Surface Preparation for 3C-SiC Growth on 3C- and 6H-SiC by In Situ Etching in HCl

Janessa Smith, Mechanical Engineering, University of Delaware
NNIN REU Site: Howard Nanoscale Science & Engineering Facility, Howard University

NNIN REU Principal Investigator: Dr. Gary Harris,
Director, Howard Nanoscale Science & Engineering Facility, Howard University
NNIN REU Mentor: Crawford Taylor, HNF, Howard University
Contact: draupadi@udel.edu, gharris@msrce.howard.edu

Abstract:

Large-area, device-quality thin active layers of cubic silicon carbide (3C-SiC) are desirable for semiconductor applications but are difficult to manufacture. The only method of manufacture is chemical vapor deposition (CVD) upon a substrate, known as epitaxial growth. The surface quality of the substrate is critical to the growth of a high quality epilayer. In this project, we investigate hydrochloric (HCl) gas as an in situ etchant to improve the surface morphology before growth in a CVD reactor. We determined etch rates for HCl on hexagonal silicon carbide (6H-SiC), and found that the etching resulted in a terraced surface, as reported in literature. After the etching, growth of 3C-SiC was attempted on substrates of 3C- and 6H-SiC. The effect of the in situ HCl etching upon the quality of the SiC epilayer could not be determined from the results.

Introduction:

SiC has many desirable characteristics that make it an excellent material for semiconductor applications. It can withstand high temperatures, high radiation and harsh environmental conditions and has excellent electronic qualities, such as high thermal conductivity, a wide band gap, large saturation drift velocity, and a large breakdown field. Unfortunately, because SiC sublimes, it is difficult to manufacture. It cannot be melted and then cooled into a crystal. In addition, SiC is susceptible to a high density of crystal defects by any manufacturing method. Due to these factors SiC technology, although promising, is still relatively immature.

Commercially available bulk 3C-SiC has been manufactured by heteroepitaxial growth using chemical vapor deposition. Though 4H- and 6H-SiC can be produced by more convenient methods, 3C-SiC has at least two advantages over the other polytypes. It lacks micropipe crystal defects, which is the bane of the other polytypes, and it is better for CMOS applications because the hole mobility is almost equal to the electron mobility.

While many factors contribute to high quality growth of SiC, we will be considering the surface morphology of the substrate. Other literature has shown that an in situ HCl etch on 6H-SiC will create a smooth surface with periodic microsteps [4]. These microsteps have specific heights determined by the lattice size of the crystals and theoretically would encourage more orderly deposition with fewer crystal defects. An in situ HCl etch on 3C-SiC would theoretically result in a smoother surface. The goal of this project was to obtain an etch rate for HCl on 6H- and 3C-SiC and evaluate the etchant's effectiveness in producing smooth epilayers during subsequent growth on 6H- and 3C-SiC substrates.

Procedure:

All etching and growth took place in a horizontal cold-wall CVD reactor. Because etch heights could only be measured using a removable mask that would

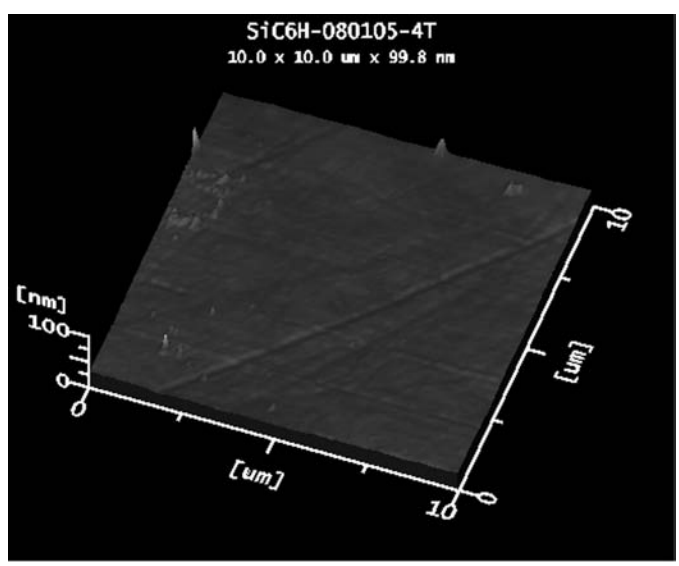

Figure 1: 6H-SiC surface before etching.

allow the "step" between the etched and unetched area to be measured, we used SiO_2 as a partial mask on 6H-SiC samples. Typically, 180 nm of SiO_2 was grown on <100> 6H-SiC. Using this mask necessitated limiting the temperature to less than 1250°C to prevent the complete degradation of the mask by the carrier gas. For all trials, the carrier gas of H_2 was 10 slpm, and the chamber pressure was 200 Torr. The HCl concentration varied between 30 and 120 sccm, the temperature varied between 1050-1200°C, and the time varied between 15-45 minutes.

Growth on 3C- and 6H-SiC occurred in the chamber after an HCl etch of 30 minutes at 120 sccm and 1200°C. After a short lag time to ramp up the temperature, the growth took place at 1300°C for 30 minutes. The silicon to carbon ratio in the gas phase was varied from 1 to 0.85.

Results:

We only obtained measurable etching results at a temperature of 1200°C. Under varying HCl concentrations and times, we obtained a maximum etch depth of about 100Å. Etch depths for all samples were measured using a surface profilometer. There was no discernible difference between the etch depth using 60 or 120 sccm of HCl. The effect of the time on the etch depth was inconclusive. Qualitatively, the HCl-etched material had a terraced surface, with pits and scratches that were not removed but exaggerated by selective etching.

The growth of SiC on the SiC substrates tended to be polycrystalline. We failed to obtain an epilayer of 3C-SiC on the 6H substrate.

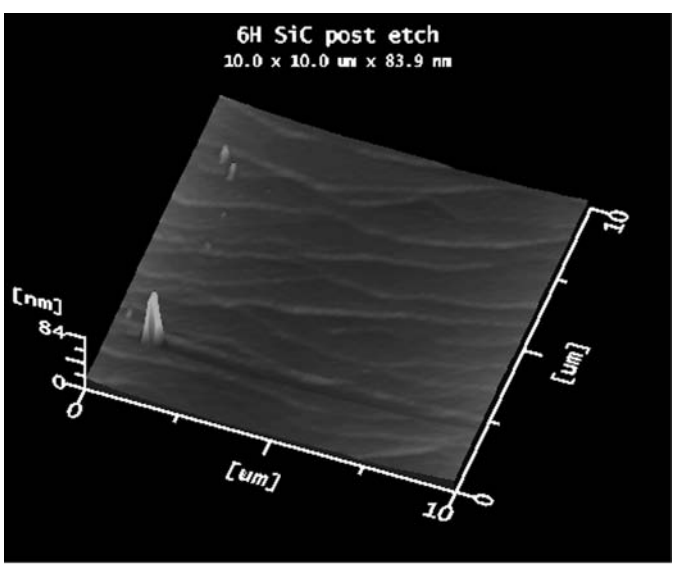

Figure 2: 6H-SiC surface after etching.

Conclusions:

We found in our experiment that the minimum temperature for in situ etching that will yield etch rates of any significance is 1200°C. At this temperature, 60 sccm of HCl produced the maximum etch rate, as doubling this amount did not result in an increase in etch rate. The effectiveness of using in situ HCl etching before epitaxial growth of SiC is still unknown, and further testing is needed to determine its merit.

Acknowledgements:

I would like to thank Mr. Crawford Taylor, Dr. Gary Harris, Mr. James Griffin, Dr. Peizhen Zhou, and all of the staff, graduate students and interns at the HNF.

References:

[1] P. G. Neudeck, J. A. Powell, A. J. Trunek, X. R. Huang, M. Dudley, Mat. Sci. Forum, 389-393 (2002) p. 311.
[2] K. Teker, J. of Crystal Growth, 287 (2003) p. 245.
[3] J. A. Powell, P. G. Neudeck, A. J. Trunek, G. M. Beheim, L. G. Matus, R. W. Hoffman, L. J. Keys, App. Phys. Lett., 77 (2000) p. 1449.
[4] J. Zhang, O. Kordina, A. Ellison, E. Janzen, Mat. Sci. Forum, 389-393 (2002), p. 239.
[5] Z. Y. Xie, C. H. Wei, L. Y. Li, J. H. Edgar, J. Chaudhuri, C. Ignatiev, MRS Internet J. Nitride Semicond. Res. 4S1, G3.39 (1999).
[6] A. A. Burk, L. B. Rowland, J. of Crystal Growth, 167 (1996) p. 586.
[7] C. Hallin, F. Owman, P. Martensson, A. Ellison, A. Konstantinov, O. Kordina, E. Janzen, J. of Crystal Growth, 181 (1997), p. 241.