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3D TCAD Simulations for More Efficient SiC Power Devices Design

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Summary

In this study, cases where 3D simulations can add valuable additions to SiC power devices design are investigated. From PiN diodes to thyristors, different structures are introduced and studied when 3D becomes helpful. This present abstract introduces simulations results from a 3D SiC PiN diode periphery at breakdown.

Motivations

SiC devices design received much attention from the power electronics industry for the development of very high voltage applications such as railway or high voltage distribution network. Indeed, technology is now mature enough to foresee short-term solutions.

Semiconductor industry heavily relies on TCAD simulations, which allow engineers to design their devices, provided the models invoked by the simulator are accurate. While interdigitated devices such as conventional transistors can be modeled thanks to a 2D structure, devices such as diodes or, more especially, thyristors often rely on concentric designs in order to maximize their active area. One way to deal with this category of devices is to switch to pseudo-3D simulations by performing a revolution along vertical axis of a 2D structure, for example. However, it does not give enough flexibility since it is only applicable to circular devices. The challenge arises especially when trying to optimize thyristor switch-on process, for example. However, today computer farms have enough processing resources to deal with fully 3D structures.

Results

High voltage devices design must consider a periphery protection to mitigate electric field crowding that occurs at the junction edge. This well-know phenomenon, when not addressed properly, can lead to a drastic decrease in breakdown voltage since the thickness of the epilayer is no longer exploited for the intended purpose. JTE, MESA and guard rings are the common technics to overcome this phenomenon [1-4].

Devices such as diodes or thyristors often rely on concentric designs in order to maximize their active area. Those designs could be rounded shaped or even rectangular shaped. In such case, electric field crowding still remains at the periphery and depends on the bend radius [5]. For example, diodes peripheries can easily illustrate the common crowding observed at the periphery. A schematic 2D structure is shown Fig. 1 [6]. Simulations are performed on these two structures to estimate their breakdown voltages. When dealing with off-state simulations, running times are kept reasonable thanks to adaptive refinements on the electric field or space charge regions spreading.

Simulations results below are performed by finite elements method thanks to Sentaurus^{TM} TCAD software [7] for two JTE bend radiuses R_{JTE}: 120µm and 450µm.

Space charge regions at breakdown are plotted for both structures in Fig. 2. These plots show that the JTE acts as expected while Table 1 summarizes breakdown voltages that are obtained from the very same two bend radiuses and from a 1D diode. One can notice the crowding effect is more pronounced in the case where the bend radius is small hence a lower breakdown voltage than expected.

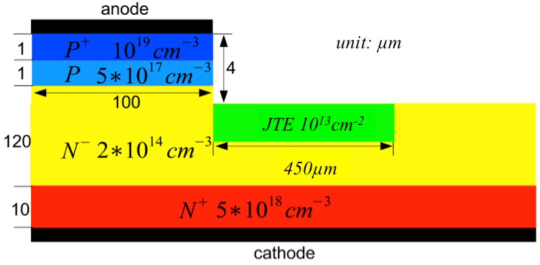
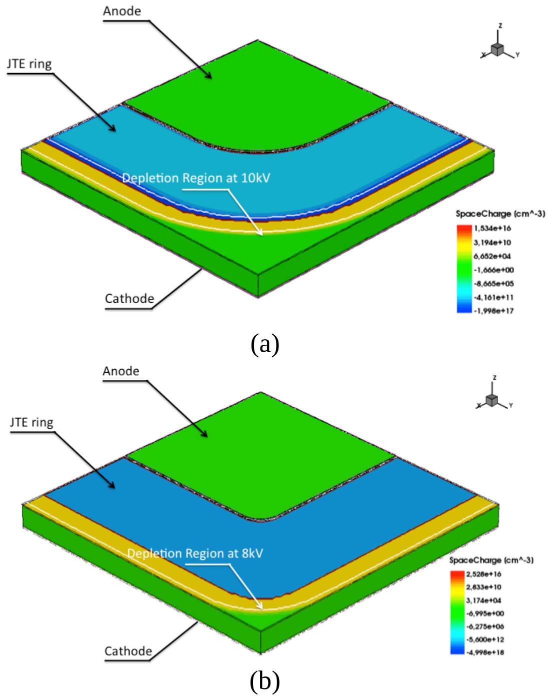


Fig.1: 2D schematic cross-section view of mesa JTE from a 10kV SiC PiN diode.



(a)

(b)

Fig.2: 3D PiN SiC diode structures for two different JTE bend radiuses R_{JTE}. (a) R_{JTE} = 450µm, (b) R_{JTE} = 120µm.

Table 1: Comparison between simulated breakdown voltages obtained from 3D structures of two different JTE bend radiuses and 1D ideal SiC diode.

JTE bend radius	**Breakdown Voltage**
120 µm	8kV
450 µm	10kV
NA (Ideal 1D diode)	12kV

This 3D diode structure can easily be converted into a thyristor one. In the final paper, more precise turn-on and turn-off behaviors will be presented as a well as its voltage holding capability. Better trade-offs can be obtained by designing mask layouts accordingly.

References

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