Atmospheric Pressure Helium Plasma Treatment on 3C-SiC/Si Surface

N.F. Mohd Nasir^{1, a}, S.K. Zaaba^{1, b}, N. Md Zuki^{1, c}, M.N.F.M Kazim^{1, d}, M. Mazalan^{2, e}, Y. Wahab^{2, f}, P.W. Leech^{3, g}, P. Tanner^{4, h} and A.S. Holland^{3, i}

¹Biomedical Electronic Engineering Program, School of Mechatronics, Universiti Malaysia Perlis, Malaysia

²Advanced Multidisciplinary MEMS-Based Integrated Electronics NCER Centre Of Excellence (AMBIENCE), Universiti Malaysia Perlis, Malaysia

³School of Electrical and Computer Engineering, RMIT University, Melbourne, Australia

⁴Queensland Micro and Nanotechnology Centre, Griffith University, Brisbane, Australia

^anashrul@unimap.edu.my, ^bkhadijah@unimap.edu.my, ^cnorsaidahmdzuki@yahoo.com, ^dfakhzan@unimap.edu.my, ^emazleemazalan@unimap.edu.my, ^fyufridin@unimap.edu.my, ^gpatrick.leech@rmit.edu.au, ^hp.tanner@griffith.edu.au and ⁱanthony.holland@rmit.edu.au

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Abstract. In this paper, the effect of inert gas plasma to the morphology of 0.29 μ m thick 3C-SiC/Si is studied. Helium was used for the plasma treatment and its effect as the etchant gas to the polished side of 3C-SiC/Si surface was determined. The changes of the surface morphology were monitored using Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). From the results obtained, it has shown that the morphology of surface properties of 3C-SiC was modified by differences in helium plasma time of exposure and the degree of roughness of the surface changes. The results show by the SEM and AFM shown that plasma treatment had been successfully implemented for the 0.29 μ m thick 3C-SiC/Si.

Introduction

Silicon carbide (SiC) has been studied for more than 25 years as an alternative microelectronic material for the use in high temperature and high power applications [1]. This is due to its excellent electrical, mechanical and chemical properties [1, 2] SiC has approximately 250 crystal structures but the only cubic variety known to exist is 3C-SiC [3-5]. Apart from high temperature applications, SiC is also investigated as potential material to be used in devices intended for used in intense vibration, high wear resistance and corrosive environment [2-4].

SiC has a bandgap (2.3 eV for 3C-SiC) which is suitable for low noise semiconductor devices [4, 5]. Epitaxial layers of 3C-SiC can be grown on silicon substrates using chemical vapor deposition [3]. Thus, it may have shown great potential in micro and nanoelectromechanical system (MEMS and NEMS) applications [3].

Plasma applications are widely used in microelectronic industries. Gasses such as SF₆, NF₃, CBrF₃, and CHF₃ had been used effectively for the plasma etching of SiC for microfabrication of semiconductor devices[6]. However, different type of plasma may impose different effect on the properties of 3C-SiC. For an example, fluorinated plasma can improve the biocompatibility of 3C-SiC but on the other hand, this decreases the ohmic characteristics of the material [7,8]. Thus, the effect of inert gas plasma to the morphology of 3C-SiC/Si surfaces is investigated.

Materials and methods

Preparation of the 3C-SiC Samples. A layer of n-type 3C-SiC with the thickness of $0.29\mu\text{m}$ were grown epitaxially on $650\mu\text{m}$ thick, $\langle 100 \rangle$ Silicon (Si) substrates by chemical vapor deposition (CVD) as described by Wang et al. [9, 10]. Later, 3C-SiC/Si samples were diced into rectangular pieces of $5 \times 6\text{ mm}^2$. The samples were cleaned with acetone and de-ionized water and dried. The plasma was exposed to the center point of 3C-SiC/Si.

Fig. 1 The dimensions of 3C-SiC sample and the plasma point of exposure

Experimental Set-Up. The experiment was conducted at room temperature (27°C) and in atmospheric pressure. Helium gas flowed through the glass tube, gas regulator, gas tube, flow meter glass tube and the plasma discharge was shot as pulses to the surface of 3C-SiC/Si.

Fig. 2 Schematic diagram of experimental setup

The copper electrodes were attached to the glass tube with the distance between two electrodes is approximately 20mm. The gap between the mouth of glass tube and the sample is around 5mm. For the discharge power, the total flow rate (ml/min) used was 500 ml/min. The samples were exposed to the plasma in different times which are 180s and 300s. Then 3C-SiC/Si samples were later sent for surface analysis using Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM).

Scanning Electron Microscopy (SEM). SEM micrographs of 3C-SiC/Si surfaces were taken using a JSM-6460 LA (JEOL), using 30 kV beam voltage and spot size of 5.

Atomic Force Microscopy (AFM). 3D and phase images of 3C-SiC/Si using AFM were taken using SPI 3800 N with SPA 400 HV (Seiko Instrument Inc.) and the area scanned was about $5\mu\text{m}^2$.

Results and Discussion

Scanning Electron Microscopy (SEM).

Fig. 3 Scanning electron micrographs image of the 0.29 μm 3C-SiC layer surfaces treated at 10,000X magnifications a) control b) 180 seconds and d) 300 seconds.

The figures show the morphological differences between the untreated samples (which act as the control) and other treated samples. As shown in Fig. 3(a), the control surface was relatively smoother before the treatment. The effect of the helium plasma resulted in the increment of the grain size after prolonged exposure. The last samples which were treated for 300s showed the largest grain size and the boundaries between the grains were lesser in comparison to the other samples. Thus, plasma treatment has affected and altered the surface morphology of 3C-SiC/Si.

Atomic Force Microscopy (AFM). The morphology of untreated and plasma treated surfaces were further analyzed by Atomic Force Microscopy (AFM). The 3D AFM images of untreated and treated 3C-SiC are shown Fig. 4.

Fig. 4 3D AFM and phase images of 0.29 μm thick 3C-SiC/Si layer. (a) control (b) 180s and (c) 300s treated with Helium plasma.

The untreated surfaces were comparatively smooth with most of the structures having low points with the maximum height of 42nm. In the images of the treated surfaces, there were an increased number of high points with low points could no longer be visible. The 180s exposed surfaces had a maximum of 310nm of points' height while the 300s samples had a maximum points' height at

365nm. The surfaces of the 300s samples resemble the structure of an anisotropic etched Si surface [11]. Thus, it is suggested that significant amount of the 3C-SiC layer of the samples could have been etched away in the process especially for the 300s samples.

Conclusion

For the surface analysis, SEM is used to observe the surface morphological changes of the 3C-SiC/Si after Helium plasma exposure for certain duration of time. The surface morphology of the treated samples indicates modifications which were represented by the surface roughness and the formation of a grain-like structure. The grainy structures became larger and nearer when the duration of the plasma treatment was prolonged. The 300 seconds samples showed the biggest grain structures of all and the boundaries are lesser to the others. From the AFM analysis, the untreated samples' surface was made of the low points and occasionally, few high points. For the treated surfaces, there was an increment of high points topography with lower points (lesser than 50nm) were no longer visible. This may suggest that significant amount of 3C-SiC might be etched away which then, revealed the Si portion of the samples after the plasma treatment. The AFM results had confirmed the observations made from the SEM analysis regarding to the roughness of the 3C-SiC surface. Thus, the inert plasma treatment was proven to be able to etch 3C-SiC surface and revealed the Si portion of the samples after a specified duration of time.

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