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Avalanche Breakdown of Highly Doped Passivated Si Schottky Barriers

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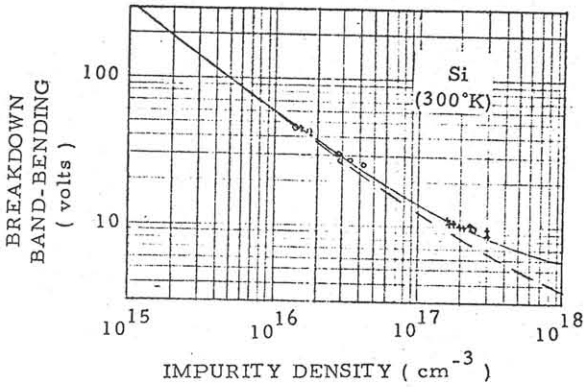
This work represents efforts to demonstrate consistency between published measurements of ionization coefficients in Si and measured avalanche breakdown voltages V_B in highly doped step functions. The V_B measurements were made using passivated Schottky barrier step junctions. The results provide further justification of the non-localized concept (NLC) of avalanche multiplication introduced by Okuto and Crowell [1]. In the NLC carrier multiplication is explicitly referred to an electron or hole concentration which has originated more than one electron or hole threshold energy upstream. This concept permits decoupling of electron and hole effects and expression of the measured ionization coefficients in terms of parameters from a one-carrier theory [2]. The agreement between experimentally measured and theoretically predicted ionization coefficients is excellent even in the high electric field range [1]. These data have been used to predict V_B for Si step junctions [3]. The predictions (Fig. 1, solid line) are appreciably larger than previous estimates (Fig. 1, dashed line) [4] for impurity concentration N_D is excess of 10^{16} cm^{-3} and agree well with the experimental results.

Measurements were made on Si with N_D between 1.3×10^{16} and 3.0×10^{18} atoms/cm^3.

To improve the accuracy of the measurement two kinds of Schottky diodes were developed: a self-passivated large area diode (LA diode) and a passivated small area point contact type diode (SA diode). The diodes have no conventional guard ring structure but



have nearly ideal current vs. voltage (I-V) relationships. This is due to a unique method of SiO_2 passivation. The LA diodes exhibit I-V which can be interpreted by ideal Schottky diode theory. The SA diodes have I-V characteristics of small area guard ring diodes and also exhibit a photo avalanche effect. N_D was determined from C-V measurements with an estimated error of less than 10%. Capacitances were also measured at various frequencies to confirm that the field configuration was due solely to shallow donors [5]. Apparent breakdown voltages $V_{B\,ap}$ were obtained by a linear I-V extrapolation to zero current to avoid any possible overestimation. The $V_{B\,ap}$ error is estimated to be less than 2%. To provide results independent of the barrier height the data (o : LA, + : SA) are expressed in terms of band bending at breakdown, i.e., $V_B = V_{B\,ap} + V_D$, where V_D is the zero bias band bending.

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2] Y. Okuto and C. R. Crowell, Phys. Rev. B 6, 3076 (1972).

3] Y. Okuto and C. R. Crowell, Bull. Am. Phys. Soc., Ser. II-17, 1194 (1972).

4] S. M. Sze and G. Gibbons, Appl. Phys. Letters 8, 111 (1966).

5] G. I. Roberts and C. R. Crowell, Solid-State Electron. 16, 29 (1973).