Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp548-549

Novel Vertical AlGaN Deep Ultra Violet Photo-detector on n+Si Substrate using Spontaneous Via Holes Growth Technique

Kota Ozeki, Noriko Kurose, Naotaka Iwata*, Kentaro Shibano, Tsutomu Araki, Itaru Kamiya* and Yoshinobu Aoyagi

Ritsumeikan University
1-1-1, Noji-higashi, Kusatsu, Shiga, 525-8577, Japan
Toyota Technological Institute*
2-12-1, Hisakata, Tempaku, Nagoya, Aichi 468-8511, Japan
Phone: +81-77-561-3769 E-mail: ro0012hi@ed.ritsumei.ac.jp

Abstract

Vertical AlGaN deep ultra violet (DUV) photo-detector has been successfully fabricated on n+-Si substrate by spontaneous via holes growth. The spontaneous via holes turn the insulating AlN buffer layer to be conductive, which is indispensable for growing AlGaN epitaxial layer for device applications. By introducing spontaneous via holes, direct current flow from p-electrode to n+-Si substrate becomes possible. This vertical device is easily enlarged to realize large area solar-blind photo-detector which is necessary for many applications for sensing contamination of water, biological materials, and so on, under sunshine.

1. Introduction

Solar-blind DUV photo-detector is very important for various applications, for example, sensing of water contamination in the field, tracking of rockets or vehicles, bio sensing, and so on. For these applications large area sensing device is necessary for realizing high sensitivity and alignment flexibility. AlGaN photo-detector is usually fabricated on sapphire and Si substrate. However, AlN buffer layer on the substrate for growing AlGaN, which is an insulating material, is indispensable. The photo-induced current cannot flow directly from the p-electrode to the substrate with AlN buffer layer. For this reason, so far, trench etching on the epitaxial wafer had been necessary for preparing n-contact to n-AlGaN on a horizontal position[1)] of the device. In this horizontal type detector the distance between the sensing part to the electrode is over 50 microns even though the device is smaller than the commonly used 200micron square resulting in a high series resistance of n-AlGaN. So, preparation of large area sensor had been limited. However, with a vertical type detector, the resistance in the n-AlGaN part can be suppressed since the thickness is only 1 or 2 micron, and allows easy enlargement of the device. So, we have tried and succeeded in making the AlN layer to be conductive using spontaneous via holes growth technique to fabricate the vertical type photo detector.
In this presentation we demonstrate the first vertical DUV photo-detector prepared by spontaneous via holes crystal growth.

2. Experimental Results and Discussion

Fig. 1 shows the structure of a typical

vertical DUV photo detector with spontaneous via holes. In this device an n^+-Si substrate is used and successive AlN buffer with spontaneous via holes, n-AlGaN, i-AlGaN, p-AlGaN, and thin p-GaN layers are epitaxially grown.

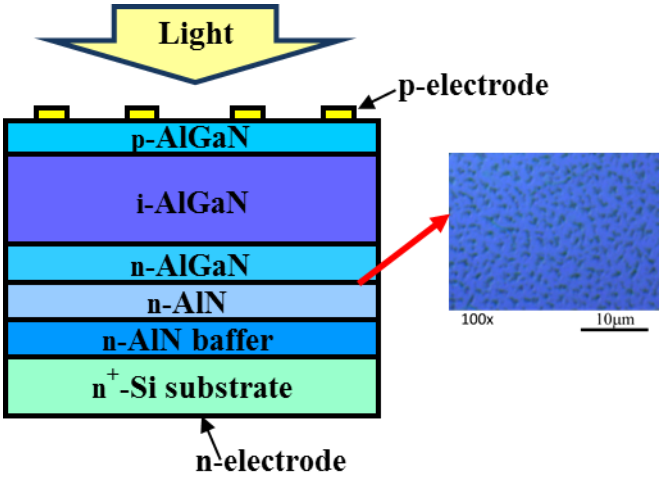

Fig.1 Schematic illustration of Vertical AlGaN DUV photo detector. The n-AlN layer becomes conductive by introducing spontaneous via holes shown in the micrograph.

The AlN buffer layer in this device is indispensable to grow AlGaN on Si substrate to exclude reaction of Ga and Si substrate. Via holes are spontaneously formed in AlN buffer layer by introducing Al injection layer at the beginning stage of the growth and is filled by conductive n-AlGaN[2)] using the growth technique we have developed. The details of the growth of the via hole will be reported in the conference. The number and area of via holes can be controlled by controlling the amount of Al injection and other growth condition. The conductance of AlN layer increases with increasing the via hole area.

Fig. 2 shows the sensitivity of the detector for the DUV light of 193nm. The photo detector can sense the DUV light but is insensitive to the visible light.

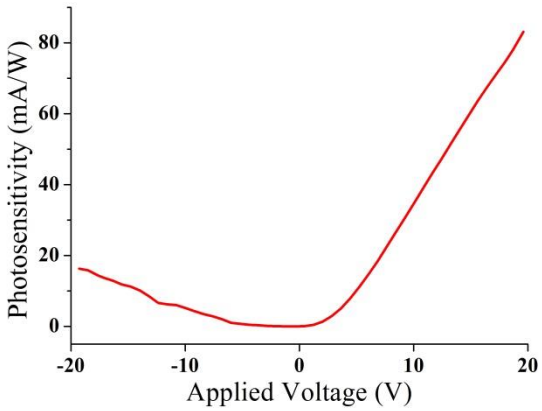

Fig. 2. Detection efficiency of the photo detector under 193nm laser irradiation with 10 Hz.

The size of the sensor is 0.4mm square. The sensitivity of the detector is typically 80-20mA/W at the applied voltage of 20V, and is comparable or more sensitive than the conventional horizontal DUV detector grown on a complicated LEO epitaxial wafer. The fabrication process of our device is very simple, in which no photo-resist process is necessary, and enlargement of the device may be easily performed because of the vertical structure.

3. Conclusion

We have succeeded in fabricating vertical type DUV photo-detector on n^+-Si substrate using spontaneous via holes growth. The sensitivity is typically 80mA/W for 193nm DUV light at 20V, and insensitive to visible light. This detector can be easily fabricated without any photoresist process nor etching process, and can be easily enlarged. This device is useful for sensing water contamination in the field and tracking rockets or vehicles and bio sensing under sunshine.

References

1) for example, P. Sandvik, *et al.* J. Cryst. Growth 231 366 (2001).
2) N. Kurose, *et al.* AIP ADVANCES 4, 027122 (2014).