# GaN substrate cut-out process and GaN on GaN device thinning process with laser slicing

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**Abstract**

**We have developed a technique to slice GaN substrates with reduced kerf loss and processing time with laser. This technique can also be applied to slicing wafers after device fabrication, allowing a thin device layer to be sliced off from the wafer. This means that the electrical and thermal resistance of the devices can be reduced while the base GaN substrate remains reusable. We believe that the use of both wafer and device processing with laser slicing will greatly reduce the cost of GaN substrates in devices. With this technique, we believe that we can realize the practical application of devices using GaN substrates.**

## INTRODUCTION

In electrical devices it is said that the better the crystal quality, the better the electrical characteristics. However, the practical application of devices using GaN substrates, which produce the best crystalline GaN device layers, has been slow to progress. One of the reasons is that GaN-on-GaN devices are very expensive compared to on-Si and on-SiC GaN devices because the GaN substrate is very expensive. To solve this issue, we developed a laser slicing technique for GaN substrates. Although techniques for partially processing GaN using lasers have been reported [1, 2], our laser slicing technique can slice substrates from a bulk crystal of GaN. It is also characterized by less kerf loss, shorter processing time, and less damage compared to the conventional wire saw processing. Because of this feature, it can be used for both wafer processing and device processing. For example, if laser slicing can be used as shown in Figure 1, the price of the substrate itself can be reduced, and the price of substrate occupying the device cost can be reduced by using same substrate multiple times after device fabrication process.

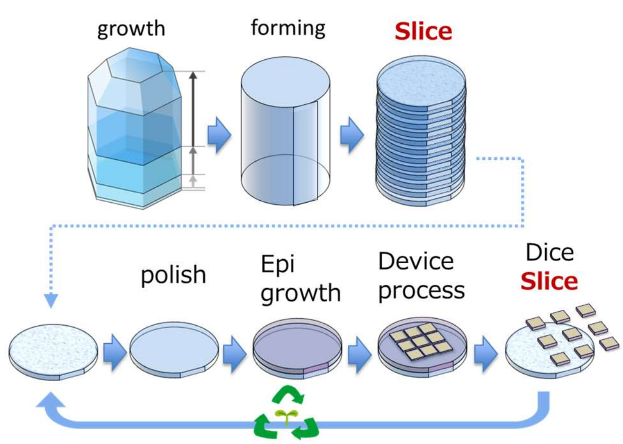


Fig. 1. Schematic image of wafer and device fabrication processing with laser slicing.

## EXPERIMENTAL

The following four experiments were conducted to verify the process shown in Figure 1. A modified SD equipment of Hamamatsu photonics is used for laser slicing. The laser used for processing is a sub-nanosecond laser with wavelength of 532nm.

1) Wafer level laser slicing

   To see how stable the slicing of large areas could be, 2-inch GaN substrates were tried being divided into two substrates.

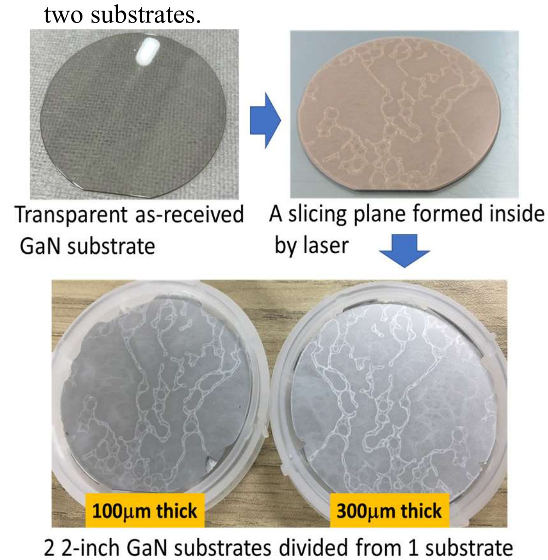


Fig. 2. Photos of laser-sliced 2-inch GaN substrates

As a result, it was possible to slice not only 2-inch but also 4-inch GaN substrate by optimizing laser processing conditions (Fig. 2, 3).


Fig. 3. Photos of laser-sliced 4-inch GaN substrates

2) Epi-growth after laser slicing

Experiments were conducted to determine the depth of damage and to determine how many micrometers of polishing and removal would allow normal epitaxial growth after this laser slicing. The depth of damage that accompanied the laser slice, measured using a multiphoton PL microscope, was about 40μm (Fig. 4). And, the amount of polishing removal required for normal epitaxial growth was also about 40μm (Fig. 5) [3].

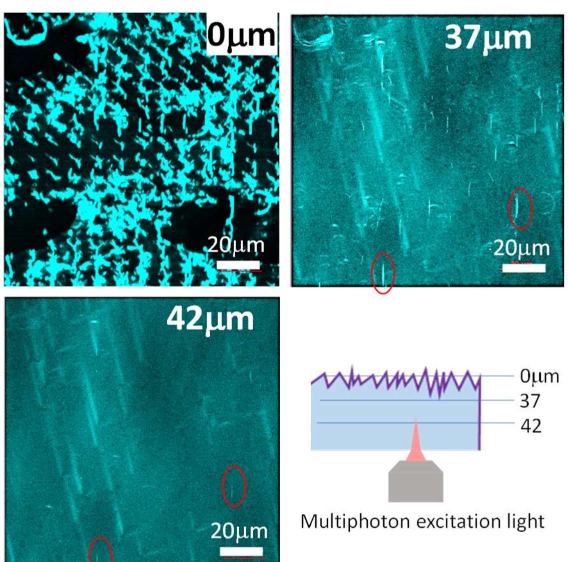


Fig. 4. Multiphoton PL microscope images of each depth position of laser sliced GaN substrates. The numbers on the upper right corner of each image are the distance from slicing plane. Red circles indicate laser damages.

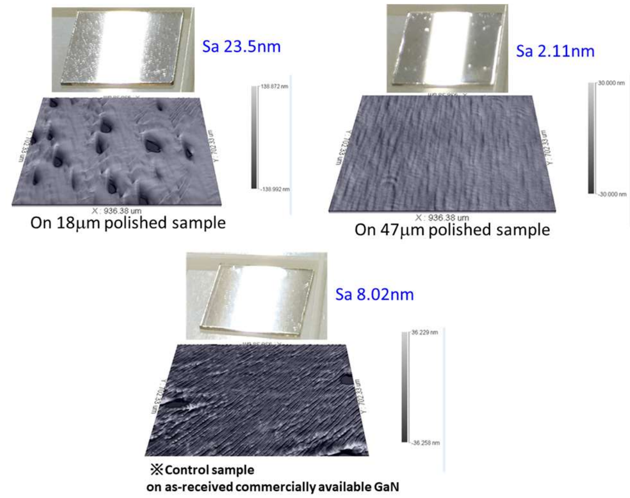


Fig. 5. Photos and white interference microscope images of epi-layer on laser sliced GaN substrates.

3) Thin chips separation from 2-inch GaN substrate

Demonstration was conducted to verify that it is possible to get thin chips while leaving the base substrate intact. After forming a slicing plane 300μm deep from the backside of the substrate, 5mm square chips were cut by SD from the frontside.

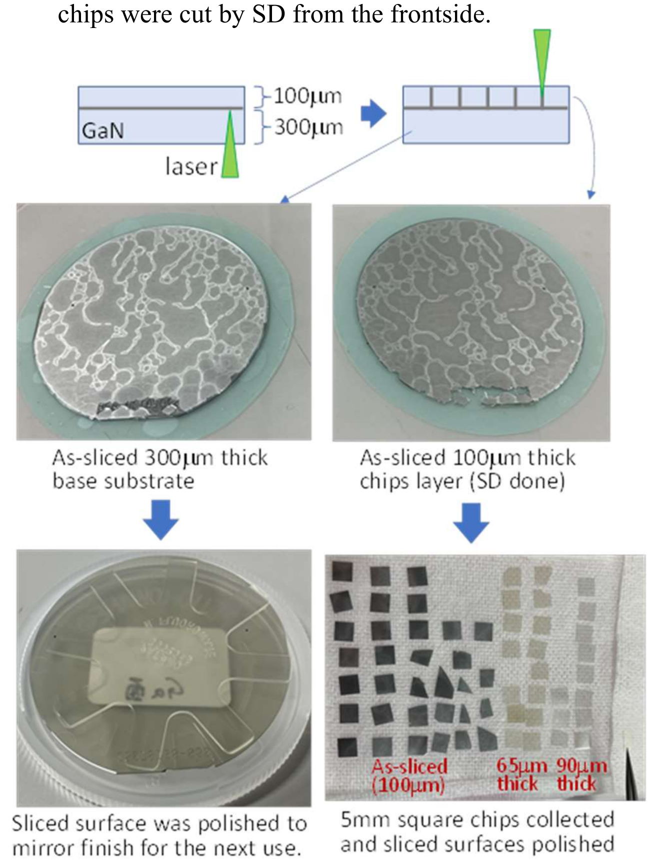


Fig. 6. Results of demonstration of chips separation. The area around the orientation flat is not well processed due to the laser-engraved serial number.

4) Device evaluation after laser slicing

HEMTs on SI-GaN substrate were measured before and after laser slicing. HEMTs were confirmed to be operable, although the resistance was slightly increased due to warping caused by the thinner substrate (Fig. 7) [4].

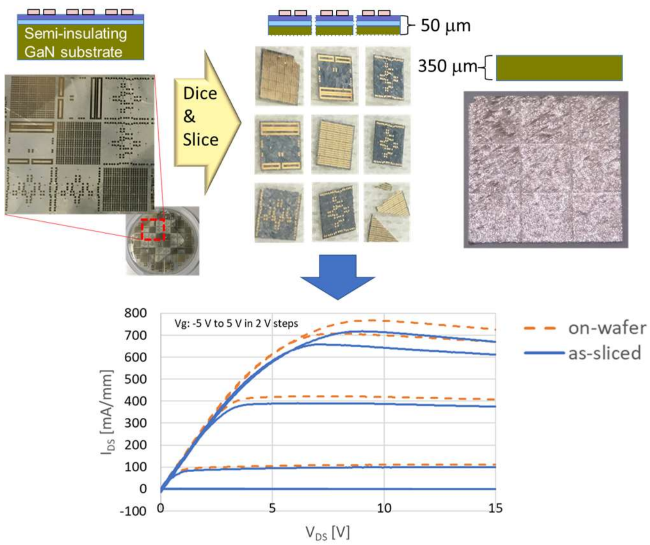


Fig. 7. Photos of laser sliced HEMTs and SI-GaN substrate, and $I_D$-$V_D$ curves of the HEMT.

## Conclusions

The key parts of the process shown in Figure 1 were demonstrated to be possible using laser slicing. We will conduct more detailed studies for the practical application of GaN-on-GaN devices using this laser slicing technique.


## Acknowledgements

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## Acronyms

SD: Stealth Dicing

PL: Photoluminescence

HEMT: High Electron Mobility Transistor

SI: Semi Insulating