Dynamic Characteristics of III-V and IV-IV Semiconductor Based Transit Time Devices in the Terahertz Regime: A Comparative Analysis

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Abstract: High-frequency characteristics of IMPATT Oscillators based on III-V Indium Phosphide (InP), III-V Wurtzite Gallium Nitride (Wz-GaN) and IV-IV Silicon Carbide (3C, 4H and 6H polytypes) are studied and their performances are compared at a frequency of 0.3*THz*. A double drift p^+ p n n^+ structure is chosen for all the materials and investigation has been carried out to obtain maximum conversion efficiency and device negative resistance by optimizing bias current density through modeling and simulation technique. A double iterative computer method based on modified drift-diffusion model has been used to study their performance. The simulation studies reveal that these devices are potential sources for generating high power in the Terahertz regime. The avalanche response time for each of the IMPATT diodes are simulated by a newly developed simulation technique and it has been observed that avalanche response time in InP, GaN and SiC IMPATTs are less than the corresponding transit time of the diodes- which is an essential condition to generate THz oscillation in these devices. The conversion efficiency of III-V InP IMPATT diode is found to be 18.4% at 0.3*THz* with an output power of 2.81*W*, whereas, III-V Wz-GaN IMPATT is found to generate much higher output power of 6.23*W* with a conversion efficiency of 15.47% at 0.3*THz*. On the other side, IMPATTs based on IV-IV SiC generate output power of 11.5*W* (3C-SiC), 20*W* (4H-SiC) and 7.5*W* (6H-SiC) with corresponding conversion efficiencies of 12.5% (3C-SiC), 15% (4H-SiC) and 12% (6H-SiC) at 0.3*THz*. The extensive simulation results reveal that though IMPATT diode based on SiC gives better performance in terms of higher output power in the Terahertz domain compared to other materials, GaN IMPATT has the advantage of higher efficiency. The design data and the proposed fabrication methodology, presented in this paper, will be helpful to realize InP, SiC and GaN based IMPATT oscillators for Terahertz communication.

Keywords: Terahertz frequency, Indium Phosphide, Silicon Carbide, Gallium Nitride, Double Drift Impatt Diode, wide band gap semiconductors, avalanche response time, transit time limitation, bias current optimization

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1. Introduction

Terahertz (THz) wave technology, a very upcoming field, is on the verge of significant growth [1]. This technology is poised to move into substantial market in the next few years. The terahertz frequency ranges (0.1-10*THz*), sandwiched between microwave and infrared, bridges the gap between electronics and optics. The terahertz radiation, which can penetrate to some degree in most materials, is one of the upcoming research areas drawing immense interest among the scientist all over the world. The ongoing research and development in this arena have brought up the possibility of opening up an extra ordinary range of new markets in this decade [2]. Owing to the exposed position in the electromagnetic spectrum and tremendous versatile nature, this technology has spanned its application not only in medical care, food and security sectors but also to the studies of fundamental physics and cultural heritage [3]. Today, terahertz technology is extensively used in airport screening of passengers for hidden weapons, explosives, drugs or other contraband, remote sensing, imaging, spectroscopy, secure wireless communication, biological and medical applications, cancer detection, bio-chip analysis of DNA, proteins or other biological materials, detection of land mines, inspecting defects in semiconductor wafers, detection of chemical and biological warfare agents, monitoring manufacturing processes, determining thickness of a layer of paint, etc. While technological developments remain an ongoing need, commercially products are coming up to address some of the needs of the high profile markets. With the availability of CW and pulse sources, investigators are pursuing potential THz wavelength applications in many fields. To keep pace with such rapid developments, a tremendous urge is observed among scientist worldwide to develop high power Terahertz solid state sources.

Among all the solid state sources already available, IMPATT diode have emerged as the most powerful one at microwave and millimeter wave frequency range. Thus covering a wide range of frequency spectrum, this diode find wide applications as solid state transmitters in tracking radars, missile seekers, radiometers and in various civilian, military and space communication systems.

However IMPATTs operating in the THz regime using the conventional base materials viz., Si, Ge, GaAs is not possible owing to some fundamental limitations in the material parameters of these semiconductors. Even though Si Impatts operating at lower sub-millimeter wave/Terahertz wave have recently been reported [4], extensive research is still going on to find new materials for IMPATTs suitable for high power operation in the THz domain.

Fortunately THz Impatts based on III-V Indium Phosphide (InP) and wide band gap (WBG) semiconductors viz., IV-IV Silicon Carbide (SiC) and III-V Gallium Nitride (GaN) have recently been reported [5-12]. The wide band gap semiconductors SiC and GaN, possessing excellent material properties, offer better alternative to traditional Si, Ge and GaAs based Impatts [13]. At THz domain, SiC and GaN based Impatts offer a higher output power resulting from increased critical electric field, higher band gap energy, higher saturation velocity and much better thermal conductivity [14]. These WBG semiconductors are recently been used as base materials for various electronic and opto-electronic devices [15]. The expected excellent performances of WBG devices can be assessed by considering Keyes' FOM (considering the speed of transistors and their thermal limitations) and Johnson's FOM (considering the HF and high power capability of devices). Assuming Keyes' and Johnson's FOM for Si as unity, the same for GaAs are 0.45 and 7.1 respectively while those for SiC are 5.1 and 278 respectively and those for GaN are 1.6 and 756 respectively [13]. The data clearly indicates that high frequency and high temperature performance of SiC and GaN are much superior as compared to conventional Si and GaAs. Even InP possess high value of critical electric field, thereby permitting the incorporation of higher doping level in the depletion layer of the device and subsequent reduction of active region width. Thus thin InP based IMPATT enables it to operate even at THz zone.

Gallium Nitride (band gap energy=3.39eV at room temperature) supports peak internal electric field (E_c) about five times higher than those using Si and GaAs, resulting in higher break-down voltage, which is extremely important for devices handling high power. Hence GaN based Impatts can operate at higher voltage at the same operating frequency. With high value of Ec much higher doping level can be achieved. These features also allow reduction of drift region width. GaN is also found to be less noisy and chemically very stable at higher temperatures. Despite all the high frequency operating advantages, it is yet to hit the main stream owing to the difficulties in growth and device fabrication. Considerable progress in the growth of Nitrides during the last five years makes this material suitable for fabrication of various electronic devices. High quality GaN film can be grown on SiC substrate by MOCVD technique by using a SixNy inserting layer [16]. Hence, in the light of maturity of the fabrication technology and the unique material properties, GaN appears to be one of the best choices for development of semiconductor devices, especially in THz region, in the coming decade. GaN exists in different polytype forms, viz., hexagonal Wurtzite GaN (α-GaN or Wz-GaN) and cubic Zinc Blende GaN (β-GaN or ZnB-GaN). Even though no experimental results on GaN Impatt diodes at THz region is yet available in the literature, to the best of authors' knowledge, some studies on GaN Impatts have been carried out lately [17-19].

Indium Phosphide based flat profile, single drift p+nn+ Impatts have already been fabricated at 9.78*GHz* (X-band), giving an output RF power of 1.6*W* with 11.1% DC-to-RF conversion efficiency [20]. It was further observed that InP Impatts sustained relatively high operating temperature and that the breakdown and operating voltages are even greater than GaAs counterpart. However, to the best of authors' knowledge no experimental reports are available on the design, fabrication and characterization of InP Impatts at THz frequencies. Few reports based on simulation study of THz InP IMPATTs have been reported lately [5, 21].

Silicon Carbide is also an excellent material for high power and high frequency application owing to its high breakdown electric field strength (approx. ten times that of Si), high electron saturation drift velocity, high thermal conductivity, wide band gap (between 2.2 – 3.5*eV* depending on polytype), high thermal stability and chemical inertness. Owing to its high breakdown field and high electron saturation velocity, the peak power capability of SiC based Impatt diode is expected to be at least two orders of magnitude higher than the existing Si and GaAs Impatts. The unusually high electric strength of SiC is the major material advantage for application in high power electron devices. SiC exists in many different polytype forms, viz., cubic 3C-SiC, hexagonal 4H-SiC, hexagonal 6H-SiC, rhombohedral 15R-SiC etc. Amongst the different polytypes, the availability and quality of single crystal wafers in 4H-SiC and 6H-SiC make these polytypes the most promising materials for electronic devices. With the advent of VLS growth technique, it is now possible to grow thick and controlled doped layers on 4H-SiC. Moreover, owing to superior transport properties, research is also focused on 3C polyptype to grow good quality 3C-SiC epilayer on Si, thereby making it a cheaper alternative to costly 4H-SiC and 6H-SiC commercial epilayer and also make it compatible with present Si technology.

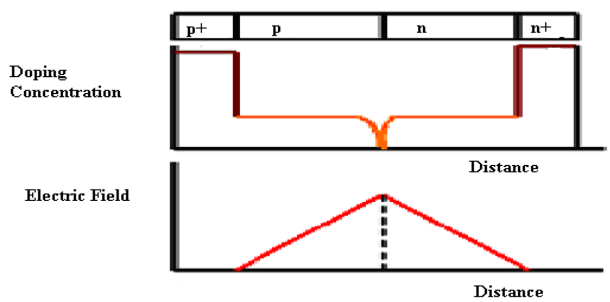

Fig.1 Schematic diagram of p+pnn+ double drift Impatt diode and corresponding Doping and Electric Field profile.

To satisfy the quest of increasing demand for high power THz sources, the authors have designed a symmetrically doped flat profile p+pnn+ double drift avalanche transit time diode based on Silicon Carbide (cubic 3C-SiC, hexagonal 4H- and 6H-SiC), InP and α-GaN and have studied and compared their DC and small signal properties at 0.3*THz* and at the optimum bias current density. The bias current density is actually optimized with respect to highest efficiency and output power. The results presented in this paper along with the proposed fabrication methodology will be very helpful to realize THz Impatt diode based on above mentioned materials.

2. Material, design parameters and avalanche response time of DDR Impatt Diode

The present paper dealing with a flat profile p+pnn+ double drift Impatt structure has highly doped p+ and n+ substrates and n and p as epilayer. Fig. 1 depicts the p+pnn+ double drift structure and the corresponding doping and electric field profile of the diode. Computer simulation is carried out at an operating frequency of 0.3*THz* and the width of the epilayer are accordingly chosen using the transit time formula [23] given by W = 0.35*vsn/f* where W, vsn and f are the total depletion layer width, saturation velocity of electrons and operating frequency respectively. The proposed methodology of fabricating the device and the method to study its DC and high frequency properties are discussed elsewhere [5, 9].

The values of the material parameters of α-GaN, InP and SiC (3C-SiC, 4H-SiC and 6H-SiC) are taken from recent published papers mentioned earlier and electronic archive [22]. The structural parameters of the symmetrically doped p+pnn+ α-GaN, InP and SiC (3C-SiC, 4H-SiC and 6H-SiC) Double drift Impatt diode at 0.3*THz* are enlisted in Table-1. The operating frequency of Impatt diode essentially depends on the transit time of charge carriers to cross the depletion layer of the diode. Double Drift Region (DDR) structure of Impatt diode are designed and optimized through a generalized double-iterative simulation scheme used for analysis of Impatt action. The prime action underlying Impatt behaviour is Avalanche breakdown caused by high electric field. The main factor is the response time of the charged particles (electrons and holes) which is related to the avalanche multiplication and leads an important role in determining the device characteristics for high frequency performance.

If τ_n and τ_p be the response times for electrons and holes respectively, then these are expressed as

$$\tau_n = \frac{1}{v_{sn} + v_{sp}} \int_0^{W_A} \exp[-\int_0^x (\alpha - \beta) dx] dx \tag{1}$$

$$\tau_p = \tau_n \exp[\int_0^{W_A} (\alpha - \beta)] dx \tag{2}$$

where α and β are the ionization coefficients expressed as $\alpha = A_n \exp(-B_n/E)$ and $\beta = A_p \exp(-B_p/E)$. When avalanche process is initiated by a mixture of electrons and holes then the corresponding response time τ_1 is given by

$$\tau_1 = \tau_n [(1-k) + k \exp\{-\int_0^{W_A} (\alpha - \beta) dx\}]^{-1} \tag{3}$$

where k is the injection ratio, defined as J_{ps}/J_s and W_A is the avalanche width. Now for oscillation at higher frequency, the value of avalanche response time τ_1 should be smaller than the value of the transit time (τ). Table 2 reflects the values of Avalanche response time and Transit time of InP, α-GaN, and SiC (3C-SiC, 4H-SiC and 6H- SiC) based Double drift Impatt diode at 0.3*THz*.

3. Computer Simulation Technique to study the Static and Dynamic properties of Double-Drift IMPATTs.

The simulation method based on modified drift-diffusion model starts with DC analysis described in details elsewhere [9,11,24-26]. The following assumptions are made in the computer analysis of DC and small signal behavior of IMPATT diodes: (a) One dimensional model of the p-n junction is treated; (b) The electron and hole velocities are taken to be saturated and independent of the electric field throughout the space charge layer. In this method the computation starts from the field maximum near the metallurgical junction. The distribution of DC electric field and carrier currents in the depletion layer is obtained by the double-iterative computer method, which involves iteration over the magnitude of field maximum (E_m) and its location in the depletion layer. A computer algorithm has been developed for simultaneous numerical solution of Poisson's equation, carrier continuity equations and the space charge equation taking into account the effect of mobile space charge and carrier diffusion in order to obtain the electric field profiles and carrier current profiles. The effect of velocity overshoot of electrons taking place in III-V semiconductors has also been incorporated in the drift-diffusion model. The boundary conditions for the electric field at the depletion layer edges are given by,

$$E(-x_1) = 0 \quad \text{and} \quad E(+x_2) = 0 \tag{4}$$

where $-x_1$ and x_2 define the p^+ and n^+ edges of the depletion layer.

The boundary conditions for normalized current density $P(x)=(J_P-J_n)/J_0$ (where J_p=hole current density, J_n=electron current density) at the two edges are given by

$$P(-x_1) = (2/M_p - 1) \quad \text{and} \quad P(x_2) = (1 - 2/M_n) \tag{5}$$

The necessary device equations have been simultaneously solved satisfying the appropriate boundary conditions mentioned in equations (4-5). The field dependence of electron and hole ionization rates and saturated drift velocities of electron ($v_{s,n}$) and holes ($v_{s,p}$) at 300*K* are made use of in the computation for the profiles of electric field and carrier currents. The conversion efficiency, η is calculated from the approximate formula [27]

$$\eta(\%) = (1/\pi) \text{ x } (V_D / V_A+V_D) = (1/\pi) \text{ x } (V_D / V_B) \tag{6}$$

where Breakdown voltage $V_B=V_A+V_D$=(Voltage drop across the avalanche region+Voltage drop across the drift region). Avalanche breakdown occurs in the junction when the electric field is large enough such that the current multiplication factors (M_n, M_p) become infinite. Again, the breakdown voltage is calculated by integrating the spatial field profile over the total depletion layer width, i.e.,

$$V_B = \int_{x_1}^{x_2} E(x)dx \tag{7}$$

Where $-x_1$=n-side depletion layer width and$+x_2$= p-side depletion layer width.

The high-frequency analysis of the Impatt diode provides insight into its small signal performance. The range of frequencies exhibiting negative conductance of the diode can easily be computed [28]. From the dc field and current profiles, the spatially dependent ionization rates that appear in the Gummel-Blue equations are evaluated, and fed as input data for the small signal analysis. The edges of the depletion layer of the diode, which are fixed by the dc analysis, are taken as the starting and end points for the small signal analysis. On splitting the diode impedance Z(x,ω) obtained from Gummel–Blue method, into its real part R(x,ω) and imaginary part X(x,ω), two differential equations are framed. A double-iterative simulation scheme incorporating modified Runge-Kutta method is used to solve these two equations simultaneously. The diode negative resistance ($-Z_R$) and reactance ($-Z_x$) are computed through numerical integration of the -R(x) and -X(x) profiles over the active space-charge layer.

Thus,

$$-Z_R = \int_{x_1}^{x_2} -R dx \quad \text{and} \quad -Z_X = \int_{x_1}^{x_2} -X dx$$

The negative conductance (G), Susceptance (B) and the quality factor (Q) of the device can be calculated using the following relations:

$$-G = -Z_R / [(Z_R)^2 + (Z_X)^2] , \qquad B = Z_X / [(Z_R)^2 + (Z_X)^2] \quad \text{and}$$

$$-Q_{peak} = (B / -G)_{\text{at peak frequency}}$$

It may be noted that both -G and B are normalized to the area of the diode. The frequency at which the imaginary part (B) of the admittance changes its nature from inductive to capacitive is known as the avalanche frequency (fa). It is also the minimum frequency at which the real part of admittance becomes negative and oscillation starts to build up in the circuit. At resonant frequency of oscillation, the maximum power output PRF from the device can be obtained from the following expression,

$$P_{RF} = V^2_{RF} (G_p) A/2 \tag{8}$$

where V_{RF} is the amplitude of the RF swing ($V_{RF}=V_B/2$, assuming 50% modulation of the breakdown voltage V_B), G_p is the diode negative conductance at the operating frequency and A is the area of the diode (10^{-10} m^2).

4. Results and Discussions

The structural or the design parameters of symmetrically doped SiC, InP and α-GaN based DDR Impatt diode at 0.3*THz* are enlisted in Tab. 1. The avalanche response time (τ_1) and the transit time (τ) of the diodes are given in Tab. 2. The avalanche response time in case of InP is found to be 2.45 x 10^{-13} *s* at 0.3*THz* with its transit time value of 2.3 x 10^{-13} *s*. The avalanche response time for the wide band gap semiconductor SiC based Impatt diodes are 4.07 x 10^{-15} *s* (3C-SiC), 8.08 x 10^{-15} *s* (4H-SiC) and 8.23 x 10^{-17} *s* (6H-SiC) with their corresponding transit time as 2.5 x 10^{-12} *s* (3C-SiC), 2.3 x 10^{-12} *s* (4H-SiC) and 2.3 x 10^{-12} *s* (6H-SiC). The same for WBG semiconductor α-GaN based double drift Impatt diode is τ_1=2.47 x 10^{-16} *s* and τ=1.33 x 10^{-16} *s*. Hence at 0.3*THz* operating frequency, the value of τ_1 is less than τ for all the materials; thereby clearly indicating that the diode can produce oscillations at THz frequencies.

Tab. 3 reflects the simulated DC and small signal properties of the Impatt diodes at 0.3*THz* and at the bias current density which is the optimized one with respect to highest efficiency and highest output power.

Design Parameters	3C-SiC	4H-SiC	6H-SiC	InP	α-GaN
Width of n epilayer, W_n (*nm*)	250 nm	250 nm	250 nm	120 nm	575 nm
Width of p epilayer, W_p (*nm*)	250 nm	250 nm	250 nm	121 nm	570 nm
Doping concentration of n region (m^{-3})	8×10^{23}	6.5×10^{23}	8×10^{23}	6.5×10^{23}	1.5×10^{23}
Doping concentration of p region (m^{-3})	8×10^{23}	6.5×10^{23}	8×10^{23}	6.5×10^{23}	1.5×10^{23}
Current Density (A/m^2)	3.7×10^{9}	3.4×10^{9}	3.5×10^{9}	8.0×10^{8}	0.5×10^{8}
Substrate Doping concentration (m^{-3})	1×10^{26}	1×10^{26}	1×10^{26}	1×10^{26}	1×10^{26}
Area of the diode (m^2)	1×10^{-10}	1×10^{-10}	1×10^{-10}	1×10^{-10}	1×10^{-10}

Tab.1 Design parameters of SiC, InP and WZ-GaN based DDR IMPATTs at 0.3 *THz*.

Parameters	3C-SiC	4H-SiC	6H-SiC	InP	α-GaN
Avalanche response time (sec)	4.07×10^{-15}	8.08×10^{-15}	8.22×10^{-17}	2.45×10^{-13}	2.47×10^{-16}
Transit Time (sec)	2.5×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	2.3×10^{-13}	1.33×10^{-12}

Tab.2 Avalanche Response time and Transit Time of SiC, InP and WZ-GaN based DDR IMPATTs at 0.3 *THz*.

Parameters	3C-SiC	4H-SiC	6H-SiC	InP	α-GaN
Bias Current Density (A/m^2)	3.7×10^{9}	3.4×10^{9}	3.5×10^{9}	0.8×10^{9}	0.5×10^{8}
Peak electric field (V/m)	4×10^{8}	4.25×10^{8}	4×10^{8}	0.89×10^{8}	1.8×10^{8}
Breakdown voltage (V)	110	140	109	14.68	110.26
Peak frequency (THz)	0.353	0.325	0.350	0.304	0.300
Peak Conductance (S/m^2)	-1.52×10^{8}	-1.65×10^{8}	-1.01×10^{8}	-10.42×10^{8}	-0.41×10^{8}
Quality Factor, $\|Q\|$	1.8	1.26	2.7	0.36	3.5
Efficiency (%)	12.5	15	12	18.38	15.47
Output power (W)	11.5	20	7.5	2.81	6.23

Tab.3 Static and Dynamic properties of SiC, InP and WZ-GaN based DDR IMPATTs at 0.3 *THz*

Considering the optimized design parameters of the DDR diodes, enlisted in Tab. 3, it is observed that compared to InP and α-GaN based Impatt diode, the SiC based Impatt diode is a high current and high power device at the same operating frequency. From the DC properties of the devices, obtained after simulation, the peak electric field in case of SiC (for all polytypes) Impatt is about 4 x 108 *V/m* while that for the InP and α-GaN counterpart are 0.89 x 108 *V/m* and 1.8 x 108 *V/m* respectively. GaN and SiC based Impatts has a very high breakdown voltage (almost 8 times) than that obtained with InP Impatts at 0.3*THz* operating frequency. The breakdown voltage in case of 4H-SiC Impatt is 140 V, for 3C-SiC Impatt is 110*V* and for 6H-SiC Impatt is 109*V* as compared to 110.26*V* for α-GaN Impatt and 14.68*V* for InP Impatt at the same operating frequency of 0.3*THz*. The results are commensurate with theory as both SiC and GaN are wide band gap semiconductors having high value of breakdown voltage. From the simulated results, it is observed that the output power produced by SiC Impatts is much higher than that produced by both GaN and InP Impatts. The output power at 0.3*THz* from 3C-SiC Impatt obtained is 11.5*W*, from 4H-SiC Impatt is 20*W* and that from 6H-SiC Impatt is 7.5*W*. α-GaN Impatt is found to produce an output power of 6.23 W while that from InP counterpart is only 2.81*W*. Thus wide band gap semiconductor IV-IV SiC based Impatt is seen to produce the maximum power in comparison to InP based Impatt and WBG semiconductor III-V α-GaN based Impatt at the same operating frequency.

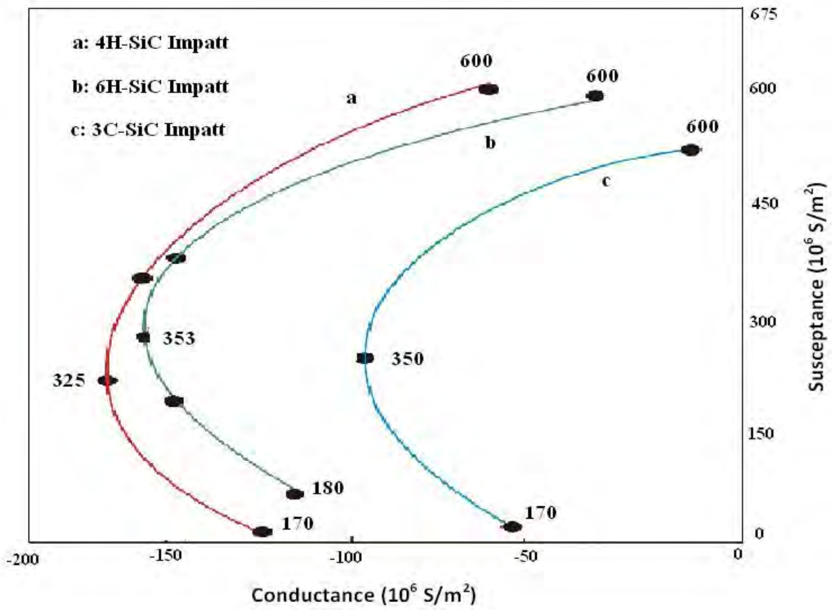

Fig. 2 Conductance-Susceptance plot of p^+pnn^+ double drift Silicon Carbide IMPATT diodes at THz regime.

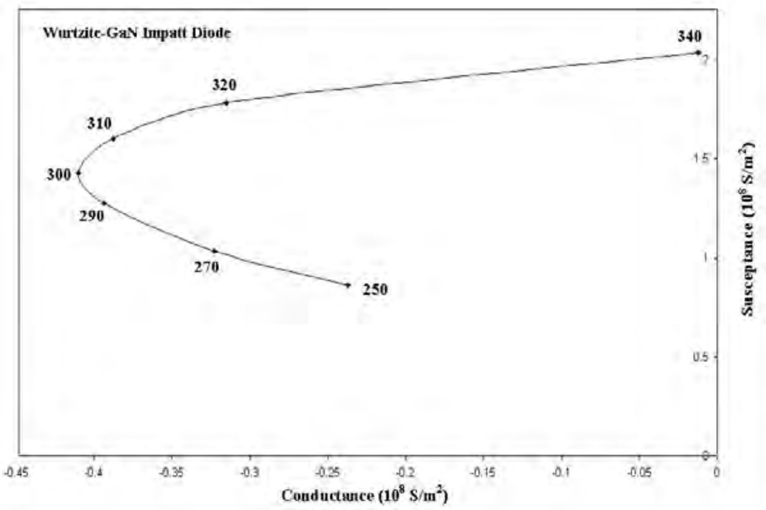

Fig. 3 Conductance-Susceptance plot of p^+pnn^+ double drift Wz-GaN IMPATT diode at THz regime.

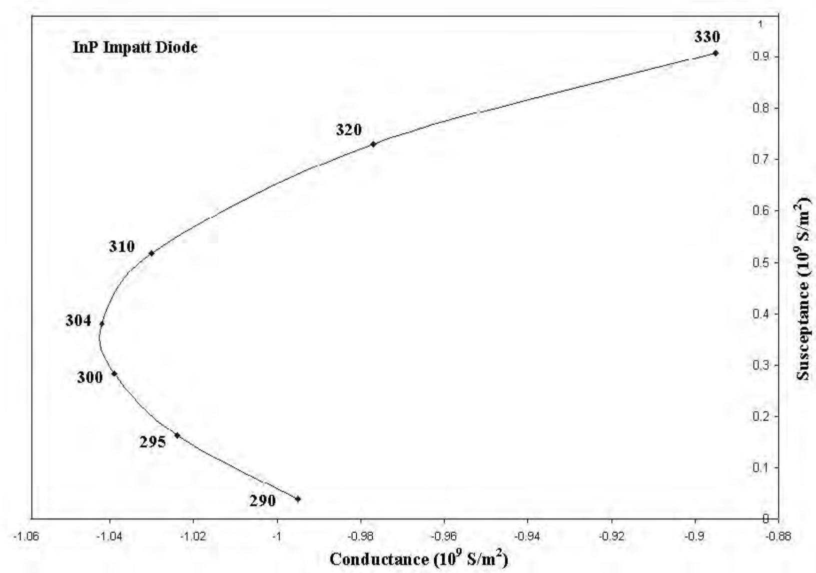

Fig. 4 Conductance-Susceptance plot of p^+pnn^+ double drift Indium Phosphide IMPATT diode at THz regime.

5. Proposed methodology for THz -IMPATT fabrication

InP or GaN p-n junction can be obtained using metal organic chemical vapor deposition (MOCVD) technique [9]. The most advanced results may be obtained by MOCVD technique, which includes the growth of InP or GaN epitaxial layer from vapor phase. During the growth, the substrate may be kept at growth temperature ranging from 800 to 1100°*C*. Using MOCVD process, thin layers of InP or GaN can be grown. Through photolithographic process, windows can be opened on p^{++} InP or GaN layer for subsequent metal deposition. Using photolithography low resistance contact metals, an alloy of Al/Pd, can be deposited by an electron beam evaporator. The metal contacts should then be annealed in air, nitrogen and oxygen ambient conditions at different annealing temperatures. Effective etching techniques are useful for diode fabrication. There are various methods of dry etching involving sources of external energy to initiate and sustain the break up of the high-energy bonds in InP and GaN. PEC etching is highly isotropic etching of InP and GaN. It is a very effective technique for forming mesa structure for design of InP and GaN IMPATT diode.

After finishing the fabrication process, on-wafer DC testing should be performed before the diodes are packaged [9]. DC testing will serve as the initial screening step of the device and the test results will be used for process evaluation. The packaging should provide a low thermal resistance between the InP or GaN diode chip and wave guide mount and should be mechanically rugged and hermetically sealed. The device can be bonded to a pill-type package. In pill-type configuration, the diode is bonded to a heat sink, which is usually gold plated. A ceramic or quartz ring encloses the diode and separates the heat sink from the package cap. The packaging should provide a low thermal resistance between the InP or GaN diode chip and waveguide mount and should be mechanically rugged and hermetically sealed. The device can be bonded to a pill-type package. In pill-type configuration, the diode is bonded to a heat sink, which is usually gold plated. A ceramic or quartz ring encloses the diode and separates the heat sink from the package cap [9].

SiC epiwafer (n^{++} substrate and n-type epilayer) can be procured from Cree Inc., Durham, NC, USA. The n-type doping is usually realized at Cree using nitrogen gas as the precursor. A SiC IMPATT device can be fabricated on the epiwafer following the process steps described elsewhere [9].

Characterization of THz properties might be possible with the device embedded in a corrugated wave guide described elsewhere [9]. Measurement of THz power and frequency may be done with a THz Vector Network Analyser as described elsewhere [9].

6. Conclusions

The simulation of DC and high frequency properties of InP, WZ-GaN and SiC based DDR Impatt diodes are compared at 0.3*THz* frequency. To the best of authors' knowledge, this is the first report on comparative analysis of these important devices for generating high-power at THz region. The comparison reveals that a much better performance in terms of output power is expected with 4H-SiC based Impatt as compared to other counterparts at the same operating conditions. The results are very encouraging and portray the strong potentiality of InP and wide band gap semiconductors WZ-GaN and SiC (3C, 4H and 6H polytypes) based Impatt diodes as a powerful solid state source for future Terahertz communication.

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