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A New High Speed Switching Bipolar Power Transistor with Corrugated Base Junctions

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Introduction

High speed switching bipolar power transistors have been used widely in power converting systems. But slow turn-off transition time due to the excess majority and minority carriers stored in the base and collector region has been considered of a major drawback of the bipolar transistor [1]. In order to enhance turn-off transition speed, a new structure of the bipolar power transistor with corrugated base junctions is proposed in this paper. This new structure bipolar transistor has been fabricated without any additional masks and process steps, evaluated the electrical characteristics including turn-off transient times and compared with conventional bipolar transistors with parallel plane base junctions.

Device Structure and Fabrication

Fig. 1 shows the vertical structure and net doping distributions of a proposed bipolar power transistor with a corrugated base junction. The conventional bipolar transistors have parallel plane base junctions and lateral uniform doping except for the junction termination edge region. As shown in the figure, the proposed bipolar transistors have many corrugated base junctions below the base electrodes and base electrodes contact to high doped base region and low doped base region simultaneously. These corrugated base junctions have been formed by the selective implantation at the base step by means of the oxides remained partly in the base contact region afterward. Consequently we have fabricated a bipolar power transistor with corrugated base junctions by using conventional bipolar power transistor process except for the base mask to form corrugated base junctions.

Results and Discussion

Fig. 2 shows clearly the differences of the base doping between the corrugated base region and conventional parallel plane base region. The doping profile of a corrugated base region shown in Fig. 2 is taken from the line of AA' of Fig. 1.
In the switching operation, bipolar transistors go into saturation state when the conduction currents flow and go into cutoff state when the conduction currents stop. Fig. 3 shows the simulated results of electron concentration distributions of a corrugated base transistor and a conventional base transistor at a saturation state when the external switching conditions are identical. The electron concentrations of a conventional base transistor are higher than those of a corrugated base transistor, which causes deeper saturation and results in longer turn-off time for the conventional transistor than for the corrugated base transistor.
Measured current gain and saturation voltage between the collector and base of a corrugated base transistor and a conventional transistor are shown in Fig. 4 and Fig. 5 respectively. Fig. 6 shows the measured switching waveforms of collector currents and base currents at turn-off transient. Since the corrugated base transistor has a lateral gradual doping in the base region below the base electrodes, excess electrons in the base region move easily from bulk to the surface base electrodes by the built-in electric field of lateral gradual doping region. These effects accelerate the recombination of excess electrons and holes and cause shorter storage time in turn-off stage.

Conclusion

A new structure of the bipolar power transistor with corrugated base junctions is proposed for fast switching application. The proposed bipolar transistor shows relatively shallow saturation, has built-in field accelerating the recombination of excess electrons and holes and has shorter storage time above 20 % than the conventional transistor.

References

[1] J. Narain, "A Novel Method of Reducing the Storage Time of Transistors", IEEE Electron Device Letters, vol. EDL-6, pp578-579, 1985.

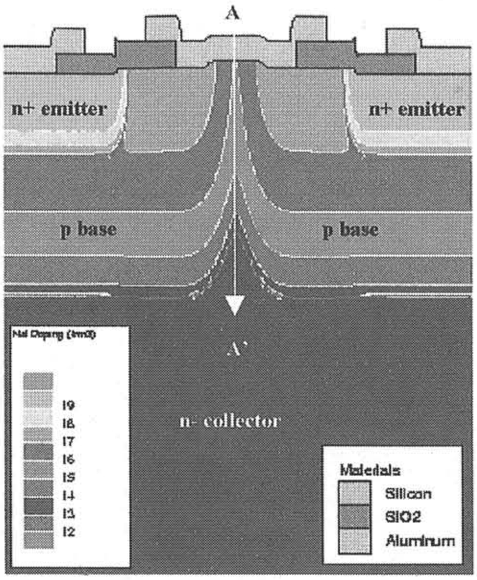

Fig. 1 Vertical structure and doping distributions of a bipolar power transistor with a corrugated base junction.

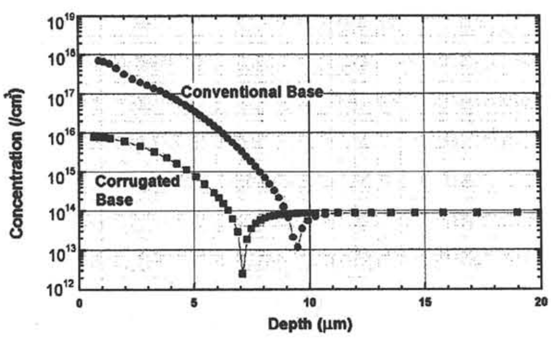

Fig. 2 Base doping profiles of a corrugated base region and a conventional base region.

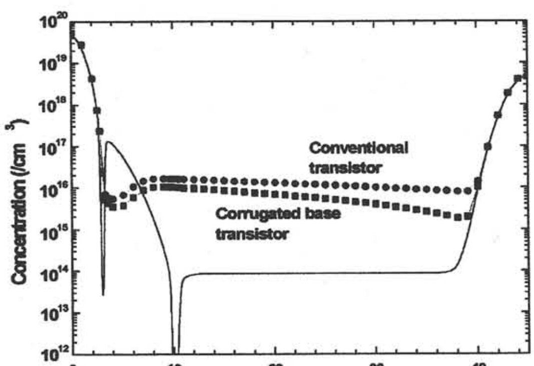

Fig. 3 Simulated electron concentration distributions of a corrugated base transistor and a conventional base transistor at a saturation state.

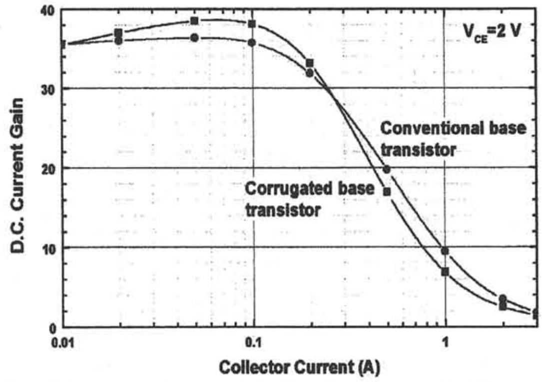

Fig. 4 Measured current gain of a corrugated base transistor and a conventional base transistor.

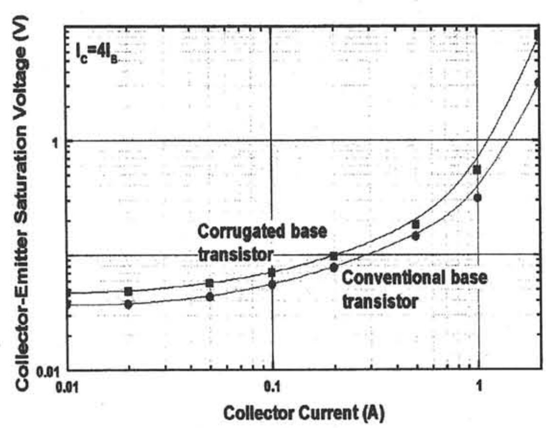

Fig. 5 Measured collector-emitter saturation voltage of a corrugated base transistor and a conventional base transistor.

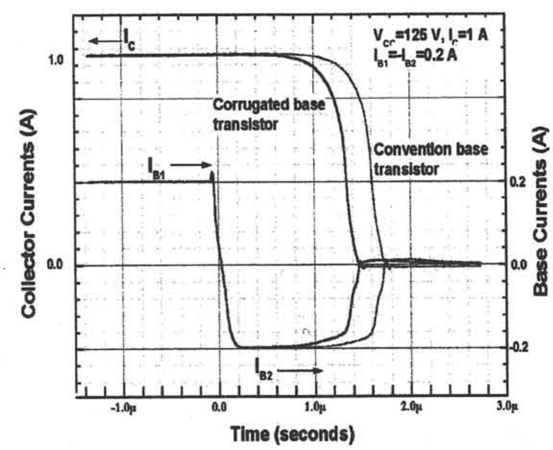

Fig. 6 Measured switching waveforms at turn-off transient of a corrugated base transistor and a conventional base transistor.