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Modulation of Resistivity of Two-Dimensional Electron Gas in AlGaN/GaN Structure

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1. Introduction

AlGaN/GaN high electron mobility transistors (HEMT) have been the subject of intense research during the last ten years. A two-dimensional electron gas (2DEG) with a very high sheet carrier concentration is normally presented in the AlGaN/GaN heterostructure. The 2DEG is induced by a large piezoelectric polarization of the strain AlGaN layer and is therefore very sensitive to the surface condition. Gated or Gateless HEMT structures have been demonstrated the ability to perform as gas [1] and chemical sensors. [2]

The resistance response of the device when photons with sub-bandgap energy are illuminated on the surface of the AlGaN/GaN HEMT structure is studied in this report. A decrease of the resistivity between the drain-source electrodes is observed, which is consistent with the report from a different group. [3] The resistivity increases under the same condition except an UV excitation is presented at the same time. The evolution of the changes in resistivity is recorded and analyzed in this report.

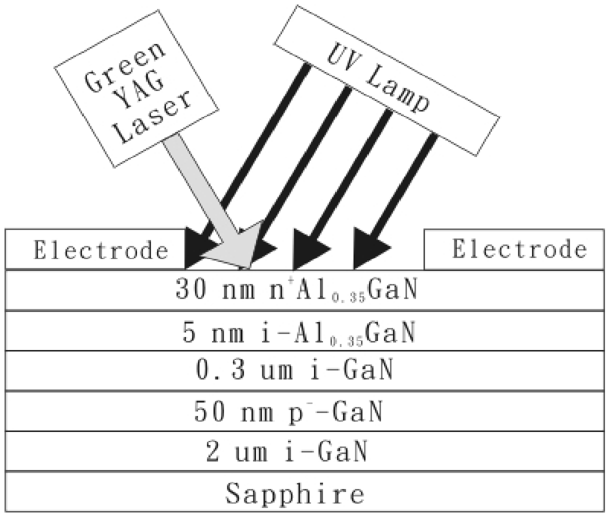

Fig. 1 Experiment Setup and Sample Structure

2. Experimental results and discussion

The experimental setup and sample structure is shown in Figure 1. The AlGaN/GaN heterostructure was grown by MOCVD on a (0001) sapphire substrate. The sheet carrier concentration of the 2DEG is around 1×10^{13} cm^{-2}. Ohmic contacts were formed by evaporating Ti/Al (50 nm/150 nm) and subsequently alloying in 650°C for 30 seconds. The width of the electrode is 700 μm and the distance between the electrodes is 800 μm.

The resistance responses of the AlGaN/GaN HEMT device to different excitation sources were investigated. Schematic set-up of the experiment is shown in Fig.1. The 532 nm green laser is a continuous (CW) second harmonic Nd: YAG laser with a 5 mW output power. The emission wavelength of the UV lamp (Spectroline B-14N) is 365 nm with a typical peak intensity of 730 (μW/cm^2). The device under investigation is biased by a constant current of 10 mA and the voltage drop between the electrodes is measured by the Keithley 2400 Sourcemeter. An around 45 mV of voltage drop is observed when the surface of the device is illuminated by the green laser light. The voltage drop takes about 200 seconds to reach a stable value. After the green laser light is turned off, the voltage drop gradually returns to its original level. The evolution

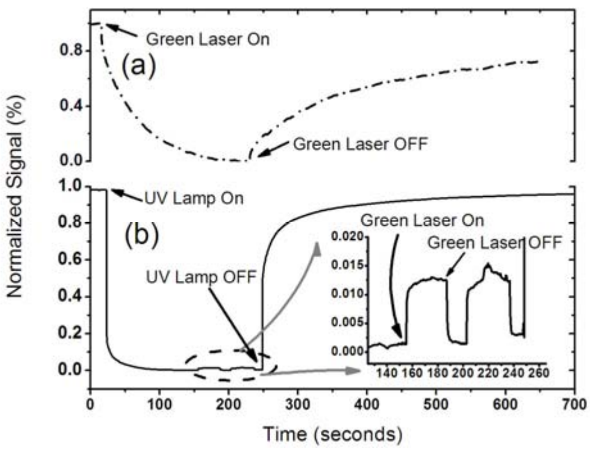

Fig. 2 Evolution of Normalized voltage signal when (a) only light from green laser is (b) light from both UV lamp and green laser are illuminated on the gate region. The biased current is 10 mA. The inset of Fig. 2(b) is an enlargement of the circle area in Fig. 2(b)

of the decay and the recover are recorded and shown in the Fig. 2(a).

However, during the above measurements, we observe different phenomena with indoor fluorescent light on and off. Thus, more detailed experiments need to be designed to verify the influence of the fluorescent lamp. First, the experiment setup is kept in dark and 10 mA of constant current is applied to the HEMT device. A significant voltage drop is observed (~0.5 V) right after the UV lamp is turned on. The voltage drop takes several tens of seconds to reach a stable status. The green laser is subsequently turned on and a small voltage increase (~18 mV) is observed. After the green laser is turned off, the readings of the voltage are back to its original voltage reading, shown in Fig. 2(b). Note that the amplitude and the sign of the voltage change induced by the same green laser excitation with or without UV light illumination are different. In addition, the evolution time constant for the voltage change is also different, which indicates different mechanisms are responsible for each change even though both are induced by the same laser excitation. The detailed experimental results about the parameters of the resistance response are summarized in Table I.

Table I Time evolution parameters of the optical response of drain-source voltage under different illumination conditions

Description	Time Constant (s)	Correlation	Amplitude (V)
Green laser ON	52.21	0.9967	0.0455
Green laser OFF	136.65	0.9975	0.0320
UV+ Green Laser ON	0.0649	0.9447	0.0180
UV+ Green Laser OFF	0.1164	0.9731	0.0190

The decrease of the resistivity under the green laser excitation is very slow. Mizutani et al.[3] has observed similar phenomenon and suggested that surface states are responsible for this phenomenon. This is also consistent with our observation. Photons with sub-bandgap energy slowly filled up the surface states and the resistivity decreases because of a increasing of 2DEG concentration. The origin that is responsible for the fast voltage modulation under UV light illumination is still not clear and is currently under further investigation.

3. Conclusions

In conclusion, a HEMT device with high 2DEG is investigated. It is found that the decrease of resistivity between drain and source under sub-bandgap optical excitation is very slow. This phenomenon is speculated owing to surface states. On the other hand, an increase of resistivity is observed when the sub-bandgap optical excitation is performed under an UV source. Thus, this device can be fast modulated due to fast response time. This is not a familiar phenomenon and is confirmed that the mechanism is different from photoconductivity effect. Further experiments will be conducted to help us understand the details.

References

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