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**E-2-5**

# The Study of GaN and InGaN Metal-Semiconductor-Metal Photodetectors with Different Schottky Contact Metals

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## 1. Introduction

The characterization of n-type doped GaN, p-type doped GaN and n-type doped $In_{0.2}Ga_{0.8}N$ Schotty metal-semiconductor-metal (MSM) photodetectors are reported. The epilayers were grown on sapphire by metal organic chemical vapor deposition (MOCVD). Schottky contacts were made with Au, Ti, Ni and Pt metals. The dark and illuminated current-voltage characteristics for GaN and InGaN MSM photodetectors with different Schottky metals were studied. The n-GaN MSM photodetectors with Au Schottky contacts have better responsivity than those of other metals and are also better than Au/p-GaN and Ti/n- $In_{0.2}Ga_{0.8}N$ MSMs. The effects of the pitch width between the interdigitate fingers and the thickness of Schottky metals on the characteristics of photocurrents were also studied.

## 2. Results and Discussions

The photo-currents in Ti/GaN and Au/GaN MSM PD are shown in Fig.1. In Au/GaN photodiodes, the response curve has a turn-on voltage of 1V, but there is no turn on voltage in the Ti/GaN MSM photodiode. It is due to the lower barrier height of Ti Schottky contacts with GaN.

The life time and mobility product ($\tau\mu$) can be estimated from the photo-conductor gain $G=\tau\mu V/d^2$ where d is the pitch width in the MSM device of 5 $\mu$m. The photo-conductor gain for Ti contact $G_{Ti}$ is $1.32\times10^5$ at 6V. Therefore, $\tau\mu$ is equal to 0.0055 $cm^2V^{-1}$ where $\mu$=350 $cm^2V^{-1}s^{-1}$. Thus the life-time ($\tau$) can be estimated to be about 15.7 $\mu$s.

The response curve has a 1V turn on voltage and the photo currents increase linearly from 1V to 2.5V, then saturate after 3V. The photo-currents exhibit saturation phenomenon which may be due to generation-recombination centers in the MS interfaces.

The photo-conductor gain $G_{Au}$ for Au is equal to 3.09 $\times10^6$ at 6V bias. Therefore, $\tau\mu$=0.12875 $cm^2V^{-1}$ where $\mu$=350 $cm^2V^{-1}s^{-1}$. Thus the whole life-time ($\tau$) in the Au/GaN MSM photo-diodes is estimated to be about 132 $\mu$s[1]. So from the comparisons of the dark currents, it is found that the MSM photo-diodes with Au Schottky contacts have better detectivity than those with Ti contacts.

As shown in Fig.2, the dark currents in Au/$In_{0.2}Ga_{0.8}N$ MSM photo detectors are larger than those in Au/n-GaN photodetectors. And the photo response in the Au/ $In_{0.2}Ga_{0.8}N$ photodiodes are very weak. It is attributed to the low barrier height of Au contacts with $In_{0.2}Ga_{0.8}N$ and a great volume of defects in $In_{0.2}Ga_{0.8}N$ films. So the GaN photiodes have better detectivity than $In_{0.2}Ga_{0.8}N$ for UV deuterium lamp. Figure 3 shows the photo currents of $In_{0.2}Ga_{0.8}N$ MSM photodiodes with different contact metals of Au and Ti, respectively. The Au Schotty contacts have lower dark currents than Ti contacts with $In_{0.2}Ga_{0.8}N$ due to the low barrier height of Ti contacts with $In_{0.2}Ga_{0.8}N$.

In Fig.4, the Ni metals with different thickness were evaporated onto the p-type GaN. It is found that the semi-transparent contacts with thinner metal thickness of 60 nm have larger response currents. But the dark currents are almost the same for Ni metals with different thicknesses. When the metal thickness reaches a critical value above 200 nm, the photo response will not occur. The photo-electrons must be generated under the electrode otherwise they will not be collected. In the pitch region between interdigitate fingers, the generated e-h pairs in the p-GaN layers must close to the electrode otherwise they will not be collected. This is because of the great volume of trap centers in p-GaN. Before the carriers sweep to electrode, they are captured by trap centers.

Figure 5 shows the comparisons of photo-currents in p-type GaN MSM photodetectors with those in n-type GaN. The Au/n-GaN photodetedtors have larger photo-response than Ni/p-GaN's. So, among the n-GaN, p-GaN and n-InGaN epilayers with different Schottky metals of Au, Ti, Ni and Pt, the n-GaN MSM photodetectors with Au Schottky contacts are the best structure which can generate very much photo-currents from UV illuminations.

## References

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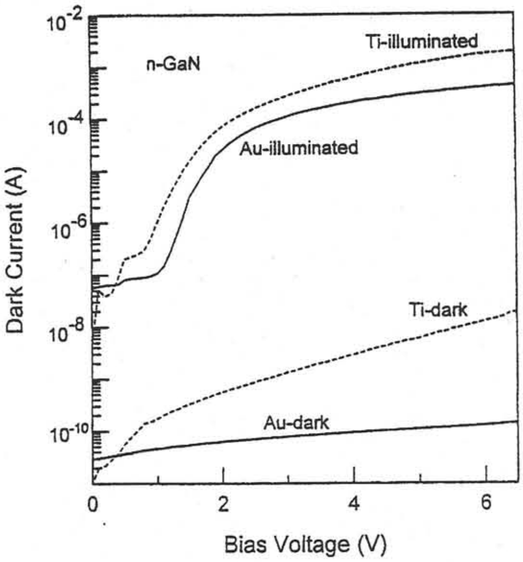


Fig.1 Dark and illuminated current-voltage charcteristics of n-GaN MSM photodetectors with Schottky contact metals of Au and Ti, respectively.

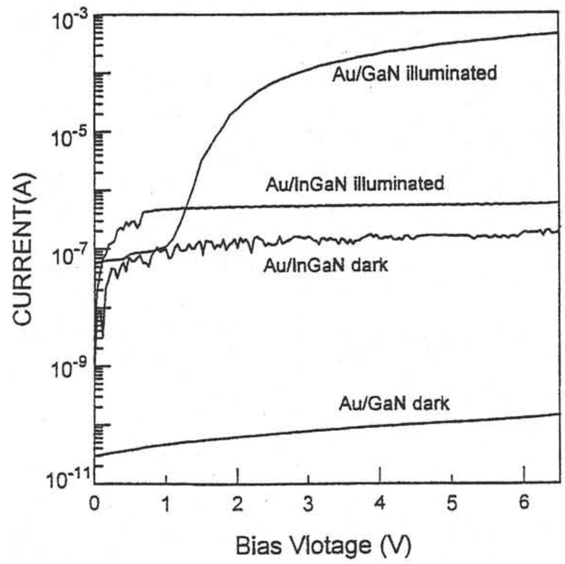


Fig.2 Dark and illuminated current-voltage charcteristics of n-GaN and n-$In_{0.2}Ga_{0.8}N$ MSM photodetectors, respectively, with Schottky contact metals of Au.

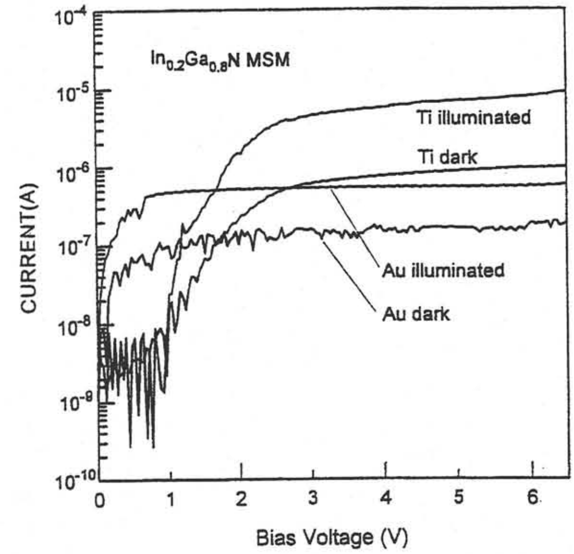


Fig.3 Dark and illuminated current-voltage charcteristics of n-$In_{0.2}Ga_{0.8}N$ MSM photodetectors with different Schottky contact metals of Au and Ti, respectively.

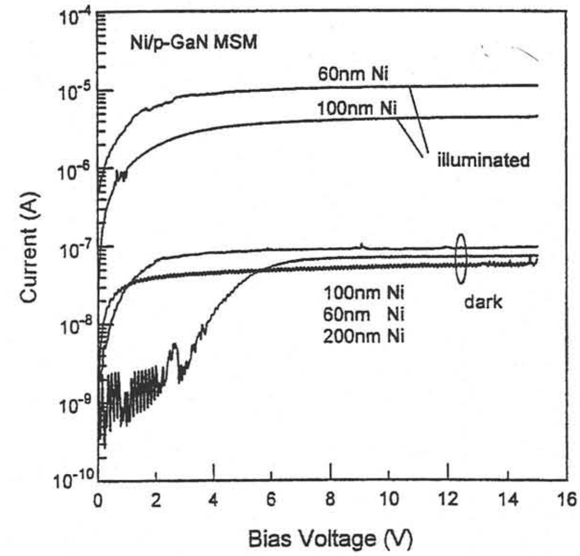


Fig.4 Dark and illuminated current-voltage charcteristics of Ni/p-GaN MSM photodetectors with different Schottky contact thicknesses.

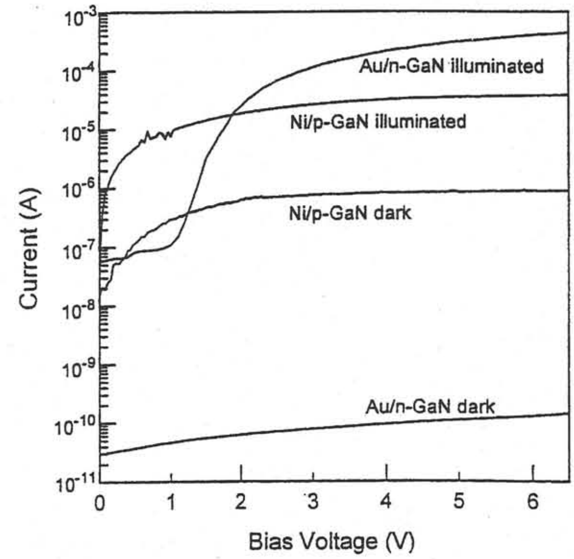


Fig.5 Dark and illuminated current-voltage charcteristics of Au/n-GaN and Ni/p-GaN MSM photodetectors, respectively.