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Determination of ambipolar lifetime and epilayer thickness of 5 kV SiC bipolar devices by switching transient studies

Tarek Ben Salah¹⁾, Damien Risaletto¹⁾, Christophe Raynaud¹⁾, Kamel Besbes²⁾,

Dominique Bergogne¹⁾, Dominique Planson¹⁾, Hervé Morel¹⁾

¹⁾ AMPERE INSA Lyon, 21 Av. Jean-Capelle ; 69621 Villeurbanne, France

Christophe.raynaud@insa-lyon.fr

²⁾ μ EI, Faculté des Sciences de Monastir, Monastir, Tunisia

1. Introduction

A new experimental set-up is developed and validated to characterize high voltage diodes in switch transient regime. Parameters extracted from DMTVCA (Depletion Mode Transient Voltage Current Analysis) and OCVD (Open Circuit Voltage Decay) techniques, that are the ambipolar lifetime, the epilayer thickness, the doping thickness and the device area, are validated in a buck converter on a resistive load. The experimental set-up enable to measure nice current and voltage transient characteristics, i.e. without noise and high parasitic wiring influence. Experimental results are compared to device simulations and a good agreement is found.

2. Description of the samples

High voltage 4H-SiC bipolar diodes have been realized by AMPERE laboratory. A complete description and static characterization in forward and reverse bias is given in [1]. N-type 4H-SiC epilayer from Cree Research of $40 \mu\text{m} \pm 25\%$ thickness and a doping level of $1.1 \times 10^{15} \text{ cm}^{-3}$ ($\pm 100\%$) grown on a N⁺-type substrate has been used for fabrication of high voltage bipolar diodes. Emitter has been realized by implantation of Al and results in a P⁺ region doped at $4 \times 10^{19} \text{ cm}^{-3}$ on $\sim 0.45 \mu\text{m}$. Junction Termination Extension (JTE) have been realized by implantation of Al ($2 \times 10^{17} \text{ cm}^{-3}$ on $\sim 0.45 \mu\text{m}$). Different diameters of the emitter have been realized. Biggest diodes ($\varnothing 1 \text{ mm}$) show a forward current $\sim 300 \text{ mA}$ at 5 V , but low breakdown voltage ($\sim 700 \text{ V}$) in regard to the theoretical value ($\sim 5\text{-}6 \text{ kV}$). For simulation, the device simulator DESSISTM enables mixed-mode simulation and is used to simulate the diode recovery within the switching-cell.

3. Experimental procedure and results

The main idea of our extraction procedure is a decoupling between high level injection and space charge region phenomena.

3.1 DMTVCA technique

The DMTVCA technique [2] is based on the unclamped inductive switching circuit. It is used to study the blocking of the diodes from an initial state with a null current. DMTVCA technique is an alternative to classical C-V measurements, but it does not have voltage limitations. Parameters extracted from these figures are the effective area $S = 1.25 \text{ mm}^2$, the doping level of the epilayer $N_D = 7.65 \times 10^{14} \text{ cm}^{-3}$, and the width of the epilayer $W = 42 \mu\text{m}$.

3.2 OCVD technique

A second more classical technique, the OCVD technique [3] is used to extract the ambipolar lifetime τ . This technique consists in switching the diode from a forward state to zero volt and to measure the subsequent transient decrease of the current. The decrease of the voltage is related to τ . To achieve a higher accuracy, experimental characteristics are compared and fitted with calculated characteristics using finite-element simulation software (DESSIS).

The estimation of the ambipolar lifetime τ is based on an optimization process where experimental and simulation data are compared. From these measurements, τ is found in the range $41 - 46 \text{ ns}$.

3.3 Model validation in switching cell

The validity of these 4 parameters, identified from DMTVCA and OCVD techniques, is highly dependent on the agreement between simulation and experimental data. This agreement can be further validated once the diode is measured in the high injection level. The validation process needs a comparison between simulation and measurements in a circuit closed to real working conditions, i.e. a

converter.

Conclusion

For the first time, a new OCVD technique has been applied to SiC devices. A good correlation between measurements and simulations has been verified. The final paper will describe the complete parameter extraction process and will detail the switching cell.

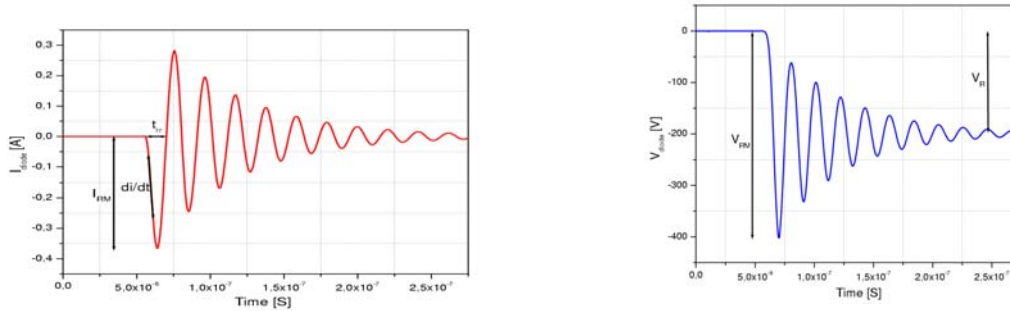


Figure 1: DMTVCA current (left) and voltage (right) measurements for the SiC bipolar diode.

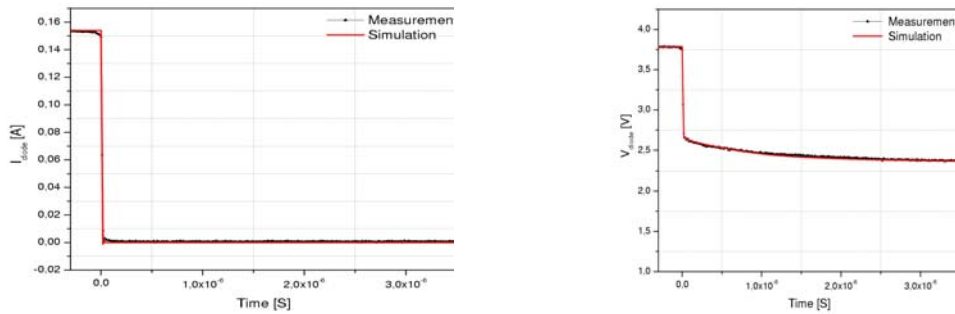


Figure 2: current (left) and voltage (right) measurements for the SiC bipolar diode in the OCVD circuit.

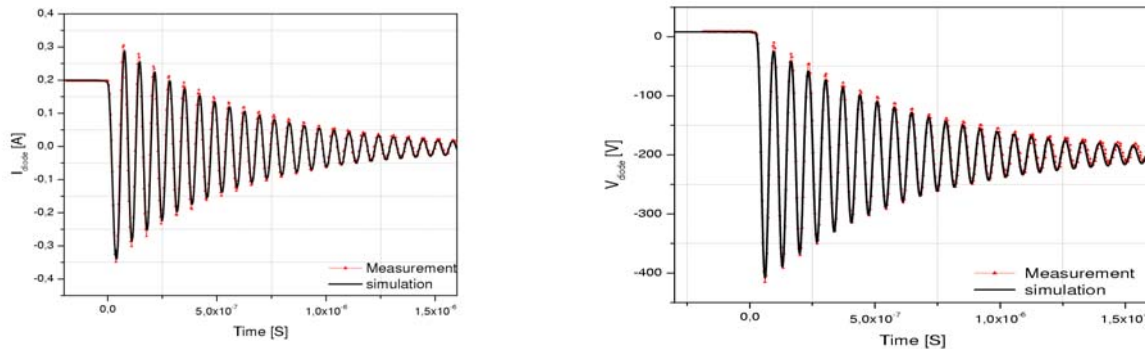


Figure 3: Comparison between simulated and measured current (left) and voltage (right) for the SiC bipolar diode in the resistive switching cell.

References

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