A CONSISTENT ANALYSIS OF BULK-BARRIER DIODES

E.LANGER(1), S.SELBERHERR(1), H.MADER(2)

(1) Institut für Physikalische Elektronik
TU Wien, Gußhausstraße 27, A-1040 Wien, AUSTRIA

(2) Siemens AG, Zentrale Forschung und Entwicklung
Otto-Hahn-Ring 6, D-8000 München 83, GERMANY

SUMMARY

The operation of Bulk-Barrier Diodes (BBD) has been investigated by comparison of mesured and simulated characteristics. The distributions of physical variables in the interior of a BBD are discussed.

ABSTRACT

Bulk-Barrier Diodes are relatively new devices - just recently patented /1/ - which promise to have impact on integrated circuits henceforth. Current flow in BBD's is essentially accomplished by majority carriers and controlled by a 'Bulk-Barrier' which is adjustable with standard technological steps. At first glance the BBD is comparable to a Schottky diode which is also a majority carrier device. As a remarkable difference the barrier of a Schottky diode is located at the metal-semiconductor interface and not in the bulk, and is thus not controllable by technological steps.

For our investigations we used a BBD with a p^+np-doping profile (Fig. 1). The fundamental idea of the operation of a BBD is the following: The n-layer is relatively thin, so that without an applied voltage the complete n-layer is depleted of free electrons - the p^+np-diode is 'punched through' . If one applies a positive voltage between the p- and p^+-layer, the p^+n-junction - henceforth called the first junction - is reverse biased and the np-junction - the second junction - is forward biased. As the doping in the p^+-layer is higher than in the n-layer, the depletion region of this reverse biased diode extends mainly into the n-layer. As result of punch through a hole current flows from the p- to the p^+-layer at relatively low voltages; the BBD is forward biased. The knee voltage of the BBD can be controlled by the doping level and the thickness of the n-layer alone; i.e. by technological steps. If one applies a negative voltage between the p- and p^+-layer, the second junction is reverse biased. This junction is, owing to the low substrate doping, able to block, because the depletion region extends mainly into the substrate; the BBD is reverse biased.

We performed a numerical analysis of the BBD by a computer program to get more detailed principal understanding of the operation of a BBD. The physical model this program is based on just consists of the well-known fundamental semiconductor equations (Poisson's equation, continuity equations, current relations and heat flow equation); we thus avoid errors introduced by regional approximations which are inherent in analytical considerations. Great efforts have been made in modeling the physical parameters (e.g. intrinsic number dependent on doping and temperature; carrier mobilities temperature-dependent because of lattice-, ionized impurity-, free carrier-scattering, and velocity saturation; thermal- and Auger-recombination and avalanche generation /2/) to obtain an optimum on accuracy.

Fig. 1 shows the doping profile and the carrier density distributions for -1.0 V reverse bias and 0.5 V forward bias. At reverse bias one can see the depletion region of the second junction while at the forward biased operating point the holes are dominating throughout the whole device by nearly reaching the electron density in the n-layer.

Fig. 2 shows the forward characteristics of the BBD drawn in a logarithmic scale. The shift of the characteristics, owing to small changes of the doping parameters, is quite pronounced, so that the offset between simulation and measurement is based on the uncertainty of the doping profile.

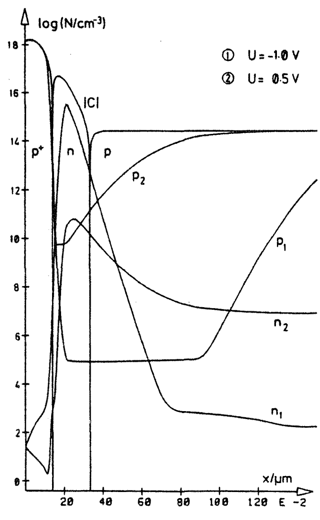

Fig. 1

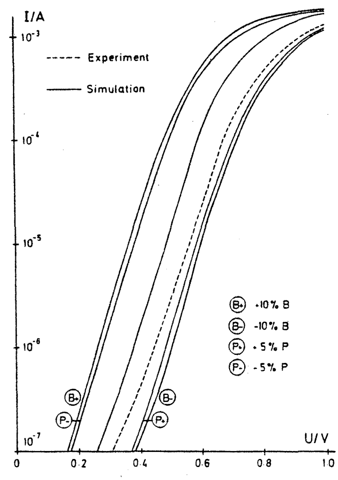

Fig. 2

/1/ Mader H.; European Patent No. 0003101979.

/2/ Langer E.; "Numerische Simulation der Halbleiterdiode", Diplomarbeit, TU Vienna, 1980.

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