

A Novel SOI Carrier-Inducing Barrier-Controlled LIGBT with High Switching Speed

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1. Introduction

SOI LIGBT is a promising device for Power ICs due to its low on-state voltage drop and high input impedance¹⁾. However, its slow turn-off, which is caused by a large amount of holes stored during forward conduction state, limits its application area²⁾. Although various approaches have been performed to improve switching speed, they cause the on-state voltage drop to increase considerably³⁻⁴⁾. In order to achieve high switching speed and low on-state voltage drop, the trade-off relation between the switching speed and on-state voltage drop should be decoupled.

In this paper, a novel LIGBT, entitled CB-LIGBT (Carrier-induced Barrier-controlled LIGBT), is proposed and verified. In the CB-LIGBT, the potential barrier at the n-drift region/p-well junction are controlled so that the carriers stored in the drift region may be extracted rapidly during the turn-off process in order to speed up the switching.

2. Device Structures

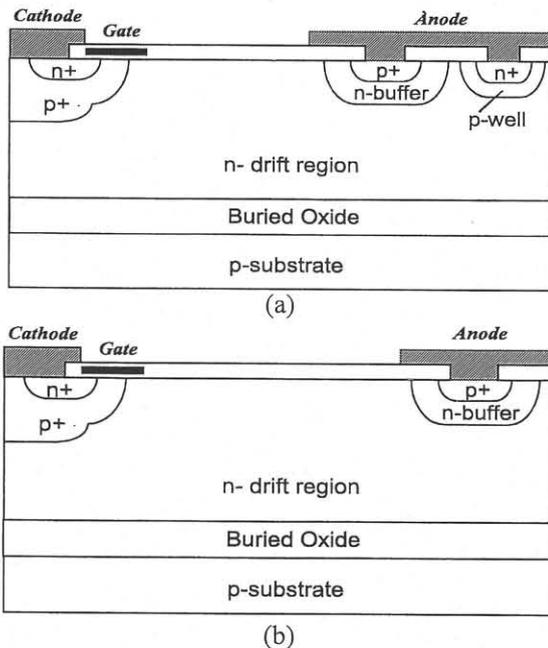


Fig.1. Cross-sectional views of (a) the SOI CB-LIGBT and (b) conventional SOI LIGBT .

The cross-sectional view of the CB-LIGBT is shown in Fig. 1. The key feature of the CB-LIGBT is that the anode

consists of two regions shorted together by a common anode metal electrode: one is a p⁺ anode region surrounded by the n-buffer, which is identical with the anode of the conventional LIGBT, and the other is an n⁺ anode region surrounded by p-well.

3. On-state Voltage Drop

We have carried out the 2-D device simulation to investigate the operation of CB-LIGBT. Fig. 2 shows the I-V characteristics of CB-LIGBT together with those of the conventional LIGBT and LDMOS. The I-V characteristics of the CB-LIGBT are similar to that of the conventional LIGBT, but its on-state voltage drop increases than that of the conventional LIGBT due to its lower current gain resulted from the flow of the electron through the p-well and the n⁺ anode. However, this increase of the on-state voltage drop is negligible at the normal operating point of 100A/cm².

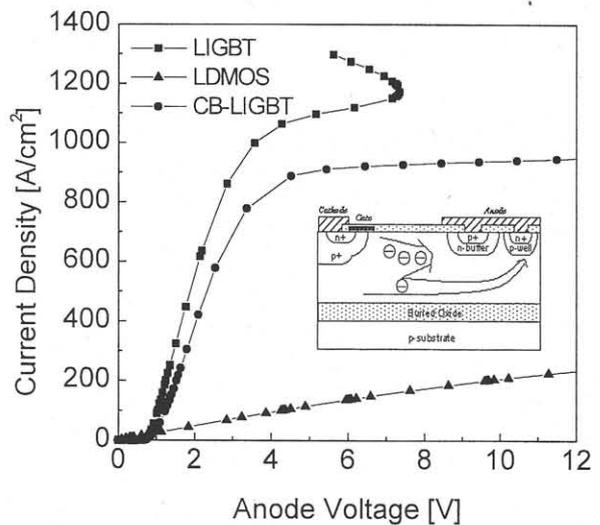
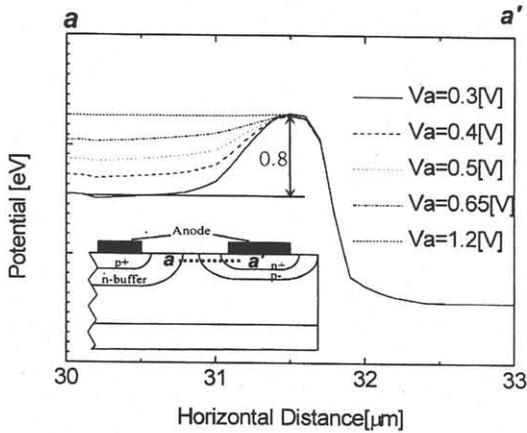


Fig. 2. I-V characteristics of the CB-LIGBT, conventional LIGBT, and LDMOS.

The forward conduction operation of the CB-LIGBT is almost identical with that of the conventional LIGBT except that the potential barrier at the p-well/ n-drift region junction is controlled by electron carriers injected from the channel. In order to turn-on the CB-LIGBT, firstly a positive bias above the threshold voltage is applied to the gate and the

anode voltage is increased. When the anode voltage becomes larger than 0.7V, the holes are injected from the p⁺ anode and the device turns into the forward conduction state. On the other hand, before the anode voltage is applied to the anode terminal, the magnitude of the potential barrier of p-well/n-drift region junction is about 0.8V. So the n⁺ anode electrode is disconnected by the p-well. When the anode voltage increases, the potential barrier starts to decrease because the electrons injected from the channel induces the barrier lowering as shown in Fig. 3. When the anode voltage is 0.7V, the potential barrier is almost eliminated, so that a part of electrons flows into the n⁺ anode.



4. Switching Characteristics

The 2-D device simulation has also been performed under the resistive load condition to investigate the switching speed of the CB-LIGBT together with the conventional lateral devices. The simulated devices were turned off by grounding the gate terminal with the ramp-time of 20ns and the minority lifetime of 0.1 μs. The CB-LIGBT, LDMOS, and the typical LIGBT exhibit the turn-off times of 100ns, 70ns, and 3 μs, respectively, as shown in Fig. 4.

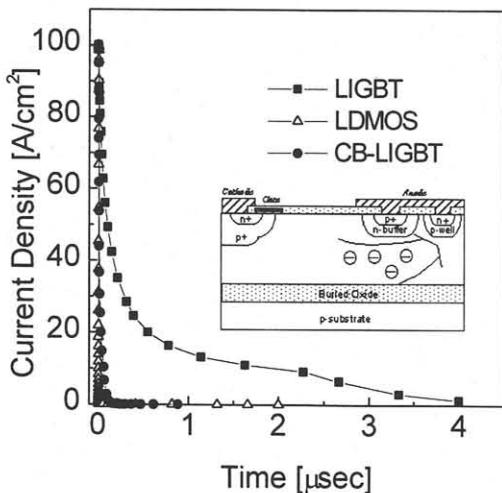


Fig. 4. Turn-off transient characteristics of the CB-LIGBT, conventional LDMOS, and LIGBT.

The turn-off mechanism of CB-LIGBT is quite different with that of the conventional device. When the gate voltage is turned-off, the electrons provided into the drift region from the channel would decrease and become terminated. Then, the holes injected from the p⁺ anode during the conduction state and the electrons existing to satisfy the charge neutrality with the holes remain stored in the drift region. For recovering the forward blocking capability of the device, these carriers should be removed. The eliminating mechanism of the carriers in the drift region is unlike in the case of the conventional LIGBT where the carriers are eliminated by only recombination. In the CB-LIGBT, there exists the conduction path for the electrons stored in the drift region after the gate voltage is eliminated. That is, the stored electrons are rapidly extracted into the n⁺ anode, so that the corresponding holes are also extracted. As the carriers disappear, the barrier between the p-well and the n-drift region begins to recover as shown in Fig. 5.

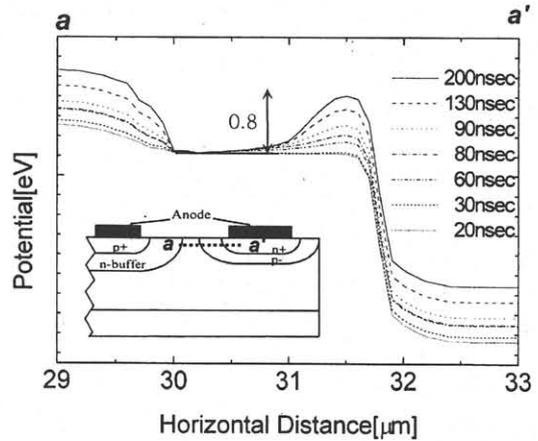


Fig. 5. The process of the potential barrier recovering during turn-off.

5. Conclusion

A novel LIGBT structure, entitled Carrier-induced Barrier-lowering LIGBT(CB-LIGBT), has been proposed and verified through 2-D simulation. The CB-LIGBT exhibits the high switching speed comparable to that of LDMOS and the low on-state voltage drop of LIGBT. The simulation results show that the on-state voltage drop increases by only 0.25V when compared with the conventional LIGBT and its turn-off time is 100ns which is almost identical with that of LDMOS.

Acknowledgement

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References

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