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A room temperature Nb_5N_6 microbolometer for detecting 100 GHz radiation

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Abstract**──Based on Nb_5N_6 thin film microbolometers, detectors have been designed, fabricated and characterized for detecting 100 GHz signals at room temperature. Such a detector typically consists of two parts, a Nb_5N_6 thin film microbolometer for detecting the radiation and an Al planar bow-tie antenna with a center frequency of 100 GHz for coupling the radiation from free space to the microbolometer.**

Using radio frequency (RF) magnetron sputtering, at a high pressure of gas mixture of 2Pa (N_2:Ar, 4:1), 100 nm thick Nb_5N_6 film is grown on a high resistance Si (100) substrate with a SiO_2 layer 100nm thick. The resistance vs temperature relationship of the Nb_5N_6 thin film is of semiconductor type with a negative temperature coefficient of resistance of about 0.6 – 0.7 % and a sheet resistance $R_\square$ of about 500 Ω at room temperature. The root mean square (rms) surface roughness of Nb5N6 thin film with a thickness of 100 nm is 0.45 nm over an area of 2µm×2µm.

Bearing in mind that the sheet resistance $R_\square$ of Nb_5N_6 thin film is about 500 Ω and considering that the impedance of the planar metallic antenna should be matched to that of the Nb_5N_6 microbolometer, the impedance of the bow-tie antenna is designed by Ansoft HFSS to be 800 Ω, corresponding to the microbolometer sizes of 3µm ×1.5µm. The detector based on Nb_5N_6 microbolometer is fabricated using lithography and reaction ion etching.

The high frequency response of the detector is characterized by a quasi-optical system. The electrical responsivity S_E of the detector can be evaluated from the I – V curve using Jones' expression

$$S_e = (Z - R)/2IR \qquad (V/W)$$

where Z = dV/dI and R are the resistances of the bolometer with and without 100 GHz irradiation respectively. At room temperature, the electrical responsivity of the detector is about 400 volts per watt at a bias of 0.4 mA and a modulation frequency of 200 Hz.

To evaluate the electrical noise equivalent power (NEP) we first measure the noise voltage spectrum of the detector and then divide it by the responsivity. Using a low noise preamplifier, the noise voltage is measured to be about 7 nV/ $Hz^{1/2}$ at a frequency of 1 KHz. Thus the NEP is as low as 2×10^{-11} W/$Hz^{1/2}$. If we correct the result by taking into account the contribution of the noise of the preamplifier, which is 4 nV/ $Hz^{1/2}$, even lower NEP can be obtained. The response time of the detector is less than 50 µs. It is good enough for many practical applications.

Such detectors based on Nb_5N_6 microbolometers and fabricated on Si substrates offer tremendous opportunities in making Si-based hybrid integration circuits, which can be used in detecting and imaging arrays at terahertz frequencies.