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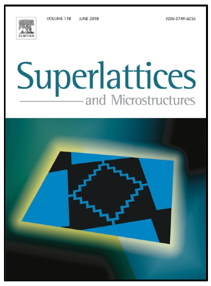

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Analysis of the Novel Si/SiC Heterojunction IGBT Characteristics by TCAD Simulation

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***Abstract*—In this paper, a novel insulated gate bipolar transistor (IGBT) structure with a wide bandgap semiconductor material heterojunction is proposed for the first time. The main feature of the new IGBT structure device is the combine of the wide bandgap material SiC and the Si material to form a heterojunction, which utilizes the high critical breakdown electric field of SiC materials. When the proposed device breaks down, the innovative terminal technology of Breakdown Point Transfer which elevates device longitudinal electric field peak begins to play a role, while introducing a high electric field peak near the gate of the IGBT device into the SiC material and making the device can bear a higher breakdown voltage (*BV*). The analysis results show that the *BV* of the Si/SiC IGBT is 3 to 4 times higher than that of the Si IGBT. The switching characteristics of the Si/SiC IGBT can be improved due to the low minority carrier lifetime of SiC materials compared with the Si IGBT. The interfacial effect of the Si/SiC is analyzed to guide the preparation of the Si/SiC IGBT.**

***Index Terms*—IGBT, Si/SiC Heterojunction, Breakdown Point Transfer, Breakdown Voltage, Interfacial effect.**

I. INTRODUCTION

Insulated Gate Bipolar Transistor (IGBT) is a kind of power semiconductor device that combines microelectronics with power electronics. It has a wide range of applications, large market demand and good prospects for development. With the development of technology, the functions of Si-based power devices gradually approach for the limits of Si materials [1-2]. The SiC-based semiconductor has the characteristics of wide bandgap, high critical breakdown electric field and high thermal conductivity over conventional Si-based power devices. At present, the performance of the Si IGBT has been quite perfect with the development of structural design and manufacturing process and close to the theoretical limit determined by the material characteristics which can be further improved by utilizing the excellent properties of SiC materials. Meanwhile the process of Si-based IGBT devices has been very mature which limits the development and application of SiC devices greatly, such as the poor quality of the SiC/SiO_2 interface results in poor gate oxide reliability and the poor source Ohmic contact derived from various problems. Although the SiC material has been commercialized, there is still a long way to go for large-scale practical application of SiC devices.

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In this paper the novel IGBT structure which combines the wide bandgap material SiC with Si materials to form a heterojunction is proposed. By using Si materials in the upper part of the IGBT device and SiC materials in the remaining part, it is well compatible with the manufacturing process of Si-based IGBT devices to solve the process challenges associated with fabricating IGBT devices entirely from SiC materials, while the excellent properties of SiC materials are also available. Hence, the Si/SiC IGBT is an innovative semiconductor power device that integrates the advantages of both SiC and Si materials [3-7].

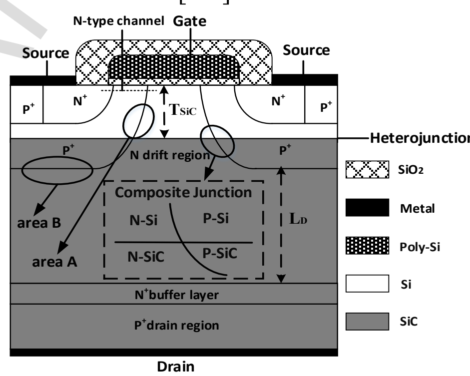

Fig.1. Cross-section of the novel Si/SiC IGBT.

II. DEVICE STRUCTURE

This paper presents a novel IGBT device structure with Si/SiC heterojunction as shown in Fig.1. The proposed structure follows the basic structure of the PT IGBT device, and the differences are that the overall device is separated by a heterojunction formed of Si and SiC materials and that the JFET region and the part of P^+ base fall into the region formed by the SiC material. The structure including the P^+ drain region, the N^+ buffer layer and the N^- drift region are formed of SiC materials, and the region formed by the Si material is mainly the portion where the active region and the gate oxide are in contact.

In this simulation, a perfect monocrystalline silicon structure is assumed with related electrical and material parameters. In fact, there must be a lattice mismatch at the interface between Si and SiC layers. Due to the difference of lattice mismatch and thermal expansion coefficient, in growing Si layers on SiC, obvious residual stress and high density defects are often