Design and Simulation of a Silicon Carbide Photoconductive Semiconductor Switch

Prof. Lochan Jolly, Isha Nair

Department of Electronics and Telecommunication Engineering, Mumbai University, Mumbai.
Email: lochanjolly@ gmail.com
Department of Electronics and Telecommunication Engineering, Mumbai University, Mumbai.
Email: nairabhi203@gmail.com

ABSTRACT

A Photoconductive semiconductor switches (PCSS) using a new material called Silicon Carbide (SiC) with its advantages as compared to GaAs is considered for the research work. A 2D SiC PCSS is created for optimal performance under different operating conditions. In addition compensation method to make different types ie DDSA and SDDA of SiC PCSS, their designing and simulation process is discussed. High breakdown field, extreme thermal stability, wide energy band-gap, crystal robustness, and large electron saturation velocity are likely to make devices made from SiC more reliable under extreme operating conditions.

Keywords – DDSA, PCSS, SDDA ,Silicon Carbide, Vanadium

1.INTRODUCTION

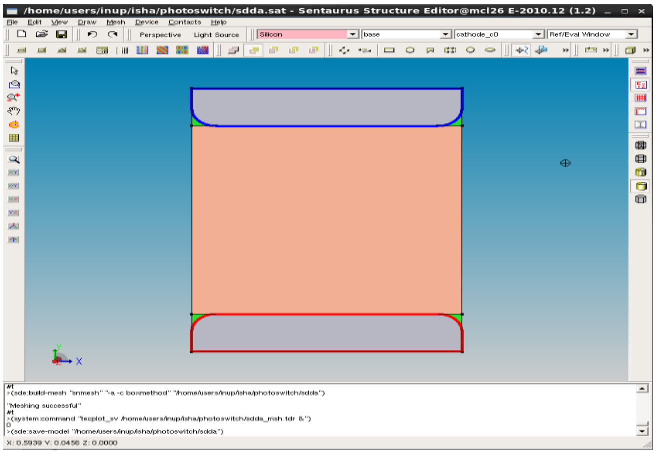
PCSS are optically activated type of switches which are commonly used in pulsed power system for generation of high power. High voltage, high current, low inductance, fast resistive transition, and precise control are the critical component parameters of a semiconductor switch that can enable the fielding of a compact pulse power system. Extrinsic, semi-insulating Silicon Carbide (SiC) photoconductive switches have the potential to fulfill these critical requirements. In addition to low jitter switching, optical activation provides a high degree of electrical isolation between the triggering and switching power systems simplifying pulsed power design[1].

Silicon carbide has gained popularity as a high-power high-temperature device material because of its wide band gap (3.23–3.35 eV), high breakdown field (4 MV/cm), and high thermal conductivity(3.7 W/(cm · K)). These characteristics make SiC well suited as a high-power PCSS material[3].

2. SWITCH THEORY AND CONSTRUCTION

The basic optically controlled semiconductor switch is used to connect a source to a load. The planer, insulating, photoconductive medium is changed into a conductor by illuminating the face of the switch with a uniform optical intensity source between the contacts [1].

A typical SiC PCSS used in this study is shown in Fig.1 The device is a 1µm x 1µm 2D switch with Nickel Silicide contacts of thickness of 0.2µm.The small rectangular disc in the middle of the Nickel Silicide contacts is SiC wafer.



```
#t
>(sde:build-mesh "snmesh" "-a -c boxmethod" "/home/users/inup/isha/photoswitch/sdda")

"Meshing successful"
#t
>(system:command "tecplot_sv /home/users/inup/isha/photoswitch/sdda_msh.tdr &")
0
>(sde:save-model "/home/users/inup/isha/photoswitch/sdda")
X: 0.5939 Y: 0.0456 Z: 0.0000
```

Figure 1.Switch Geometry

3. COMPENSATION MECHANISM

SiC photoconductive switches employ semi-insulating materials grown through the compensation process [2]. Compensation comes from a donor or acceptor type deep trap level and a shallow dopant, which can also be donor or acceptor. At room temperature the shallow dopant level is completely ionized and the deep traps are partially ionized. Compensation between the two levels makes the material semi- insulating [1]. The two deep trap levels, both acceptors and donors are formed by Vanadium in SiC. The shallow dopants can be Nitrogen and Boron. Compensation results when the ionized donor and acceptor densities effectively cancel each other such that the net density of free carriers in the semiconductor is very small. Vanadium is responsible for two different trap levels in SiC and hence was considered further. The two types of compensation structures investigated are: (1) deep trap donor levels compensated by shallow level dopants, termed the DDSA structure and (2) shallow donor dopants compensated by deep acceptor levels, termed the SDDA structure [1].

4. DEVICE SIMULATION AND MODELING

Simulation of a compensated semiconductor material involves the solution of the basic semiconductor continuity and Poisson's equations [2], with models emphasizing such parameters as trap level, its density of states, energy states and their cross sections.

4.1 Software

Sentaurus Structure Editor is a two-dimensional (2D) and three-dimensional (3D) device structure editor, and a 3D process emulator. Sentaurus Structure Editor can be used as a two-dimensional (2D) or three-dimensional (3D) structure editor, and a 3D process emulator to create TCAD devices .In Sentaurus Structure Editor, structures are generated or edited interactively using the graphical user interface (GUI). Doping profiles and meshing strategies can also be defined interactively.

4.2 Steps Involved In Creating the Device

The device of dimension mentioned above was created in the Sentaurus structure editor, by using the coordinate system available. SiC was doped with Vanadium concentration of $2x10^{16}/cm^3$ for creating traps to make the material compensated and followed by doping concentration of $2x10^{15}/cm^3$ of Nitrogen to create SDDA type SiC. To create DDSA type Boron doping concentration of $2x10^{17}/cm^3$ was used. Before starting the simulations, the meshing of the device was done.

5. RESULT

The two device structures that is DDSA and SDDA which were created in Sentaurus are as shown below in Fig.2 and Fig 3 respectively.

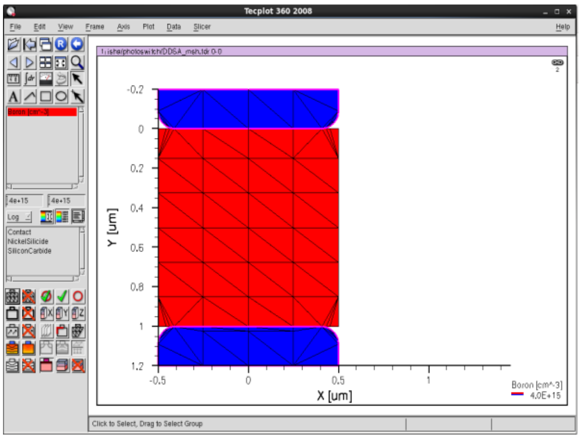


Figure2. DDSA

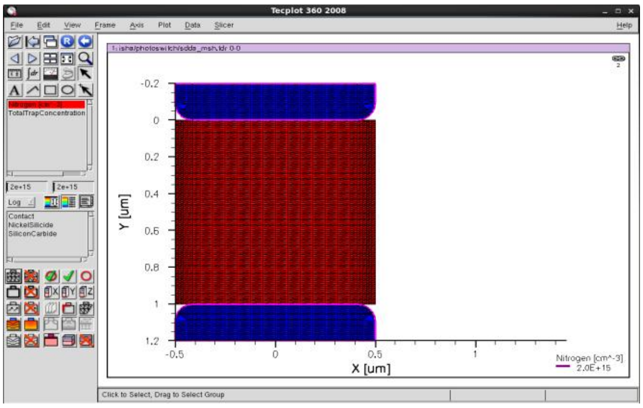


Figure3.SDDA

6. CONCLUSION

Two different compensation mechanisms have been created to determine the material characteristics, namely shallow donor deep acceptor with vanadium deep acceptors and nitrogen shallow donors and deep donor shallow acceptors with vanadium deep donors and boron shallow acceptors in SI SiC. The simulations are in process which will help to characterize these devices.

ACKNOWLEDGEMENTS

An acknowledgement to the Indian Institute of Technology, Bombay, who allowed me to use SENTAURUS SOFTWARE.

REFERENCES

Theses:

[1]Silicon Carbide as a photoconductive switch material for high power applications by Kapil.S Kelkar, Dr. Naz E. Islam, Dissertation Supervisor December 2006.

Journal Papers:

[2].Experimental And Simulation Characterization Of Semi insulating 6H SiC Photoconductive Switch For Pulsed Power Applications Kapil Kelkar, Chris Fessler, W. C. Nunnally and N. E. Islam *University of Missouri – Columbia Department of Electrical and Computer Engineering Columbia, Missouri 65211 0-7803-91 89-6/05/$20.00 ©2005 IEEE*.

[3] Design and Evaluation of a Compact Silicon Carbide Photoconductive Semiconductor Switch
Colt James, Member, IEEE, Cameron Hettler, Member, IEEE, and James Dickens, Senior Member, IEEE. *Ieee Transactions On Electron Devices, Vol. 58, No. 2, February 2011*