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A BREAKDOWN VOLTAGE SIMULATOR FOR SEMICONDUCTOR DEVICES TONADDEIIB

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A breakdown voltage simulator for optimizing semiconductor devices, TONADDEIIB has been developed. This simulator calculates avaranche multiplications and punch-through current solving only the Poisson equation.

The TONADDEIIB program can be applied to devices with lightly doped floating regions using an improved method. In conventional methods([1],[2]),the quasi-Fermi potentials for floating regions are determined as the lowest potential along the metallurgical junction periphery if the floating regions are P-type. However, these methods can not be applied to lightly doped floating regions, because the neutral portions for the floating regions have moving boundaries. In the improved method, the quasi-Fermi potential for floating regions are chosen as the potential at saddle points of the potential distribution(Fig.1,Fig.2), which are independent from the position of the metallurgical junction periphery. Therefore, this method is applicable even if the floating regions have low impurity concentrations.

Once the potential distribution have been determined, exact avaranche multiplication calculations are performed.

This program was applicated to a device shown in Fig.3 which has four P^--guard rings. Fig.4 shows a calclated dependency of the avalanche breakdown voltage on impurity dose of P^--guard rings.

The punch through current is estimated by using only the potential distribution ψ as follows([3]):

$$I_{PT} = -qD_n n_i \frac{Z^*}{L^*} \exp\left(\frac{q}{kT}(\psi_{sp}-V_1)\right)\left\{1-\exp\left(-\frac{q}{kT}(V_2-V_1)\right)\right\}$$

where ψ_{sp} is the potential at the saddle point of the potential distribution and V_1,V_2 are electrode voltages (Fig.5). In the TONADDEIIB program, the tearm Z^*/L^* is approximately determined as:

$$\frac{Z^*}{L^*} = \sqrt{-\frac{\lambda_+}{\lambda_-}}$$

where λ_+, λ_- are positive and negative eigenvalues of Hessian for ψ at the saddle point.

The validity of this method can be seen by showing good agreement between the results obtained using this method and TONADDEIIC, which solves the current continuity equations besides the Poisson equation. Using the approximation, the current can be accurately estimated even if the current direction is skew to the rectangular mesh for FDM(Fig.6,Fig.7).

(REFERENCES)
[1]M.S.Adler et al., IEEE Trans. Electron Device, ED-24, p103(1977)
[2]S.Yasuda et al., Solid-State Electron., vol.25 p423(1982)
[3]J.A.Greenfeild et al., IEEE Trans. Electron Device, ED-27 p1520(1980)

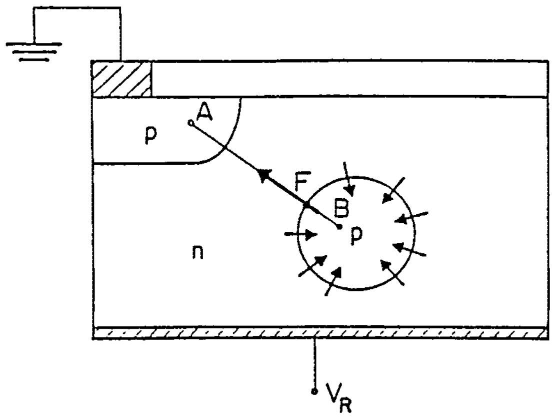

Fig.1 Device structure for explanation.

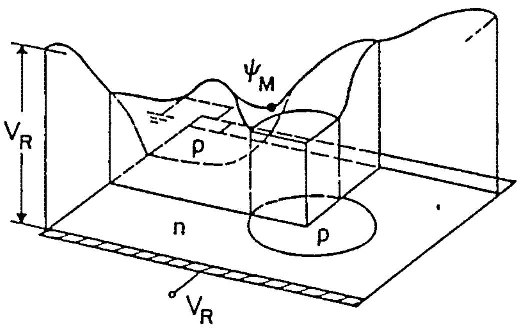

Fig.2 Saddle point of the potential distribution.

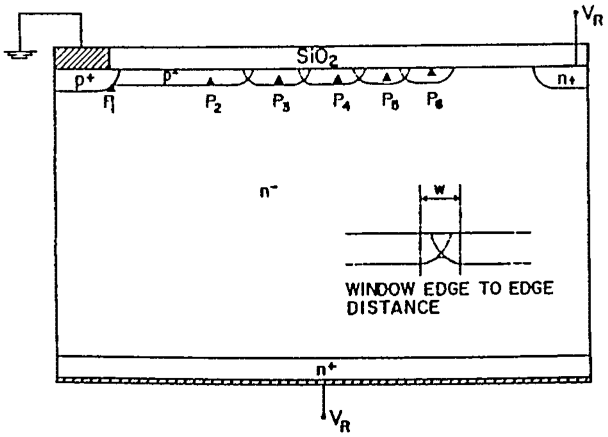

Fig.3 Device structure with lightly doped guard rings which are depleted in a high reverse bias. P1 P6 are the positions of electric field peaks.

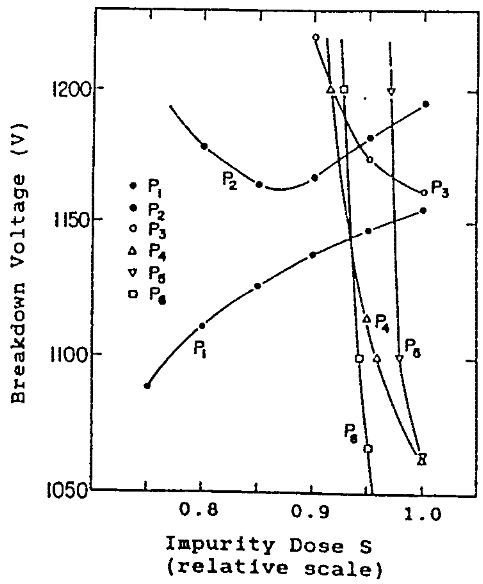

Fig.4 Calculated breakdown voltages for 6 electric field peaks.

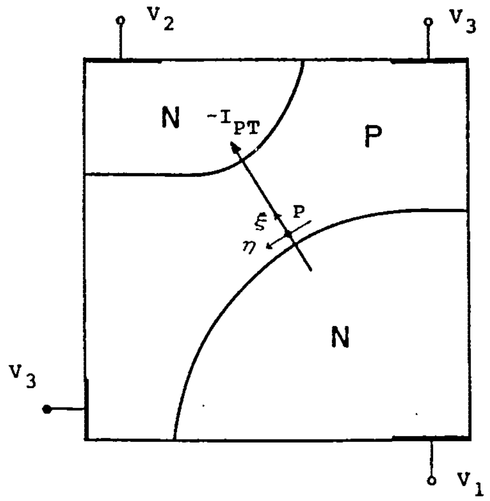

Fig.5 Device structure used for punchthrough current calculations.

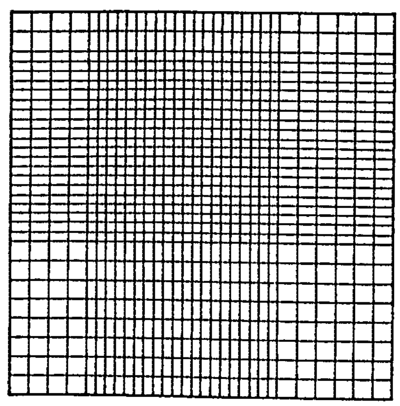

Fig.6 Rectangular mesh used to discretize the Poisson equation. The nodes occur at the intersection of holizontal and verticval lines.

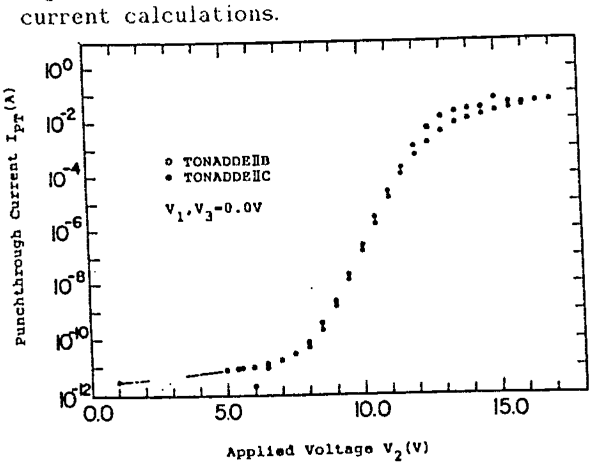

Fig.7 Comparisons of punchthrough current versus applied voltage V_2 obtained by TONADDEIIB and TONADDEIIC (V_1, V_3=0.0V).