Homoepitaxial Growth of Iron Doped 4H-SiC by Bis-Trimethylsilylmethane and Ferrocene Precursors for Semi-Insulating SiC

Ho Keun Song, Jae Kyeong Jeong, Soo Gil Kim, Myung
Yoon Um, Hoon Joo Na, Sang Yong Jung and
Hyeong Joon Kim

School of Materials Science and Engineering,
Seoul National University, Seoul 151-742, Korea

Among the wide band-gap semiconductors, silicon carbide is the most promising material for high power and high frequency devices due to its high breakdown field and high thermal conductivity. In spite of recent progress in SiC epitaxial and bulk crystal growth technique, background doping concentration of epitaxial layer is still relatively high and growth of high reisistivity SiC substrate is difficult. Because semi-insulating SiC is the foundation of many SiC-based devices, semi-insulating SiC growth is the key technique for application of SiC on many electrical devices. So we tried a homoepitaxial growth of iron doped 4H-SiC for semi-insulating SiC epilayer.

In this research, SiC epitaxial films were grown by MOCVD using BTMSM (bis-trimethylsilylmethane) [1,2] and we used ferrocene (Cp_2Fe, bis(cyclopentadienyl)iron) precursors for in-situ iron doping. Ferrocene was also used in other semiconductor materials, such as GaN and InP for semi-insulating properties due to its tendency of making deep levels in band gap like other transient metals [3,4].

4H-SiC homoepitaxial films were grown on the 8^o off axis 4H-SiC substrate acquired from Cree Inc., and the n-type, p-type, and semi-insulating substrates were used. The epitaxial layer was deposited in a cold-wall CVD reactor, where the substrate were heated using a SiC coated graphite susceptor by radio-frequency induction heating. The growth temperature was fixed to 1370℃ and the H_2 gas was used for the BTMSM source bubbling. In-situ iron doping was carried by H_2 bubbling of ferrocene metal organic source in a bubbler. For controlling of Fe doping concentration into SiC epilayers, the carrier gas flow rate and the temperature of ferrocene bubbler were varied. For characterization of electrical properties of epilayer, schottky contacts were formed by evaporation of Ni through a shadow mask and ohmic contact was formed on the backside of the substrate by Ni evaporation and annealing.

Fig. 1 shows ferrocene partial pressure dependence of the 4H-SiC (0004) FWHM of rocking curves in DCD mode for SiC epilayer before and after the epitaxial growth. In spite of iron addition, degradation of the crystal quality was relatively small, as shown Fig. 1. But degradation of crystal quality was shown in high doping concentration.

Fig. 2 shows the background doping concentration of SiC epilayer shown in Fig.1 and we can see the decreasing tendency of background doping concentration with added iron contents increasing. Residual n-type background dopants were expected nitrogen and concentration of nitrogen donor was profiled by C-V measurements. As shown in Fig. 2, dopant Fe atoms were supposed to act as compensation center of background nitrogen donors.

In summary, high resistivity SiC epilayer with background doping concentration of mid $10^{13}/cm^3$ was achieved by Fe doping. The effect of iron doping on crystal quality was relatively small. But we can expect that in higher iron doping concentration, crystallographic degradation will be happened. From the above results, iron doping on SiC epilayer could be applied to semi-insulating SiC.

Acknowledgements

This work was supported by SiC Device Development Program under Ministry of Commerce, Industry, and Energy republic of Korea through Inter-University Semiconductor Center.

References

[1] Wook Bang and Hyeong Joon Kim, Appl. Phys. Lett. 69(26), 4053, 1996.
[2] Jae Kyeong Jeong and Hyeong Joon Kim, J. Elctrochem. Soc. 150(2), G90, 2003.
[3] Sten Heikman, Stacia Keller, Steven P. DenBaars and Umesh K. Mishra, Appl. Phys. Lett. 81, 439, 2002.
[4] J. A. Long, V. G. Riggs and W. D. Johnston, Jr., J. Crystal Growth 69, 10, 1984.

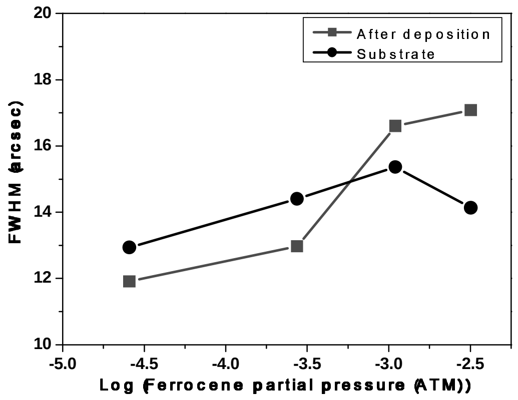

Fig. 1. Ferrocene partial pressure dependence of the 4H-SiC (0004) FWHM rocking curve in DCD mode.

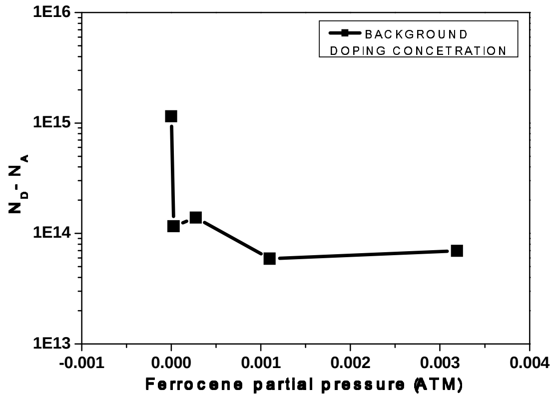

Fig. 2. Background doping concentration of iron doped SiC epilayer.