19-3 The Growth of Cubic SiC Films by OMCVD Using Single Molecular Precursors

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1. Introduction

Silicon carbide (SiC) is an interesting semiconductor material with electronic and optoelectronic applications due to its excellent thermal stability and wide band gap. Cubic SiC has a relatively narrower band gap of 2.23 eV than hexagonal SiC (2.93 eV) at room temperature, and is considered to be a good candidate material for transistors operating at high temperatures.

SiC films are mostly grown by chemical vapor deposition above 1,200 ℃ using separate sources for silicon and carbon, such as silanes or chlorosilanes and various hydrocarbons. It is desirable to grow the SiC films on silicon substrates, however, high growth temperature results in high tensile stress and lattice defects in the SiC films because of the differences in lattice constants and thermal expansion coefficients between silicon carbide and silicon. Such defects and strains in heteroepitaxial films degrade the carrier mobilities and increase junction leakage currents.

In addition to this temperature problem, synthesis of SiC device structures by CVD requires precise control of the silicon to carbon ratio. The use of separate sources for silicon and carbon in the growth of SiC films may result in some deviations from stoichiometry in the films, leading to point defects or inclusions and precipitates. Single precursors of SiC offer the advantage of such control, and perhaps lower growth temperatures as well.

In this study, therefore, the growth of cubic SiC films on Si(100) surfaces and WC cutting tool inserts has been carried out at the low temperature of 830 ℃ using new single molecular precursors, dimethylisopropylsilane and tetramethylsilane.

2. Experimental

The (100) oriented *p*-type Si substrates (thickness: 600 μm, resistivity: 5.0 ~ 8.0 Ω cm) and WC cutting tool inserts were degreased in an ultrasonic cleaner, just prior to deposition, with trichloroethylene, followed by rinsing with acetone, deionized water, and methanol, and dipping in a 20 % HF solution to remove the surface oxide layers. Using a simple CVD apparatus, dimethylisopropylsilane and tetramethylsilane which are single molecular precursors containing both silicon and carbon atoms were employed to deposit SiC on Si(100) substrates and WC cutting tool inserts. The deposition temperature was adjusted to the desired value in the range 700 ~ 1,000 ℃ and the precursors were admitted into the deposition chamber. The substrate temperatures were controlled either by resistive heating or by RF heating and measured by an optical pyrometer. The deposition pressures, measured by a Convectron gauge during deposition, were adjusted between 25 and 55 Pa, and the deposition was carried out for 4 to 6 hours. The films produced were characterized by XPS, XRD, and SEM. For XPS work, the Al $K\alpha_{1,2}$ X-ray (1486.6 eV) was used.

3. Results and Discussion

Fig. 1 shows the X-ray diffraction pattern of the SiC film deposited on a Si(100) surface at 960 ℃. The figure clearly indicates that the film consists of cubic SiC, since the characteristic peaks due to cubic SiC appear at 2θ = 36^0, 60^0, and 72^0 which are ascribed to SiC(111), SiC(220), and SiC(311), respectively. There is no other detectable phase in the diffraction pattern. The film was examined by scanning electron microscopy. Fig. 2 shows a surface of cubic SiC consisting of fine grains mostly less than 0.3 µm in size. The film thicknesses and growth rates were measured from the SEM cross sections. They are 1 ~ 3 µm and 0.2 ~ 0.5 µm/hr, respectively, and they increase with deposition temperature and pressure.

Fig. 3 shows the X-ray photoelectron survey spectrum of the cubic SiC film deposited on a Si(100) surface at 960 ℃ using dimethylisopropylsilane. The survey spectrum clearly shows the photoelecton peaks of Si 2*s*, Si 2*p*, and C 1*s*, and C(*KVV*) Auger signals indicating formation of silicon carbide film. Besides these relevant peaks, there also appear O 1*s* photoelectron peak and O(*KVV*) Auger peaks. Oxygen invariably shows up in the spectra of almost all the silicon carbide films, and can be attributed to surface contamination of the newly formed films by air and/or moisture during sample transfer.

Fig. 4 shows the X-ray diffraction pattern of the SiC film deposited on a WC cutting tool insert using tetramethylsilane as precursor at 830 ℃. The result indicates that the film is polycrystalline, because the characteristic peaks due to cubic SiC appear at 2θ = 36^0, 60^0, and 72^0, etc. However, the figure shows more complex peaks than Fig. 1.

4. Conclusions

We have grown cubic SiC films on Si(100) substrates and WC cutting tool inserts in the range of 830 ~ 960 ℃ by low pressure organometallic chemical vapor deposition using dimethylisopropylsilane and tetramethylsilane as single molecular precursors. This growth temperature is much lower than previously reported values of SiC deposition, and it is the first report of cubic SiC films formed from these precursors. At lower temperatures amorphous SiC films are obtained.

The films produced by CVD were characterized by XPS, XRD, and SEM, and the film thickness and growth rate were measured from SEM cross sections. Judging from the granular structures of the films, it is thought that the deposition temperature should be higher to obtain smooth planar surfaces.

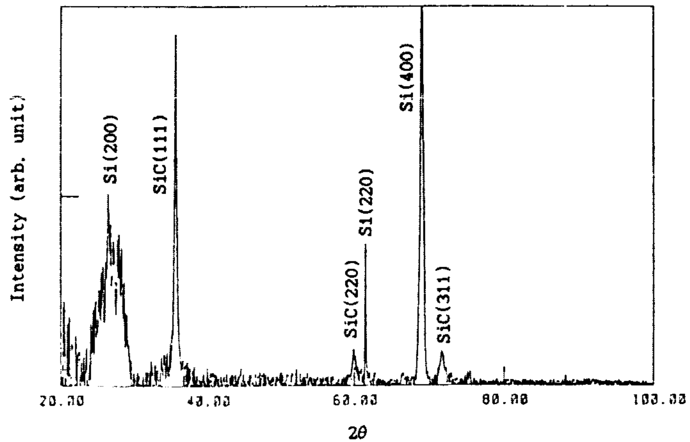

Fig. 1. X-ray diffraction pattern of the film deposited using dimethylisopropylsilane at 960 ℃ on carbonized Si(100) substrate.

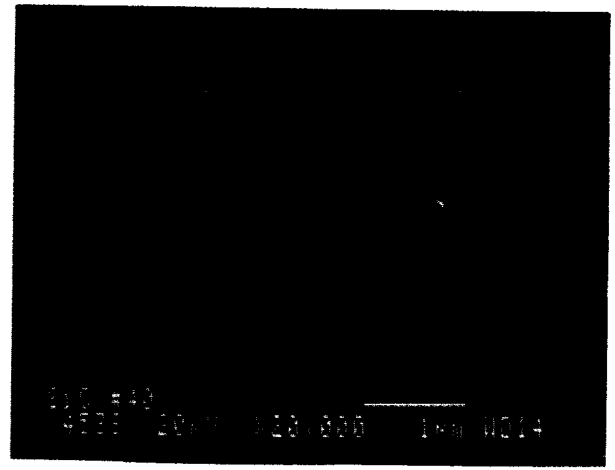

Fig. 2. SEM image of the film deposited using dimethylisopropylsilane at 960 ℃ on carbonized Si(100) substrate.

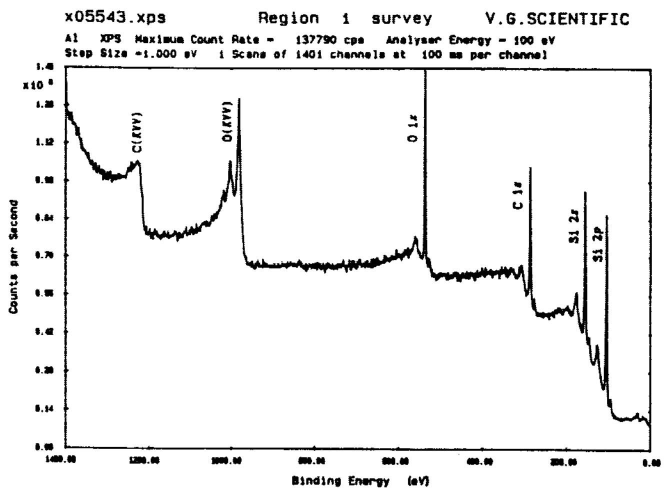

Fig. 3. X-ray photoelectron survey spectrum of the film deposited using dimethylisopropylsilane at 960 ℃ on carbonized Si(100) substrate.

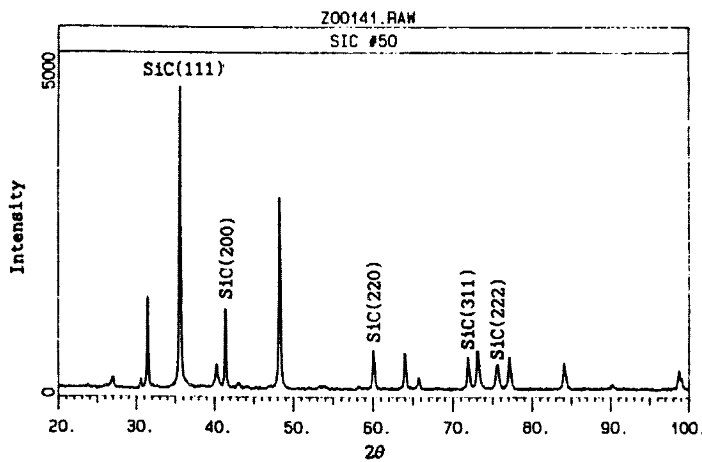

Fig. 4. X-ray diffraction pattern of the film deposited using tetramethylsilane at 830 ℃ on a WC cutting tool insert.