GaN on Si (111) nanostructure for solar cells application

M. Al-Jassim[1], G. Grüner[2], J. Guo[3,]*

[1]National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401, USA
[2]Department of Physics, University of California Los Angeles, 405 Hilgard Avenue, Los Angeles, CA 90095, USA
[3]Department of Industrial Engineering and Operations Research, Columbia University in the City of New York, New York, NY, 10027, USA
*) Email: guojj@gsb.columbia.edu

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The fabrications of nanostructured GaN by electrochemical etching and laser-induced etching have been attempted. Laser processing has the advantages of not causing damage or contamination, as well as of special selectivity with high resolution and high efficiency. The studies on the fundamental properties of these nanostructures are very important due to their unique structural and optical properties relative to the bulk form of the corresponding material. To the best of our knowledge, this has never been reported before.

Keywords: GaN; Si; Solar cells.

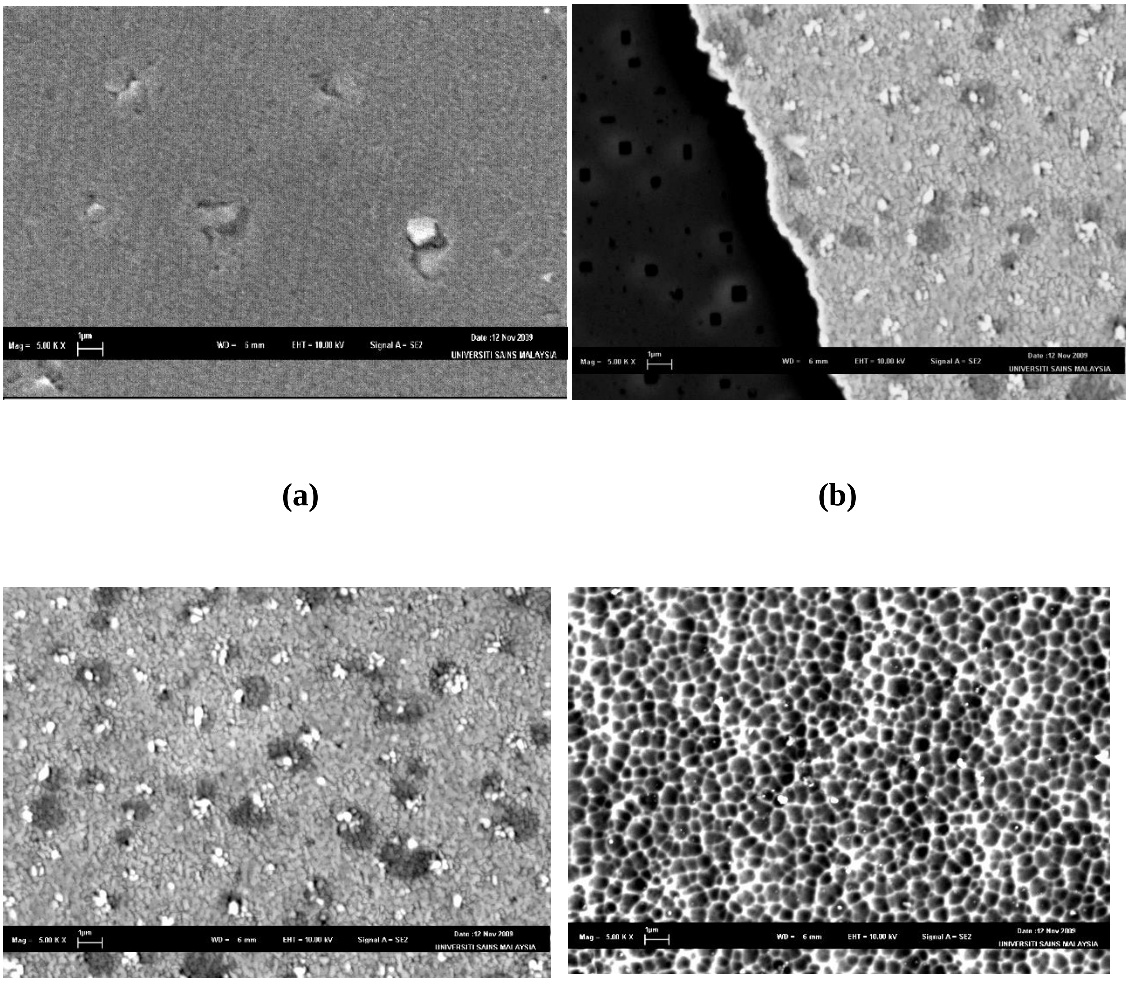
1. INTRODUCTION

The optimum etched parameters in the nitrides group are still infancy. The objective of this work is to investigate the selected etching parameters to control the size, shape, surface chemistry, and the emission properties of the nanostructures. This technique could open a new and promising field in the binary III-nitride material's group if it transforms the material's properties to make them similar to the ternary nitride material's group.

Hydrogen gas sensor based on nanostructured GaN surfaces prepared by electrochemical etching were fabricated, and the effect of the of Selected optimal etching parameters on the gas sensor performance was investigated.

2. RESULTS AND DISCUSSION

Figure 1 shows the top view SEM image of the porous GaN surface prepared using electrochemical etching with varying current densities, while keeping the etching time at 12 min (Fig. 1(a)) shows the surface morphology of the as-grown GaN sample. Pits were found on the GaN surface but they were in a small ratio to that observed by another researcher group, if the carrier concentration value of Si-doped GaN films grown with AlN buffer layers is approximately 1×10^{18} cm^{-3}, then many grooves, V-shapes, and cracks were noticeable on that surface[15].Although our sample had a high carrier concentration value of 2.1×10^{19} cm^{-3} it showed fine and non-cracked formation. The effect of varying the current density on the morphology of porous GaN layer is observed. The chemical reaction was initiated at a current density of 25 mA/cm^2, and due to the insufficient structure interaction, the etched area was irregular. In addition, the existence of the edges of the remaining non-etched layer were observed as shown in (Fig. 1 (b)), which may be attributed to insufficient etching time in relation to thickness of the porous layer. This meant that electron-hole pairs that were generated were insufficient [16,17].When current density was increased to 50 mA/cm^2, well-defined layers of pores with sizes ranging from5 to15nm over the whole surface area were observed, as shown in (Fig. 1(c)). This means the etch rate in the crystal centers is slow enough so that the grain boundaries are etched at a sufficient accuracy. On the other hand, by increasing the current density to 75mA/cm^2, the formation of pore structures with different sizes and shapes could be seen in (Fig. 1 (d)) etched surface became hexagonal, and the pore structures are smaller in size. In addition, the pore walls were very thin with some short thin tips at the top. This indicated that when the etch rate is too fast, the grain boundaries are etched significantly slower than the centre of the crystals. This leads to a hexagonal and rough morphology[18].

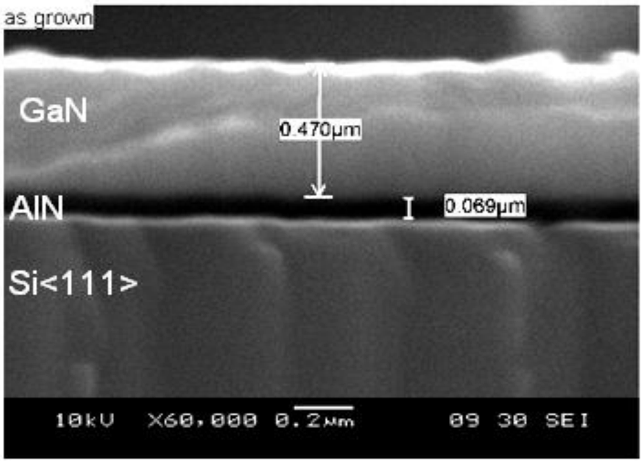


(a) **(b)**

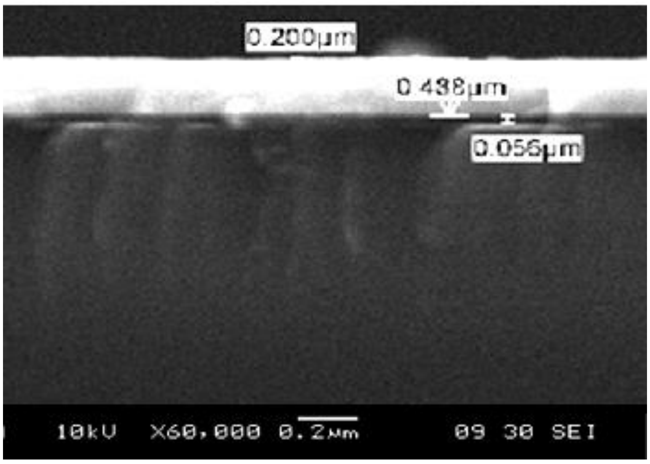
(c) **(d)**

Figure 1 SEM of nanostructured GaN prepared by electrochemical etching with time of 12 min and different current densities (a) as-grown (b) 25 mA/cm^2 (c) 50 mA/cm^2 (d) 75 mA/cm^2

Figure 2 presents the cross section of the n-GaN thin films before and after the etching process. The thickness of the AlN buffer layer and n-GaN epilayer are 0.069µm and 0.47 µm respectively. We estimated the GaN growth rate is about 0.5µm/h and the AlN growth rate is 1.03µm/h as shown in [Fig. 2 (a)]. The depth of porosity for the selective sample presented was approximately 0.22µm. as shown in Fig. 2 (a)].



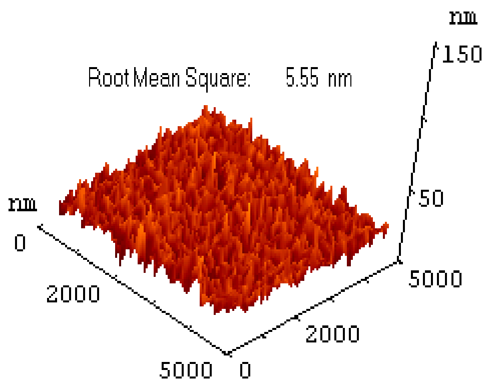
(a)



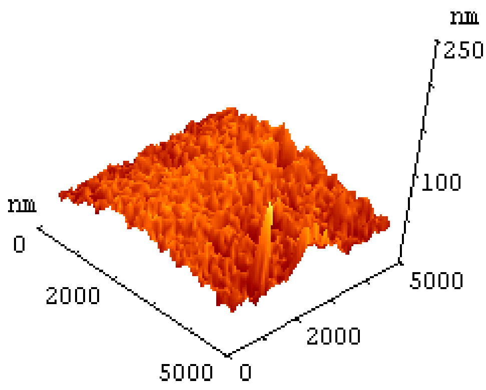
(b)

Figure 2 Cross section images of the GaN (a) before (b) and after etching process

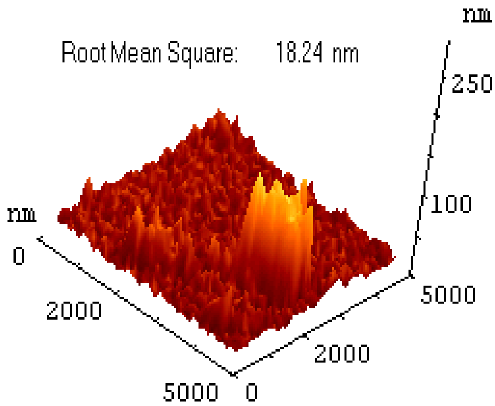
Figure 3 shows AFM images of GaN before and after etching process. Fig. 3(a) describes the three-dimensional topographic image of the as-grown sample. The etched surface with the pyramidal shape was distributed over the entire surface. The pyramidal shape indicated that the increase in the surface roughness is attributed to the etching parameters affecting the surface characterization. Because the porous surface texture has a high degree of roughness, this suggests a possible use for the porous layer as an antireflective coating since it reduces the light reflection. Because roughness is a function of layer thickness, the layer thickness of an antireflective coating increase as roughness increases; this leads to changes in the optical, electronic and vibrational transitions. The attenuation of the reflectivity is due to scattering and transmission at the porous and bulk interfaces. The etched surfaces range in heights nanoparticles from 50-200nm relative to the etch current density, as shown in Figs. 3(b) (c) and (d).



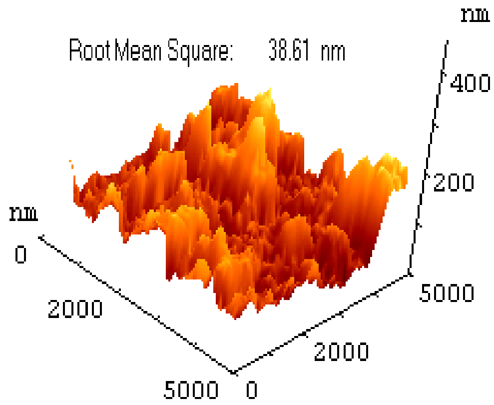
(a)



(b)



(c)



(d)

Figure 3 AFM images of porous GaN prepared by electrochemical etching with time of 12 min and varying current densities (a) as-grown (b) 25 mA/cm^2 (c) 50 mA/cm^2(d) 75mA/cm^2.

3. CONCLUSIONS

The synthesis of nanostructured GaN was been achieved successfully. The investigations have shown unique structural and optical properties in the nanoscale that reflect appropriate applications for solar cells.

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