Development of Millimeter Wave CW and Pulsed IMPATT Diodes and Oscillators

Sitesh Kumar Roy, Nabin Chandra Mandal, Dibyendu Ghoshal
Centre of Advanced Study in Radiophysics & Electronics,
1, Girish Vidyaratna Lane, Kolkata – 700009

siteshroy@yahoo.com

Abstract
Institute of Radiophysics & Electronics (IRPE), Calcutta University research group has undertaken the development of Ka-Band 26-40 GHz CW and Pulsed IMPATT diodes starting from junction formation in silicon epitaxial wafers by diffusion process and the characterization of corresponding mm wave oscillators. Few CW single drift region (SDR) and double drift region (DDR) Silicon IMPATT diodes have been imported and their millimeter wave power and frequency characteristics have also been obtained.

Key words : IMPATT , Ka-Band, CW and Pulsed, Oscillator.

Introduction :

Fabrication of silicon SDR IMPATT diodes by diffusion process has been found to be a simple and economic method and it involves diffusion of p-type impurities (in the present case, Boron) in n on n^+ epitaxial wafers. An accurate microprocessor based temperature controlled diffusion furnace located in a centrally air-conditioned laboratory has been used to follow a pre-determined doping profile of Boron impurities. This has been obtained using a silicon d.c and high frequency computer designed method starting from the field maximum in the depletion layer which was first developed by the IRPE group and presented in NASECODE Conference held in 1979 and 1985[1,2]. CW wafers have lower doping density compared to those required for pulsed operation which need high doping concentration operated at a high current density level as found from computer analysis. A depletion layer width of 1.5 μm at suitable junction depth was formed by diffusion process for both CW and pulsed mode of operation. Sequential process steps have been developed to fabricate the packaged SDR IMPATT diodes. These steps involve wafer cleaning, activation of Boron, stabilization,predeposition of Boron, drive-in, low temperature oxidation, metallization of p^+ side, electroplating, substrate thinning, metallization of n^+ side, photolithography, mesa etching, chip separation and bonding of the chips into the appropriate packages. For packaging, S_4 packages mounted on gold-coated copper cylinders have been used. The diagrams for the different steps for processing the IMPATT diode are shown in Fig.1.

The fabricated IMPATT devices [3,4] have been found to deliver more output power with improvement in the design, of the heat sink of the oscillator and specially on thinning of the substrate of IMPATT chips. The diagram of the packaged IMPATT device has been shown in fig.2.

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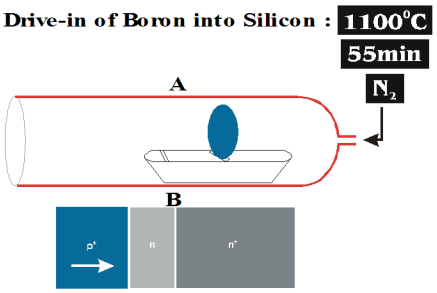

Fig.1

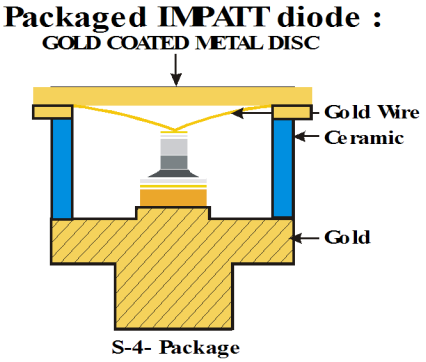

Fig.2

Results and discussion:

Various characteristics of indigenous SDR IMPATT diodes for CW and pulsed operation have been obtained and the I-V characteristics for the indegenous diodes indicate the onset of breakdown phenomenon and corresponding breakdown voltage The I-V characteristics of the CW IMPATT is shown in Fig.3.

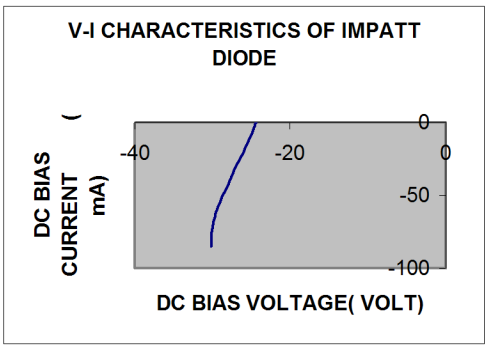

Fig.3

The breakdown voltage for the fabricated CW and pulsed SDR IMPATTs have been found to be 24.4 volts and 25 volts respectively. The diodes have been mounted in rectangular cavities fitted with a resonant cap structure. The Ka-band millimeter wave oscillation characteristics have been obtained by studying the variation of output power with d.c current and oscillation frequency. The oscillator power vs d.c bias current graph has been shown in Fig.4 and the corresponding frequency variation has been shown in Fig.5.

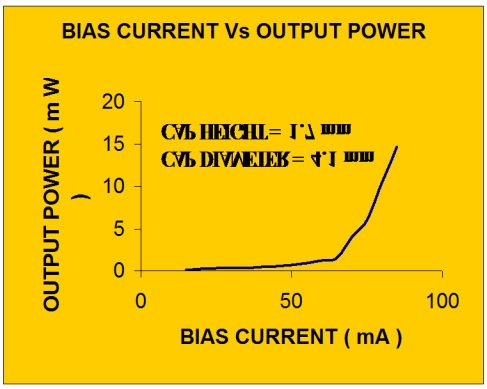

Fig.4

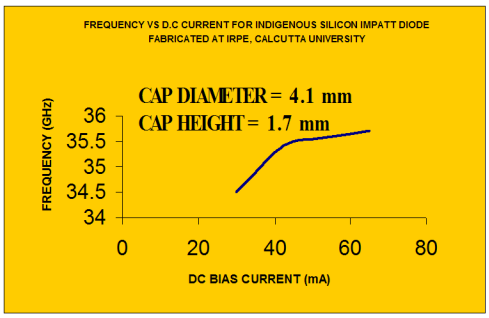

Fig.5

A maximum power output of nearly 15 mW has been obtained at a dc current of 85 mA and the corresponding oscillator frequency has been found to be 35 GHz which indicates IMPATT oscillation at the lower end of the ka-band.

For pulsed operation, the fabricated Ka-band silicon IMPATT diodes have been found to deliver 280 mW of pulse power. The variation of pulsed power output from the indigenous pulsed SDR IMPATT diode has been shown in Fig.6.

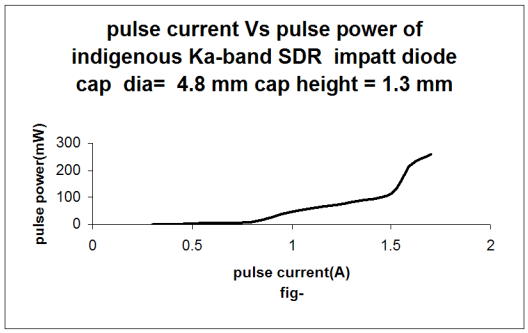

Fig.6

The modulator for pulsed source has been developed through bipolar and MOSFET amplification with transformer coupling.

A number SDR CW and DDR pulsed silicon IMPATT diodes have been imported and the corresponding characteristics have been obtained by putting the diodes under a resonant cap cavity. For CW SDR diode (ISTOK, Russia), a maximum of CW 140 mW has been obtained for a bias current of 180 mA with an oscillation frequency 39.6 GHz.

The output power from the SDR IMPATT oscillator against d.c bias has been shown in Fig.7 and the corresponding variation of oscillation frequency has been shown in Fig.8

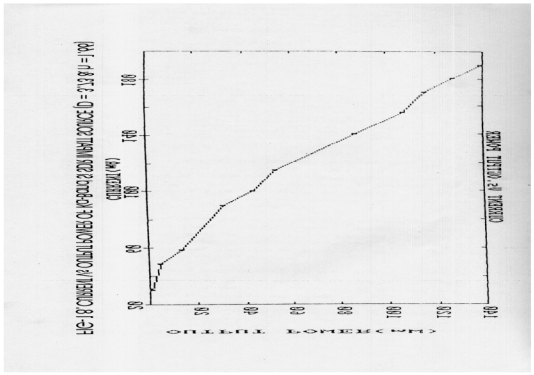

Fig.7

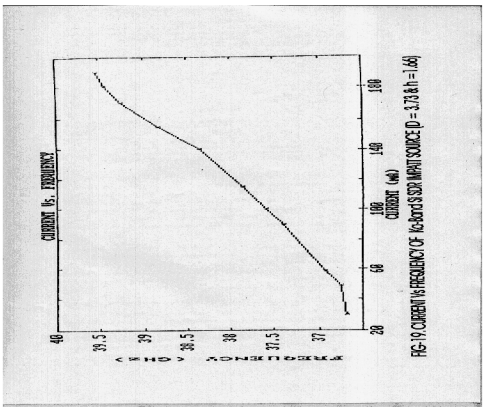

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Fig.8

The imported pulsed DDR diodes have been found to deliver 5-Watts of pulse power for a pulse voltage input of 70 volts magnitude. The variation of pulsed power output against the pulse bias voltage has been shown in Fig.9.

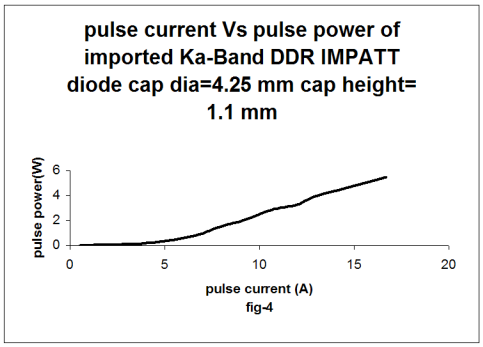

Fig.9

Conclusion :

With further improvement of diode fabrication process the power output from indigenous CW and pulsed diode would improve when mounted in the rectangular resonant cap cavity. The better heat sinking arrangement may also lead towards larger amount of mm wave power output

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