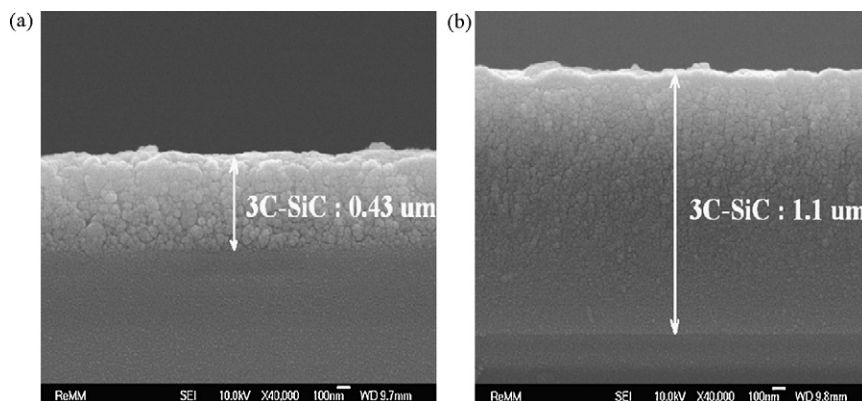


Fig. 3. SEM images of the grown poly 3C-SiC in different flow rates. Cross-section: (a) 5 sccm, (b) 8 sccm.

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