FIELD LIMITING RING WITH IMPROVED CORNER BREAKDOWN

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ABSTRACT – This paper proposes a new scheme of FLR for improving corner breakdown voltage. The major difference from the conventional FLR is to build extra rings and floating field plates in the corner region. In this structure the additional field plate and ring have reduced the electric field at the junction in the corner region. Thus it improves the breakdown characteristics which are critical for obtaining high breakdown voltage.

1. INTRODUCTION

The breakdown voltage of the discrete devices without termination is far less than the ideal breakdown voltage of a parallel plane junction. The termination technique using FLR (Field Limiting Ring) has been widely used to increase the breakdown voltage of discrete power devices. The FLR contributes in reducing the effect of junction curvature on the breakdown voltage in the planar devices.[1,2] A planar junction by the diffusion process with a rectangular window has a spherical junction at the corner regions. The electric flux is congested at the convex area and the breakdown voltage of this region can be worse than in the edge region.

The efficiency of the FLR is the key factor to improve device performance when developing a discrete high voltage device.[3] Generally, the die shape of high voltage discrete planar device is a rectangular for efficient utilization of the chip area.

The conventional FLR structure, as depicted in Fig. 1, has a semicircle with a different radius at the corner region. The ring separations are not changed either at the corner or at the edge region of the rectangle. The electric field in the corner region increases more rapidly than that in the edge region. If the edge region is optimally designed, which means using minimum ring area for a given breakdown voltage, then the corner region shows a lower breakdown voltage. The breakdown voltage of the device can be determined by the breakdown in the corner region. The impact ionization is a function of the electric field. [4]

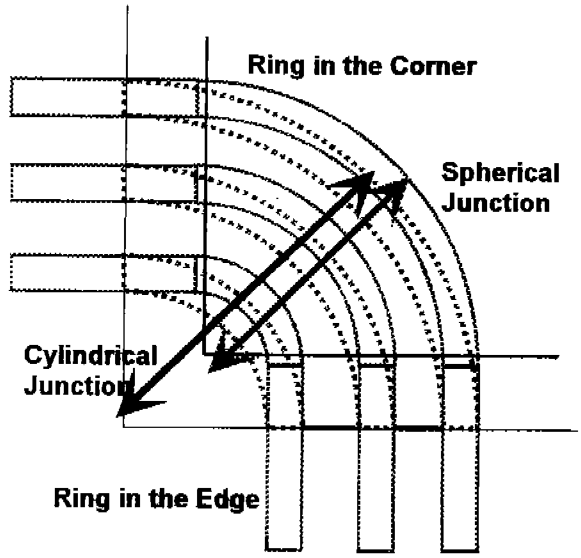


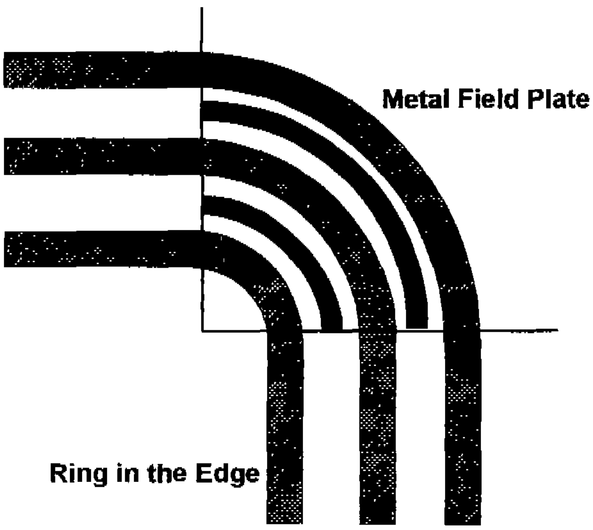
Fig.1. FLR structure and rounding in the corner region

Achieving an efficient FLR is the key factor when designing the discrete device. In this structure, the electric field in the corner has increased due to the cylindrical effect of the corner radii. To achieve safe reliable FLRs, the designer should use a large radius circle, what we called rounding in the corner region as depicted in a dotted line of Fig. 1. By reducing the ring space in the corner region, thus one decreases the maximum electric field between rings.

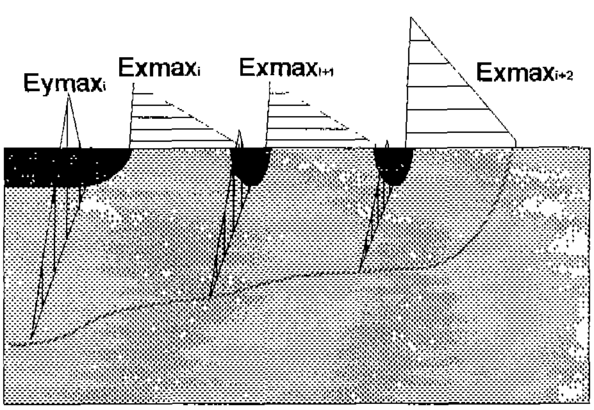
2. FLR DESIGN

The breakdown voltage of a spherical junction gives a smaller value than that of the parallel plane junction. To avoid the detrimental effects on breakdown voltage due to the floating ring in the corner region, a method of reducing electric field is proposed in this paper.

By reducing the ring space, one can reduce the spherical effect in the corner, but this results in a loss of chip area.[4] The second method is by adding a field plate only in the corner region, as depicted in Fig. 2. The additional field plate in the corner region causes effective reducing the ring space. The surplus voltage, over each ring can sustain, is applied to the last ring. The last ring has the maximum electric field. Thus the breakdown phenomena might easily occur at the junction of last ring. This is unwanted phenomena for reliability problems. The maximum electric field is reduced with decreasing ring spaces. The third method is adding an extra ring in the corner region as shown in Fig. 3. Reducing the ring space means that the voltage of the first ring is decreased but reversed for the last ring as shown in the Fig. 2.



(a) Additional field plate in the corner region



(b) E field distribution at the surface

Fig.2. FLR with extra field plate in the corner region

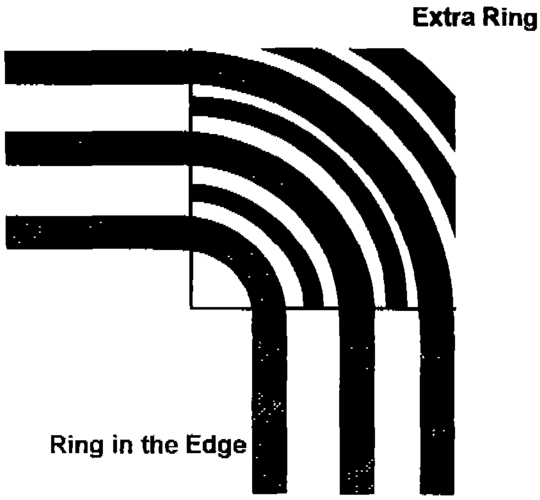


Fig.3. Proposed FLR with extra field plate and extra ring in the corner region

3. FLR with 300V Breakdown

The epi layer specification is determined in order to obtain the lowest R_{on} for a given breakdown voltage. The thickness and doping concentration of the epi layer is 23μm and $4x10^{14}/cm^3$ respectively for 300V breakdown voltage. The results of the initial ring design based on the analytical calculations are shown in table 1. We find the ring space for uniform surface electric field. The maximum electric field decreases with increasing number of rings. When the device size is very large compared to the ring area, then the efficiency should be considered. The FLR with a large number of rings is preferable for efficiency. (*Efficiency preferred design*) When the device size is small, such as in a low current device, then the ring area should be reduced. The designer should choose a structure with a smaller number of rings. (*Area preferred design*) To achieve a better reliability performance, it is recommended to induce a breakdown at the main junction of the FLR. (*Reliability preferred design*) This can be done to increase the ring space between the first ring and main junction, but this causes the structure to be inefficient.

FLRs with 300V BV with 2 to 5 ring structures are designed for simulation.[4,5] The FLR structure is designed for x_j= 5μm and diffusion windows of 5μm. Table 1 shows the design results for the 300V FLRs. The area represents the estimated ring area including the depletion width of the last ring when breakdown occurs.

Table 1. The floating ring position for 300V FLR
W_{epi}=23μm,N_{epi}= 4x10^{14}/cm^3

	Ring structure			
n th ring	2 Ring	3 Ring	4 Ring	5 Ring
1st	14μm	13μm	12μm	12μm
2nd	36μm	32μm	30μm	29μm
3rd		54μm	49μm	47μm
4th			71μm	66μm
5th				87μm
Area	63um	80um	96um	112um

4. SIMULATION RESULTS

A. 2 Ring structure – Edge Region

Fig.4 shows the breakdown simulation results using 2D device simulator, ISE DESSIS.[6] The breakdown voltage from DESSIS simulation results is 306V for the 2 ring structure of table 1. The arrow in Fig.4 indicates the maximum valued region for a given variable representing. The major breakdown occurs at a main junction, which is necessary for a reliable FLR structure.

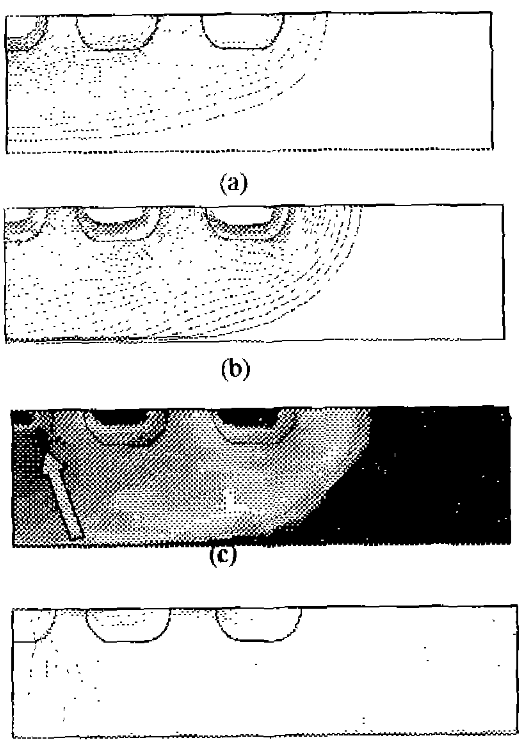


Fig.4. 2D device simulation results at breakdown.
a) Potential b) E field c) Impact Ionization
b) d) Current Flow at BV=306V

B. 2 Ring structure – Corner Region

The simulation was performed for a 2 Ring structure. Device simulation for the cylindrical junction was performed. The simulation results show the BV of 213V with a maximum electric field of 3.5x10^{5}V/cm at the junction of the first ring which is a much larger value than the maximum electric field of 2.78x10^{5}V/cm for the simulation results without considering the cylindrical effect.

C. Ring structure – Field Plate and Extra Ring

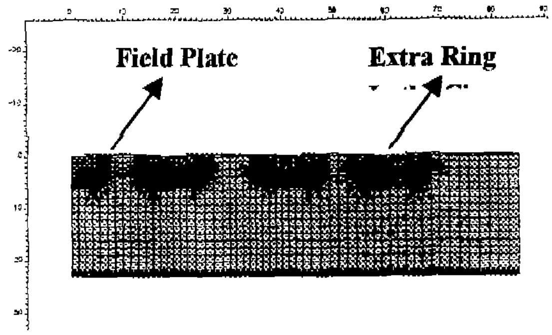


Fig.5. FLR structure with field plate and extra ring for simulating in the corner region.

The two dimensional device simulation with cylindrical option was proceeded for the structure given in Fig.6. The structures are generated using MDRAW of ISE TCAD. By adding a field plate over the ring space region to the first ring, the breakdown is more prone to a plane junction breakdown. The reduction of the electric field prevents increasing electric fields at the main junction, thus the breakdown voltage increases from 213V to 312V. But the field at the last ring should take over the amount of voltage not covered by the rings with reduced space.

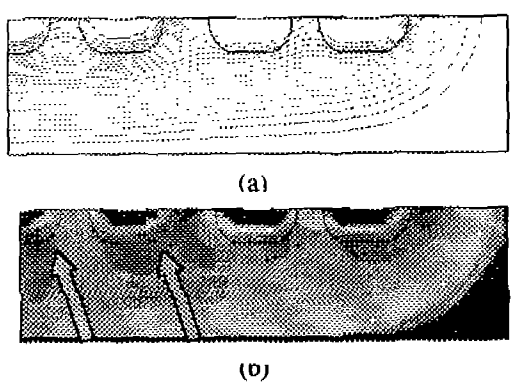


Fig.6. 2D device simulation results at breakdown with field plate and extra ring
a) Potential b) Impact Ionization BV=312V

5. CONCLUSION

In this paper, we present an idea that can improve the breakdown voltage by adding extra rings and field plates in the corner region. The efficient design method has been presented to improve the corner breakdown voltage without sacrificing area. The proposed structure is more efficient than that of commonly used FLRs. The simulation for the 3D structure is on the way of process using DESSIS from ISE.

6. ACKNOWLEDGEMENT

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