High Performance Oxide Engineered Lateral Schottky Bipolar Transistor

Sajad A Loan, *Member, IAENG,* Humyra Shabir, Faisal Bashir, M. Nizamuddin, Asim. M. Murshid, Abdul Rahman Alamoud and Shuja A Abbasi

***Abstract*— A novel lateral Schottky Collector Bipolar Transistor (SCBT) employing multi zone base and multi step buried oxide has been proposed and simulated. The numerical simulation study of the key characteristics of the proposed devices has been performed by using a 2D numerical simulator MEDICI. The simulation study has revealed that the proposed device with two base doping zones has ~30% higher breakdown voltage than the conventional device. The breakdown voltage increases further and is ~75% higher, when the number of zones in the proposed devices is increased to three. The increase in breakdown voltage can be attributed to the creation of extra electric field peaks in extended base region by multi doping zones in the base. Further, the substrate region under the collector also shares some of the applied potential and hence increases the breakdown voltage of the device.**

Index terms----Bipolar transistor, breakdown voltage. oxide engineering, Schottky collector, silicon-on-insulator, electric field.

I. INTRODUCTION

The bipolar junction transistors used in switching circuits usually face the problem of storage charge due to minority carrier injection into the base and collector. This results in the degradation of switching speed of the device. G. A. May [1] fabricated a Schottky Barrier Collector Transistor (SBCT), which possess Schottky barrier for the collector-base junction and a p-n junction for the emitter-base junction. In such a device, no injection of minority carriers take place from the metal to semiconductor, while carriers injected into the metal have practically zero life time. Hence SBCT does not have a significant storage time in a saturated switch mode. Further, such a device possesses negligible collector series resistance, as the collector is metallic [2-3]. The SCBT on SOI offers the advantages of ultimate isolation, reduced crosstalk and substrate noise. There is also an enhancement in the operating speed of devices, due to reduction in parasitic capacitances. However, there is a problem in the integration of the vertical SCBT with SOI-CMOS technology. The vertical bipolar device requires the SOI layer to be thicker for the collector region. This gives rise to additional cost of SOI wafers and compatibility problems with the thin film SOI [4].

An attractive alternative to vertical SCBT is the lateral SCBT on SOI. The lateral SCBT on SOI possess low parasitic capacitance and promise low power consumption. Besides, it allows tuning of the SOI layer to optimize CMOS device performance without degradation of the bipolar device performance. The lateral SBCT on SOI has promising applications in high speed analog and mixed signal circuit designing and in non-saturating VLSI circuits in BiCMOS technology. However, the major drawback of the SBCT on SOI is its extremely low breakdown voltage (VCE $\leq$ 3V). This can be attributed to the presence of an accumulated or depleted space charge region, producing high electric field at the Schottky collector-base interface. Further, the field induced barrier lowering effect and the image force increases the reverse leakage current, which causes early breakdown of the device [5-6].

In this paper, we performed the numerical simulation study of a multi doping zone base Schottky collector transistor on buried oxide multistep using MEDICI [7]. Two types of structures have been simulated and studied, one with two doping zones and other with three doping zones in the base and both of them use buried oxide double step (BODS) [5] wafer. They have been named as two zone proposed (2ZP) and three zone proposed (3ZP) devices. The simulations have shown that the 2ZP and 3ZP devices have 30% and 75% higher common emitter breakdown voltage (*BV*CEO) than the conventional two zone base device. The multizone base creates additional electric field peaks which reduce the electric field at the metal-base interface and hence increases the breakdown voltage of the device. The breakdown voltage is further increased by using buried oxide double step (BODS) under the metal collector. The silicon island under the collector and BODS share more potential and hence increases the breakdown voltage-further

II. DEVICE SCHEMATICS

The schematic cross-sectional views of three devices simulated in this paper are shown in Figure 1. They are conventional, two zone and three zone proposed devices. Table 1 shows various device and process parameters used in simulation.

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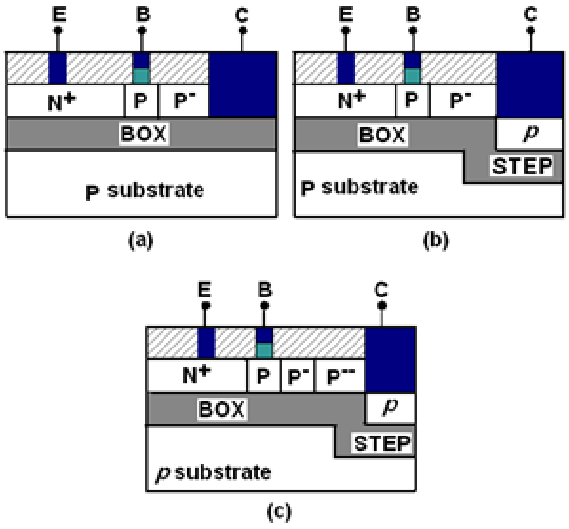

Figure 1. Schematic cross-section of (a) conventional (b) two zone and (c) three zone SBCT on BODS.

Table 1: Simulation parameters used

Parameter	2ZC	2ZP	3ZP
Substrate Doping (cm^{-3})	1 x 10^{15}	1 x 10^{15}	1 x 10^{15}
Emitter doping (cm^{-3})	5 x 10^{19}	5 x 10^{19}	5 x 10^{19}
Base doping B_1 (cm^{-3}) B_2 (cm^{-3}) B_3 (cm^{-3})	7 x 10^{17} 5 x 10^{16} – – – – –	7 x 10^{17} 5 x 10^{16} – – – – – –	7 x 10^{17} 5 x 10^{16} 1 x 10^{16}
Emitter length	3.8 µm	3.8 µm	3.8 µm
Base length B_1(µm) B_2(µm) B_3(µm)	1.2 1 ---------	1.2 1 --------	1.2 1 0.8-1
Collector length	4 µm	4 µm	3 µm
SOI thickness	0.2 µm	0.2 µm	0.2 µm
T_{BOX} (µm)	0.2 -1.0	0.2 -1.0	0.2 - 1.0
Field oxide thickness	1 µm	1 µm	1 µm

III. SIMULATION RESULTS AND DISCUSSIONS

To increase the accuracy of simulations, various models representing various physical phenomena have been incorporated. These models include *analytic*, *prpmob*, *fldmob*, *consrh*, *auger* and *BGN* [7]. Figure 2 and Figure 3 show the Gummel plot and the current gain of conventional and 3ZP devices. As can be seen from these figures, the plots are overlapping for most of base voltage. This can be attributed to the same base area and base current in both the devices. The reason of same base current and base area is that the buried oxide is fully covering base in both the devices, hence keeping base area and base current constant. By choosing proper doping concentration in base, the current gain has been chosen to be 42 in all devices for better comparison of results.

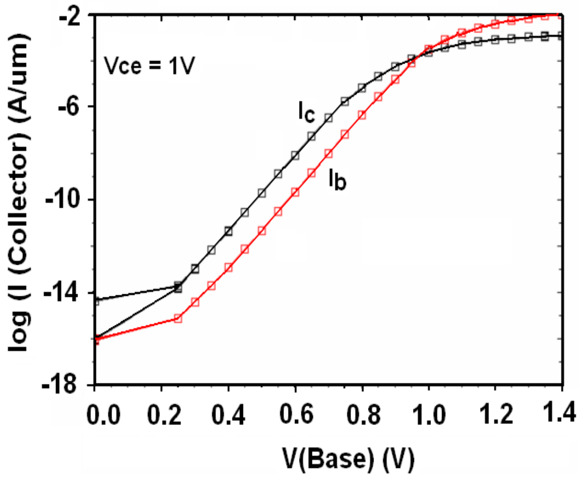

Figure 2. Gummel plot of conventional and three zone proposed (3ZP) device.

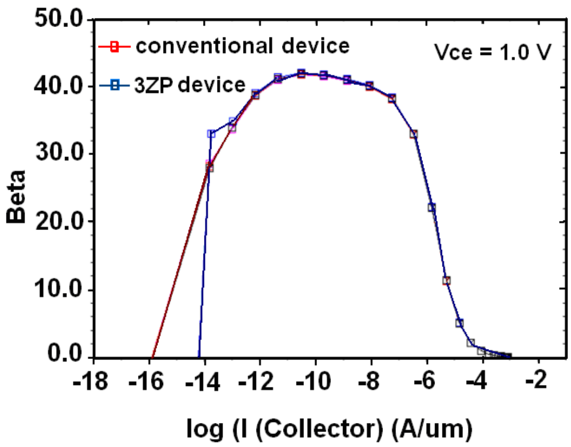

Figure 3. Current gain versus collector current of conventional and SCBT 3ZP device.

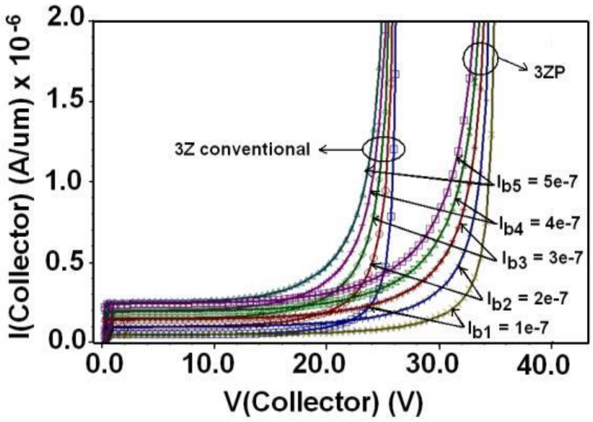

Figure 4. Common–emitter *I–V* characteristics of the 3ZP device and conventional devices with 3Z base.

The output characteristics of conventional, 2ZP, conventional device with three zone base and 3ZP devices are shown in Figure 4 and Figure 5. For each device the common emitter breakdown voltage (*BV*CEO) is calculated at a collector current of 1×10^{-6} A/µm. It is observed from the analysis that the 3ZP device possesses about 40% more breakdown voltage than the conventional device with three doping zone base. On comparing 3ZP device with 2ZP device, we see that the breakdown voltage is 59% more in

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3ZP device. The comparison of 3ZP and 2ZP devices with the conventional

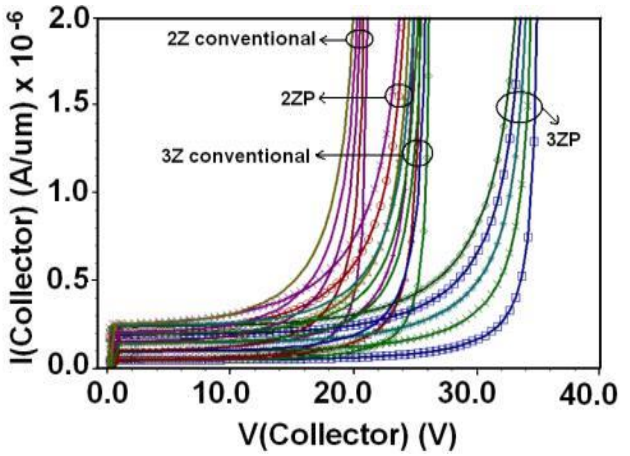

Figure5. Common emitter *I*–*V* characteristics of the 2Z conventional, 3Z conventional, 2ZP and 3ZP devices

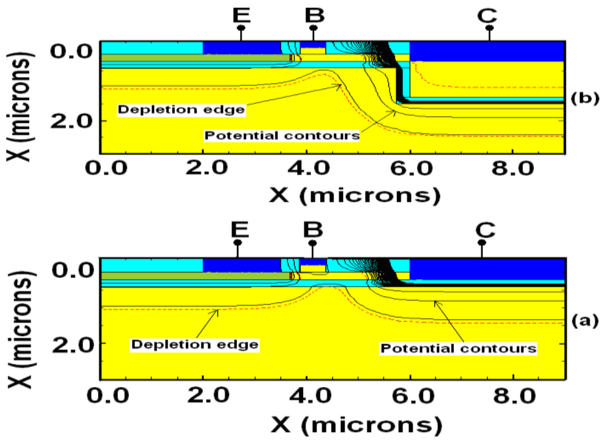

Figure 6. Potentials contours in (a) conventional SBCT and in (b) 3ZP SBCT device.

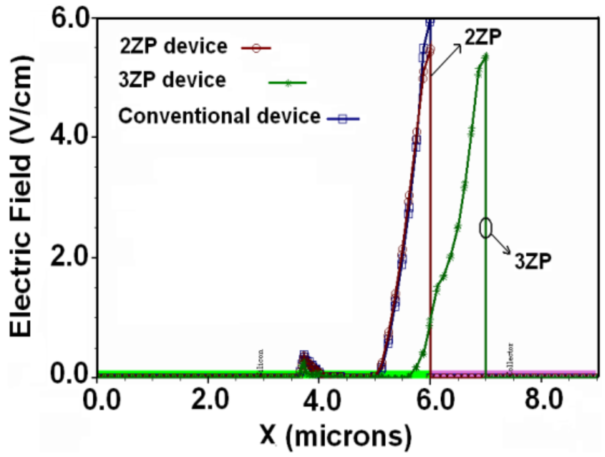

Figure 7. Electric field profile along the silicon film in 3ZP, 2ZP and in conventional SBCT devices.

devices show an increase of 75% and 30% in breakdown voltage respectively. The uniformity of the lateral surface electric field is increased by the multi zone base, as it creates additional electric field peaks in the base which reduce the electric field at the metal- base interface, thus increasing the breakdown voltage of the device. The buried oxide double step (BODS) under the metal collector also helps in increasing *BV*CEO as it shares some applied potential along with a substrate island under the collector. The potential contours in the conventional and in the 3ZP

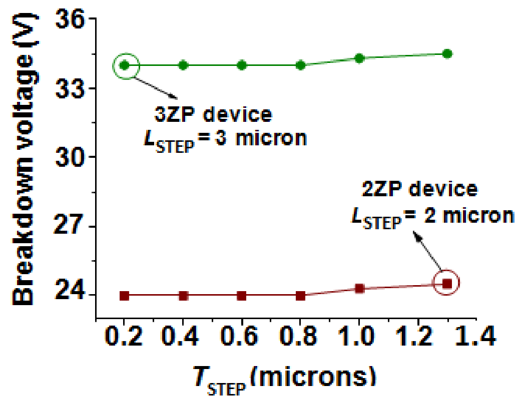

Figure 8. Effect of change in T_{STEP} on breakdown voltage in 2ZP and 3ZP devices.

device is shown in Figure 6. As can be seen from Figure 6(a), the potential contours crowd along the oxide layer and hence the critical field at which breakdown occurs is obtained at a lower voltage of ~20 V. On the other hand, in 2ZP device, the critical field at which the breakdown occurs results at a higher voltage of ~25 V. Although, the crowding of potential contours is still there in oxide, however, the depletion region width is more, which can sustain more electric field and hence can result higher breakdown voltage. Further, the low doping at the collector side and the high doping at the emitter side is chosen so that it gets fully depleted in the absence of externally applied bias. This helps in improving the breakdown voltage by reducing the electric field at the metal-base interface.

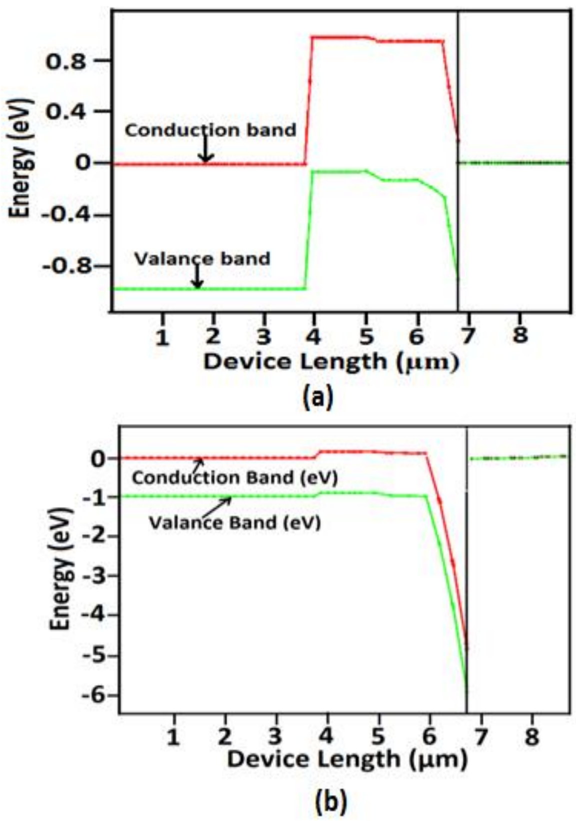

Figure 9. Energy band diagram (a) under equilibrium and (b) forward active mode.

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Figure 7 shows the electric field profile in the conventional, 2ZP and the 3ZP devices. It is clear that the electric field peak at the metal-base junction in conventional device is more than that of 2ZP device. The magnitude of electric field peak is least in the 3ZP device. This reduced electric field results in an increase in breakdown voltage of 3ZP device. Figure 8 shows the effect of increasing the thickness of step oxide on breakdown voltage. It is seen that increasing *T*STEP in upward direction towards collector does not change the breakdown voltage significantly. As we go on increasing the T_{STEP} in the upward direction, an SCBT on extended box [4] can result. Such a structure has more or less same breakdown voltage as that of SCBT on BODS. However, SCBT on BODS is thermally efficient in comparison to extended box structure, due to thin oxide and a silicon island under collector The energy band diagrams of the proposed structure has been obtained for both equilibrium and active mode conditions, as shown in Figure 9. It clearly shows a barrier at metal semiconductor interface which is responsible for negligible reverse saturation current.

IV. CONCLUSION

A high performance multi doping zone base Schottky collector bipolar transistor on buried oxide double step has been proposed. The 2D numerical simulations have revealed that the 2ZP and 3ZP devices have 30% and 75% higher common emitter breakdown voltage (BV_{CEO}) than the conventional SCBT device. The increase in breakdown voltage is attributed to the generation of additional electric field peaks which reduce the electric field at the metal-base interface, thus increasing the breakdown voltage of the device. The BODS under the metal collector and the silicon island under the collector share some potential and hence increase the breakdown voltage further.

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