Plasmonic Focusing of Light

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Abstract:

The goal of this project is to develop a terahertz detector. Terahertz is a portion of the electromagnetic spectrum that lies between the microwave and optical ranges. The device consisted of a periodic array of Schottky diodes with interdigitated comb fingers on a low-resistivity gallium arsenide (GaAs) substrate. Schottky diodes are used for terahertz detection because their nonlinear current-voltage characteristic aid in the detection of high frequency signals. In operation, the alternating electrodes are connected to a voltage source through a bias resistance. The sinusoidal electric field of the terahertz radiation modifies the average voltage difference between the electrodes, due to the nonlinear characteristics of the diode. The periodic arrangement of the Schottky diodes assists collecting a large portion of the incident terahertz radiation. Due to the time constraints, testing of the final device was not fully completed. In this paper, we present the fabrication process and the initial electrical characterization results.

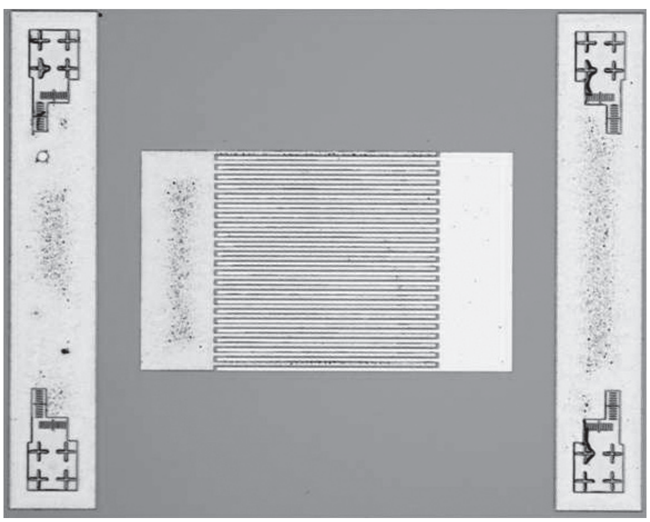

Figure 1: Completed device consisting of alternating ohmic and Schottky contacts.

Introduction:

Terahertz (THz) radiation is an electromagnetic radiation in 0.1-10 THz frequency range. This radiation lies between the optical and microwave regions of the electromagnetic spectrum. Some applications of terahertz technology include medical imaging and surveillance. For medical imaging, terahertz radiation is desirable because unlike x-rays it is not damaging to the tissue or deoxyribonucleic acid (DNA). Terahertz radiation is highly absorbed by water. Therefore, the waves can only penetrate into the body a few millimeters. This allows changes in water content to be imaged near the surface of the body, which can be used to identify tumors. For surveillance, the radiation is transmitted through fabric, plastic and several packaging materials but is highly absorbed and/or reflected by metals. This allows concealed weapons to be seen.

This paper presents a terahertz detector. The fabricated device was composed of alternating ohmic and Schottky, interdigitated comb fingers on a highly doped n-type gallium arsenide (GaAs) substrate, as seen in Figure 1. The alternating fingers formed an array of Schottky diodes. Applying a positive voltage to the Schottky contact placed the device in forward bias mode. This decreased the potential barrier resulting in an increase in the output current. The incident terahertz field between the fingers effectively added a small sinusoidal voltage to the applied bias voltage. Since Schottky diodes exhibit an exponential current gain with respect to the applied voltage, the average output current would be larger when illuminated with a terahertz radiation.

Purpose:

The size of a terahertz detector plays an important role in the total absorbed terahertz power. By choosing the geometry of the device to excite plasmonic resonances in the metal fingers, the wave can be channeled around the fingers to cause the radiation to be more intense in the active region. This allows the gap between the electrodes to be reduced, increasing the speed of the device, while using a large device size. Therefore, the presented terahertz detector is expected to provide greater sensitivity than the prior art.

Experimental Procedure:

To fabricate the terahertz detector, we first patterned the ohmic contact followed by the Schottky contact. The process consisted of two photolithography steps using Shipley 1827 photoresist spun on the GaAs wafer at 4000 rpm for 30 seconds. Using photolithography we defined the first set of fingers and one contact pad using a SUSS MA/BA6 mask aligner. The sample was exposed to an ultra violet light for twelve seconds followed by development in Microposit MF-319 for fifty seconds. The ohmic contact was formed using a SJ-20 metal evaporator to deposit nickel/germanium/gold/titanium/gold (250/325/650/200/3000 Å). For liftoff, the sample was soaked in heated acetone for approximately twenty-four hours. Cleanroom tape was applied to the sample to peel off excess metals. After liftoff, the metal was annealed at 385ºC for 60 seconds to alloy the metals. The photolithography step was then repeated to pattern the Schottky contacts. The Schottky contact of platinum/gold (1500/3425 Å) was then deposited by an EnerJet evaporator. The same liftoff procedure was followed, completing the fabrication.

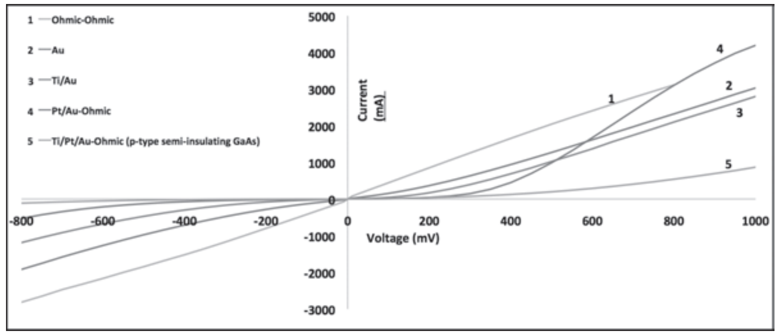

Figure 2: Schottky contact tests.

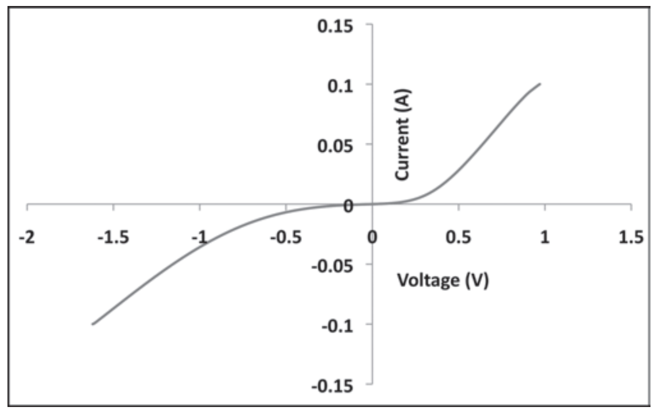

Figure 3: Current-Voltage characteristics of the final tested device.

Results:

To identify the best Schottky contact, we tested a couple of different metals on our substrate. The current-voltage results are shown in Figure 2. The platinum/gold contact responded the best, with an exponential growth with increasing voltage as is characteristic of a Schottky diode. Using the platinum/gold Schottky contact, several devices were fabricated. The current-voltage characteristics of a representative device can be seen in Figure 3. The device exhibited exponential current gain from 0 to 0.5 V. In Figure 3, the graph is not symmetrical, meaning that the diode allowed less reverse current than in the forward direction. The exponential current gain with applied voltage suggests that this device may be able to detect terahertz radiation. Due to time constraints, we were not able to obtain all of the needed equipment to fully test the terahertz radiation detection during the project.

Conclusion and Future Work:

The fabrication of a terahertz detector was optimized to create a functioning Schottky diode consisting of interdigitated fingers on a highly-doped GaAs substrate. Future work includes testing the detectors with a terahertz source and optimizing the device geometry to respond to different frequencies of terahertz radiation.

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