LIGBT with Dual Cathode for Improving Breakdown Characteristics

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Power transistors to be used in Power Integrated Circuits(PIC) are required to have low on resistance, fast switching speed, and high breakdown voltage. The lateral IGBTs(LIGBTs) are promising power devices for high voltage PIC applications, because of its superior device characteristics. In this paper, dual cathode LIGBT(DCIGBT) for high voltage is presented. We have verified the effectiveness of high blocking voltage in the new device by using two dimensional devices simulator. We have analyzed the forward blocking characteristics, the latch up performance and turn off characteristics of the proposed structure. Specially, we have focused forward blocking capacity of LIGBT. The forward blocking voltage of conventional LIGBT and the proposed LIGBT are 120V and 165V, respectively. The forward blocking characteristics of the proposed LIGBT is better than that of the conventional LIGBT. This forward blocking comparison exhibits a 1.5 times improvement in the proposed LIGBT.

Keywords : Forward Blocking Capacity, Double Cathode, High Voltage, Balanced Potential Distribution, LIGBT

1. INTRODUCTION

Power transistors to be used in Power Integrated Circuits(PIC) are required to have low on resistance, fast switching speed, and high breakdown voltage. The lateral IGBTs(LIGBTs)[1,2] are promising power devices for high voltage PIC applications, because of its superior device characteristics. In these devices, the high current handling capability relies on conductivity modulation of the high resistivity drift region. However, device latch-up, which leads to loss of gate control, may occur at high current due to the existence of the parasitic thyristor. Modification of the structure to improve the latch up characteristics of the LIGBT has been carried extensively[3-5].

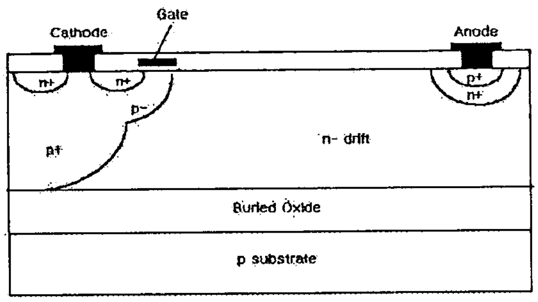
In the other hand, Research of the breakdown voltage to improve is not carried. Today, Since LIGBTs to be used information and communication industry are required to low voltage, conventional LIGBTs are sufficient to this fields. However, LIGBTs to be used PDP driving circuits and motor driving circuits are required to high voltage(>200V)[3,6].

In this paper, dual cathode LIGBT(DCLIGBT) for high voltage is presented. We have verified the effectiveness of the snap back suppression in the new device by using two dimensional device simulator, MEDICI.

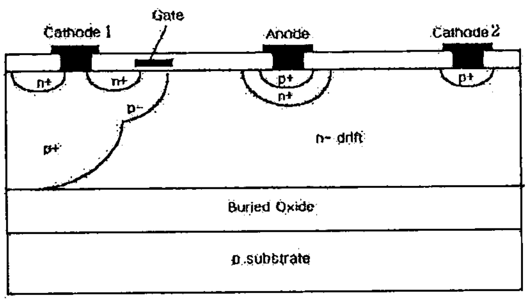
2. STRUCTURES OF DEIVCE AND OPERATION MECHANISM

Fig. 1 illustrates both the conventional LIGBT and the presented LIGBT structures. The main differences between the conventional LIGBT and the presented LIGBT are adding p+ - cathode. Fig. 1(a) is the conventional LIGBT structure. Fig. 1(b) is the proposed structure forming dual cathode. Operation of the proposed LIGBT has difference to compare with the conventional LIGBT. The proposed LIGBT has two current paths. One is identical to that of the conventional LIGBT. In the forward active mode of operation, a positive voltage is applied to the anode relative to the cathode. Anode current starts to flow at gate voltages higher than the threshold voltage and an anode voltage at approximately one diode drop. At a higher anode voltage, the anode pn junction starts to turn on and injects holes into the n-epi of the transistor. Some of these holes will recombine with the electrons flowing in from the vertical channel, and some of them will flow from the n-epi to the p-well and be collected by the p+ cathode without flowing through the area underneath the n+ cathode. The other current path is to flowing to another cathode. When the anode pn junction starts to turn on, holes to be injected into the n epi of the transistor flow to the other cathode. Therefore, Distribution of electric field from anode electrode is balanced between right and left, effectively.

To analyze the latch up performance and turn off characteristics of the proposed LIGBT, numerical simulations were performed using the two dimensional device simulator MEDICI. MEDICI allows the characteristics of the on state and off state performance of such a complex structure to be simulated. The device parameters employed in the device simulation are listed in Table 1.



(a)



(b)

Fig. 1. Structures of conventional and the proposed LIGBT. (a) conventional LIGBT (b) Dual cathode LIGBT

Table 1 - Design parameter for simulation

	Conventional LIGBT	Dual Gate LIGBT
n- drift concentration	$1\times10^{14}cm^{-3}$	$1\times10^{14}cm^{-3}$
p+ anode layer concentration	$1\times10^{20}cm^{-3}$	$1\times10^{20}cm^{-3}$
n+ layer concentration	$1\times10^{21}cm^{-3}$	$1\times10^{21}cm^{-3}$
p+ base layer concentration	$1\times10^{18}cm^{-3}$	$1\times10^{18}cm^{-3}$
p-base layer concentration	$1\times10^{16}cm^{-3}$	$1\times10^{16}cm^{-3}$
n channel length	3μm	
Oxide Thickness	100nm	

3. RESULTS AND DISCUSSION

The p+ - cathode is formed by a boron diffusion with the junction depth of 1μm. Its concentration is 1.0×10^{19} cm^{-3}.

For comparison, the simulated I-V characteristics of the proposed LIGBT and the conventional LIGBT are shown in Fig. 2. After n-channel gate is applied 15V, the simulated I-V characteristics show that the latch up occurs when Anode voltages and Anode currents is 1.5V and 1.2×10^{-4}A/μm. Latch up current characteristics is alike because that main current is identical current of conventional LIGBT.

The turn off simulation was performed when the device is operating at anode current of 1.2×10^{-6} A/μm by ramping the gate voltage form 15V to 0V in 20ns. The simulated waveforms of the proposed LIGBT and conventional LIGBT are shown in Fig. 3. The proposed LIGBT show a little faster turn-off speed than that of the conventional LIGBT. Turn off mechanism of the proposed LIGBT is identical to that of conventional LIGBT.

The simulated forward blocking characteristics of the proposed LIGBT and the conventional IGBT are shown in Fig. 4. Forward blocking voltage of conventional LIGBT and the proposed LIGBT are 120V and 165V, respectively. The forward blocking m characteristics of the proposed LIGBT is better than that of the conventional LIGBT. This forward blocking comparison exhibits a 1.5 times improvement in the proposed LIGBT.

Electric field distribution of the conventional and proposed LIGBT are shown in Fig. 5. Because the proposed LIGBT has two cathodes, current path is two. Therefore, distribution of electric field from anode to cathode is uniformed comparison with conventional LIGBT.

Fig. 6 shows ionization rate of conventional and the proposed LIGBT. When breakdown of devices is occurred, ionization of conventional LIGBT is occurred throughout entire device. In the other hand, the proposed LIGBT is occurred to cathode of MOS region, only.

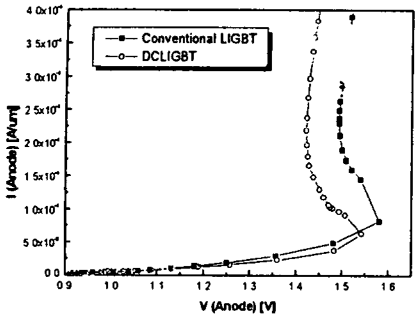


Fig. 2. I-V characteristics of the conventional and the proposed LIGBTs.

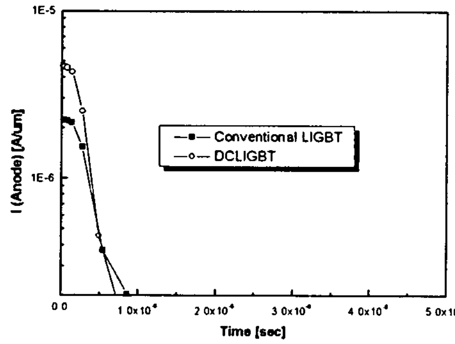


Fig. 3. Characteristics of turn-off the conventional and proposed LIGBTs.

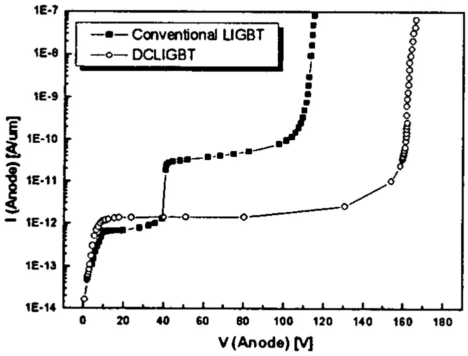
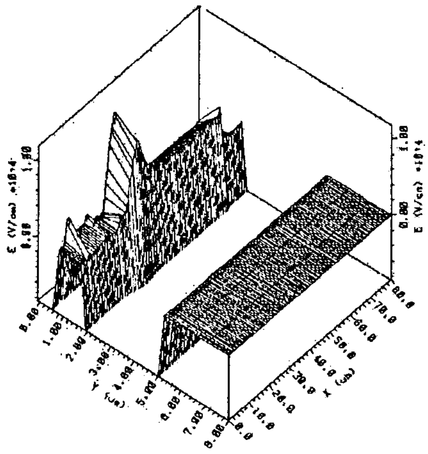
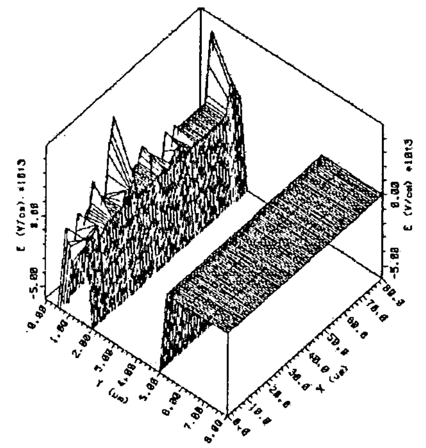


Fig. 4. Characteristics of forward blocking mode the conventional and proposed LIGBTs.

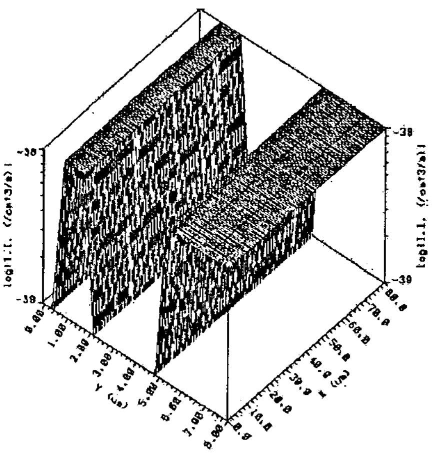


(a)

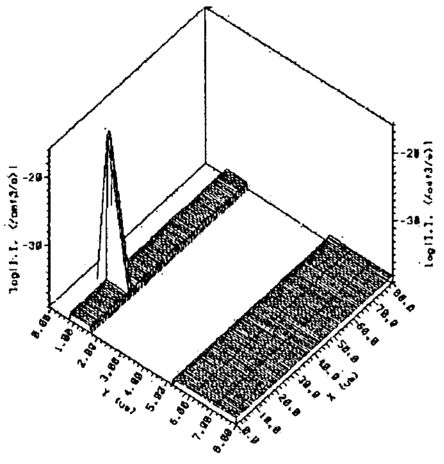


(b)

Fig. 5. Electric field distribution of the conventional and the proposed LIGBTs. (a) Conventional LIGBT (b) Dual cathode LIGBT



(a)



(b)

Fig. 6. Impact Ionization rate of conventional and the proposed LIGBT. (a) Conventional LIGBT (b) Dual cathode LIGBT

4. CONCLUSION

In this paper, dual cathode LIGBT(DCIGBT) for high voltage is presented. We have verified the effectiveness of high blocking voltage in the new device by using two dimensional devices simulator. We have analyzed the forward blocking characteristics, the latch up performance and turn off characteristics of the proposed structure. Specially, we have focused forward blocking capacity of LIGBT. The forward blocking voltage of conventional LIGBT and the proposed LIGBT are 120V and 165V, respectively. The forward blocking characteristics of the proposed LIGBT is better than that of the conventional LIGBT.

This forward blocking comparison exhibits a 1.5 times improvement in the proposed LIGBT. A new LIGBT structure to be presented at this paper will be applied many LIGBT structure for improving latch up effect because additional process is needed.

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