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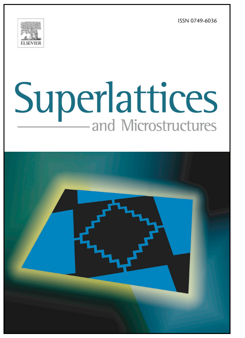

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Gate Field Plate IGBT with Trench Accumulation Layer for Extreme Injection Enhancement

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***Abstract-* A gate field plate IGBT (GFP-IGBT) with extreme injection enhancement is proposed and verified using TCAD simulations. The GFP-IGBT features a gate field plate (GFP) inserted into n-drift region directly and a tiny P-base region separated from the GFP. In the ON-state, the accumulation layer is formed near to not only the bottom but also the side of the trench, which enhances electron injection efficiency. And the tiny P-base region reduces the holes extracted by reverse-biased P-base/N-drift junction. Both the GFP and tiny P-base contribute to achieving extreme injection enhancement, leading to a low forward voltage drop. In the OFF-state, due to the low stored charges in N-buffer layer, GFP-IGBT shows a short current fall time, leading to a decrease of turn-off loss. The simulation results show that, compared with the conventional IGBT, the GFP-IGBT offers a forward voltage drop reduction of 25% or current fall time reduction of 89% (*i.e.* turn-off loss reduction of 53%), resulting in low power loss. The excellent device performance, coupled with a commercial IGBT-compatible fabrication process, makes the proposed GFP-IGBT a promising candidate for power switching applications.**

***Keywords*—insulated-gate bipolar transistor (IGBT), injection enhancement, breakdown voltage, forward voltage drop, turn-off.**

1. Introduction

The insulated gate bipolar transistor (IGBT) has now been widely employed in power systems such as power supplies, motor controlling, tractions [1-3]. Many structures have been proposed to optimize the trade-off between the forward voltage drop and turn-off loss [4, 5]. Sumitomo *et al.* reported a new IGBT using a partially narrow mesa IGBT (PNM-IGBT) structure to suppress the hole current and reach low forward voltage drop [6, 7]. However, the PNM-IGBT, which features an extremely narrow mesa (*e.g.*, 200 nm), presents some challenges in the manufacturing and reliability. M. Jiang *et al.* proposed an injection enhanced IGBT with P-base Schottky contact (SC-IGBT), which achieves low forward voltage drop [8]. In SC-IGBT, the Schottky barrier potentially degrades the breakdown voltage. H. Takahashi *et al.* reported a carrier stored trench-gate bipolar transistor (CSTBT) using an n-type buried layer under the p-well region as a hole barrier to store the hole in n-drift region and realize low forward voltage drop [9]. But CSTBT requires a deep diffusion process to form the n-type buried layer, leading to some tradeoff on device breakdown voltage.

In this paper, a new type IGBT with extreme injection enhancement is proposed in which a gate field plate (GFP) and a tiny P-base region are implemented. The GFP structure can increase the carrier concentration in the emitter side and decrease the holes extracted by the reversed junction simultaneously, which contributes to low forward voltage drop [10]. This will considerably simplify the IGBT fabrication process to achieve conductivity modulation enhancement in comparison with the state of the art [1-2, 5-9]. We report the TCAD simulation work of breakdown voltage, current density, threshold voltage, turn-off time, turn-off loss, and short-circuit test to validate this new concept.

2. Device structure and mechanism

The cross-section of the proposed GFP-IGBT structure is shown in Fig. 1 Compared with the conventional IGBT (C-IGBT) [11], the GFP-IGBT features a GFP inserted into N-drift region directly and shared the same electrode with trench gate, as well as a tiny P-base region separated from the GFP.

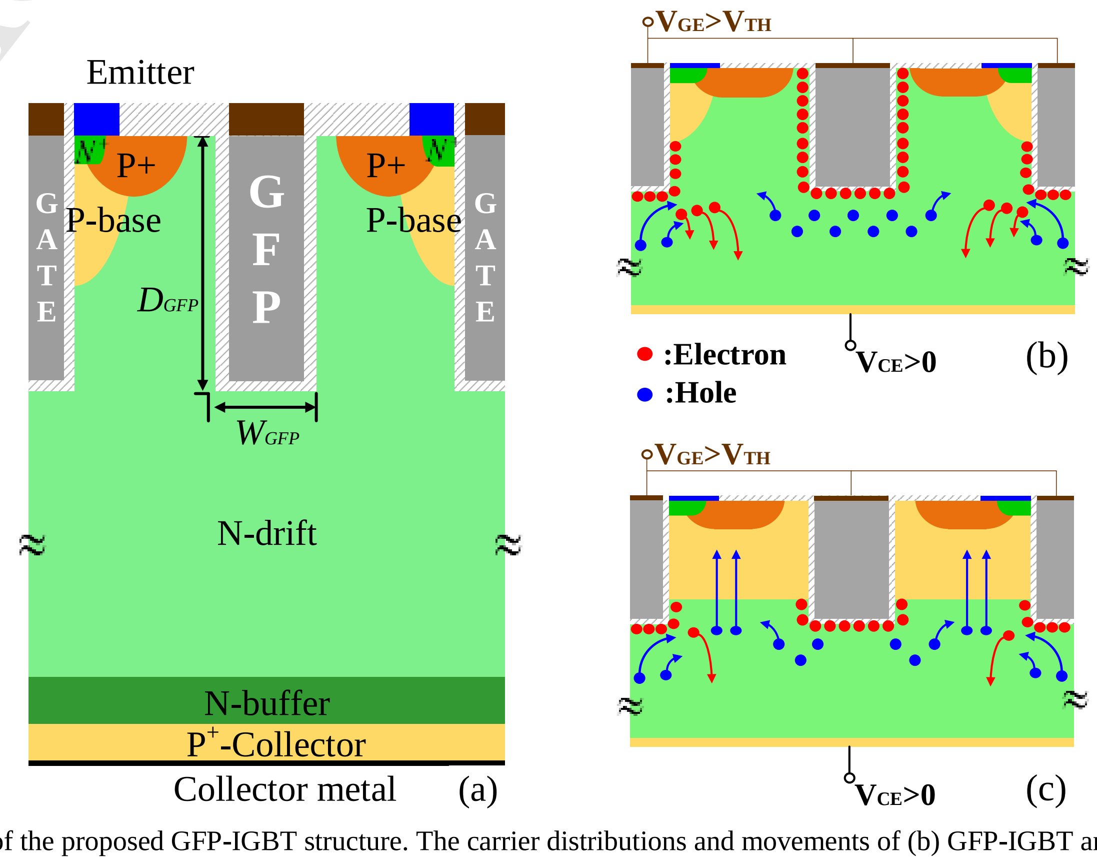

Fig. 1. (a) The cross-section of the proposed GFP-IGBT structure. The carrier distributions and movements of (b) GFP-IGBT and (c) C-IGBT, respectively.