CVD로 in-situ 도핑된 다결정 3C-SiC 박막의 전기적 특성

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Electrical characteristics of in-situ doped polycrystalline 3C-SiC thin films grown by CVD

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Abstract : This paper describes the electrical properties of polycrystalline (poly) 3C-SiC thin films with different nitrogen doping concentrations. The in-situ-doped poly 3C-SiC thin films were deposited by using atmospheric-pressure chemical vapor deposition (APCVD) at 1200°C with hexamethyldisilane (HMDS: $Si_2(CH_3)_6$) as a single precursor and 0 ~ 100 sccm of N_2 as the dopant source gas. The peaks of the SiC (111) and the Si-C bonding were observed for the poly 3C-SiC thin films grown on SiO_2/Si substrates by using X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FT-IR) analyses, respectively. The resistivity of the poly 3C-SiC thin films decreased from 8.35 Ω·cm for N_2 of 0 sccm to 0.014 Ω·cm with N_2 of 100 sccm. The carrier concentration of the poly 3C-SiC films increased with doping from 3.0819×10^{17} to 2.2994×10^{19} cm^{-3},and their electronic mobilities increased from 2.433 to 29.299 cm^2/V·S.

Key Words : Poly 3C-SiC, In- situ doping, Electrical properties

1. INTRODUCTION

In recent years, electronic and mechanical microdevices that can function at high temperatures and in corrosive environments have been sought, particularly by the automotive, aerospace, and shipping industries, as well as by companies that manufacture nuclear power instrumentation, satellites, space exploration equipment,and geothermal wells [1]. Among semiconductor materials, 3C-SiC is a suitable material for these applications because it has the following properties: wide bandgap energy, high power, high voltage, high frequency, high temperature, high thermal conductivity, high breakdown field, and high-saturation velocity [2]. Moreover, SiC has attracted substantial attention for use as protective coatings on Si structures and microcantilevers due to its high hardness, wear resistance, and thermal stability.

In this research, poly 3C-SiC thin films were deposited by using atmospheric pressure chemical vapor deposition (APCVD) with different *in-situ* doping concentrations. The physical properties of poly 3C-SiC were investigated using X-ray diffraction (XRD), Fourier transform-infrared spectroscopy (FT-IR), and scanning electron microscopy (SEM). The electrical properties of poly 3C-SiC were also evaluated by using a Hall measurement system.

2. EXPERIMENTS

The oxide Si substrate at the center of the reactor tube was horizontally parallel to the gas flow. After 5 slm of Ar (mixed with 1 slm of H_2) carrier gas had been injected into the reactor tube, an Ar purging cycle was performed three times to clean the reactor tube. The graphite susceptor was heated by using an RF coil, and the ramping-up time for reaching the growth temperature was less than 2 min [8]. The temperature holding time was 2~3 min to stabilize the temperature and to ventilate the residual precursor. At a stable temperature, HMDS (1 sccm) and N_2 gas were flowed into the reaction tube for *in-situ* doping. The growth time and temperature were 30 min and 1200 °C, respectively.

3. RESULTS AND DISCUSSION

Fig. 1 compares the XRD spectra of poly 3C-SiC thin films deposited using N_2 flow rates of 0 sccm, 10 sccm, 30 sccm, and 100 sccm. The shape of the SiC (111) peak changed as a function of the N_2 flow rate, and its full width at half maximum (FWHM) became wider with increasing N_2 flow rate. Notably, the SiC(111) peak disappeared at N_2 flow rate of 100 sccm. These results indicate that the SiC lattice structure was not normally formed. Because the covalent radius of N (0.70Å) is smaller those that of C (0.77Å) and Si (1.17Å), the substitutional incorporation of N_2 into SiC results in a shrinkage of the SiC lattice.

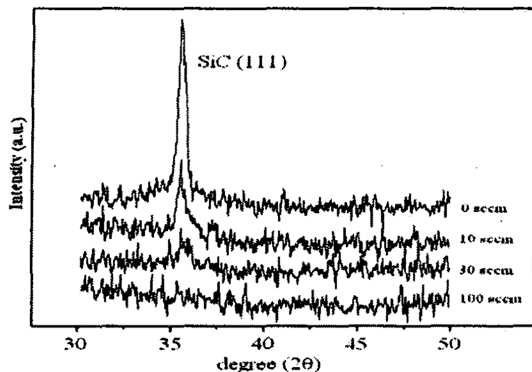

Fig. 1. XRD spectra of poly 3C-SiC thin films for various N_2 *in-situ* doping ratios.

Fig. 2 presents the resistivity as a function of the N_2 gas flow. The resistivity was obtained by using four-point probes along with the film thickness measurements. The resistivity at a flow rate of 0 sccm N_2 is approximately 10 Ω·cm. With increasing N_2 flow rate, the resistivity decreases to a limiting value as shown in Fig. 3. It has been shown that this limiting resistivity depends on the dopant source. In this work, the initial variation of the resistivity dropped suddenly with increasing N_2 flow rate, and then gradually stabilized. The resistivity of the poly 3C-SiC thin films at N_2 flow rate of 0 sccm was 10 Ω·cm, and it decreased to 0.01 Ω·cm at N_2 flow rate of 100 sccm.

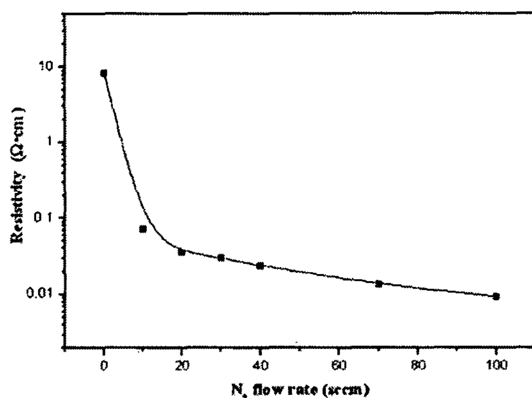

Fig. 2. Various in the resistivity of poly 3C-SiC thin films with the N_2 *in-situ* doping ratio.

The mobility variations of poly 3C-SiC thin films were measured and are depicted in Fig. 3. The mobility of each sample increased with increasing N_2 flow rate, regardless of the carrier concentration. The mobility of the poly 3C-SiC thin films at a flow rate of 0 sccm N_2 was 2.433 $cm^2/V{\cdot}S$ and increased to 29.299 $cm^2/V{\cdot}S$ at a N_2 flow rate of 100 sccm.

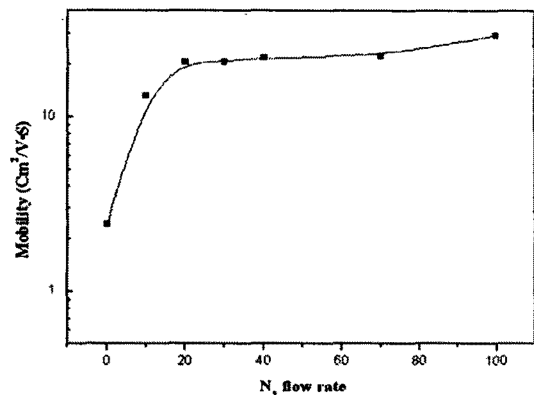

Fig. 3. Variations in the electronic mobility of poly 3C-SiC thin films with the N_2 *in-situ* doping ratio.

4. CONCLUSIONS

In this work, nitrogen-doped (n-type) polycrystalline 3C-SiC thin films were deposited by using APCVD with an HMDS single precursor, and their electrical properties were studied for various doping concentrations. The carrier concentration and mobility increased suddenly with increasing N_2 flow rate, and then gradually stabilized. The carrier concentration of poly 3C-SiC films increased with doping from 3.0819 x 10^{17} to 2.2994 x 10^{19} cm^{-3}, and the electronic mobility increased from 2.433 to 29.299 $cm^2/V{\cdot}S$, respectively. Therefore, the growth of 3C-SiC thin filmsis suitable for micro/nano electronic mechanical systems because the electrical properties of these thin films can be controlled by using N doping.

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