

Sub-Terahertz detection using 0.18 μm UMC MOSFET with 250nm gate length: Variable Power Sensitivity

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Abstract: In this paper presented the sub-Terahertz (sub-THz) radiation detection at 220 GHz using 0.18 μm UMC Metal Oxide Semiconductor Field Effect Transistor (MOSFET). The detector was design using CADENCE and the devices were sent to Europractice for fabrication. As a results the photoresponse of the MOSFET are observed by measuring a gate voltage against a drain current descendent at ambient temperature. The variable power sensitivity were also been measured with peak photoresponse is generally increasing response by increasing the input power and with peak approximately at threshold voltage. There is evidence that the MOSFET with a gate length (Lg) of 250 nm can be a room temperature sub-THz detector with variable power sensitivity.

Keywords: sub-Terahertz, detector, photoresponse, sensitivity.

1. Introduction

Recent race on developing compact Terahertz detectors is one of the hot issues in modern Terahertz electronics. Many application across scientific used of THz radiation, such as detection of weapons and explosives, remote sensing, and sensing of chemical and biological systems. Therefore the development of sensitive and compact THz detectors is important to the advancement of these technologies. Many different types of THz detectors have been developed and most recently Plasma Waves detectors in Field Effect Transistors (FETs) [1], [2]. Previous sub-THz and THz radiation detection was reported by W.Stillman et al using Complimentary Metal-Oxide-Semiconductor Field Effect Transistor or MOSFET in conventional CMOS process where both N channel and P channel of MOSFETs can be used as sub-THz and THz detector [3]. Later on, it had been reported that Silicon-On-Insulater Metal Oxide Semiconductor Field Effect Transistor (SOI MOSFET) can be used as THz detector at different temperature from 8K -350K [4]. All these devices were tuned to the THz frequency by varying the gate bias. THz detection by FETs is one of promising technologies since it can be both selective and tuneable. Recently, experimental evidence of detection of THz signal was demonstrated in commercial AlGaAs/GaAs FETs[5], a double quantum well FET with periodic grating gate[6] and HEMTs[7].

2. Design Procedure and Experimental Setup

The purpose for this paper is to present the photoresponse of a MOSFET devices and the effect of variable power sensitivity were also been measured. In these experiments, the devices are biased so that it detects continuous wave (CW) sub-THz radiation up to 220 GHz, where as the author knowledge that these experiments have never been done before at above 200 GHz in CW sub-THz detection. Several MOSFET devices were designed using CADENCE in UMC 0.18 μm CMOS process technology. In this design the MOSFET's gate length is $L_g = 250$ nm with the gate width, $W_g = 5$ μm . These MOSFET devices design then, were simulate in Layout vs Schematic (LVS) process to make sure the connection between layout and schematic are same. In the MOSFET devices design, the devices in this work are different from the previous published work since the gate and drain were connected directly to the RFPADs which allows electrical (both DC and RF) connections to be made by using RF Probes which have a 75 μm pitch. The maximum frequency of operation of the Picoprobe GGB Industries RF-Probe is 0.22 THz [8].

The observation of photoresponse and variable power sensitivity has been done by a function of gate voltage and with drain current enhancement. All these measurements were made in open laboratory at ambient room temperature. From Fig.1, the sub-THz radiation was produced by an Olsen Microwave Lab (OML) vector network analyser extender (V03VNA2-T/R module) which operates between 140 GHz up to 220 GHz. The VNA extender was connected to an Anritsu Broadband Network Analyzer ME7808B that operating in CW mode. MOSFET devices were placed on to the XYZ Probe station, so that the 75 μm pitch RF probe can be easily placed on to the appropriate RF pads which allow the connections to the drain, gate and source of the device. Note the devices are configured in common source mode so the source is connected to ground. The biasing gate voltages and drain currents are supplied by Keithley Source Measurement Units model numbers 236 and 237 respectively. The drain-source voltage (VDS) was measured using a Keithley Digital Multimeter 238.

The power from the VNA extender at 10 μwatts was coupled into the MOSFET devices using a length of rectangular waveguide connected with 75 μm pitch RF probe. The RF probe was placed directly onto RF pads so that the maximum power and frequencies can be couple towards MOSFET devices. This method is called quasi-static. In measuring the photoresponse of the device to the incident radiation, the value of VDS measured when the incident radiation was on, was subtracted from the value obtained when the radiation was off. The power of the incident radiation was turn off by removing the incident RF power to the VNA extender. Since the photo-response is small, the measurements had to be repeated 100 times and the average taken. The experiment was conducted using LabView programed and all the measurements data were analyse using Matlab.

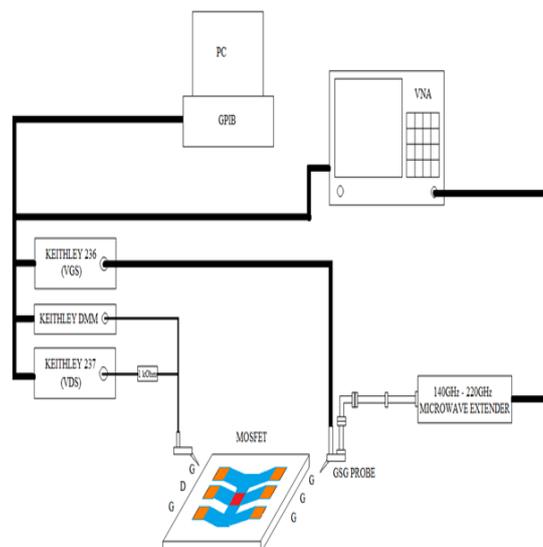


Fig. 1: Experimental setup for this work.

3. Results and discussions

The photoresponse of the MOSFET devices is shown in Fig. 2. This photorepsonse was measured as a function of VGS with 10 dBm power transmitted from VNA extender with biasing at 5 μ m. The frequency in all these measurements was constant and set to be 220 GHz. In the beginning of the experiment, the photoresponse is very small until VGS is close to the threshold voltage of the device (0.2V~0.3V). The photoresponse begins to increase when the VGS is reduced near to the threshold voltage and then levels off. Recent works on the use of THz detectors just shows a single broad peak in the responsivity whose maximum approximately occurs at the threshold voltage of the device. The peak photoresponse for each variable power is shown in Fig. 3. The variable power was varied form 2 dBm up to 13 dBm. From the graph there is a linear relationship between the photoresponse and variable power sensitivity. Several points of discussion were put forward regarding this matter.

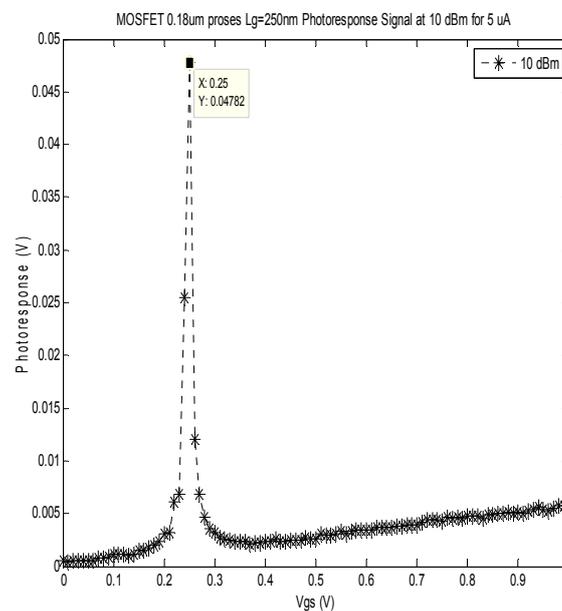


Fig. 2: Sub-THz detection photoresponse at 10 dBm which bias at 5 μ A .

Firstly, the device in these measurements is totally different from previous researchers worked. Most of the transistors from previous published papers have generally sourced them from IBM [9]. Physically, the IBM devices have a different gate length and width. The physics of the 2D plasma will depend strongly on the device layout, size and CMOS process. Secondly, the methods on measurement setup were totally different. In this experiment the THz radiation been detected using quasi-statically where the THz radiation was transmitted through RF probe on to RF pads, and went to the metal connection between RF pads and the metal at gate transistor[10]. This kind of method is contrast with the method that has been used in previous works. Previous published work used a Gunn diode as the source of the radiation, and then the THz radiation being chopped using mechanical chopper. The signal was then measured using standard lock-in techniques.

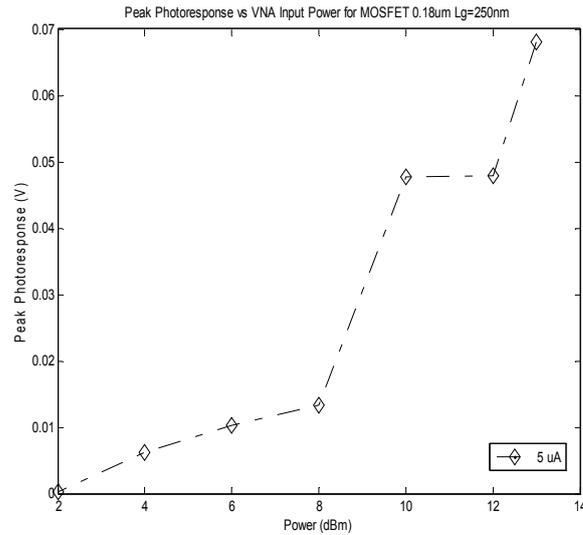


Fig. 3: Experimental setup for this work.

Thirdly, in general previous published paper measured peak width was approximately 0.2V. It could be that the result presented is just one side of an unobserved peak. However, VGS could not be reduced any further to test this criterion. As VGS is reduced below pinch off, the resistance of the channel between the source and the drain rapidly increases. Since, the drain is driven by a constant current source, the drain voltage will increase and reaches 3V the maximum permissible VDS of this device. Fourthly, in term of variable power sensitivity, there is a linear relationship between peak photoresponse and the VNA input power. As the VNA input power increases the peak photoresponse also increases. As the author concern there have no published work indicating the power sensitivity in sub-THz detector. This experiment proof that the MOSFET can be a sensitive sub-THz detector. Finally, the measured photoresponse of MOSFET THz detector depends critically on the orientation of the polarisation with radiation with respect to the gate finger. However, there was none of the published photoresponse-VGs characteristic look like the measured characteristic of this work. The high sensitivity of MOSFET devices due to CW sub-THz radiation detection gives evidence that it can be a sensitive sub-THz detector.

4. Conclusion

In summary, the photoresponse and the variable power sensitivity of MOSFET devices with gate length, $L_g = 250$ nm, and the gate width of $W_g = 5 \mu\text{m}$ to the sub-THz radiation has been demonstrated. In general, the shape of the response is different to previously reported results and several explanations have been put forward to account for these differences. There is evidence that the MOSFET can be a sensitive sub-THz detector. In the future research, an array of MOSFETs can be design and fabricate so that the sub-THz detector with a higher photoresponse and sensitivity can be achieve.

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6. References

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