# 256x256 GaN ULTRAVIOLET IMAGING ARRAY

Z.C. Huang, D.B. Mott and P.K. Shu
NASA/Goddard Space Flight Center,
Solid State Device Development Branch, Code 718.1,
Greenbelt, MD 20771
301-286-7020, Fax: 301-286-1672

## Abstract

We have successfully developed a 256x256 photoconductive GaN area imaging array using a metal-semiconductor-metal structure. The array, with its pixels (30 $\mu m^2$) indium bump bonded to a readout integrated circuit, showed a 90% of yield. The spectral response of the array is consistent with the measured spectral response of the single photoconductors fabricated elsewhere on the source wafer.

## INTRODUCTION

There has been a strong demand for compact solar blind solid-state ultraviolet (UV) photodetectors for high temperature operations in both private sectors and government. The use of III-V nitrides for photodetector applications is expected to yield high responsivities with low dark currents over a wide range of temperature operations. GaN and aluminum nitride (AlN) have direct bandgaps of 3.4 and 6.2 eV, respectively, with corresponding cutoff wavelengths of 365 and 200 nm. Since they are miscible with each other and form a complete series of aluminum gallium nitride (AlGaN) alloys, it should be possible to develop detectors with wavelength cutoffs anywhere in this range.

During the past three years, prototype nitride-based single element photodetectors and linear arrays have been fabricated and studied by several groups (Khan 1992, Kung 1995, Chen 1995, Huang 1996, and 1997). It is commonly reported that the detector performances varied from sample to sample depending on the material quality. Although these materials show great promise, there is still a great deal of work to be done to develop their manufacture so that their properties reach their full potential. Despite the need for continued research, these materials have reached sufficient maturity to warrant a vigorous device development effort to create UV image sensors out of these materials. Device development of detectors from these materials will require extensive effort over several years. In this work, we report for the first time our success in making large area photoconductive arrays on GaN using metal-semiconductor-metal (MSM) structures. The spectral response of the array is consistent with those reported on the element GaN photoconductors.

## METHODS AND RESULTS

Semi-insulating undoped GaN materials were grown by metalorganic chemical vapor deposition (MOCVD) at 1100°C (Wickenden 1995). The MSM 256x256 area array with each

CP420, *Space Technology and Applications International Forum-1998*
edited by Mohamed S. El-Genk

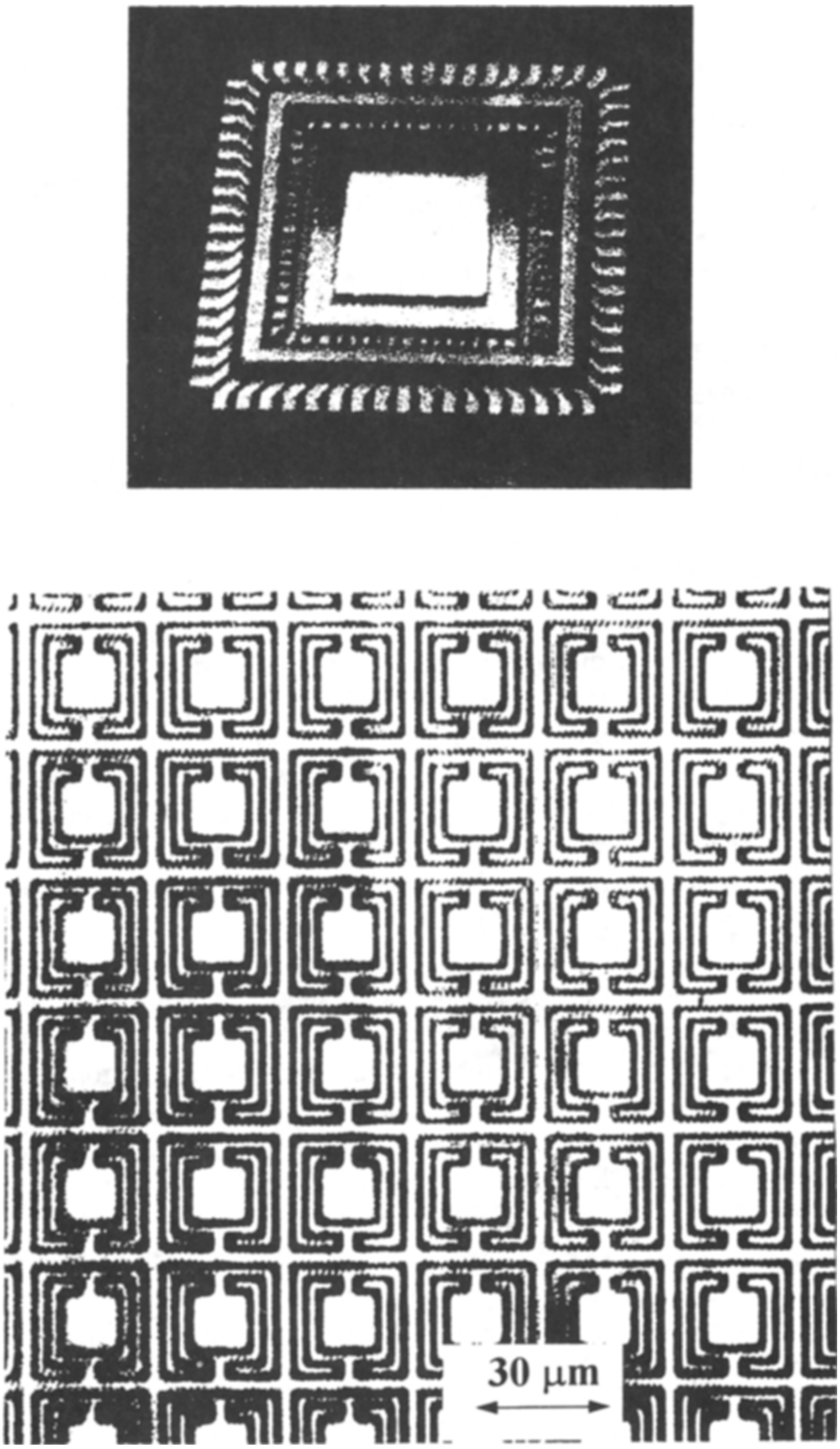


FIGURE 1. The GaN Area Photoconductive Array.

pixel size of 30 μm² was made by conventional lift-off technique. The part of the array is shown in Fig.1. The ohmic contacts were made by evaporating 200A Ti, and then 300A Al followed by 1200A Au, and annealing at 450°C for 5 minutes in a $N_2$ environment. After the fabrication, each array was sliced and bump bonded to a Lockheed Martin Fairchild Systems LT9601 Readout Integrated Circuit (see Fig.1). Due to the insulating nature of the sapphire substrate, it is impossible to collect the signal through the substrate as it is done in Si-based detector arrays. Instead, the incident light was illuminated on the GaN array through the back side, i.e. sapphire side, and the readout system was bonded through the front side. No absorption loss was observed by the buffer layer as long as it is not too thick (in our sample, the thickness of buffer layer is 500A). Fig.2 shows a comparison of the spectral responses between the front and the back illuminations from a single element detector. The responsivity through the front illumination is even smaller than that through the back illumination, presumably due to the absorption and/or reflection by the GaN surface.

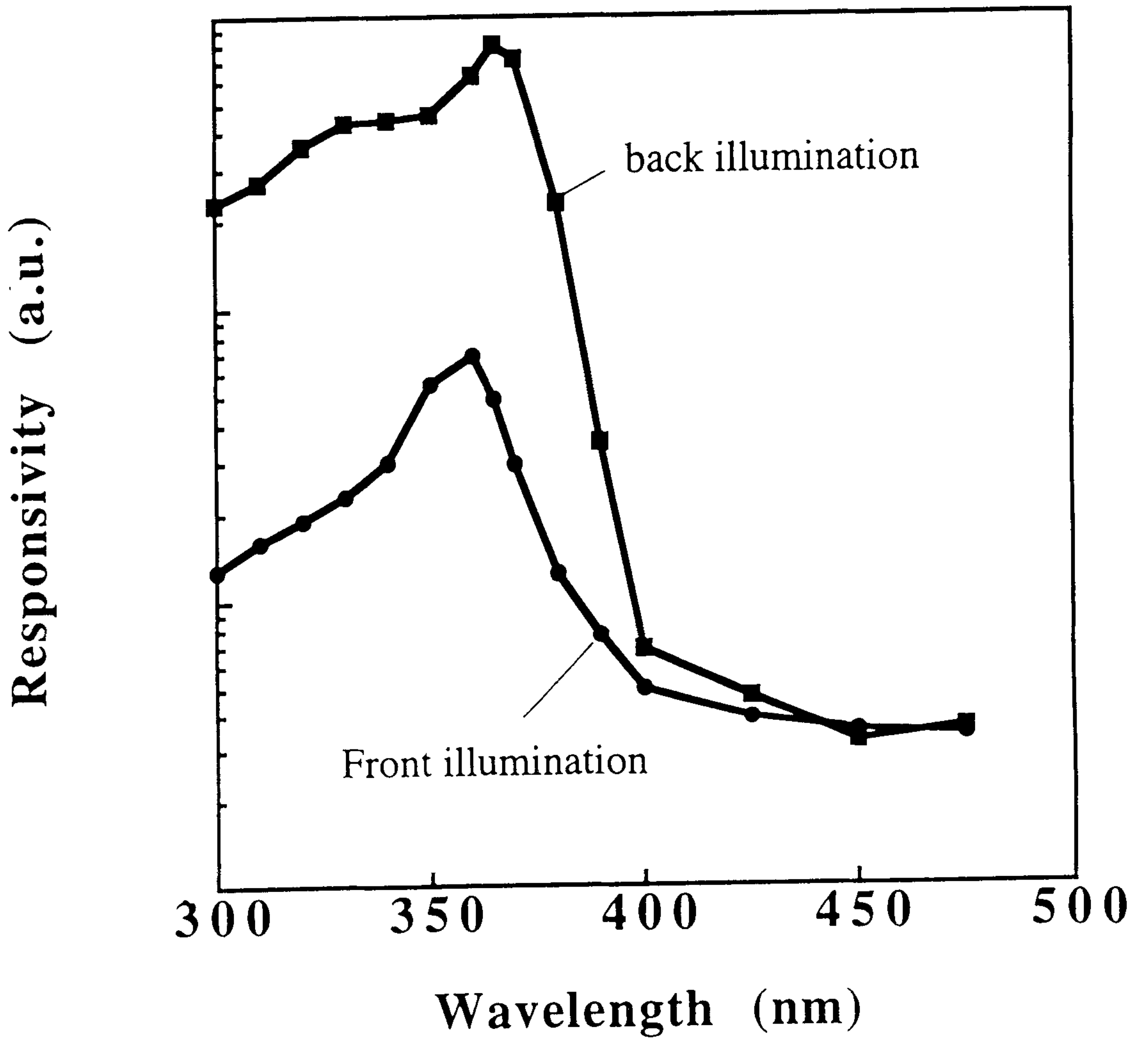


FIGURE 2. The Comparison of the Spectral Response from a Single Element Detector Between the Front and the Back Illumination.

Fig.3(a) shows a mean spectral response from our first array under an operation bias of 5 V. The response from an unmated individual pixel located elsewhere on the starting wafer showed a similar result. Since the starting material has a pretty high conductivity, the visible response in

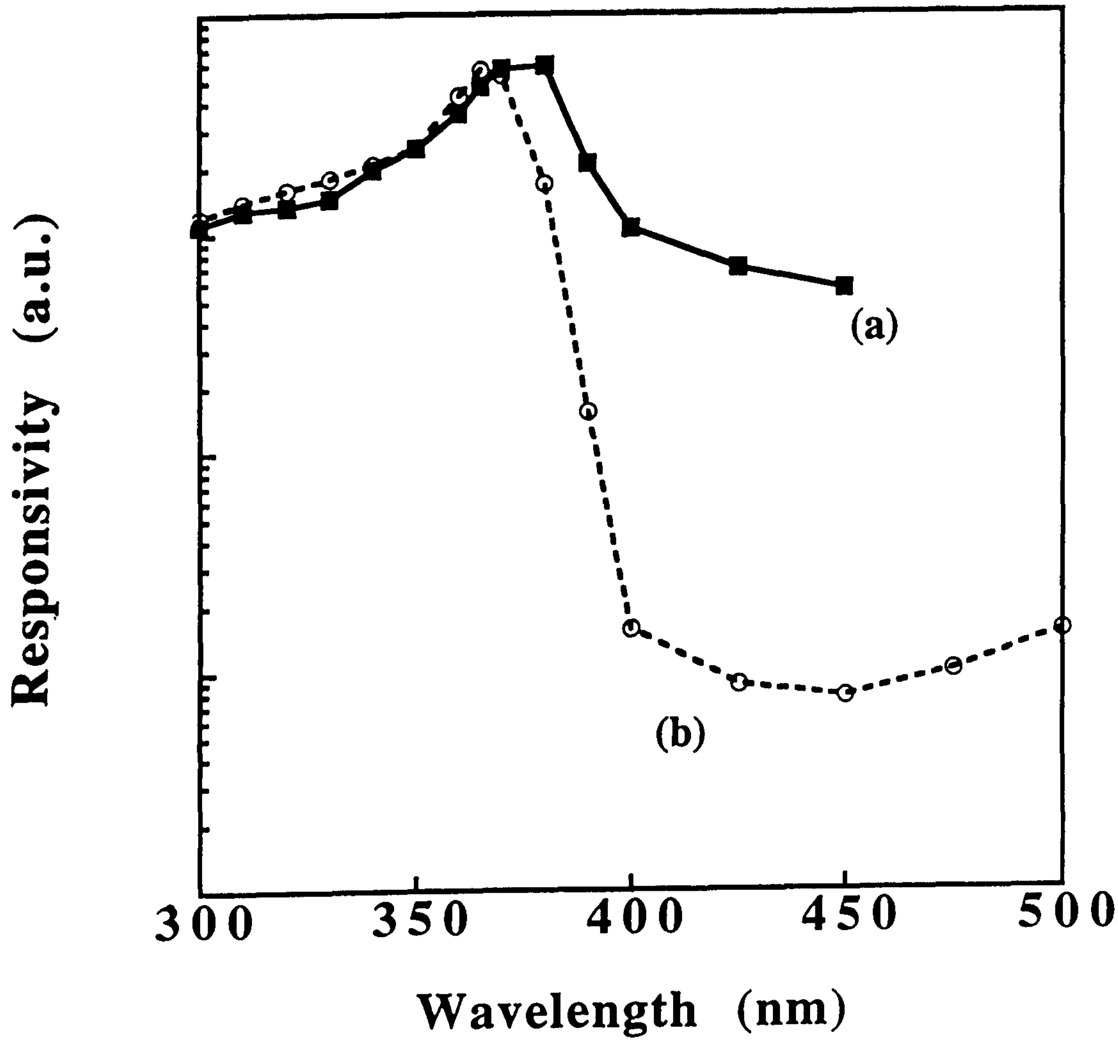


FIGURE 3. (a) The Mean Spectral Response of the GaN Array Under a Bias of 5V Through Back Illumination. (b) The Spectral Response from a Test Pixel of the GaN Array in the Second Production Run.

Fig.3(a) is due to large leakage current, rather than a result of light leakage to the silicon readout chip, because we used an extra layer to protect the readout chip from the light. Also shown (in Fig.3(b)) is the spectral response of a test pixel from a GaN wafer in the second production run, indicating much improved visible light rejection. These results are consistent with the previous reported spectral responses from the GaN single element (Huang 1997) and linear detectors (Huang 1996).

The success of GaN area array makes it possible to replace the current UV detection devices, such as photomultiplier tubes and silicon-based sensors in Earth observation applications.

## SUMMARY

In conclusion, we have reported for the first time the fabrication of large area GaN array using a metal-semiconductor-metal structure through back illumination. The device consists of a 256x256 array of 30 μm square GaN photoconductors indium bump bonded to a Lockheed Martin Fairchild Systems LT 9601 Readout Integrated Circuit. About 90% of the pixel are responsive. The spectral response showed a good visible light rejection.

## Acknowledgments

We would like to thank Dr. D.K. Wickenden for sample preparation and valuable discussions.

## References

Khan M.A., Kuznia J. N., Olson D. T., Van Hove J. M., Blasingame M., and Reitz L. F., (1992) "High-responsivity photoconductive ultraviolet sensors based on insulating singe-crystal GaN epilayers," Appl. Phys. Lett., 60: 2917

Kung P., Zhang X., Walker D., Saxler A., Piotroski J., Rogalski A. and Razeghi M., (1995) "Kinetics of Photoconductivity in N-Type GaN Photodetector," Appl. Phys. Lett., 67: 3792

Chen Q., Khan M. A., Sun C. J. and Yang J. W., (1995)"Visible-Blind Ultraviolet Photodetectors Based on GaN p-n Junctions," Electron. Lett., 31: 1781

Huang Z. C., Chen J. C. and Mott D. B. (1997) "Improved Performance of GaN Ultraviolet Detectors," J. Electron. Mater., 26: 330

Huang Z.C., Chen J.C., Mott D.B. and Shu P.K., (1996) "High Performance GaN Linear Array," Electron. Lett., 32: 1324

Wickenden A.E., Wickenden D.K. and Kistenmacher T.J., (1995) "The Effect of Thermal Annealing on GaN Nucleation Layers Deposited on (0001) Sapphire by MOCVD," J. Appl. Phys., 75: 5367