Contributed paper

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# Properties of metal-semiconductor-metal and Schottky barrier GaN detectors

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*We report on development of MSM and Schottky barrier visible blind detectors on gallium nitride which exhibit responsivities of 0.5 A/W and 0.1 A/W respectively. GaN band edge absorption occurs at 365 nm and naturally provides "visible blindness" of devices. The fabricated Schottky barrier devices exhibit flat spectral response for the UV light. Typical dark current of detector is 1 nA per square millimetre. The estimated detectivity and noise equivalent power of our devices are close to the best reported elsewhere.*

**Keywords:** GaN, visible blind photodetector.

## 1. Experimental

The epitaxial structure of both types of devices is described in Table. 1.

Table 1. Epitaxial structure of devices.

| Material | Doping/concentration | Thickness |
|---|---|---|
| GaN | Undoped | 1.00 μm |
| GaN | Silicon / $10^{17}$ cm$^{-3}$ | 0.50 μm |
| GaN | Silicon / $2.5\times10^{18}$ cm$^{-3}$ | 0.75 μm |
| GaN buffer | Undoped | 3.00 μm |
| Sapphire substrate | | |

This structure was grown in the MOCVD reactor using standard metalorganic chemistry. The processing of a Schottky barrier type of detector was the following. The ohmic metal contact to the buried $n^+$ layer was in a shape of the rectangular frame placed at the bottom of mesa. We etched mesa in the RIE system using $BCl_3$ gas. The contact sandwich consisted of Ti/Al/Ni/Au layers sputtered in one single process. Contact metallisation has been alloyed at 400°C in the $N_2$ atmosphere for 5 minutes.

At the mesa top we deposited Schottky barrier metal in the two steps. First, we evaporated Ni/Au thin metallisation which was semitransparent in the UV range (transmission was checked in Beckman spectrum analyser and its value was 55% for the wavelength of 350 nm). Second, we evaporated 0.5-μm thick gold frame at the perimeter of a thin contact area using lift off technique. The general view of the chip is presented in Fig. 1.

Processing of the MSM detector was different. We started with $SiO_2$ passivation of an entire wafer and then we defined isolation of the bonding pads leaving the rest of surface exposed. Then we evaporated Ni/Au metallisation which has a very fine pattern. In Fig. 2, one can see different device geometries integrated in one mask. We report here on devices which have 1-μm wide metal strips separated by 1 μm gap of exposed GaN. Effective detector area has a shape of the square 100×100 μm.

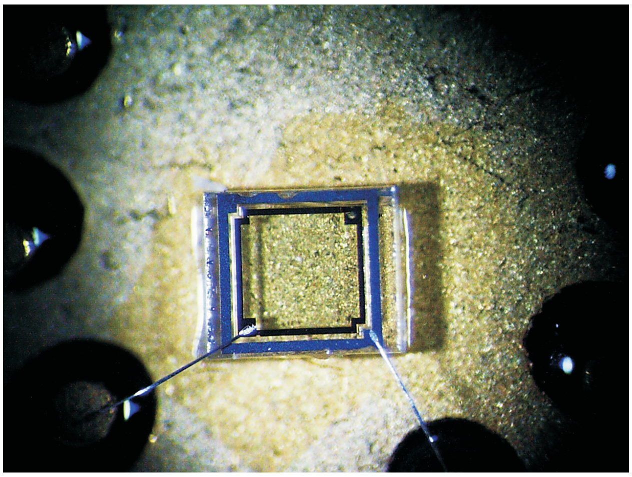

Fig. 1. Chip of the Schottky barrier detector.

## 2. Photoelectrical properties of devices

In both types of devices we used the nickel Schottky barrier. Its height we estimated out of the capacitance-voltage (C-V) characteristics. Generally, we noticed different values of barrier height (0.5–1 V) depending on semiconductor doping and on surface preparation before the metal deposition step.

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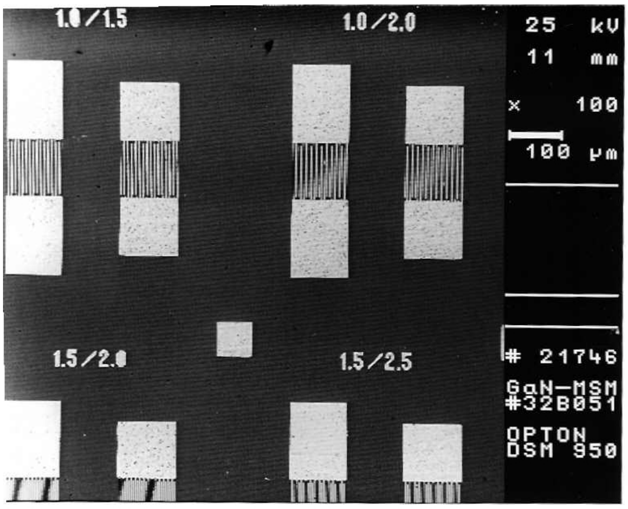

Fig. 2. A set of MSM detectors on GaN.

The intentionally undoped top-layer exhibits, after the C-V analysis, n-type conductivity with donor concentration of (2–5)×$10^{15}$ $cm^{-3}$. This value is an indicator of a good reactor status. The current-voltage (I-V) dark current characteristic of the Schottky type of detector is presented in Fig. 3. We reached a level of approx. 1 nA per millimeter square which value is frequently reported. The ideality factor of diodes was smaller than 1.05. The I-V curve of MSM detector is presented in Fig. 4. The dark current value is $10^{-7}$ A.

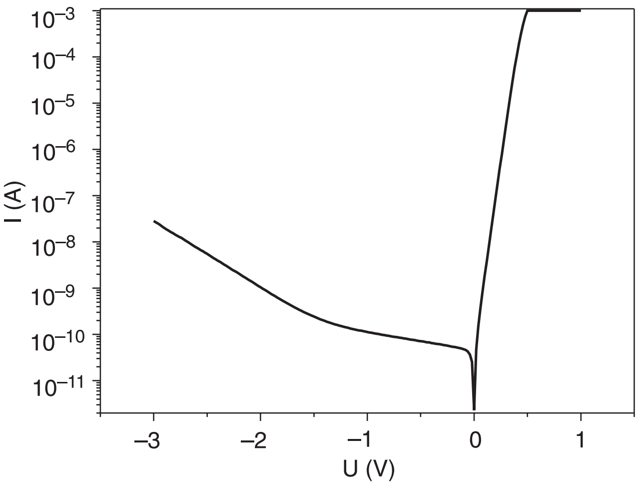

Fig. 3. I-V characteristics of GaN Schottky barrier detector. Detector area of 0.8 $mm^2$.

Responsivities of detectors have been measured in an arrangement consisting of xenon arc lamp, dense diffraction grating and the lock in amplifier. Devices were illuminated from the front side and operated without external bias in a case of the Schottky barrier detector and with a bias of 1.5 V in the case of the MSM detector.

In Fig. 5, we can see semiconductor absorption edge at 365 µm, responsivity of 0.1 A/W and a UV/visible rejection ratio of $10^3$.

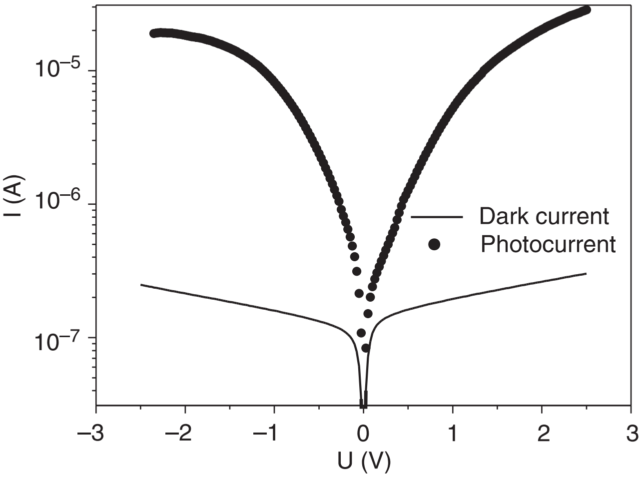

Fig. 4. I-V characteristics of GaN MSM detector. Electrode width 1 µm, separation of electrodes 1 µm. Effective detector area 100×100 µm. Illumination with Pen-Ray IISC-1 lamp equipped in filter G-278 (365 nm). Light power 65 µW.

The same analysis for MSM type of device shown in Fig. 6 reveals the record value 0.5 A/W of responsivity which has been obtained due to the high internal gain of the device. This feature can be predicted out of Fig. 4, where the photocurrent I-V curve has a very steep slope compared to the dark current I-V relationship.

We have estimated detectivity of our Schottky barrier detector after direct measurements of the low frequency noise. Measurements set up consisted of the home made current preamplifier and the Agilent 35670 A dynamic signal analyser. In Fig. 7, one can see that after applying external bias noise spectra become of 1/f type. Using the values of noise intensities for frequencies above 500 Hz we estimate minimum Jones type detectivity at 2.2×$10^{11}$ $cmHz^{1/2}W^{-1}$ and NEP at 2.2×$10^{-13}$ $W/Hz^{1/2}$. Values of these parameters found in the literature are similar [1–3] except record values estimated for p-i-n photodetectors [4,5].

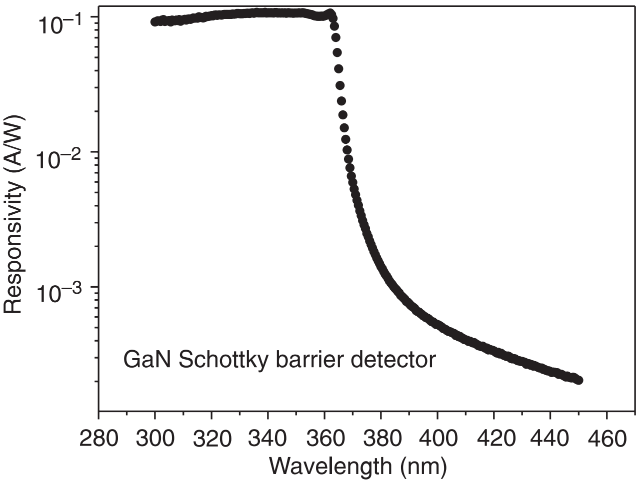

Fig. 5. Spectral response of GaN Schottky barrier detector for unbiased device.

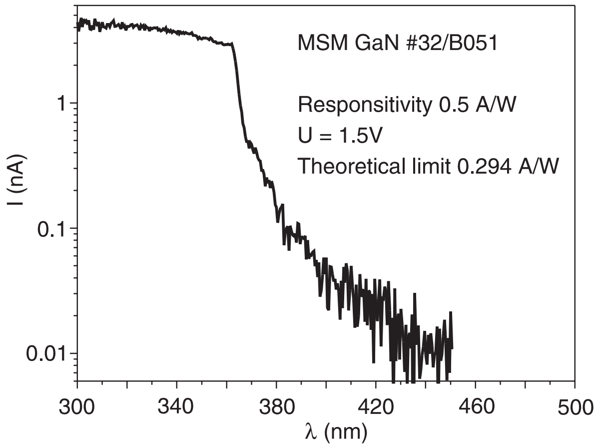

Fig. 6. Spectral responsivity of GaN MSM detector.

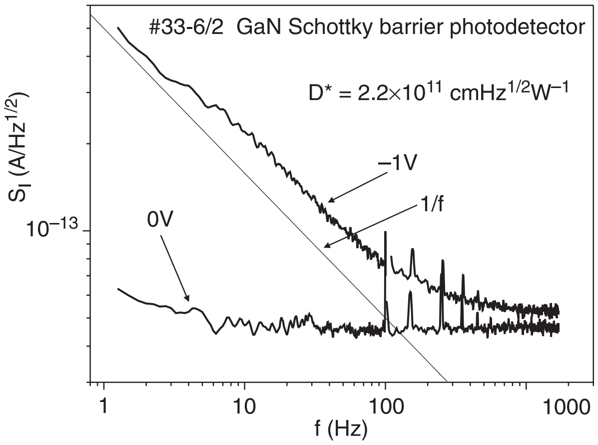

Fig. 7. Low frequency current spectral noise densities of GaN Schottky barrier detector.

## 3. Conclusions

We have described experimental studies of the visible blind detectors on gallium nitride and report the following parameters of our Schottky barrier detector on GaN:

- responsivity 0.1 A/W,
- UV/visible rejection ratio $10^3$,
- detectivity $2.2\times10^{11}$ cmHz$^{1/2}$ W$^{-1}$,
- noise equivalent power $2.2\times10^{-13}$ W/Hz$^{1/2}$, and
- responsivity of 0.5 A/W of MSM detector.

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