A Millimeter-wave CPW-fed twin slot / Infrared dipole antenna coupled Ni-NiO-Ni diode

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1. Introduction

Millimeter-wave (mmW) imaging systems offer a good complement to infrared (IR) imaging systems. High resolution IR systems suffer high attenuation in cloudy and foggy atmospheres, while mmW systems will penetrate through clouds and fog offering an excellent all-weather imaging system. In our application, we aim at integrating both mmW and IR detection capabilities in one sensor and thus combining the advantages of high resolution and all-weather detection capabilities.

Antenna-coupled metal-oxide-metal (MOM) diodes have been used in the past for detection and mixing in the IR [1] and mmW [2] portions of the spectrum. A MOM diode with low enough junction capacitance, corresponding to a small enough junction area, to rectify IR radiation will also rectify mmW radiation; thus is a good candidate for this application. CPW-fed twin slots were successfully coupled to Schottky diodes [3] and SIS mixers [4] for detection in the mmW region. Dipole antennas were also successfully coupled to MOM diodes for detection at 10.6μm [1].

In this paper we integrate both types of antennas and report on a Ni-NiO-Ni diode coupled to a dipole antenna for 28 THz response and a CPW-fed twin slot antenna for 94 GHz response.

2. Sensor configuration

The sensor configuration is shown in Fig.1. Two mmW slot antennas are CPW-fed. The CPW is modified to allow placing the MOM diode. The MOM diode is connected to an IR dipole antenna as shown in Fig.2 and Fig.3. The two horizontal cuts in the ground plane are defined to allow for detector bias [5]. The diode contact area is $0.075\mu m^2$. The length of the mmW slot is 1250μm, its width is 25μm; the CPW strip width is 50μm corresponding to a 47O CPW characteristic impedance. The IR dipole was designed for ?/2 resonant operation at 28 THz; its total arm length is 3μm and its cross-arm width is 0.25μm.

3. Sensor fabrication

The device is fabricated on a high resistivity Si substrate coated with a 500nm layer of SiO_2 for electrical isolation. The substrate was coated with a 15nm layer of Cr and 150 nm layer of Au. The CPW-fed twin slot structure was then patterned in electron beam positive resist and ion milling was used to etch the slots into the Au ground plane. The bottom MOM diode electrode and an IR dipole antenna arm were defined and a Ni layer of 140nm was then deposited using DC magnetron sputtering. The top electrode along with the second IR antenna arm were patterned. A NiO layer of 3.5nm was then deposited using RF diode sputtering followed by another 140nm Ni layer deposited using DC magnetron sputtering.

4. Experimental Results

For testing THz response, the detector was irradiated by a CO_2 laser at 10.6μm. An F/1 lens is used to focus the beam into a diffraction limited spot onto the device. A mechanical chopper was used to modulate the laser beam at a frequency of 2.6 kHz. For testing in the GHz region, radiation from a 92.5 GHz Gunn oscillator at 25mW of output power was input into a PIN diode switch that is modulated at 3 kHz using a function generator and finally a horn antenna was used to irradiate the device. The modulated detector response signals were amplified and then captured using a lock-in amplifier. Fig.4 shows a plot for the IR, mmW response and the second derivative of the I-V characteristic curve vs. bias voltage of the diode. The sensor was measured to have a detectivity (D*) of 1×10^{6}cmHz$^{0.5}$/Watt and 1×10^{7}cmHz$^{0.5}$/Watt in the IR and mmW respectively at the above mentioned modulation frequencies.
For simultaneous response verification, IR and mmW radiation were modulated at 2.6 and 3 kHz respectively and made simultaneously incident on the device. An image of the spectrum analyzer output, Fig.5, verifies simultaneous dual-band operation of the device.

5. Conclusions

The simultaneous response to 94 GHz and 28 THz radiation using a dual-band antenna coupled MOM diode was verified. mmW response can be further improved by using a substrate lens for reducing surface-wave losses. IR response can be further improved by decreasing the junction which will decrease the junction capacitance and therefore increase the cut-off frequency of the device.

References

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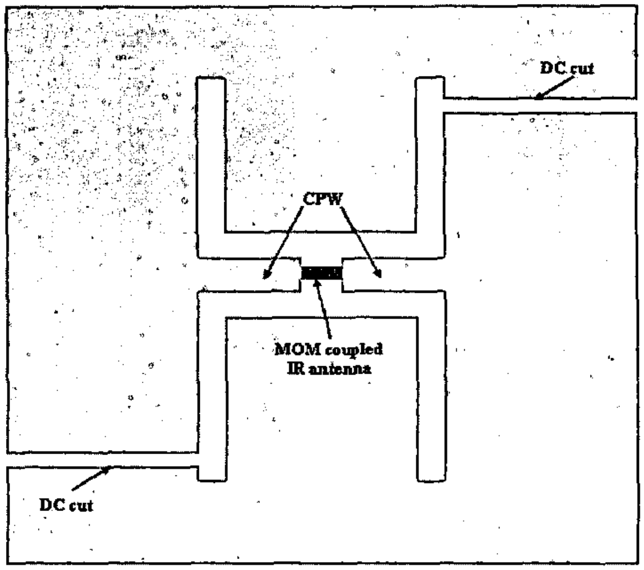

Fig.1 CPW-fed twin slot antenna-coupled MOM diode configuration

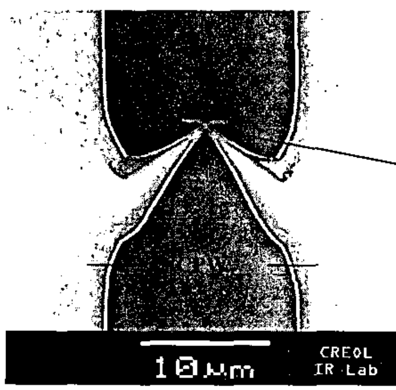

Fig.2 SEM image showing connection between the MOM diode and the bond pads.

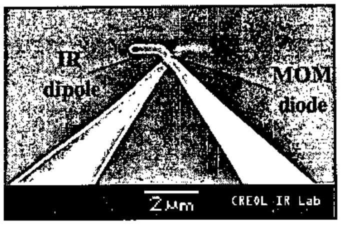

Fig.3 SEM image of MOM diode coupled to an IR dipole antenna.

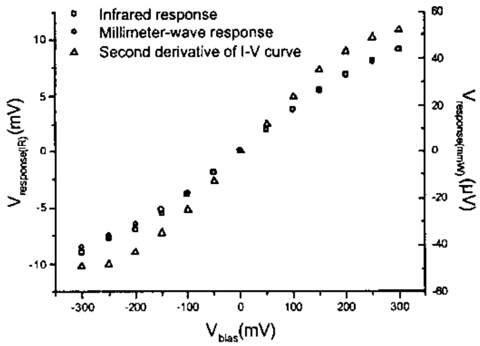

Fig.4 IR, mmW response and the second derivative of the I-V characteristic curve (In arbitrary units) vs. diode bias.

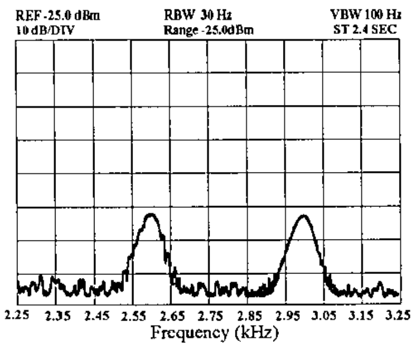

Fig.5 Spectrum analyzer output showing simultaneous response for 94 GHz and 28 THz