PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Marco Boccarossa

Cycle: XXXVII

Training and Research Activities Report

Year: First

Tutor: prof. Andrea Irace

Co-Tutor: prof. Luca Maresca

Date: October 31, 2022

1. Information:

- **PhD student: Marco Boccarossa**
- **DR number: DR995862**
- **Date of birth: 02/06/1995**
- **Master Science degree: Electronic Engineering**
- **University: Federico II**
- **Doctoral Cycle: XXXVII**
- **Scholarship type: DIETI**
- **Tutor: prof. Andrea Irace**
- **Co-tutor: prof. Luca Maresca**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Cyber security in Akka Technologies	Seminar	2	0.4	03/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	Y
Vehicular Hacking in Akka Technologies	Seminar	1.5	0.3	03/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	Y
SSM Scientific Colloquia (1)	Seminar	1.5	0.3	04/11/2021	Dr. M. Benetti, Dr. M. Coraggio	N
Connecting the dots: Investigating an APT campaign using Splunk	Seminar	2	0.4	26/11/2021	Prof. D. Cotroneo, Prof. S.P. Romano, Dr. R. Natella	Y
Designing Quantum Algorithms	Seminar	2	0.4	16/12/2021	Prof. A. S. Cacciapuoti	Y
Gallium Nitride: the new disruptive power technology	Seminar	1.5	0.3	13/01/2022	Università di Catania	N
SSM Scientific Colloquia (8)	Seminar	1	0.2	13/01/2022	Dr. M. Benetti, Dr. M. Coraggio	N
Intelligenza artificiale e sistemi d'arma autonomi	Seminar	1.5	0.3	19/01/2022	Gruppo Interdisciplinare su Scienza, Tecnologia e Società (GI-STS)	N
SSM Scientific Colloquia (9)	Seminar	1.5	0.3	20/01/2022	Dr. M. Benetti, Dr. M. Coraggio	N
Sviluppa il tuo futuro con Enel	Seminar	1.5	0.3	01/02/2022	Prof. D. Cotroneo,	N
SSM Scientific Colloquia (11)	Seminar	1.5	0.3	03/02/2022	Dr. M. Benetti, Dr. M. Coraggio	N

Bench to Bytes to Bedside: Converting genomic data into healthcare tools	Seminar	1	0.2	04/03/2022	Prof. M. Ceccarelli	N
SSM Scientific Colloquia (16)	Seminar	1.5	0.3	10/03/2022	Dr. M. Benetti, Dr. M. Coraggio	N
IEEE Authorship and Open Access Symposium Tips and Best Practices to Get Published from IEEE Editors	Seminar	1.5	0.3	30/03/2022	Rachel Berrington, IEEE	Y
Potential and challenges of next generation railway signaling systems: Moving Block and Virtual Coupling	Seminar	1	0.2	06/04/2022	Prof. V. Vittorini	Y
Matrix Analysis for Signal Processing with MATLAB Examples	Course	8	2	22-23/03/22, 05-07/04/22	Prof. A. De Maio, Prof. A. Aubry, Dr. V. Carotenuto	Y
Explainable Natural Language Inference	Seminar	1.5	0.3	13/04/2022	Prof. F. Cutugno	Y
Using delays for control	Seminar	1	0.2	21/04/2022	Prof. S. Santini	Y
Population and medical genomics applications to human traits and diseases	Seminar	1	0.2	29/04/2022	Prof. M. Ceccarelli	Y
SSM Scientific Colloquia (24)	Seminar	1	0.2	12/05/2022	Dr. M. Benetti, Dr. M. Coraggio	N
Symbiotic Control of Wearable Soft Suits for human motion assistance and augmentation	Seminar	2	0.4	20/05/2022	Prof. F. Ficuciello	Y
English Language - Cambridge First Certificate B2	Course	50	6	25/03/2022 – 10/06/2022	Centro Linguistico di Ateneo - CLA	Y
Imprenditorialità Accademica	Course	20	4	26/05/22 – 14/07/22	Prof. P. Rippa	Y
SSIE 2022	Doctoral School	30	5	11-15/07/22	Prof. M. Rossi, Prof. M. Meneghini, Prof. G. Meneghesso	Y
CI-LAM 2022	Doctoral School	28.5	4	18-22/07/22	Prof. G. Breglio Prof. G. D'urso	Y

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	1.8	8.2	0	10
Bimonth 2	0	1.7	8.3	0	10
Bimonth 3	2	1.7	6.3	0	10
Bimonth 4	6	0.6	3.4	0	10
Bimonth 5	8	0	2	0	10
Bimonth 6	5	0	5	0	10
Total	**21**	**5.8**	**33.2**	**0**	**60**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

Semiconductor electronic devices are the fundamental elements of power electronics application, such as conversion, control, and processing of electric power. The most widespread semiconductor in power electronic is Silicon (Si). Decades of research allowed silicon devices to reach very high performances, but the market is constantly evolving and demands for devices with increasingly strong features in terms of performance, robustness, and reliability, but, lately, silicon is not able anymore to meet those requirements due to its physical limits imposed by the material properties. Nowadays, particular attention is paid to the environment, so the main objective of the scientific and industrial community is to minimize the losses between the various energy transformations and wide bandgap (WBG) materials are the most promising materials to realize conversion circuits (i.e., inverts and DC/DC) with very low losses. There are many interesting WBG materials, such as gallium nitride (GaN) and gallium oxide (GaO), but the most mature WBG semiconductor from a technological point of view is Silicon Carbide (SiC). SiC devices solve the main problems of Si devices, since they do not have switching losses and can reach high switching frequencies, affecting the dimension of the power circuit in which the device will be placed.
A fundamental tool to design and study electronic power devices are TCAD simulations. *TCAD* stands for *Technology Computer Aided Design* and refers to the use of simulations to develop and optimize semiconductor devices. More in detail, a TCAD simulator is a finite element simulator that solves the semiconductor equations (i.e., carrier transport equations, Poisson's equation, and continuity equation) for a physical model of a semiconductor device. It is a tool of paramount importance because it allows to predict the performances of a semiconductor device before its physical realization, strongly reducing development time and costs, and it also permit to investigate physical phenomena rising inside the device.

Study on fast recovery epitaxial Si diodes (in collaboration w/ Vishay Semiconductor Italia)
Since the technological development of silicon has been pushed to its maximum, to support the market of Si diodes it is necessary to optimize their design to manage the trade-offs in terms of on-state, off-state, and commutation performance. The main portion of the device supporting the current conduction during its normal operation is called active area: fixing the desired breakdown voltage (V_{BR}) of the device, the main parameters on which the performance of a diode can be evaluated are the on-state

voltage (V_{ON}) and the commutation features. More in detail, the commutation performances of a diode can be evaluated by peak reverse recovery current (I_{rr}), reverse recovery time (t_{rr}), reverse recovery charge (Q_{rr}), and snappiness factor (S). The aim of this activity is to use TCAD simulations to individuate the design variables that control these performance parameters and individuate the best trade-offs between them. To obtain accurate results from the simulations, a first phase of calibration of the simulator has been necessary: starting from the electrical characterization of an existent device provided by the technological partner, a TCAD model was implemented and calibrated so that the behavior of the model in simulation was coherent with the real behavior of the device. In this way, the simulator has been calibrated on the technology available to the technological partner, in order to obtain more predictive simulations. Subsequently, a simulation campaign varying the design of the active area was launched, in order to analyze the effect on the performances of the device.
Nowadays, a power semiconductor device is not evaluated only by its electric properties, but also by its reliability; so, after individuating some interesting designs of the active area, they should be validated. In particular, a high ruggedness to avalanche operating conditions is required. The latter is typically evaluated by the Unclamped Inductive Switching (UIS) test, through which the maximum energy that the devices can withstand during avalanche operation is measured. The avalanche performance strongly depends on the design of the termination region of the device. Such a region is necessary to reduce the gradient of the electric field in boundary region of the main P/N junction, which otherwise would have a V_{BR} significantly lower than that of the active region. Another significant feature required for a diode is the ruggedness to the ElectroStatic Discharge (ESD). The ESD may affect the device in different ways, from temporary faults to permanent damages. One of the main causes of the ESD is the contact with the human body: in this case, the phenomenon can be simulated using the Human Body Model (HBM).
The objective of this activity is to obtain trends for the performance of the device varying the design of the active area, in order to have a matrix of possible designs, evaluated on conduction performances and reliability, suitable for different kind of applications.

Study on design parameters of SiC diodes (in collaboration w/ Vishay Semiconductor Italia)
Among SiC devices, SiC diodes represent the most mature component for this type of semiconductor, with the Schottky barrier diode (SBD) being the first to be commercially released. Differently from PiN diodes, SBDs are unipolar devices, hence exhibiting higher voltage drop at high current. Therefore, current SiC diodes usually feature regularly spaced p+-wells within the structure to reduce the leakage current by shifting the peak of electric field away from the metal–semiconductor interface and, possibly, to assist the current conduction during surge events. The resulting device is referred to as Junction Barrier Schottky (JBS) diode if the metal chosen for the anode contact inhibits the conduction of the p+-zones, or merged PiN-Schottky (MPS) diode if the metal on the p+-wells forms an Ohmic contact that allows their conduction. More in detail, to ensure that the p+ implantation can actually help the forward conduction by minority injection, the selection of the Schottky barrier height forming at the p+/metal interface is essential. Consequently, defining a single anode contact that behaves as Schottky when interfaced with n-regions and as Ohmic when interfaced with p-wells might not be possible.
The aim of this activity is to define a methodology to correctly simulate MPS diodes, in order to find the impact of the design parameters on its electric features and, after that, to investigate how the design of the active area of a SiC diode influences the static behavior of the device.

Compact models for mixed mode simulations

Diodes are not stand-alone devices, but they are always included in complex circuits. After simulating the behavior of a diode with TCAD simulations, it is necessary to simulate its interaction with the other components of the circuit. Creating a physical model for every single electronic component can not be possible, due to the high simulations time required. To overcome this problem, *mixed mode simulations can* be performed, in which the physical model of the device of interest can be simulated together with compact models. The TCAD simulator provides some simple compact models compatible with the physical devices, suitable for passive components like resistors, capacitors, or inductor. For active components, such as MOSFETs, the compact models embedded with the simulator may not be enough accurate.
This activity has as objective to overcome this problem implementing a compact model of a commercial SiC MOSFET compatible with TCAD physical models, in order to obtain fast but accurate simulations. More in detail, the existing compact models of commercial components provided by the manufacturers are not compatible with TCAD simulations, so it necessary to create a behavioral model using a C++ interface. In this way, it is possible to use the compact model created, and the compact models provided by the simulator to simulate the physical device of interest in complex circuits and to obtain accurate results in accettable time.

4. Research products:

- **M. Boccarossa**, A. Borghese, L. Maresca, M. Riccio, G. Breglio, A. Irace, *"Numerical Analysis of the Schottky Contact Properties on the Forward Conduction of MPS/JBS SiC Diodes"*, International Conference on Silicon Carbide and Related Materials (ICSCRM), 2022. (*Accepted*)
- **M. Boccarossa**, A. Borghese, L. Maresca, M. Riccio, G. Breglio, A. Irace, *"TCAD Analysis of the Impact of the Metal-Semiconductor Junction Properties on the Forward Characteristics of MPS/JBS SiC Diodes"*, Workshop on Wide Bandgap Power Devices and Applications in Europe (WiPDA Europe), 2022. (*Accepted*)
- A. Borghese, **M. Boccarossa**, M. Riccio, L. Maresca, G. Breglio, A. Irace, *"Short-circuit and Avalanche Robustness of SiC Power MOSFETs for Aerospace Power Converters",* The International Conference for Aerospace Experts, Academics, Military Personnel, and Industry Leaders, 2022. (*Submitted*)

5. Conferences and seminars attended

- *Summer School of Information Engineering (SSIE 2022), Brixen (BZ), Italy, 11-15 Jul 2022.*
- *China-Italy Joint Laboratory on Advanced Manufacturing (CI-LAM 2022), Bergamo, Italy, 18-22 Jul 2022.*
- *IEEE Workshop on Wide Bandgap Power Devices and Applications in Europe (WiPDA Europe 2022),* University of Warwick (UK), 18-20 Sep 2022. **Poster presentation**.

6. Activity abroad:

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7. Tutorship

- Co-supervision of MSc student (Vincenzo Terracciano) thesis on *"Analysis of the Impact of the Design of the Active Area on the Electrical Characteristics of a SiC Power Diode"*.
- 13-hour tutorship assistance to 2nd year course *"Metodi Matematici per l'Ingegneria"*.