Comparison of Performance of Impatt Diode For Various Materials

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Abstract: In this paper the efficiency of the IMPATT diode is an important criterion. The efficiency varies with the semiconductor material used to design the IMPATT diode. The Efficiency plays an important role in the choice of material that should be used for a given applications. The efficiency of IMPATT diode for Si, GaAs, SiC, InP, GaN is measured and compared.

Keyword: **Efficiency, Electric field Distribution, space charge**.

Introduction: D.C analysis of the DDR structure was carried out by solving Poission's equation [A. Acharyya (2010)] including mobile space charge in the depletion layer of the diode.

Poission's equation is given as,

$$dE/dx=(N_D-Na+p(x)-n(x))$$

The conversion efficiency is calculated from the approximate formula

$$\eta(\%)=\frac{2m}{\pi}\times\frac{V_D}{V_B}$$

Where, *VD* = Voltage drop across the drift region, *VB* = Breakdown voltage and m = multiplication factor.

Avalanche breakdown occurs in the junction when the electric field is large enough such that the charge multiplication factors (*Mn, Mp*) become infinite. Again, the breakdown voltage is calculated by integrating the spatial field profile over the total depletion layer width, i.e.,

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

Doping Profile: A double drift p+pnn+ structure IMPATT have been designed by using computer simulation technique for operation at ka Band frequency by using the transit time formula of Sze and Ryder which is Wn,p = 0.37 vsn,sp / f; where Wn,p, vsn,sp and f are the total depletion layer width (n or pside), saturation velocity of electrons/holes and operating frequency respectively. Here n+ and p+-layers are highly doped substrates and n and p are epilayer

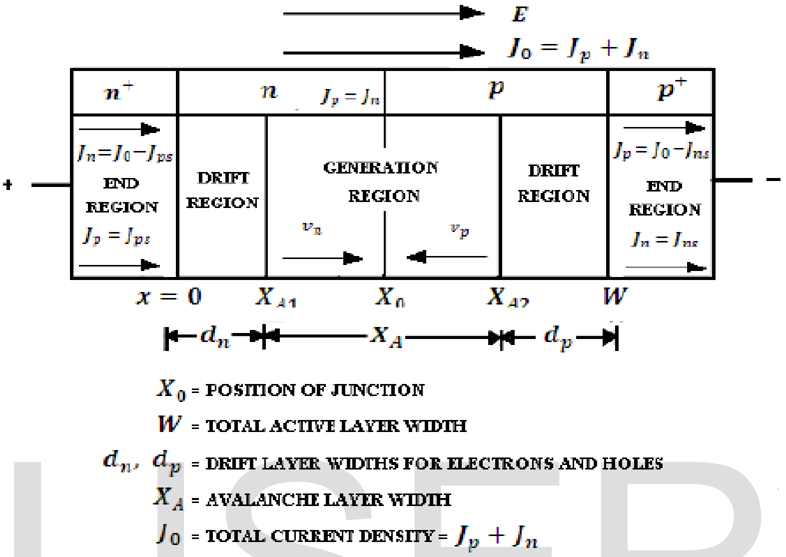


Fig. 1 The Active Layers of a Reverse Biased p-n junction.

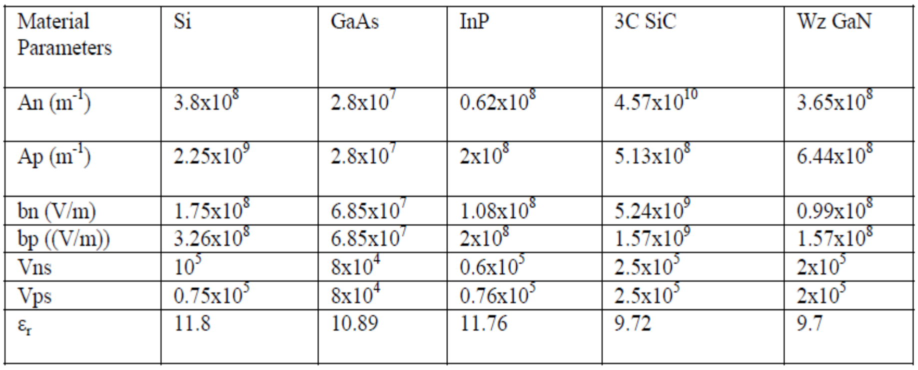
Simulation: The simulation method starts with DC analysis described in details. In this method the computation starts from the field maximum near the metallurgical junction. The distribution of DC electric field and carrier currents in the depletion layer is obtained by the double-iterative computer method, which involves iteration over the magnitude of field maximum (*Em*) 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 boundary conditions for the electric field at the depletion layer edges are given by,

$$E(-x1)=0 \quad \text{and} \quad E(x2)=0$$

The Poission’s equation is simulated using MATLAB. The flat doping profile is used in the simulation. The various material parameters used in the simulation are given in the table below.

In the computer simulation of DC and small-signal behaviour of the Si DDR IMPATT diode, the following assumptions are made, viz., (i) one dimensional model of the p-n junction is treated (Fig. 1); (ii) the electron and hole velocities

Materials parameters.



Material Parameters	Si	GaAs	InP	3C SiC	Wz GaN
An (m^{-1})	$3.8x10^8$	$2.8x10^7$	$0.62x10^8$	$4.57x10^{10}$	$3.65x10^8$
Ap (m^{-1})	$2.25x10^9$	$2.8x10^7$	$2x10^8$	$5.13x10^8$	$6.44x10^8$
bn (V/m)	$1.75x10^8$	$6.85x10^7$	$1.08x10^8$	$5.24x10^9$	$0.99x10^8$
bp ((V/m))	$3.26x10^8$	$6.85x10^7$	$2x10^8$	$1.57x10^9$	$1.57x10^8$
Vns	10^5	$8x10^4$	$0.6x10^5$	$2.5x10^5$	$2x10^5$
Vps	$0.75x10^5$	$8x10^4$	$0.76x10^5$	$2.5x10^5$	$2x10^5$
ε_r	11.8	10.89	11.76	9.72	9.7

*An, bn are Ionization coefficient of electrons and Ap, bp are Ionization coefficient of holes.

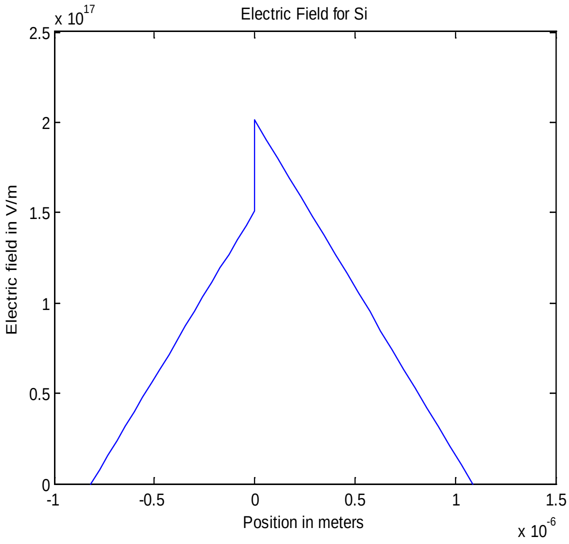
* Vns and Vps are saturation velocity of electron and hole respectively and ε_r is the relative dielectric constant of the material.

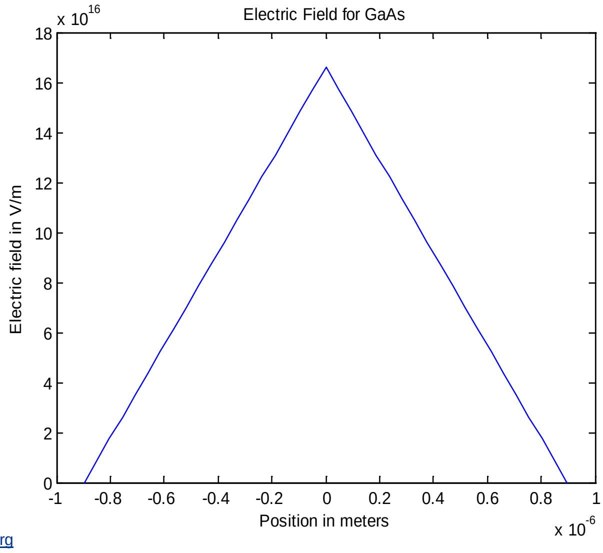
*α_n and α_p are rapidly increasing function of electric field. Experimentally obtained values of α_n and α_p can be approximately fitted with the empirical formula, α_n = An exp((-bn/E)) and α_p = Ap exp(-bp/E) respectively.

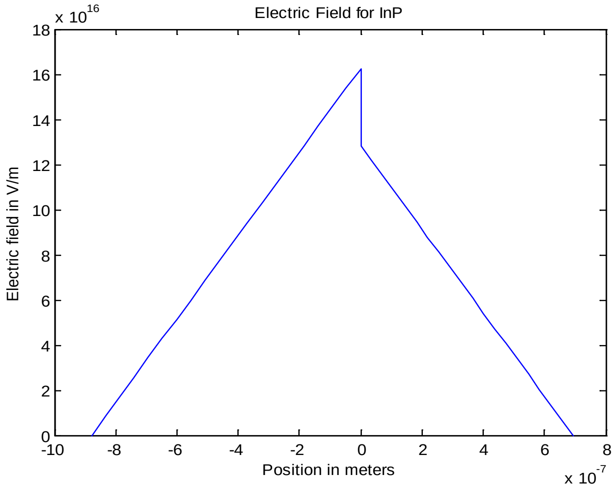
are taken to be saturated and independent of the electric field throughout the space charge layer.

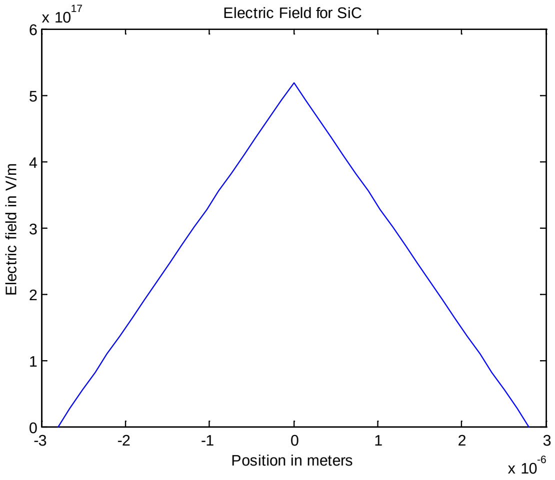
Simulation Result: The stimulation result for various materials is shown in the table given below.

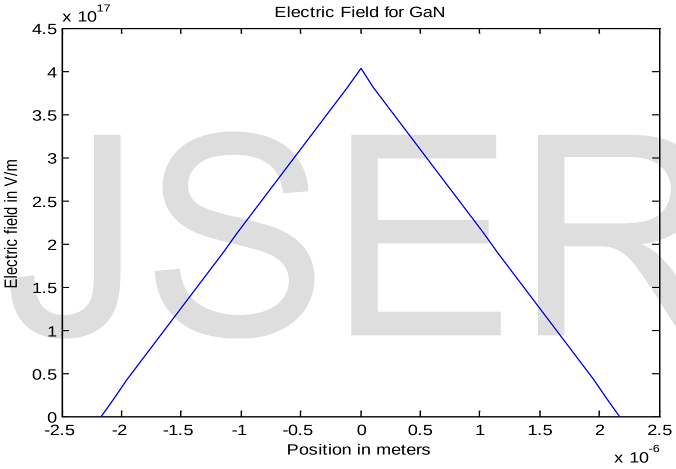
Material	m	Vb	Vd	Efficiency (%)	Peak frequency (GHz)
Si	0.5	1.7116×10^{11}	7.2016×10^{10}	13.3927	34
GaAs	1	1.4884×10^{11}	6.2625×10^{10}	26.7855	33
InP	1.5	1.1595×10^{11}	4.8785×10^{10}	40.1782	32
3C SiC	2	1.4535×10^{12}	6.1157×10^{11}	53.5709	33
Wz GaN	2	8.7635×10^{11}	3.6872×10^{11}	53.5709	34











Conclusion: The efficiency for various materials were calculated and compared. It is seen that efficiency depends on value of 'm' and electric field distribution. The efficiency of Silicon is the least. The 3C SiC and WzGaN show the maximum efficiency. The performance of the Impatt diode increases with the use of good semiconductor material. The performance increases but the cost of material also increases. Hence the choice of material depends on the application required.

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