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Pt/AlGaN Schottky-Type UV Photodetector with 310 nm Cutoff Wavelength

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Abstract

Pt/AlGaN Schottky-type UV photodetectors were designed and fabricated. A low-temperature AlGaN interlayer buffer was grown between the AlGaN and GaN film in the diode structure epitaxy to obtain crack-free AlGaN active layers. A comparison was then made of the structural, electrical, and optical characteristics of two different diodes: one with an AlGaN(0.5 μm)/n+-GaN(2 nm) structure (type 1) and the other with an AlGaN(0.5 μm)/AlGaN interlayer(150 Å)/n+-GaN(3 μm) structure(type 2). A crack-free AlGaN film was obtained by the insertion of a low-temperature AlGaN interlayer with an aluminum mole fraction of 26 % into the $Al_xGa_{1-x}N$ layer. The fabricated Pt/$Al_{0.33}Ga_{0.67}N$ photodetector had a leakage current of 1 nA for the type 1 diode and 0.1 μA for the type 2 diode at a reverse bias of -5 V. For the photoresponse measurement, the type 2 diode exhibited a cut-off wavelength of 300 nm, prominent responsivity of 0.15 A/W at 280 nm, and UV-visible extinction ratio of 1.5×10^4. Accordingly, the Pt/$Al_{0.33}Ga_{0.67}N$ Schottky-type ultraviolet photodetector with an AlGaN interlayer exhibited superior electrical and optical characteristics and improved UV detecting properties.

Key Words : AlGaN, UV photodetector, Schottky, crack-free, MOCVD

I. Introduction

Gallium nitride and its related compounds have been developed over the past ten years for various device applications due to their superior chemical and thermal properties. As such, nitride materials have already been applied to high temperature and/or high frequency electronic devices, UV opto-electronic devices, blue-green LEDs, and laser diodes.

In addition, nitrides have also been considered for application in UV-sensitive photodetectors based on their potential as solar-blind UV sensors, thereby including such applications as missile plume detection, flame detection, and ozone monitoring.[1] In particular, UV meters and fire alarms have worldwide application. Among nitride materials, the AlGaN ternary system has been used to adjust the sensing wavelength range relative to the band-gap energy from 3.4 eV to 6.2 eV based on the Al mole fraction.[2,3] Therefore,

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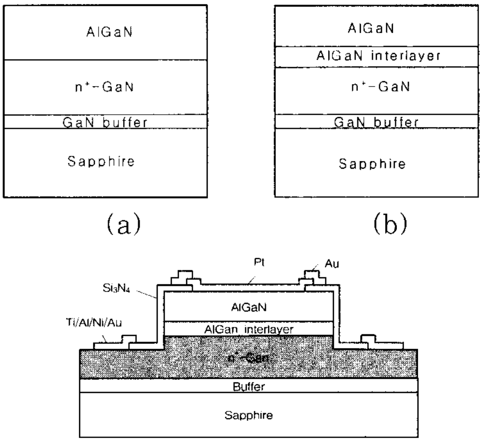
AlGaN materials have attracted much attention from researchers in the field of opto-electronics. However, there are significant lattice and thermal expansion mismatches between AlGaN and GaN or a sapphire substrate, which prevent the creation of high quality undoped AlGaN without cracks.

Accordingly, the current study fabricated Pt/AlGaN Schottky-type UV photodetectors using a low-temperature AlGaN interlayer buffer to create crack-free AlGaN active layers between the AlGaN film and the GaN film in the diode structure epitaxy. A comparison was then made of the structural, electrical, and optical characteristics of two different diodes: one with an AlGaN(0.5 ㎛)/n+-GaN(2 ㎛) structure (type 1) and the other with an AlGaN (0.5 ㎛)/AlGaN interlayer(150 Å)/n+-GaN(3 ㎛) structure(type 2). As a result, it was confirmed that the Pt/$Al_{0.33}Ga_{0.67}N$ Schottky-type ultraviolet photodetector with an AlGaN interlayer exhibited superior electrical and optical characteristics and improved UV detecting properties.

II. Experiment

Figure 1 shows a schematic diagram of the proposed layer and photodetector device structure: a top-illuminated Schottky-type mesa structure photodiode. The AlGaN interlayer was designed to be 0.5 ㎛ thick to reduce the background doping concentration and maximize the radiation absorbing area. The diodes had a circular AlGaN mesa structure with a 500 ㎛ diameter. For the UV photodetector fabrication, two kinds of epitaxial structures were grown on the same GaN nucleation buffer with a 330 thickness on a 2″ c-face sapphire substrate by MOCVD (Emcore D-120): AlGaN(0.5 ㎛)/n+-GaN(2 ㎛) structure (Type 1) and AlGaN(0.5 ㎛)/AlGaN interlayer(150 Å)/n+-GaN(3 ㎛) structure (Type 2) where the AlGaN interlayer growth temperature was 750°C.



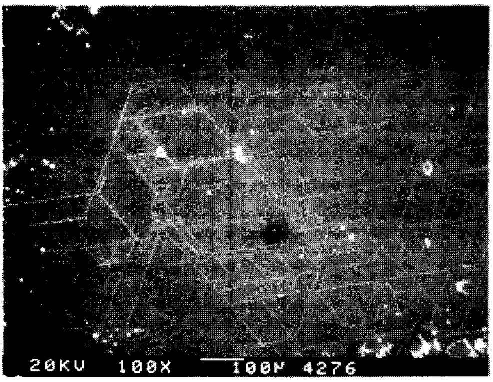
(c)

Fig. 1. Schematic structure of the Schootky type AlGaN UV photodiode.
(a) without AlGaN interlayer
(b) with AlGaN interlayer
(c) Cross-section view of the designed photodetector

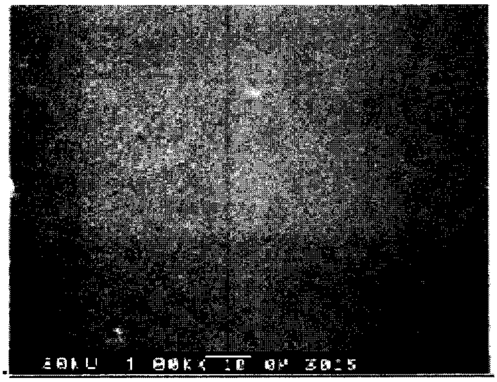
A crack-free AlGaN film was obtained by the insertion of a low-temperature AlGaN interlayer with an aluminum mole fraction of 26 % into the $Al_xGa_{1-x}N$ layer. No cracks were observed in the surface morphology of the AlGaN interlayer, as shown in Figure 2. The AlGaN interlayer was designed to be 0.5 ㎛ thick to reduce the background doping concentration and maximize the radiation absorbing area. Table 1 shows the electrical properties of the grown layers : type 1 and type 2.

For the ohmic contact process, dry etching of the AlGaN layer was conducted down to the n+-GaN layer using the Inductively Coupled Plasma (ICP) etching system. An Si_3N_4 film was deposited between the ohmic and Schottky contacts using PECVD to prevent any surface leakage current. For the top-illuminated Schottky, a thin (100 Å) Pt film was deposited for the Schottky contact, while a Ti/Al/Ni/Au ohmic contact was prepared by E-Beam evaporation of the metals.

The annealing of the devices was carried out at 500 °C in ambient N_2. The specific contact resistivity was 3.4×10^{-4} ㎠ after the annealing. A 2000 Å-thick Au film was deposited by thermal evaporation to form the bonding pad, and lift-off processes were used for the ohmic and Schottky metalization.



(a) without AlGaN interlayer



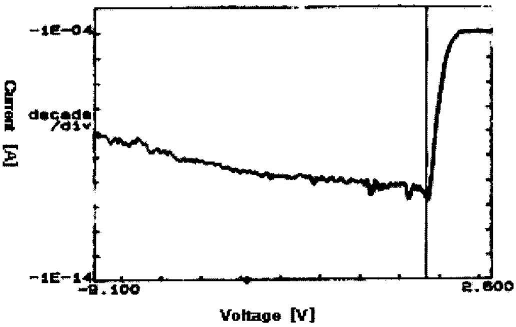
(b) with AlGaN interlayer

Fig. 2. SEM photographs of the grown $Al_{0.33}Ga_{0.67}N$ layers.

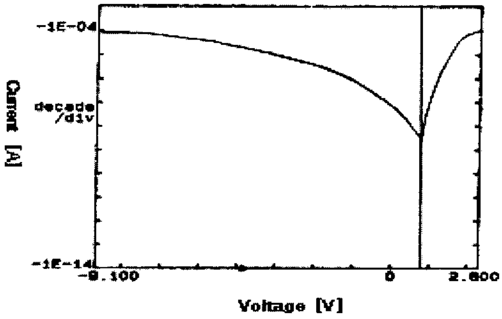
III. Results and Discussion

Figure 3 shows the I-V characteristics of the two Schottky diodes. Under reverse biased conditions, the leakage current of the diode including an AlGaN interlayer (type 2) was much lower (about two orders of magnitude) and more stable than that of the diode without an interlayer (type 1).

Figure 4 shows the spectral responsivity of the Schottky-type photodetector fabricated with an AlGaN interlayer (type 1) under 300 ~ 480 ㎚ photon irradiation using a Xenon lamp. The cutoff wavelength was 310 ㎚, the peak responsivity 0.15 A/W at 280 ㎚, and the UV/visible extinction ratio of the diode 1.5×10^4.



(a) with AlGaN interlayer



(b) without AlGaN interlayer

Fig. 3. I-V characteristics of $Pt/Al_{0.33}Ga_{0.67}N$ Schottky diodes.

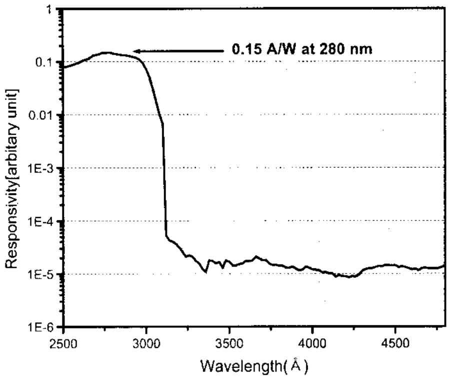


Fig. 4. Spectral responsivity of the fabricated Pt/$Al_{0.33}Ga_{0.67}N$ photodetector.

Figure 5 shows the spectral responsivity of the type 2 photodetector under a reverse bias. When the reverse bias was applied at 5 V, the photocurrent increased about 20-fold and the leakage current also increased two orders of magnitude near the cutoff edge. The increased leakage current of near 350 ㎚ was due to light absorption, which increased the number of carriers, which then diffused into a metal-semiconductor junction, thereby increasing the background leakage current.

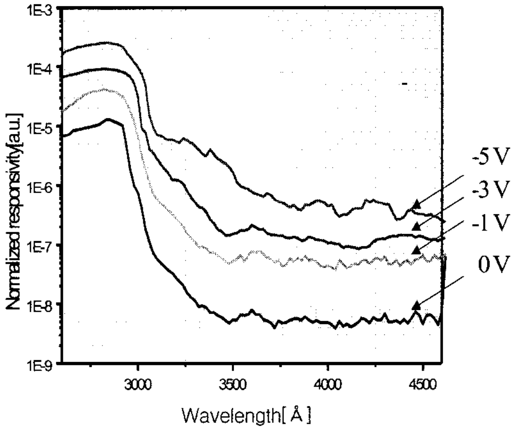


Fig. 5. Spectral responsivity of Pt/$Al_{0.33}Ga_{0.67}N$ photodiode with interlayer under different reverse bias.

Ⅳ. Conclusion

Pt/AlGaN Schottky-type UV photodetectors were designed and fabricated. Crack-free AlGaN active layers were obtained by inserting a low-temperature AlGaN interlayer between the AlGaN film and the GaN film in the diode structure epitaxy. A comparison was then made of the electrical and optical characteristics of two different types of diode: one with an AlGaN(0.5 ㎛)/n+-GaN(2 ㎛) structure (type 1) and the other with an AlGaN(0.5 ㎛)/AlGaN interlayer(150 Å)/n+-GaN(3 ㎛) structure(type 2). The fabricated Pt/$Al_{0.33}Ga_{0.67}N$ photodetector had a leakage current of 1 ㎁ with the type 1 diode and 0.1 ㎂ with the type 2 diode at a reverse bias of -5 V. For the photoresponse measurement, the type 2 diode exhibited a cut-off wavelength of 300 ㎚, prominent responsivity of 0.15 A/W at 280 ㎚ and UV-visible extinction ratio of 1.5×10^4. Accordingly, it was confirmed that the Pt/$Al_{0.33}Ga_{0.67}N$ Schottky-type ultraviolet photodetector with an AlGaN interlayer exhibited superior electrical and optical characteristics and improved UV detecting properties.

Table 1. Electrical properties of the grown AlGaN layers.

Sample / Characteristics	AlGaN with interlayer	AlGaN without interlayer
Layer thickness [㎛]	2.7	3.2
Mobility [$cm^2/V \cdot s$]	269	255
Bulk concentration [cm^{-3}]	-2.061018	-2.121018
Sheet resistance [/]	45.5	45.4

V. Reference

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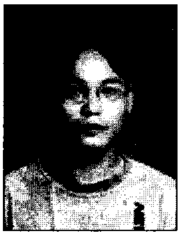

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