Electrical properties of 3C-SiC grown on Si by CVD method using $Si_2(CH_3)_6$

Y.Masuda,Y.Chen, H.Matsuura*[1], H.Harima*[2], and S.Nishino
Kyoto Institute of Technology., Osaka Electro-Communication Univ.*[1], Osaka Univ.*[2]
Matsugasaki,Sakyo,Kyoto 606-8585,Japan
Hatsu-cho 18-8, Neyagawa, Osaka 572-8530, Japan*[1]
Yamadagaoka 2-1, Suita, Osaka 565-0871, Japan*[2]
TEL: +81-75-724-7415,FAX: +81-75-724-7400
E-mail: nishino@ipc.kit.ac.jp

3C-SiC has been widely grown on Si substrates by CVD methods using $SiH_4+C_3H_8+H_2$ system for future high-power and high-frequency electronic devices. However , from the view point of safety, it is desired to grow epilayer using the other Si source materials, because SiH_4 is so flammable material. We tried to grow 3C-SiC using HMDS : $Si_2(CH_3)_6$ as Si and C source material, and investigated the electrical properties of the epilayers. In this work, we report temperature dependencies of carrier concentration and Hall mobility of the 3C-SiC epilayers. Electrical properties obtained from LO-phonon-plasmon-coupled modes of Raman spectra were compared to those obtained by Hall measurements.

Single crystal of non-doped 3C-SiC films were heteroepitaxially grown on Si (100) substrates by atmospheric pressure CVD using $Si_2(CH_3)_6+H_2$ system at 1350℃. The growth rate was about 4.3μm/h and thicknesses of the epilayers were between 7 and 32μm. Carrier concentration and the mobility of the epilayers were measured by the van der Pauw method at temperatures between 85 and 500K. Epilayers were cut into pieces of $5\times5mm^2$. Before the measurements, Si substrates were removed by chemical etching. Ohmic contacts were made by Al metal of about 0.5mm diameter deposited on four corners of the sample. A magnetic field of 5kG was used for all the measurement temperatures.

All the unintentionally doped epilayers showed n-type conduction, and was a lightly yellow- colored transparent films. Carrier concentration [n] was $1.3\text{-}5\times10^{17}cm^{-3}$, and the mobility [$\mu_H$] was $200\text{-}450cm^2/Vs$ at room temperature. Carrier concentration decreased, and the mobility increased as the SiC film thickness increased. The surface morphology of grown layers with various thicknesses was observed by use of atomic force microscope(AFM). Antiphase domains(APD's) became broader and concentration of antiphase boundaries (APB's) was reduced as the SiC film thickness increased. Therefore, we think that improvement of electrical properties was caused by decrease of defects such as APD's and APB's. Figure 1 and 2 show temperature dependencies of carrier concentration and the mobility, respectively. The carrier concentration decreases monotonically with decreasing temperature, and the mobility varies as $\mu_H \sim T^{-1.5}$ above room temperature. To estimate concentration and energy levels of several kinds of dopants, we evaluated using the relation of the product of n(T) and 1/kT. By measuring the temperature dependence of this product, each energy level is estimated.[1] The calculated carrier concentration curve is also shown in Fig.1. We obtained some different energy levels of donors in non-doped epilayers. The activation energy [E_{D1}] of 45-54meV agrees with the ionization energy(53.6±0.5meV) of the nitrogen donor reported from photoluminescence measurements.[2] On the other hand, we obtained some energy levels that were not reported, and we detected the donor ionization level with energy below 40meV. The origin of these donors is under analysis.

Figure 3 show the Raman spectra of the TO and LO phonon modes obtained from the samples used for Hall measurements and a stress-free bulk 3C-SiC, respectively. Therefore, the Raman spectra of the LO mode did not coincide with the theoretical curve obtained by Hall measurements. The stress and strain are not considered in the theoretical curve.[3] The TO and LO phonon peaks shifted to higher frequency as the SiC film thickness increased. This means that the tensile stress in films decreases gradually. In other words, the stresses and strains still remain in the SiC film thicker than 8.3 μm. We hope to explore in detail about the stresses and strains remained in the film by considering results of Hall measurements and Raman measurements.

We investigate Si/C ratio-dependence of the electrical property by adding C_3H_8 as C source for the growth of epilayer.

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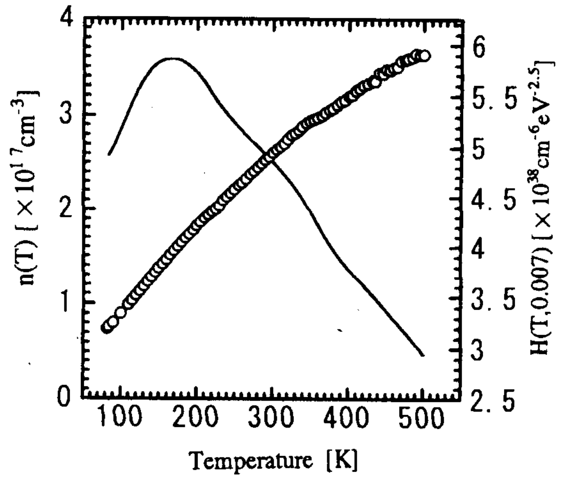


Fig.1 Temperature dependencies of carrier concentration [n]. The points are experimental results and solid line is calculated [$H(T,E_{ref})$] using the relation of the product of n(T) and 1/kT

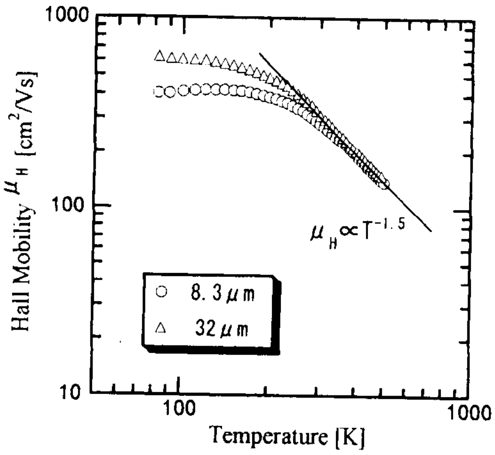
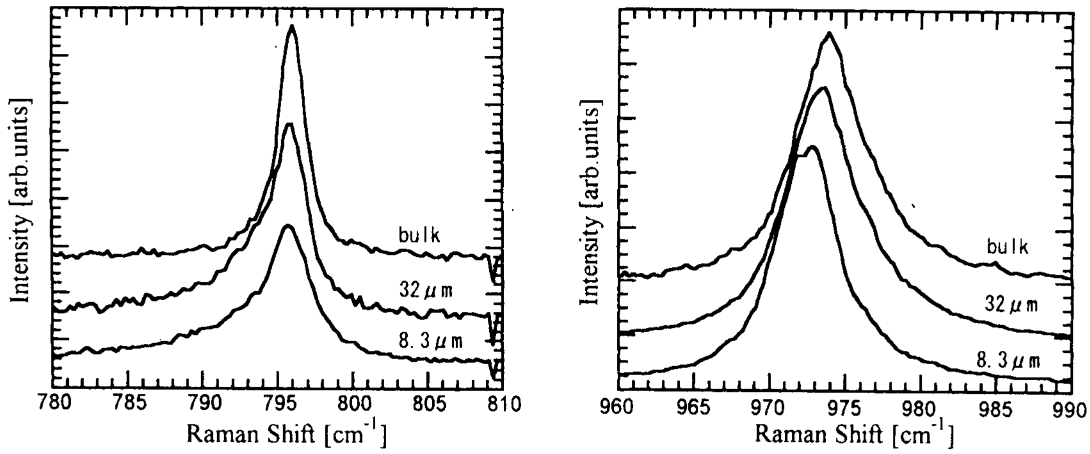


Fig.2 temperature dependencies of Hall mobility



(a)TO phonon

(b)LO phonon

Fig.3 The thickness dependent Raman spectra of (a) TO and (b) LO phonons