# Fabrication and Characterization of Metal-Semiconductor-Metal n-GaN UV Photodetector by PA-MOCVD

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## Abstract

*Metal-semiconductor-metal ultraviolet photodetectors fabricated on GaN epitaxial layers grown on (0001) sapphire by plasma-assisted metal organic chemical vapor deposition (PA-MOCVD) method. The photodetector with a thin GaN layer of 0.7 μm exhibited a low dark current with a saturation value of 1.469 x $10^{-14}$ A. The responsivity was 0.56 A/W at a wavelength of 320 nm under a bias voltage of 2.5 V.*

***Keywords: GaN, PA-MOCVD, MSM UV Photodetectors, Dark current, Responsivity.***

## Abstrak

*Telah dibuat fotodetektor ultraviolet berstruktur metal-semikonduktor-metal dari lapisan epitaksi GaN yang ditumbuhkan di atas substrat sapphire (0001) dengan menggunakan metoda metal organic chemical vapor deposition (MOCVD) berbantuan plasma. Fotodetektor yang terbuat dari lapisan GaN dengan tebal 0,7 μm memiliki arus gelap yang rendah dengan arus saturasi 1,469 x $10^{-14}$ A. Fotodetektor tersebut memiliki responsivitas 0,56 A/W pada panjang gelombang 320 nm dengan tegangan bias 2,5 V.*

***Kata kunci : GaN, PA-MOCVD, MSM-Fotodetektor, Arus gelap, Responsivitas.***

## 1. Introduction

Ultraviolet (UV) photodetectors (PDs) have a wide range of commercial applications, such as flame sensors, engine monitoring systems, UV calibration devices and secure intersatelite/underwater communications. Due to their direct and wide band gaps, GaN based compounds are an ideal choice for the fabrication of various UV detectors. Among the different types of UV photodetectors, the metal – semiconductor – metal (MSM) photodiode is a promising candidate owing to its ease of fabrication and monolithical integration with field effect transistor (FET) based preamplifiers. Recently, several high performance Schottky MSM – PDs based on GaN and AlGaN materials have been demonstrated [(1-3)]. However, they still suffer from performance limitations which impede their development toward practical applications. A well-known drawback of the MSM – PDs is the relatively low responsivity due to the shadowing of the active area by the electrodes and the consequent loss of efficiency. Although this problem has been overcome in GaAs based Schottky MSM – PDs by back illumination[(4)], there has been no comparable report on devices of the same structure based on GaN. Since sapphire substrate is transparent in the wavelength range of interest, back illumination can be readily used to improve the sensitivity of GaN/sapphire material structure MSM-PDs by avoiding electrode shadowing. In this study, back-illuminated GaN MSM-PDs with a thin active layer of 0.7 μm were thus fabricated and characterized.

## 2. Experimental Procedure

An epitaxial layer of GaN was grown on (0001) sapphire by Plasma-assisted metal organic chemical vapor deposition (PA-MOCVD) method. Trimethylgallium (TMGa) was used as a group III precursor with $H_2$ gas as carrier, and as a group V precursor, $N_2$ was used as material sources to supply N radicals of $N_2$ gases. Before the film growth, the substrate was heated at $650^0$ C in a stream of hydrogen for 10 min. A low temperature GaN buffer layer (25 nm) was deposited at $450^0$ C immediately before the growth of unintentionally doped epitaxial GaN (0.7 μm) at $700^0$ C.

The cross-sectional structure of MSM-PDs fabricated in this work and the responsivity measurement are shown in figure 1. Double-polished sapphire substrates were used for back surface illumination. For the MSM structure, interdigitated patterns with the active area of 1 $mm^2$ , finger width of 100 μm, and gap spacing of 80 μm were defined by photolithography using a Hg-Xe lamp source. The Schottky contacts of Au(100 nm) were deposited by evaporation.

In order to determine the spectral responsivity of the detector, the Xe lamp light was chopped and focused into a monochromator. The GaN detector was placed at the exit of the monochromator and a synchronous detection scheme was used. The system was calibrated using detector with known spectral responsivities (silicon photodiode) to determine the optical power density at a given distance from the output slot of the monochromator.

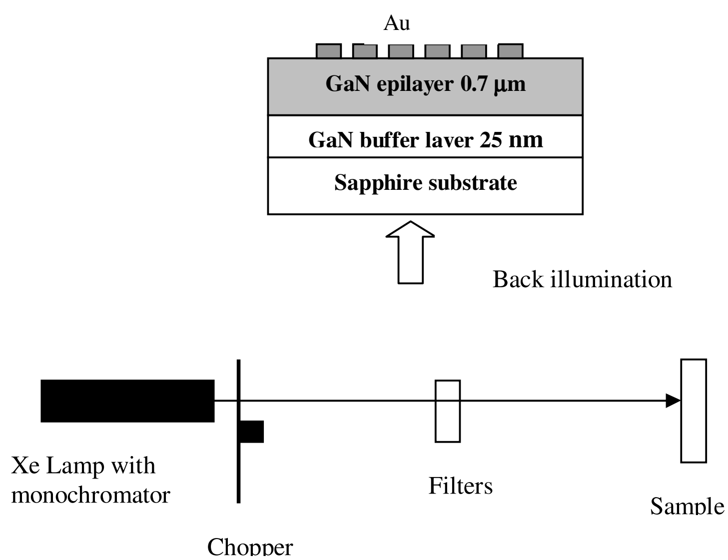


Figure 1. A schematic cross section of the structure and measurement principle of the GaN MSM-PD.

## 3. Results and Discussions

Figure 2 illustrates the transmission spectrum of the GaN epilayer. Fabry-Perot oscillation with a transmittance 0.80 at 550 nm demonstrates that the GaN epilayer is of high crystalline and optical quality.

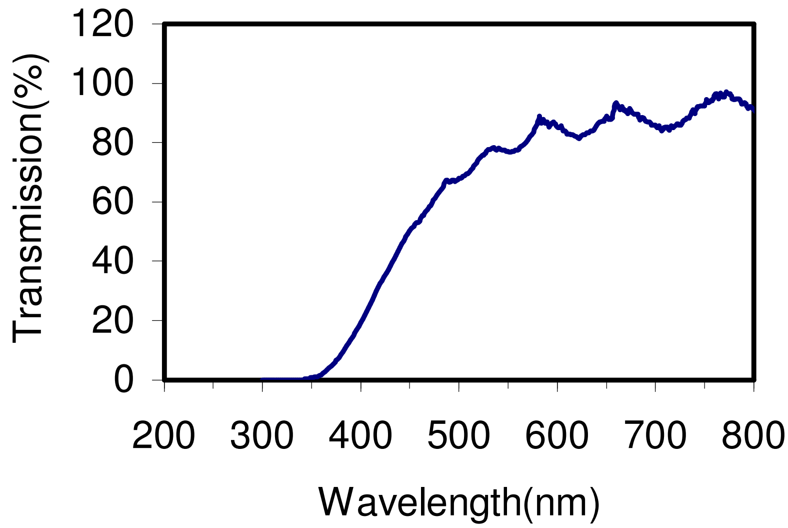


Figure 2. Tranmission spectrum of the GaN epilayer.

The dark current is a very important parameter for characterizing the reliability and detecting ability of MSM-PDs. A low dark current may effectively diminish the current noise and then lower the minimum detectable power. A Keithley 617 programmable electrometer was used to record the current-voltage (I-V) characteristics of the MSM-PDs.

As can be seen in Figure 3, the dark current was measured at room temperature. Considering the MSM structure, consisting of two Schottky contacts connected back to back, the dark current of the detector can be described as[5]

$$I = I_o\exp(eV/nkT)[1- \exp(-eV/kT)],$$
$$I_o=A^*ST^2 \exp(-\phi_B/kT), \quad (1)$$

where V is the applied bias, S is the contact area, A* is the Richardson constant, n is the ideality factor and the other symbols have their conventional meanings. A logarithmic plot of [Iexp(eV/kT)]/[exp(eV/kT)-1] vs V was shown in the inset of figure 3. The intercept of this line shows that the saturation current is $I_0=1.469 \times 10^{-14}$ A. Using the value of the effective Richardson constant of $A^* = 26.4\ cm^{-2}.K^{-2}$ [6] , T= 300 K and S = 1 $mm^2$, we obtained the effective Schottky barrier height $\phi_B = 1.08$ eV for the employed metallization scheme of Au.

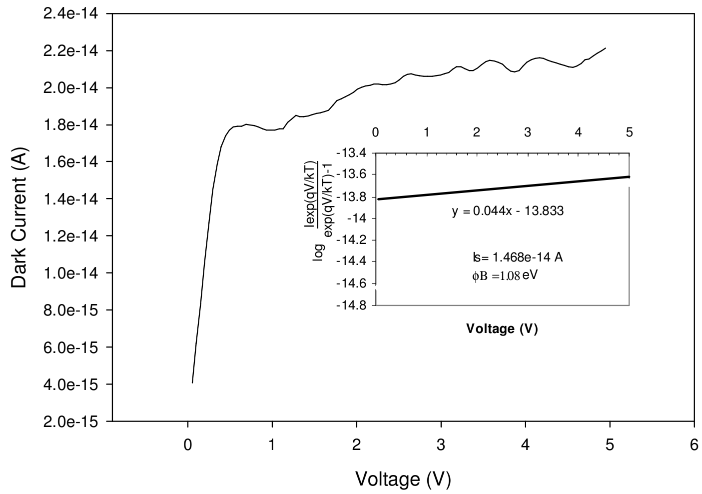


Figure 3. Dark current I-V characteristics for MSM-PD. The inset is logarithmic plot of I vs V

The spectral response of these MSM photodetectors was measured using a Xenon lamp source and a Spex scanning monochromator. The output from the monochromator was chopped at 500 Hz, and a lock-in amplifier was used to insure low-noise measurement of the photogenerated current. The incident optical intensity is normalized as a function of $\lambda$ using a UV-enhanced silicon photodetector of known responsivity. The responsivity of a typical GaN MSM shows a sharp band edge drop off at approximately 320 nm (Figure 4). The responsivity is seen to increase as a function of reverse bias (Figure 5) consistent with other published results[1].

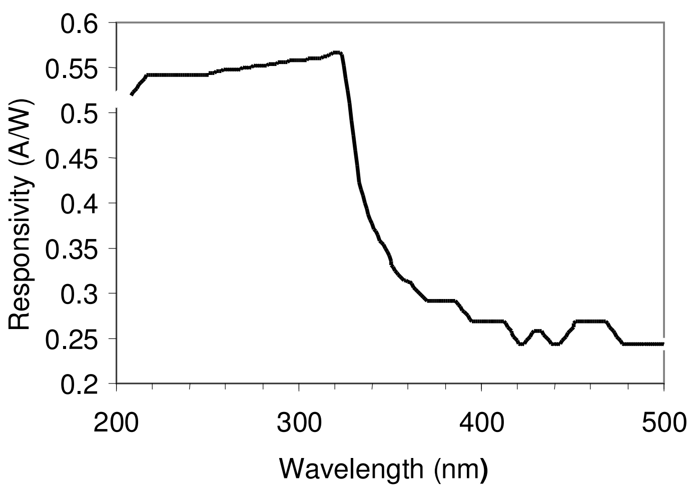


Figure 4. The spectral response of a typical GaN MSM photodetector biased at 2.5 V

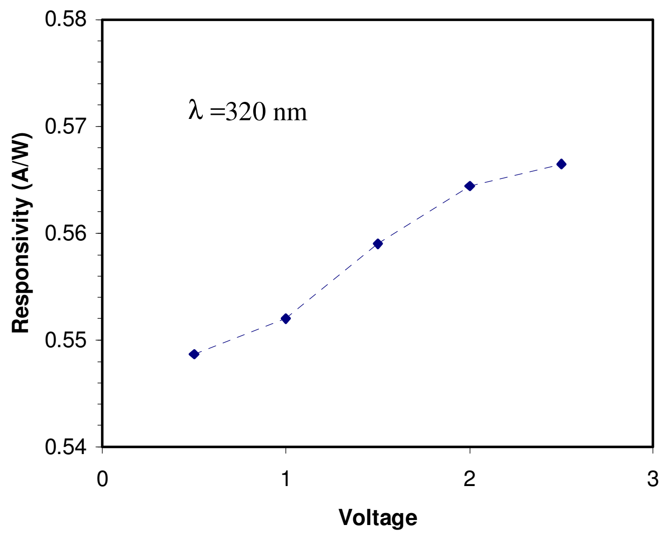


Figure 5. The responsivity as a function of reverse bias

## 4. Conclusion

In summary, we have reported on achievement of very low dark current MSM UV photodetectors based GaN epitaxial layers. The spectral response is typical of visible-blind GaN-based UV photodetectors. We believe these results demonstrate the high quality of the GaN crystals used to fabricate these devices, and the very low dark current are encouraging for future device applications.

**Acknowledgment**

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