NUMMERICAL ANALYSIS OF BEVELLED STRUCTURES

Felipe Lorenzo Della Lucia[1,2] and Jacobus W. Swart[1,2]

1- Faculty of Electrical and Computer Engineering at State University of Campinas - UNICAMP
2- Center For Semiconductor Components at State University of Campinas - UNICAMP

ABSTRACT

Simulations of different Bevelled p-n junctions (structures with lateral hewing) were made to study the behavior of the electric field in the surface and at the bulk of the junction in order to prevent precocious breakdown. It is shown that for positive Bevel angles, making the angle small reduces the electric field at the surface, preventing surface breakdown. For negative Bevel angles the reduction of Bevel angle is not strictly necessary, since the surface field is close to that of the vertical device.

1. INTRODUCTION

One method of increasing the breakdown voltage in power diodes and thyristors is to use structures with lateral hewing to create an angle between the surface and the bulk of the device (Bevel Angle) [1]. These are called Bevelled Structures. This angle can decrease the Electric Field in the device's surface by bending the Field distribution lines in the surface. Then, the breakdown occurs in the bulk instead of the surface.

There are two kinds of Bevel angles, the positive angle and the negative angle. The positive Bevel angle is defined as the angle that decreases the cross-sectional area when going from the heavily doped side to the lightly doped side of the asymmetrically p-n junction (Fig 1a). The negative Bevel angle has an increasing area going in the same direction (Fig 1b) [1].

In order to study the influence of the Bevel angles in the surface electric field, simulations using ATLAS [2] were performed to calculate the electric field in the surface and in the bulk of the device for different values of Bevel angles of both positive and negative.

2. METHODOLOGY

The main parameters used in the structure simulated are described as follows. The doping of the heavily doped side is 10^{20} cm^{-3}, the doping of the lightly doped side is 10^{14} cm^{-3}, and there is a n^{+} region heavily doped to provide ohmic contact between the n region and the metal. The structure is shown in Figure 2.

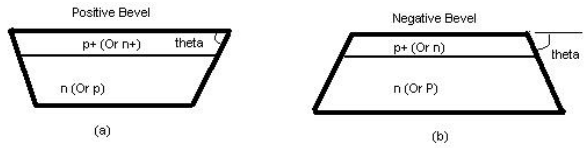

Figure 1: (a) Positive Bevel angle. (b) Negative Bevel angle

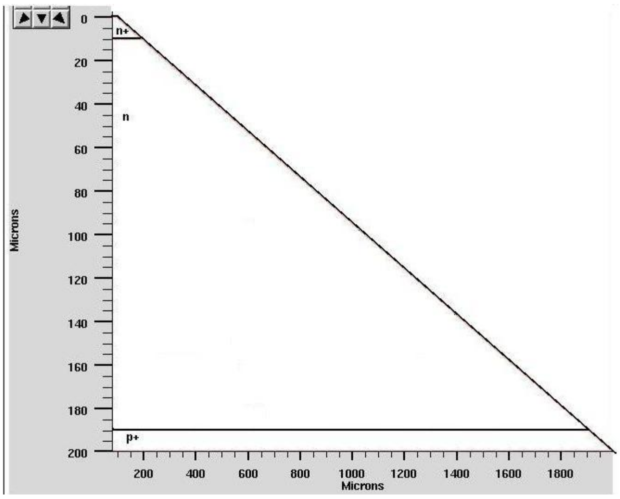

Figure 2: Geometry of the structure used for simulations. Heavily doped side: 10^{20} cm^{-3}. Lightly doped side: 10^{14} cm^{-3}. N^{+} region to provide good contact: 10^{21} cm^{-3}.

The value of the reverse voltage that will be applied at the p-n junction was decided to be 600 V once this is a common commercial value of reverse bias used at thyristors. The first test that must be done is to check if no punchthrough or breakdown occur in the junction with this voltage applied.

With the doping fixed at the previously mentioned values, simulations were made with 6, 12, 45, 75 and 90 degrees of positive Bevel angles. The surface electric fields for each angle were calculated and compared with bulk electric field.

The same procedure was done for negative Bevel angles.

3. DISCUSSION OF RESULTS

Figure 3 shows the depletion region for a 6^{o} positive Bevel angle with different voltages applied. One can see that, as expected, the higher the voltage, the greater is the depletion region, and no punchthrough or breakdown occur. In Figure 4 is shown the Electric Field of the same junction and it is possible to verify that the Electric Field at the surface is indeed much smaller than that at the bulk (about 14 times smaller).

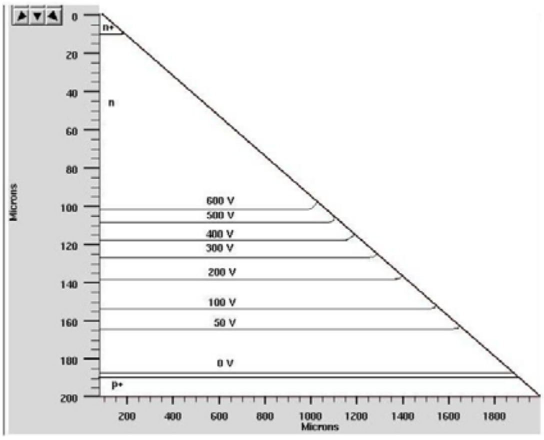

Figure 3: Depletion regions of different reverse voltages applied to the structure.

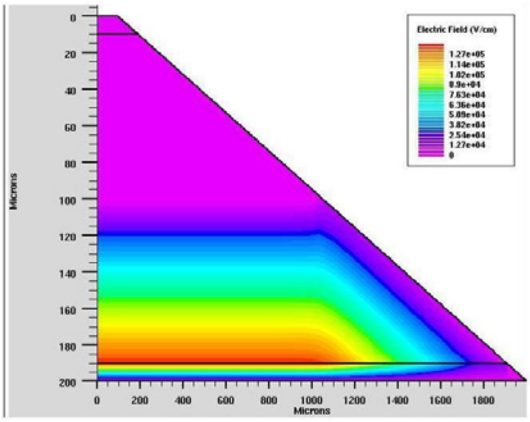

Figure 4: Electric field inside the junction. Reverse Tension: 600 V. The Electric Field in the surface is much smaller than that in the bulk.

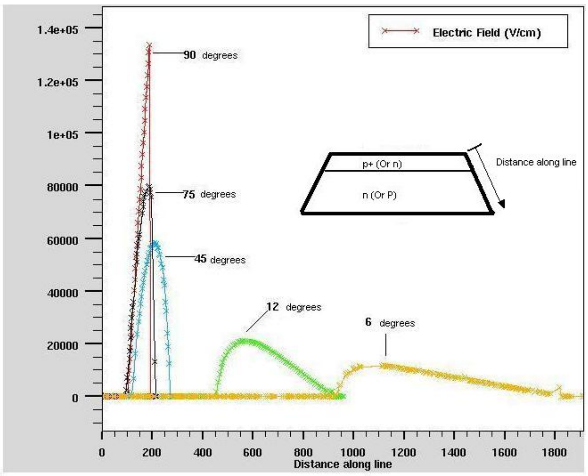

Figure 5: Electric Field along the surface of the positive Bevelled junction. The higher the angle, the higher the field.

By simulating different values of Bevel angles it was possible to construct the graphic shown in Figure 5. This figure shows the Electric Field versus the distance along the surface (Fig 5). The peak of the Electric Field versus the Bevel angle is shown in Figure 6. One can conclude that the lower the angle, the lower the field at the surface.

Performing the same procedure for negative Bevel angles, different results were obtained. Figure 7 shows a plot of the electric field versus the distance along the surface. One can see that at 45^o there is a maximum value of the electric field and the peak values at 90^o and 6^o are very close. Hence, the use of Bevelled structures with negative angles may not be very advantageous.

4. CONCLUSION

The use of Bevelled structures can strongly reduce the Electric Field at the surface of devices and prevent surface breakdown instead of bulk breakdown.

When using positive Bevel angles, the lower the angle the lower the field, yet a compromise of the magnitude of the field and the length of the device must be done, once the lower the angle, the higher de device's length.

Concerning to negative Bevel angles, there is no great advantages of using this technique or using vertical patterns of devices, once the electric field at the surface is close to that at vertical junctions.

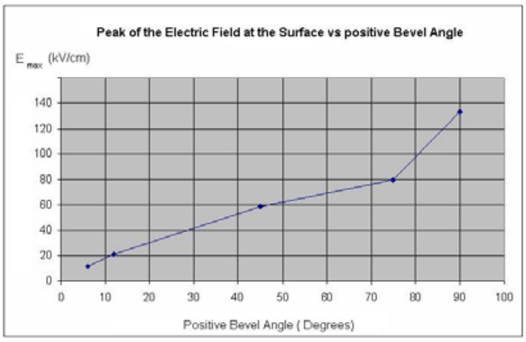

Figure 6: Peak of the Electric Field at the surface vs positive Bevel angle.

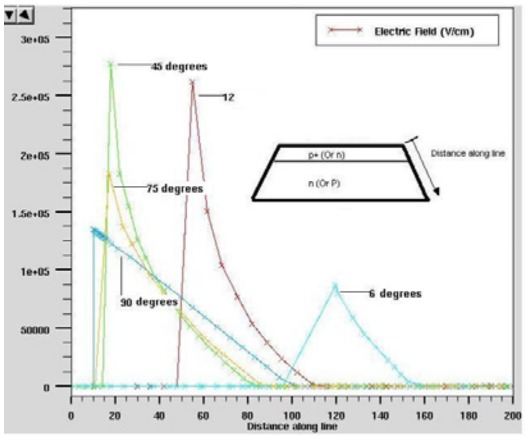

Figure 7: Electric Field along the surface of the positive Bevelled junction. Note that the electric field at 6^o is close to that at 90^o.

10. REFERENCES

[1] S.M. Sze, Physics of semiconductor devices, John Wiley & Sons, USA, pp. 196-198, 1981.

[2] ATLAS *User's Manual, Device Simulation Software*, Silvaco International, Santa Clara, CA, USA, 2004.

[3] S.K. Ghandi, Semiconductor Power Devices, John Wiley & Sons, cap. 02, pg. 33-93, 1977.

[4] M.S. Adler, V.A.K. Temple, “A General Method for Predicting the Avalanche Breakdown Voltage of Negative Bevelled Devices”, Journal of IEEE, 1975.