RES MILITARIS Social Science Journal

Design and Performance Analysis of Wide Bandgap Semiconductors-Based EV fast charger

K.Sumalatha , Sania kousar

Assistant Professor,Department of Electrical & Electronics Engineering, Kakatiya University, India suma.kucet@gmail.com

Student,Department of Electrical & Electronics Engineering, Kakatiya University, India

Abstract:

Fossil fuels are extensively utilized in the transportation sector, contributing to the daily rise in global warming. Electric vehicles are the promising solution to these problems. EVs are currently in use all over the world, but the biggest obstacle to their adoption is their quick charging capabilities through converters. EVs require a lot of storage space and time to recharge. Wide bandgap based devices are becoming more and more popular because of their improved electrical characteristics. These are the next generation of semiconductors, and what sets them apart from other semiconductors is their large energy band gap and high thermal conductivity,which provide excellent efficiency. EVs need charging stations that are dependable, quick, and efficient and don't rely as much on the grid. Better material properties offered by Wide Band Gap (WBG) semiconductors may enable future power devices to operate at temperatures, voltages, and switching speeds higher than those currently achievable with Si technology. Si-based semiconductors, however, have limited maximum junction temperature, limited heat transmission, limited voltage blocking, and limited efficiency since Si is running out of resources. Power semiconductor devices have recently been built using materials with wide band gaps, such as gallium nitride (GaN) and silicon carbide (SiC). These new power semiconductor devices will enable the development of new power converters and a significant improvement in the performance of the ones that are currently in use, leading to an improvement in the efficiency of the transformations of electric energy and more intelligent use of the electric energy. The article uses materials based on WBG to give a study of the performance analysis of an electric vehicle's charger. SiC/GaN based switches have shown to provide good results for V2G and G2V EV charging and discharging modes.

Index terms : Silicon carbide (SiC) Mosfet , AC/DC converter , DC/DC converter

Introduction :

As the power electronics sector continues to grow, power semiconductor devices are becoming more and more crucial to the transportation, medical, aerospace, and other industries. The limitations imposed by the characteristics of Si materials prevent typical Si MOSFET power devices from meeting the demands of the market today. As a result, much interest has been generated by the third-generation wide band gap semiconductor SiC MOSFET power device, which has improved performance. The classic Si MOSFET power devices are limited by the qualities of Si materials and cannot fulfill the current market demands. As a result, the third-generation wide band gap semiconductor SiC MOSFET power device with improved performance has gained significant attention.

Semiconductor technology has always played an important role in the evaluation of power electronics. Until recently, silicon-based power semiconductor devices were commonly utilized in power electronics and power system applications. The performance of silicon-based devices has improved over the previous many decades. However, as the demand for electric energy grows, silicon (Si) devices are approaching their theoretical performance limits due to inherent physical limitations in Si material properties, rendering them unsuitable for future demands, particularly for high voltage, high temperature, high frequency, high efficiency, and high power density applications. For example, modern Si insulated-gate bipolar transistors (IGBTs) can tolerate high voltage and current; nevertheless, these devices have a relatively sluggish switching speed, which affects efficiency. It increases the size and weight of power electronics systems that use these components. Si metal-oxide-semiconductor field effect transistors (MOSFETs) are well suited for high-switching frequency applications up to MHz, but they have comparatively high on-state resistance when the blocking voltage increases, resulting in substantial conduction loss.

Silicon devices have a maximum working temperature of roughly 150ºC, limiting the size and weight of thermal control systems.

As a result, there is an urgent need to design new power electronics devices for high temperature thermal environments with decreased cooling, high voltage, and high efficiency systems. The growing silicon carbide (SiC) technology is the most promising approach to increase the performance of semiconductor devices because of its better material qualities compared to Si.Silicon carbide (SiC) has excellent electrical characteristics, such as a larger bandgap, greater thermal conductivity, and a higher critical breakdown electric field, making it an appealing semiconductor material for power switching devices.

Figure 1 shows the general block diagram of electric vehicle infrastructure consisting of different bidirectional converters .

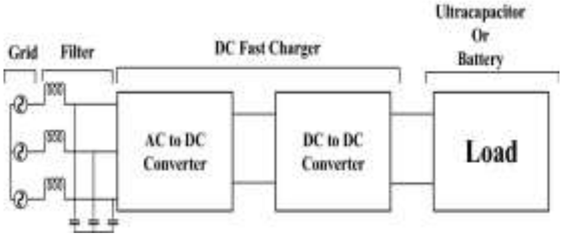


Figure 1. General Bidirectional EV charging topology

Traditional EV plug-in charging systems refuel automobiles overnight. These home-based charging systems differ from other testimony stations in that they lack power capacity, metering, and quality concerns, and may require extra circuits. Some ventures use commercial charging in parking lots, providing extra infrastructure for EV customers. Despite the existence of these stations, charging times and power availability remain challenges.Charging stations may be classified into three tiers based on their power levels and charging schemes. Level 1 chargers are usually sluggish, with a power output of 1.4 to 1.9 kW. Use a regular 120V/15A single-phase plug. Level 2 on-board systems, like level 1, have a power capacity of 4 to 19.2 kW and can charge EVs in both alternating current and direct current modes. Level 3 chargers are rapid and high-power, with a capacity of 50 to 100kW or more. There are two types of EV chargers: onboard chargers and off board chargers. The on-board solution employs a direct link between the charger inlet and connector (the charging system is within the car), whereas the off-board charger is designed for high power and is mounted outside the vehicle. Three phase bidirectional multilevel converters are ideal for high-power Level 3 charger systems. Level 3 commercial fast charging allows you to charge in less than an hour. It may be deployed at highway rest areas and city re-fuel sites, similar to petrol stations. The device runs on a three-phase circuit with a voltage of 400-420V or higher and requires an off-board charger for regulated alternating current-direct current conversion.Silicon Carbide (SiC) and Gallium Nitride (GaN) are the best semiconductor material candidates in terms of theoretical characteristics (high blocking voltage capability, high-temperature operation, and high switching frequencies), commercial availability of the starting material (wafers and epitaxial layers), and technological process maturity. Figure 1 depicts some critical material features of WBGsemiconductors contenders for replacing Si . GaN and, particularly, SiC process technologies are by far the most developed of the WBG semiconductor materials, making them more appealing to device manufacturers for high-power electronics applications. Although GaN theoretically has greater high-frequency and high-voltage performance, the paucity of high-quality bulk substrates required for vertical devices, as well as the poorer thermal conductivity, give SiC a clear advantage for high-voltage devices. In addition, certain SiC such as Schottky diodes, for example, are already competing with their silicon equivalents. However, industrial interest in GaN power devices is growing steadily. Over the past decade, GaN technology hasIt is rapidly expanding, owing mostly to the production of light-emitting diodes, but it is also emerging as a platform for high-frequency, high-voltage electronics, with a particular emphasis on

GaN-based heterojunction high electron mobility transistors. These innovative power devices offer a significant advancement in power electronics, however further development is still necessary. However, many of the material benefits are not completely realized due to material quality, technological restrictions, non optimized device designs, and reliability difficulties. Furthermore, developing modeling and electrothermal characterization methods for these power devices, as well as designing their packaging for high-temperature operation, drivers, and controllers, necessitates extensive study and represents a significant advance.

SiC DEVICES :

Silicon carbide (SiC) power devices have been widely explored over the last two decades, and several are now commercially accessible. SiC power devices can operate at greater voltages, switching frequencies, and temperatures than silicon (Si) due to inherent material advantages. Despite these developments, Si power devices are nearing their performance limit. The IGBT has a maximum blocking voltage of less than 6.5 kV and a reasonable working temperature less than 175°C. Because of the bipolar current conduction process of IGBTs, switching rates are somewhat sluggish, restricting them to lower switching-frequency applications.

Future development of Si power device technology will be modest in nature. SiC's 10× critical electric field allows for viable ultra-high voltage (>10 kV) power devices. The smaller Ron,sp allows SiC devices to be smaller, resulting in lower parasitic capacitance and faster switching speeds. Because most applications require basic two-level topologies, lesser loss allows for simpler power converter architectures. The peripheral components, such as package materials, housings, and capacitors, are still in their early stages.

The industry's key focusesare determined by application demand, cost, and process maturity. From a technological standpoint, the potential of SiC materials has yet to be completely exploited, and much more research is being conducted.

SiC DIODE :

There are three kinds of SiC diodes:

- SiC Schottky
- SiC junction barrier Schottky (JBS)
- SiC PIN.

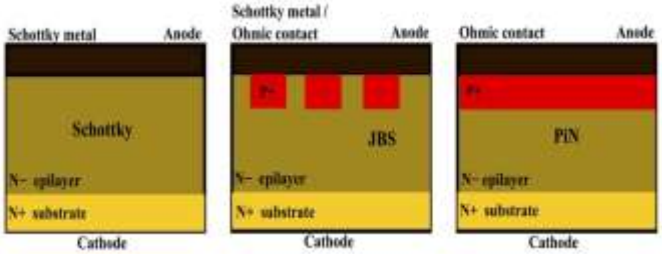


Figure 2 . SiC diodes

The device changes quickly from ON to OFF, and there is almost little reverse recovery current due to the majority carrier conduction process. The only current necessary to flow in the opposite direction is to charge the junction capacitor. This is an exceedingly quick reverse recovery trait. As a result, the JBS diode performs well throughout a large voltage range, such as 600 V to 3.3 kV. A 15-kV JBS diode has also been developed and tested for high frequency applications. Another working mode of this structure is the merged PIN Schottky (MPS) diode, in which the internal PIN junction diode is switched on only at a high forward bias, boosting current handling capabilities.

Progress has been made toward numerous generations of the SiC JBS/MPS diode in the power semiconductor industry. One of the main technological hurdles for high-voltage SiC devices is the lowering of surface electrical fields at the device's edges. Numerous planar edge termination approaches have been proven in SiC diodes, the majority of which are based on ideas similar to those utilized in Si power devices.

SiC MOSFET :

It is well suited to the 1.2-3.3 kV blocking voltage requirements of many industrial applications. It has a substantially lower switching loss than Si IGBTs due to its majority carrier conduction process. Zero switching loss may also be obtained under specific conditions, as proven recently for a 1.2 kV SiC MOSFET module that operated at 3.38 MHz. MOSFETs may be used as synchronous rectifiers in the third quadrant, dramatically lowering third-quadrant conduction loss while providing nearly nil reverse recovery losses. One of the primary issues is balancing gate-oxide dependability with low specific on resistance. The earlier gate-oxide stability issue has been resolved, resulting in good reliability performance.

There are two types of MOSFET and those are :

- Planar SiC MOSFET
- Trench SiC MOSFET

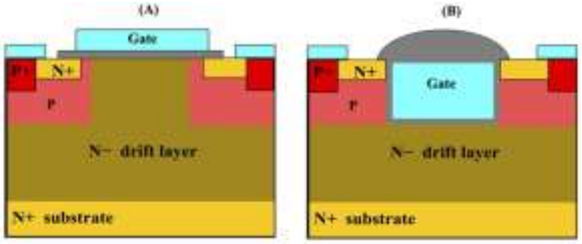


Figure 3. SiC MOSFET (A)PLANAR (B)TRENCH

SiC IGBT :

The IGBT is of two types and those are

- SiC N-IGBT
- SiC P-IGBT

The N-IGBT has a higher switching speed than the P-IGBT. • A 230 µm drift layer was used to achieve the highest known blocking voltage for an N-IGBT, which is 27 kV. • The maximum blocking voltage stated for a P-IGBT is 15 kV. • The differential specific resistance for the majority of the reported SiC IGBTs is in the range of tens of milliohms.

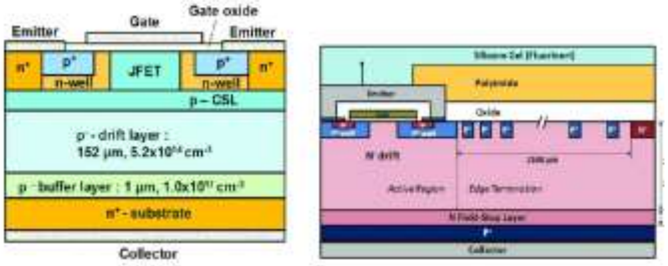


Figure 4. SiC IGBT (A) P-IGBT (B) N-IGBT

2. Modeling and Performance analysis of SiC (WBG) Power MOSFET Device :

A small circuit simulator model is used to characterize the performance of a 2-kV, 5-A 4-H silicon carbide (SiC) power DiMOSFET and to compare its performance to that of a commonly used 400-V, 5-A Si power MOSFET. The model's channel current expressions are distinctive in that they incorporate the channel regions at the corners of square or hexagonal cells that switch on at lower gate voltages, as well as the improved linear area transconductance caused by diffusion in the non uniformly doped channel. It is demonstrated that the model properly explains the static and dynamic performance of both Si and SiC devices, and that diffusion-enhanced channel conductance is required to describe SiC DiMOSFET on-state characteristics. Detailed device comparisons show that both on-state and switching performance at the 400-V Si and 2-kV SiC MOSFETs have identical 25°C operating temperatures, with the caveat that the SiC device requires twice the gate driving voltage. The key distinction between the devices is that the SiC has a fivefold greater voltage rating without an increase in specific on-resistance. Higher temperatures (over 100 C) significantly reduce the conduction capabilities of Si devices, whereas the on-resistance of SiC remains relatively unchanged.

SiC power MOSFETs are projected to outperform existing Si technology, comparable to the aforementioned SiC diodes. With a strong critical electric field (2 MV/cm), acceptable bulk electron mobility 800 cmV s, and high saturation velocity 2-10 cm/s 4H-SiC is appealing for the development of high voltage, high-speed power devices. These physical features are ideal for producing high-performance 4H-SiC unipolar devices capable of blocking 1-3 kV. For the same range of blocking voltages, conventional silicon power devices use conductivity modulation in the drift layer to limit the forward drop, which results in slower switching rates. It has simplified the cross section of the unit cell construction of a newly announced 2-kV, 5-A SiC DiMOSFET with high switching speed.

The structure of the device incorporates a 10 cm doped, 20-m thick n-type drift layer. In the on-state mode of operation, electrons flow laterally from the n source to the MOSFET channel generated in the implanted p-well, then vertically between neighboring cells and via the weakly doped drift layer to the drain contact. In a 2-kV Si MOSFET, the drift layer resistance dominates the device's on-resistance, but in a SiC DiMOSFET structure, the channel resistance dominates the specific on-resistance. The construction of the DiMOSFET begins with an n-type SiC wafer with a 2.5-10 cm doped, 20mm thick epitaxial layer.

Aluminum implantation creates the p-wells, which are then followed by a heavy-dose nitrogen implant for the n-source areas. A large amount of aluminum is implanted to produce the p contacts to the p-wells, as well as the floating guard rings that end the edges. All implants are conducted in Ar at 1600 degrees Celsius. The A2-oxide layer is formed and designed to function as the field oxide, followed by gate oxidation. A 500-thick gate oxide is thermally generated in dry O at 1200 C before being annealed in NO at 1175°C for 2 hours. A 0.25-m molybdenum layer is then sputtered and patterned to form the gate metal. The connections to the source, drain, and p regions are made of alloyed nickel. The gate is subsequently metallized with a 0.25-m thick Ni/Au layer to minimize its resistance. A plasma-enhanced chemical vapor deposition (PECVD) oxide layer is subsequently produced as an intermetallic dielectric, and via holes are created for the connections. E-beam evaporation deposits a 2-m thick

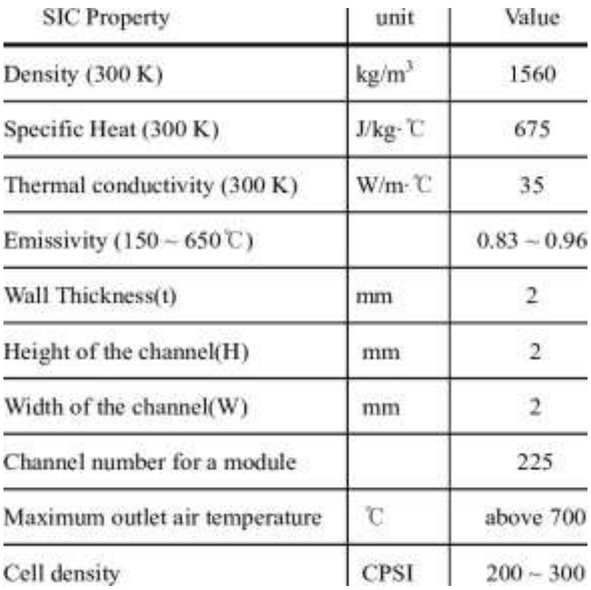
Ti/Pt/Au layer, which is then lifted as the final metal layer. The model employed in this study is based on the most recent version of the power MOSFET formulation used in the Hefner IGBT model . The model has been improved to include temperature-dependent material characteristics for 3C-, 4H-, and 6H-SiC, which may be chosen via the material type parameter switch. The model includes elements that have been demonstrated to be significant in describing the dynamic performance of vertical power MOSFETs, such as two-phase nonlinear gate-drain overlap capacitance, negative gate voltage inversion of the gate-drain overlap, and nonlinear body-drain depletion capacitance.

The model's MOSFET channel current expressions are distinctive because they include: 1) the channel regions at the corners of the square or hexagonal cells that switch on at the bottom gate. The parameter in research to evaluate the performance of SiC devices is summarized in table 1.

Parameters	Value
Energy gap (E_g)	3.36 eV
Electron mobility	1000-1140cm^2 /Vs
Hole mobility	115 cm^2/Vs
Intrinsic carrier concentration (N_i)	8.2 x 10^{-9} cm^{-3}
Dielectric permittivity	6.63
Thermal conductivity	4.9 Wm-1K-1

Table 1. Parameters in MATLAB simulation of SiC

MATLAB technology is used for performance analysis of SiC semiconductor devices . SIMSCAPE has proven to be a powerful tool to provide an in-depth understanding of device fabrication and operation. The electrical parameters are also calculated using the formulae of the MOSFET and are shown in the table 2.



SIC Property	unit	Value
Density (300 K)	kg/m^3	1560
Specific Heat (300 K)	J/kg·℃	675
Thermal conductivity (300 K)	W/m·℃	35
Emissivity (150 ~ 650℃)		0.83 ~ 0.96
Wall Thickness(t)	mm	2
Height of the channel(H)	mm	2
Width of the channel(W)	mm	2
Channel number for a module		225
Maximum outlet air temperature	℃	above 700
Cell density	CPSI	200 ~ 300

Table 2 . Electrical properties of SiC

3.Structure of SiC MOSFET Model :

The model includes a voltage-dependent current source (Ids), a gate-drain voltage-dependent capacitance (Cgd), a drain-source voltage-dependent capacitance (Cds), and a gate-source constant capacitance. The voltage-dependent current source Ids is used to explain the static characteristics of SiC MOSFETs. The parasitic capacitances have a significant impact on the dynamic behavior. The internal gate resistance (Rg), as well as the drain and source contact resistances (Rd and Rs), are provided.

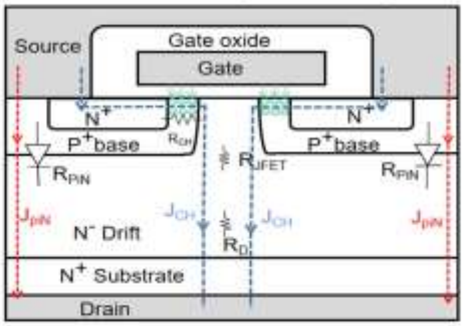


Figure 5. Internal structure of SiC MOSFET

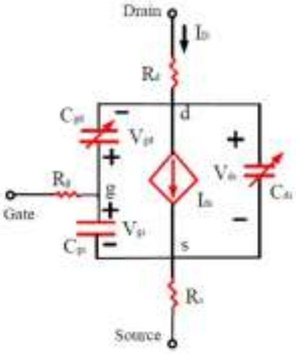


Figure 6. Equivalent circuit model of SiC MOSFET

In typical models, Ids has separate equations for the cutoff, linear, and saturation regions. However, for SiC MOSFETs, it is difficult to precisely estimate the border drain-source voltage Vds between the linear and saturation zones, and separating the Ids description into numerous parts may produce convergence issues when employed in power electronics circuit simulations. The suggested technique defines Ids by using a fitting method using smooth continuous equations. The voltage-dependent current source Ids represents the SiC MOSFET static I-V characteristic and includes both output and transfer characteristic equations. The output characteristic equation is a function of both gate-source voltage Vgs and drain-source voltage Vds, whereas the transfer characteristic equation is dependent on gate-source voltage Vgs. SiC MOSFET's transfer characteristic curve is fitted using the voltage-dependent current source Ids equation.

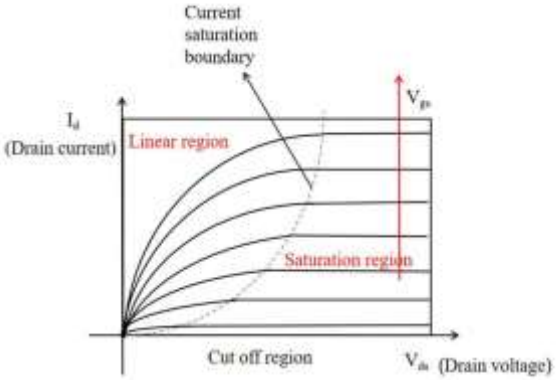


Figure 7. Output characteristics of SiC MOSFET

The Cut off region At this time, the V gs is less than the Vth , SiC MOSFET does not form an inversion channel and is in the off state. Therefore, there is almost no current in the device. 2) Linear region

At this time, the Vgs > the Vth , and the Vds < Vgs - Vth . The SiC MOSFET device is turned on and generates a drain-source current Ids.

4.SIMULATION MODEL AND RESULTS :

The SiC POWER MOSFET is designed with the help of MOSFET in SIMULINK library by entering the values of certain parameters . Those parameters are given in the following table and used to design the Sic MOSFET in MATLAB and its VI characteristics are also plotted below.

Parameter	Value
Device active area (A)	0.06 cm^2
Drift region width (W)	20×10^{-6} m
Base dopant density (N_b)	3 cm^{-3}
MOSFET threshold voltage (V_T)	5.77 V
Saturation region transconductance (K_p)	0.33 A/V^2
Transverse electric field parameter	0.03 V^{-1}
Linear region transconductance factor (K_f)	2
Series drain resistance (R_s)	0.03 ohm
Low current region transconductance factor (K_{fl})	0.07
Gate - drain overlap area (A_{gd})	0.03 cm^2
Gate - source capacitance (C_{gs})	2.68×10^{-9} F
Gate - drain overlap oxide capacitance (C_{oxd})	2.18×10^{-9} F

Table 3 . Model parameters of SiC

The output DC transfer characteristic curves are obtained by linearly increasing the drain to source voltage
(Vds) from 0 to 35 volts and sweeping the input terminal voltage (V) between 10 to 20 volts. It can be seen from Fig 9 that as the gate to source voltage is linearly increased in steps, the drain to source current (Ids) also increases. The current linearly increases in the beginning and as the NMOS enters the saturation region, the current becomes constant.

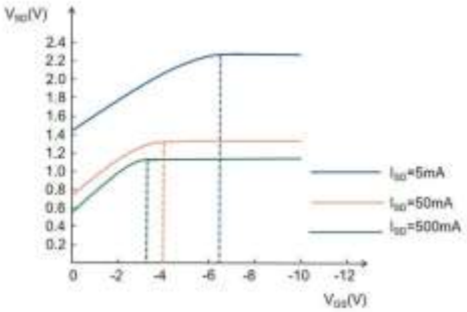


Figure 8. Change of source-drain voltage Vsd VS the change of gate-source voltage Vgs under different fixed currents.

According to Figure 8, when the current takes a fixed value, the voltage Vgs applied to the gate decreases.

According to Figure 8, when the current takes a fixed value, if the voltage Vgs applied to the grid decreases gradually, the inversion degree of the channel will be reduced. This causes an increase in RCH, and the current shunt at the body diode increases. At this time, the voltage drop at both ends of the body diode continues to increase. When Vgs is less than the threshold voltage Vth, a turning point occurs in the figure, and the conductive channel is completely closed. Whether the gate voltage Vgs decreases, the current flows completely from the valve body diode. At this time, JPiN is equal to JT. At the same time, the Vsd is the body diode voltage VSD withouta channel shunt, and remains unchanged.

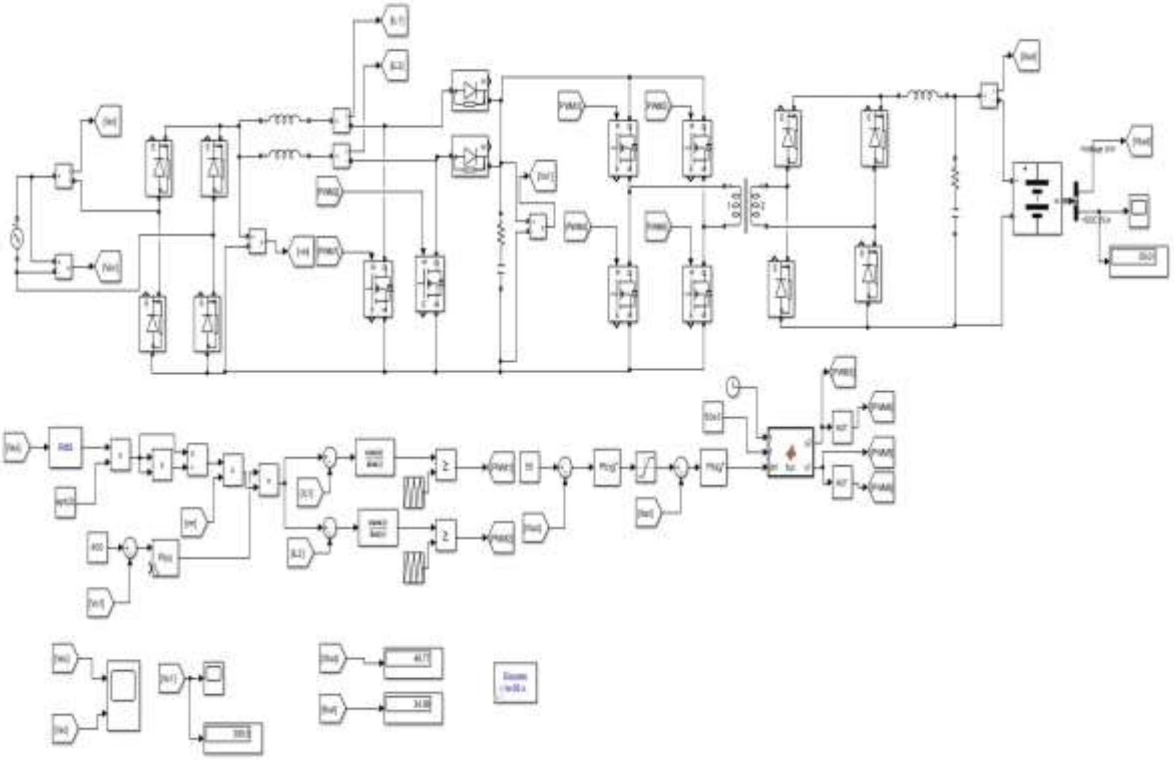
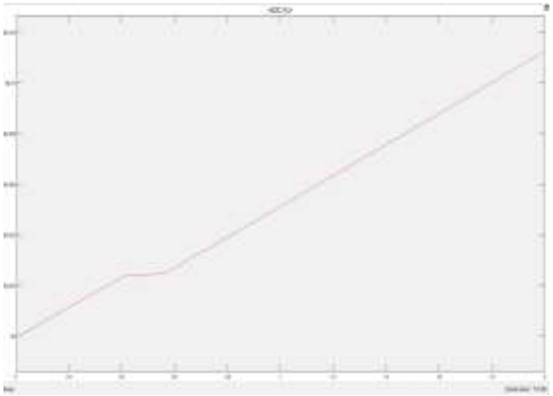
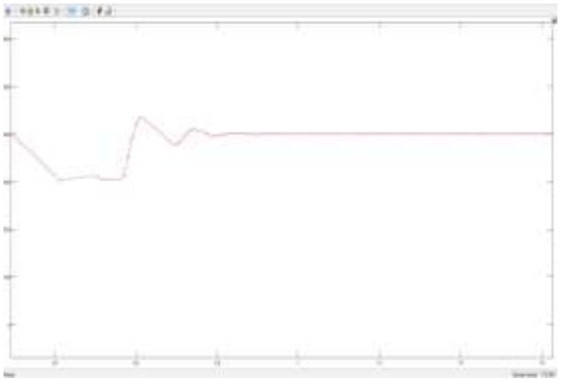


Figure 9 . Simulation model o EV charging using WBG (SiC MOSFET) semiconductor





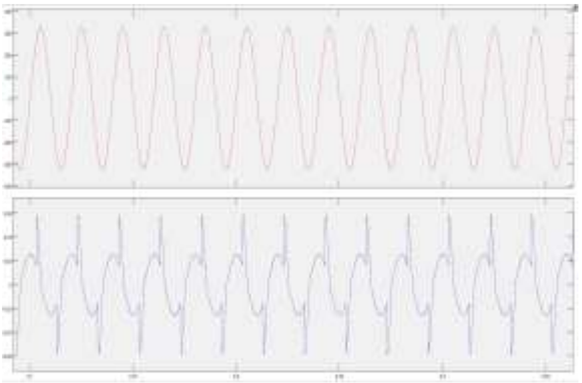


Figure 10. **Graphs observed in MATLAB**

CONCLUSION :

In conclusion, the comprehensive review of wide band gap materials for electric vehicle charging systems elucidates their pivotal role in shaping the future of sustainable transportation. By delving into the properties and applications of materials like silicon carbide and gallium nitride, the paper illuminates the remarkable potential of these semiconductors in revolutionizing EV charging infrastructure. From improved power conversion efficiency to enhanced thermal management and reduced system size, wide band gap technologies offer multifaceted advantages that address key challenges in EV adoption. Furthermore, the review underscores the importance of ongoing research and development efforts aimed at advancing wide band gap materials and optimizing their integration into EV charging solutions. Collaborative initiatives between academia, industry, and government entities are crucial for driving innovation and overcoming existing barriers in the deployment of these technologies.

Looking ahead, the insights gleaned from this review pave the way for future advancements in electric vehicle charging, including the development of high-power, fast-charging systems capable of meeting the growing demand for convenient and accessible EV infrastructure. By harnessing the full potential of wide band gap semiconductors, stakeholders can accelerate the transition to electric mobility and contribute to a more sustainable and resilient transportation ecosystem.

REFERENCES

[1]A. R. Hefner, R. Singh, J. S. Lai, D. W. Berning, S. Bouche, and C. Chapuy, "SiC power diodes provide breakthrough performance for a wide range of applications," IEEE Trans. Power Electron., vol. 16, no. 2, pp. 273–280, Mar. 2001.

[2] *T. McNutt, A. Hefner, A. Mantooth, J. Duliere, D. Berning, and R. Singh, "Silicon-carbide PiN, Schottky, and merged PiN-Schottky power diode models implemented in the saber circuit simulator," in Proc. IEEE Power Electron. Spec. Conf (PESC), Vancouver, BC, Canada, Jun. 2001, pp. 2103–2108.*

[3] *T. McNutt, A. Hefner, A. Mantooth, J. Duliere, D. Berning, and R. Singh, "Parameter extraction sequence for SiC Schottky, merged PiN Schottky, and PiN power diode models," in Proc. IEEE Power Electron. Spec. Conf (PESC), Cairns, Australia, Jun. 2002, pp. 1269–1276. [4]A. R. Hefner, "Modeling buffer layer IGBT's for circuit simulation," IEEE Trans. Power Electron., vol. 10, no. 2, pp. 111–123, Mar. 1995.*

[5]A. R. Hefner and S. Bouché, "Automated parameter extraction software for advanced IGBT modeling," in Proc. 7th Workshop Comput. Power Electron. (COMPEL), Blacksburg, VA, Jul. 2000, pp. 10–18. [6]P. G. Neudeck, "Progress in silicon carbide semiconductor electronics technology," J. Electron. Mater., vol. 24, p. 283, 1995.

[7]M. Bhatnagar and B. J. Baliga, "Comparison of 6H-SiC, 3C-SiC, and Si for power devices," IEEE Trans. Electron. Devices, vol. 40, no. 3, p. 645, Mar. 1993. [8]S. H. Ryu, A. Agarwal, J. Richmond, J. Palmour, N. Saks, and J. Williams, "27 m cm ,1.6 kV power DiMOSFETs in 4H-SiC," in Proc. Int. Symp. Power Semicond. Devices (ISPSD), Santa Fe, NM, Jun. 2002, pp. 65–68.

[9] *G. Chung, C. C. Tin, J. R. Williams, J. K. McDonald, M. Di Ventra, S. T. Pantelides, L. C. Feldman, and R. A. Weller, "Effect of nitric oxide annealing on the interface trap densities near the band edges in the 4H polytype of silicon carbide," Appl. Phys. Lett., vol. 76, no. 13, pp. 1713–1715, Mar. 2000.*

[10] *W. Choyke, H. Matsunami, and G. Pensl, Eds., SiC: A Review of Fundamental Questions and Applications to*

Current Device Technology. Berlin, Germany: Akademie Verlag, 1997, vol. II.

[11] A. R. Hefner, "Semiconductor Measurement Technology: INSTANT—IGBT Network Simulation and Transient Analysis Tool," NIST Special Publication 400-88, 1992.

[12] I. Budihardjo, P. O. Lauritzen, and H. A. Mantooth, "Performance requirements for power MOSFET models," IEEE Trans. Power Electron., vol. 12, no. 1, pp. 36–45, Jan. 1997.

[13] R.S.ScottandG.A.Franz," An accurate model for power DMOSFETs including interelectrode capacitances," in Proc.

[14] Praveen., P and Ch. Jayanth Babu. "Big Data Clustering: Applying Conventional Data Mining Techniques in Big Data Environment." (2019). Innovations in Computer Science and Engineering, Lecture Notes in Networks and Systems 74, ISSN 2367-3370, https://doi.org/10.1007/978-981-13-7082-3_58 Springer Singapore.

[15] R Ravi Kumar M Babu Reddy P Praveen " Text Classification Performance Analysis on Machine Learning" International Journal of Advanced Science and Technology, ISSN: 2005-4238,Vol. 28, No. 20, (2019), pp. 691 – 697.

[16] R Ravi Kumar M Babu Reddy P Praveen, "An Evaluation Of Feature Selection Algorithms In Machine Learning" International Journal Of Scientific & Technology Research Volume 8, Issue 12, December 2019 ISSN 2277-8616,PP. 2071-2074.

[17] T. Sampath Kumar, B. Manjula, Mohammed Ali Shaik, Dr. P. Praveen, "A Comprehensive Study on Single Sign on Technique", International Journal of Advanced Science and Technology (IJAST), ISSN:2005-4238E-ISSN:2207-6360, Vol-127-June-2019.

[18] Mohammed Ali Shaik, P.Praveen, Dr.R.Vijaya Prakash, "Novel Classification Scheme for Multi Agents", Asian Journal of Computer Science and Technology, ISSN: 2249-0701 Vol.8 No.S3, 2019, pp. 54-58.

[]19] Praveen P., Shaik M.A., Kumar T.S., Choudhury T. (2021) Smart Farming: Securing Farmers Using Block Chain Technology and IOT. In: Choudhury T., Khanna A., Toe T.T., Khurana M., Gia Nhu N. (eds) Blockchain Applications in IoT Ecosystem. EAI/Springer Innovations in Communication and Computing. Springer, Cham. https://doi.org/10.1007/978-3-030-65691-1_15.

[20] Praveen, P., Abhishek, N., Reddy, K.J., Raj, C.T., Reddy, A.Y. (2022). A Predictive Model of Handwritten Digits Recognition Using Expert Systems. In: Ranganathan, G., Fernando, X., Shi, F., El Allioui, Y. (eds) Soft Computing for Security Applications . Advances in Intelligent Systems and Computing, vol 1397. Springer, Singapore. https://doi.org/10.1007/978-981-16-5301-8_43.

[21] P. Praveen, K. Srilatha, M. Sathvika, E. Nishitha and M. Nikhil, "Prediction of Alzheimer's Disease using Deep Learning Algorithms," *2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAAIC)*, Salem, India, 2023, pp. 587-594, doi: 10.1109/ICAAIC56838.2023.10140746.

[22] P. Praveen, S. Shravani, R. Srija and M. Tajuddin, "A Model to Stock Price Prediction using Deep Learning," *2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS)*, Coimbatore, India, 2023, pp. 242-252, doi: 10.1109/ICSCSS57650.2023.10169558.

[23] P. Praveen, P. Akshitha, S. Samreen, R. Kumar and Y. Shashank, "Evaluation of Digital Banking Implementation Using Programming Paradigm," *2023 International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS)*, Erode, India, 2023, pp. 1019-1024, doi: 10.1109/ICSSAS57918.2023.10331646.

IEEE Power Electron. Spec. Conf (PESC), Jun. 1990, pp. 113–119.