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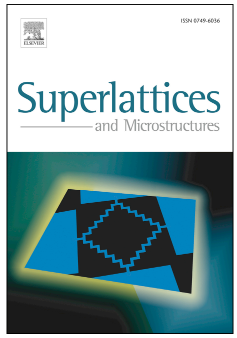

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A 4H-SiC Junction Barrier Schottky Diode with Segregated Floating Trench and Super Junction

Lijuan Wu, Bing Lei, Hang Yang, Yue Song, Yinyan Zhang

School of Physics & Electronic Science, Changsha University of Science & Technology,

Changsha 410114, China

***Abstract*—A 4H-SiC Junction Barrier Schottky Diode with Segregated Floating Trench and Super Junction (S-FT SJ JBS) is presented in this paper. By adopting segregated integrated trench and super junction, the high electric field not only focus on the bottom of trench but also gathers in the top of trench and the edge of super junction, therefore the distributions of the high electric field is more uniform, and thus to substantially improve the breakdown voltage (BV). By using the floating trench, the area of schottky contact is enlarged, thus the density of current is increased in the on state, and the specific on-resistance ($R_{on,sp}$) of the device is ultimately decreased. The results of simulation show that the BV and $R_{on,sp}$ of S-FT SJ JBS diode are 1891V and 0.16 mΩ·cm^2, and the BV is improved by 29.5% and the $R_{on,sp}$ is decreased by 50% compared with I-FT SJ JBS diode. The Baliga figure-of-merit (BFOM) of S-FT SJ JBS diode is 894W·cm^{-2} which is increased by 236.1% compared with I-FT SJ JBS diode.**

***Index Terms*—Breakdown voltage (BV); specific on-resistance ($R_{on,sp}$); surface trench （ST）; floating trench (FT); super junction (SJ).**

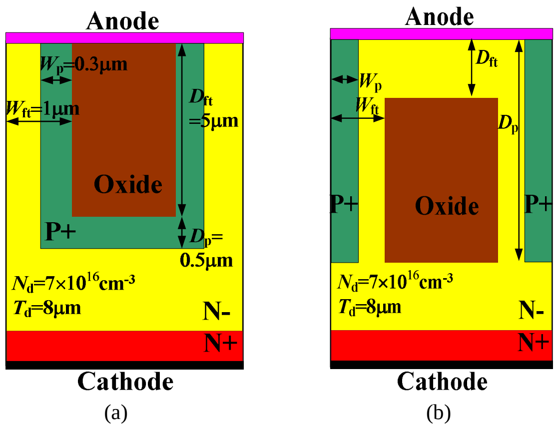
1. Introduction

4H-SiC power semiconductor devices have been being applied in power system since 2001, after more than ten years of market development and cultivation, 4H-SiC power semiconductor devices comes to a rapid developing period. As the seminar of national new power semiconductor device and its application technology successfully convened in 2017, the third generation of new semiconductor materials represented by 4H-SiC being attracted more extensive attention. 4H-SiC has superior material characteristics such as wide band gap, high critical breakdown electric field, high thermal conductivity, high electron saturation velocity, and low intrinsic carrier concentration[1-2], which means 4H-SiC power semiconductor devices can be applied in many new energy fields such as electric vehicles, rail transit, shipboard power supplies, and smart grids in the future. Schottky Barrier Diode (SBD) and PiN diode are indispensable power semiconductor rectifying devices in semiconductor integrated circuits. 4H-SiC JBS diode is a combination of SBD diode which has low $R_{on,sp}$ and PiN diode which owns high BV[3-5].

The current flows from the schottky contact anode to the ohmic contact cathode when the conventional 4H-SiC JBS diode is in the on state, which means the carrier electrons move from the ohmic contact cathode to the substrate, then arrive at the drift region, cross over the schottky barrier, and finally return to the schottky contact anode. The PN junction and schottky barrier are the main positions where the applied voltage is sustained while the conventional 4H-SiC JBS diode is in the off state. In order to get a better trade-off between the BV and $R_{on,sp}$, SJ and trench can be introduced to the conventional JBS diode. On the one hand, SJ can be used to optimize the distributions of electric filed, and thus to improve the doping concentration of drift region, which results in a higher BV and a lower $R_{on,sp}$ simultaneously[6]. On the other hand, trench can be used to form the Metal-Oxide-Semiconductor[7-8] (MIS) structure to withstand a part of potential drop, and the BV is improved further. Based on the characteristics of conventional 4H-SiC JBS diodes and the advantages of SJ technology and trench structure, the new structure of 4H-SiC JBS diode was simulated using Sentaurus2013. We design and simulate a 4H-SiC S-FT SJ JBS diode.

2. Structures and work mechanism

The schematic cross-sectional views of 4H-SiC S-FT SJ JBS diode and I-ST SJ JBS diode are shown in figure (Fig.) 1(a) and 1(b), respectively. Both S-FT SJ JBS diode and the I-ST SJ JBS diode consist of a highly N-type doped substrate, a lightly N-type doped drift region, an oxide trench, a highly P-type doped pillar, a schottky contact electrode, and an ohmic contact electrode[9]. For S-FT SJ JBS diode, Fig. 1(a) shows the two highly doped P-pillar which feature as the width of 0.3μm and the depth of 6.5μm, and the structure of SJ is formed by P pillar and drift region. In addition, the floating trench extends from the position which apart 2.5μm from the schottky contact electrode to be flush with the bottom of the P-pillar, rather than positing under the surface of the schottky contact electrode as shown in Fig. 1(b). The width of floating trench is 2.2μm. And the other simulation parameters about the structure are displayed in the Table 1.



(a) (b)

Fig. 1. Schematic cross-sectional views of 4H-SiC (a) I-ST SJ JBS and (b) S-FT SJ JBS diode.

We use Sentaurus2013 which has 4H-SiC material parameters to simulate the performances of the device. The physical models used in the simulation are mobility model, band gap model, recombination model, avalanche generation model and incomplete ionization model. In particular, as nitrogen atoms and aluminum atoms are respectively used for