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UV-light assist chemical mechanical polishing of GaN with mesh polisher made of chemical durable plastics

Shinsuke Matsui [1], Mizuki Akahori [1], Takuma Suzuki [1], Eiichi Yamamoto [2], Tsubasa Bando [2], Yasutoshi Yajima [3] and Daisuke Ninomiya [3]

[1]*Chiba institute of technology,* [2]*Okamoto machine tool works ltd. and* [3]*Maruishi sangyo co. ltd.*

Matsui.shinsuke@it-chiba.ac.jp

Abstract

We developed Ultra Violet (UV) light assist polishing system for GaN. A newly developed mesh polisher is set up on silica glass platter. The UV light is irradiated to polishing surface of a GaN substrate directly through a silica platter and the mesh polisher. The UV light which wave length is 365 nm has nearly equal the GaN band gap energy. This UV irradiation assists chemical mechanical polishing by optical chemical reaction with electron excitation. The mesh polisher has 0.2-mm fibre bundles and 0.2 mm gaps. Through this gap, the UV light reach directory to polishing surface very near polishing point. Strong alkali slurry was used for investigating UV assist polishing. Potassium permanganate and potassium peroxodisulfate are also used for oxidizing agent.

Ga surface of GaN is polished with silica slurry (70-nm diameter in average). The polishing rate with the mesh polisher made of Vectran^{tm} was almost same as the rate with SUBA 800 which is commonly used as polisher. The rate in the case of UV irradiation and strong alkali (pH = 14.5) is higher 28 times than that of no UV irradiation and no alkaline agents. The rate of UV irradiation and potassium peroxodisulfate is also 20 times higher than that of no irradiation and agents. It is concluded that UV irradiation, strong alkaline and potassium peroxodisulfate oxidants improve polishing efficiency extremely. It is also revealed that the mesh polisher developed in this study was effective for these polishing.

Keywords: polishing, mesh polisher, UV light, engineering plastics

1. Introduction

Recently, more efficient power devices are needed for future sustainable society mainly supported by electrical power. New semiconductor substrate made of SiC, GaN, and diamond are necessary for these new efficient devices. But these substrates are said commonly to be very hard and inert chemically. Especially the GaN substrate of which device has begun to develop recently is very hard to polishing. In order to get usable GaN process various effort are reported. In wet process, Ultraviolet (UV) light assisted chemical etching were reported[1]. It was also investigated for the electrochemical etching with UV light[2]. Recently these UV light assist technology applied to Chemo-Mechanical Polishing (CMP)[3],[4],[5].

In this study mesh polisher were adopted to the UV light assisted CMP. Using this type polisher, enough UV irradiation to very near the polishing point without polishing ability reduction and easy operation can be implemented. We investigate the effects of alkali and oxidant for UV-assisted polishing of GaN substrate.

2. Experiments

Figure 1 shows the mesh polisher used in our experiments. The bundle fibres are made to the meshed plane weaved cloth. It has 0.2 mm square holes through which the UV light reach to the GaN surface very near the polishing point. The rectangular holes make contact area between GaN substrate and polisher small. But it is ordinally said that the real contact area in the polishing is serval percent[6]. So, it is thought that the small contact area will be enough to polishing. The polisher is made of high strength polyalylate (Vectran^{tm}) fibre which is very durable for chemical agents and UV light.

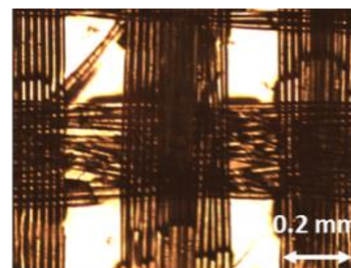

Figure 1. mesh-polisher

As polishing agent, silica slurry whose abrasive average diameter is 70 nm (Compole 80 made by Fujimi incorporated, 20 wt.%) are used. The UV light is a high pressure mercury lamp whose wavelength is 365 nm. In order to examine the effectiveness of our polisher, we measure the light power reached to GaN substrate surface. Figure 2 shows the setup to measure the light power. It simulates the UV assist polishing well.

50-mm diameter GaN substrates were used in our experimetnt. The Ga surface which is important for power device was polished. The fused silica glass platter which diameter is 0.45 m are used with 60 min^{-1} rotating speed. SUBA 800 polisher is also used as a reference one. The substrate also rotates at 60 min^{-1}. Process pressure is 17 kPa. The high-pressure mercury lamp power is 250 w. Polishing slurry were conditioned with chemical agent in order to enhance the polishing rate. For oxidization, $KMNO_4$ and $K_2S_2O_8$ (0.1 mol %) are used. KOH are

used for alkali. Polishing rate was characterized with a precision electric scale which has 0.010 mg linearity.

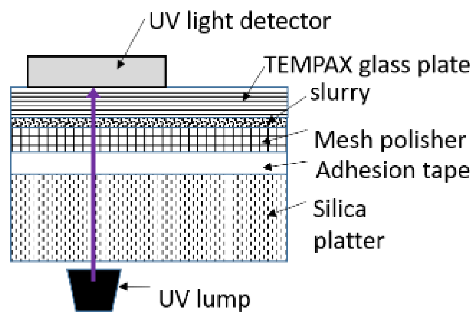

Figure 2 Schematic diagram of UV light power measurement

3. Results

Table 1 shows UV transparency measurement results. If the light transparency through only silica glass platter is set to 100%, the transmitted light rate through almost same condition with UV assist polishing is 26%. The slurry and mesh polisher absorb the light to some extent. But it is revealed that the UV light reaches at the polished GaN surface to a certain degree.

Table 1. UV light transparency rate

Condition	Transparency rate %
Only silica platter	100
Silica platter + TEMPAX glass	94
All things (+ slurry, mesh polisher and etc.)	26

The Ga surface polishing rate between SUBA 800 and mesh polisher were compared to check the mesh polisher availability. In this examination the substrate was polished without chemical agents adding and UV-light assist. As a result, the polishing rate of the mesh polisher is same as that of SUBA 800. It prove that the mesh polisher we developed is enough available for GaN polishing compared with SUBA 800 polisher. The rate is 3.3 nm/h. It is also revealed that by ordinarily CMP polishing the GA surface of GaN substrate is very hard to polishing. So chemical or optical assist is needed to polish the substrate commercially

Table 2 shows the effects of oxidants and UV light. The polishing rate assisted by the UV light increases from 3.4 nm/h to 12.1 nm/h. It is almost 4 times higher than that of without UV case. The 365 nm wavelength UV light has almost same energy with GaN band gap. So exited electrons will assist

Table 2. Effects of oxidants and UV light. Here oxidant is $K_2S_2O_8$.

Condition	Removal rate nm/h
Without oxidant	3.4
With UV	12.1
With oxidant	6.4
With oxidant and UV	68

polishing phenomenon chemically. The $K_2S_2O_8$ oxidant also enhanced polishing about rate from 3.4 to 6.4 nm/h. It is thought that the mechanical effect of polishing achieves $K_2S_2O_8$ oxidation of GaN surface. The oxidized Ga becomes rather easy to polish than GaN. But $KMnO_4$ oxidant which is very effective to enhance the SiC polishing didn't assist the polishing for GaN for pH 2 to 13 range in our experiment.

Using UV irradiation and $K_2S_2O_8$ oxidant, very high polishing rate are gotten. The rate is 68 nm/h which is 20 times higher than that without any assists. It is 10 times higher than that without UV light and with oxidant. In the case of $K_2S_2O_8$ oxidant, the UV light effect becomes larger.

Figure 3 shows alkali effects to UV assist polishing. GaN is very inert to chemical agents. But it was investigated that melt KOH can etch GaN slightly. Polishing abrasive mechanical action

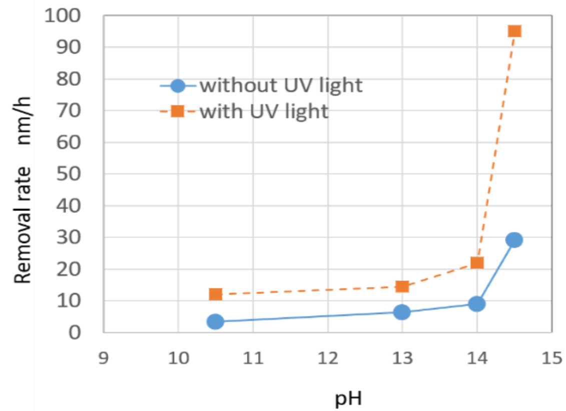

Figure 3. Effects of alkali and UV for silica polishing

help etching. From rather low alkali, the polishing late become slithgly high. AT pH 14.5 the rate indicates very high;29 nm/h. In order to achieve this high rate, polishing was done as soon as possible after the KOH is mixed to avoid silica abrasive dissolve. The UV light assists alkali effect substantially. UV assist polishing rate became 96 nm/h which is 28 times higher than that of without assist. It is also confirmed that only with pH14.5 KOH alkali requid a GaN substrate almost never dissolve.

4. Summary

Mesh polisher which is made of chemically durable engineering plastic fiber are adopted in order to irradiate the UV light very near polishing point of GaN surface.

As a result, 20- or 28-times higher polishing rates are achieved by UV assist Chemo-Mechanical Polishing (CMP) with $K_2S_2O_8$ oxidization agent and pH14.5 alkali with KOH

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