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THE SURFACE ROUGHENING OF GaN BY WET CHEMICAL ETCHING

Enhancing the light extraction efficiency is an important problem in the manufacturing of GaN-based LEDs. Many methods have been carried out to increase the external efficiency, including roughening the surface of the LED. In this study, we proposed an approach of wet chemical etching in KOH and K2S2O8 mixed solutions for roughening the surface of GaN. An analysis on change the surface of GaN is described as a function of etching time.

Keywords: *GaN, wet chemical etching, the surface roughening.*

1. Introduction

Gallium nitride as a wide-bandgap III-V compound semiconductor has been studied intensively in recent decades, due to excellent physical and chemical properties. However, GaN-based light emitting diodes have a low total light output. Increasing the efficiency of GaN-based LEDs is an area of active investigations [1]. The light extraction efficiency is limited by the total internal reflection of light. One method of improving LED efficiency is to create light scattering centers in the form of random texturing on the LED's surface. The roughened surface reduces internal light reflection and scatters light outside, increasing the light extraction efficiency by a factor of 2-3 times [2]. Many GaN etching methods have been applied. The inductively coupled plasma etching allows us to create a rough surface, on the other hand generates ion-induce damages in the epitaxial structure, and obtaining of smooth etched sidewall is difficult [3]. A wet chemical etching is less harmful for epitaxial structures and slower compared with a plasma etching [4].

In this study, we proposed an approach of a wet chemical etching in potassium hydroxide KOH and potassium persulphate $K_2S_2O_8$ mixed solutions for roughening the surface of GaN. The details and results of experiments are shown in the later sections of this paper.

2. Experimental

The roughening surface process is usually used for top p-GaN from conventional LEDs and top n-GaN from vertical LEDs. In this study, we used both types of surface. Before etching n-GaN surface in vertical LEDs, the sapphire substrate was separated by laser lift-off process [5]. For this in our experiments, samples were bonded to the ceramic carrier by a chemically stable glue. After removing of sapphire substrate, samples were immersed in a bolting solution of HCl:H_2O (1:1) for 40 seconds to clean a surface of metallic gallium. Then samples were immersed in 1M KOH and 0.1M $K_2S_2O_8$ mixed solutions.

All experiments were carried out at room temperature. A 250-W mercury-vapor lamp without a glass outer bulb was used as a source of ultraviolet light (UV), which is used for the photo-excitation of GaN. Scanning electron microscopy (SEM) images are used to estimate surface morphology.

3. Results and discussion

GaN samples were etched for different times in solution under continuous UV radiation. Figures 1 and 2 show SEM images of etching p-GaN and n-GaN surfaces, respectively. The comparison Fig. 1(a) and Fig. 1(c) shows an insignificant change of surface morphology with increasing etching time. The size of roughness is several hundred nanometers. However, samples without chemical etching have the same surface morphology. This roughness was formed during the growth of epitaxial structure by lowering the epitaxy growth temperature [6]. Nevertheless, wet etching of p-GaN is difficult.

It differs with n-GaN. After 7 minutes of etching, a formation of pyramids on n-GaN surface begins (Fig. 2(a)). After 15 minutes, the pyramids become bigger and higher, as shown in Fig. 2(b). The size of pyramids is 0.8-1 microns and density $2*10^8$ cm^{-2}. Further increase of etching time reduces density (10^7 cm^{-2}) of pyramids and changes a shape of a top of pyramids (Fig. 2(c)). The pyramids have the size of

several nanometers at the peak and 1-1.5 microns at the bottom. Similar surface morphology was formed in [7], but after 2 hours etching time.

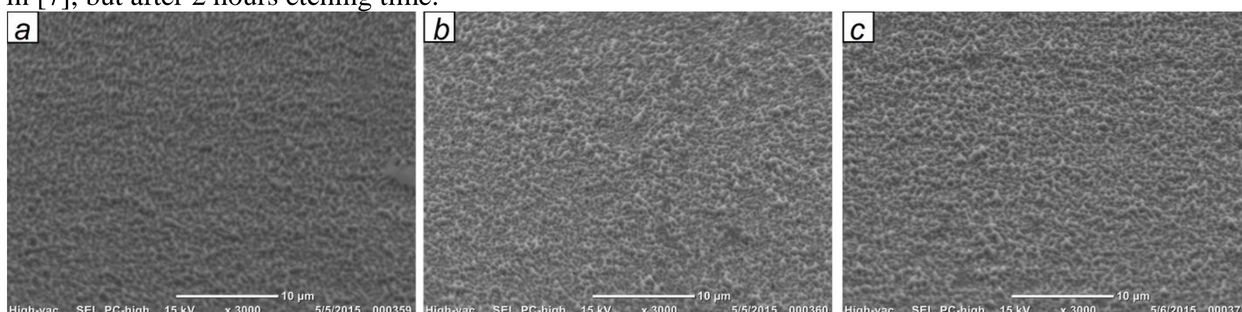

Fig. 1. SEM images of p-GaN surface etched for different time: 30 min (a), 1 h (b) and 2 h (c)

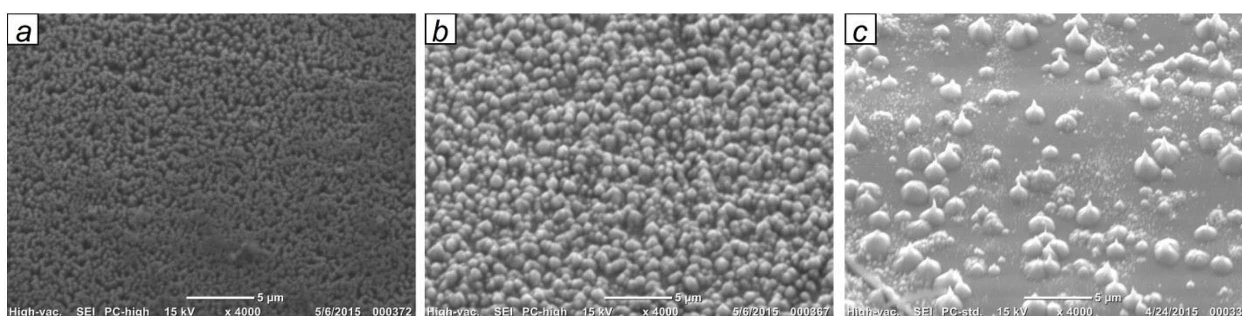

Fig. 2. SEM images of n-GaN surface etched for different time: 7 min (a), 15 min (b) and 30 min (c)

Different results after wet etching of p-GaN and n-GaN surfaces can be explained as follows. In work [8] it is reported that wet etching of GaN depends on polarity of surface. If the surface is Ga-terminated (Ga-polar) the wet etching isn't carried out, N-polar GaN can be etched. During the growth of epitaxial structure, a top layer is gallium. However, after the separation of sapphire substrate by laser lift-off process, surface is N-terminated. So, the approach of wet chemical etching is preferred for n-GaN surface after the separation of sapphire substrate.

4. Conclusions

In summary, this work provides a study on wet chemical etching of GaN in 1M KOH and 0.1M $K_2S_2O_8$ mixed solutions under a continuous UV irradiation. As a result, p-GaN surface isn't etched and on n-GaN surface pyramids are formed after 15 minutes etching. Size of pyramids is 0.8-1 microns and density $2*10^8$ cm^{-2}. This surface morphology can be used to enhance the light extraction efficiency of GaN-based light emitting diodes.

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ФОРМИРОВАНИЕ ШЕРОХОВАТОСТИ НА ПОВЕРХНОСТИ GaN С ПОМОЩЬЮ ЖИДКОСТНОГО ХИМИЧЕСКОГО ТРАВЛЕНИЯ

Одной из основных проблем изготовления светодиодов на основе GaN это увеличение эффективности светоотдачи. Для решения данной проблемы было опробовано множество методов, включая метод создания шероховатости на светоизлучающей поверхности. В данной статье, мы предлагаем метод жидкостного химического травления в смешанном растворе KOH и $K_2S_2O_8$ для создания шероховатой поверхности, изменение которой описывается как функция от времени травления.

Ключевые слова: *GaN, жидкостное химическое травление, поверхностная шероховатость.*

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