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UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

# PhD Student: **Marco Boccarossa**

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Student DR number: DR995862

**PhD Cycle: XXXVII**

PhD Cycle Chairman: Prof. Stefano Russo

**PhD program student's start date: 01/11/2021**

**PhD program student's end date: 31/10/2024**

**Supervisor: Prof. Andrea Irace**

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**PhD scholarship funding entity:**

Department of Information Technologies and Electrical Engineering (DIETI)

## General information

Marco Boccarossa received in year 2021 the Master Science degree in Electronic Engineering from the University of Naples Federico II. He attended a curriculum in Power Electronics within the PhD program in Information Technology and Electrical Engineering. He received a grant from the DIETI Department of the University of Naples Federico II.

## Study activities

### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1 <sup>st</sup>	Matrix Analysis for Signal Processing with MATLAB Examples	Ad hoc course	2	Prof. A. De Maio, Prof. A. Aubry, Dr. V. Carotenuto	ITEE
1 <sup>st</sup>	Cambridge First Certificate B2	English Language	6	Dott. ssa Christine Goeken	Centro Linguistico di Ateneo - CLA
1 <sup>st</sup>	Imprenditorialità Accademica	Ad hoc course	4	Prof. Pierluigi Rippa	ITEE
2 <sup>nd</sup>	Scientific Programming and Visualization with Python	Ad hoc course	2	Prof. Alessio Botta	ITEE
2 <sup>nd</sup>	How To Boost Your PhD	Ad hoc course	4	Dr. Antigone Marino	ITEE
2 <sup>nd</sup>	Fondi Europei e Programmazione 2021/2027	External Course	0.4	Dr. Tommaso Foglia	UNINA
2 <sup>nd</sup>	Panoramica delle Opportunità di Finanziamento	External Course	0.6	Dr. Tommaso Foglia	UNINA
3 <sup>rd</sup>	Numerical Methods for Thermal analysis, Modeling, and Simulation: Application to electronic Devices and Systems	Ad hoc course	4	Dr. Antonio Pio Catalano	ITEE

### Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1 <sup>st</sup>	Summer School of Information Engineering (SSIE) 2022	Bressanone (BZ), Italy	5	11-15/07/22	University of Padova, Italy
1 <sup>st</sup>	China-Italy Joint Laboratory on Advanced Manufacturing (CI-LAM) 2022	Bergamo (BG), Italy	4	18-22/07/22	University of Napoli Federico II, Italy
2 <sup>nd</sup>	Società Italiana di Elettronica (SIE) 2023	Messina, Italy	4	04-06/09/23	University of Messina, Italy

### Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1 <sup>st</sup>	Cyber security in Akka Technologies	0.4	Dr. Luigi Villa - Sara Belluccini - Matteo Pracchia	Akka Technologies	ITEE
1 <sup>st</sup>	Vehicular Hacking in Akka Technologies	0.3	Dr. Luigi Guida - Luigi Villa	Akka Technologies	ITEE
1 <sup>st</sup>	SSM Scientific Colloquia (1)	0.3	Prof. Paolo Natoli	Ferrara University	SSM
1 <sup>st</sup>	Connecting the dots: Investigating an APT campaign using Splunk	0.4	Dr. Antonio Forzieri	Splunk Inc.	ITEE
1 <sup>st</sup>	Designing Quantum Algorithms	0.4	Prof. Michele Amoretti	University of Parma	ITEE
1 <sup>st</sup>	Gallium Nitride: the new disruptive power technology	0.3	Dr.ssa Nicoletta Di Noto	STMicroelectronics	Università di Catania
1 <sup>st</sup>	SSM Scientific Colloquia (8)	0.2	Prof. Jürgen Kurths	Humboldt University, Berlin	SSM
1 <sup>st</sup>	Intelligenza artificiale e sistemi d'arma autonomi	0.3	Giuliano Colombetti	CNR-IBF	Gruppo Interdisciplinare su Scienza, Tecnologia e Società dell'Area della Ricerca di Pisa del CNR
1 <sup>st</sup>	SSM Scientific Colloquia (9)	0.3	Prof. Ettore Majorana	Sapienza University of Rome	SSM
1 <sup>st</sup>	Sviluppa il tuo futuro con Enel	0.3		ENEL	UNINA
1 <sup>st</sup>	SSM Scientific Colloquia (11)	0.3	Prof. Fabio Sciarrino	University of Rome La Sapienza	SSM
1 <sup>st</sup>	Bench to Bytes to Bedside: Converting genomic data into healthcare tools	0.2	Prof. Serena Nik-Zaina	University of Cambridge	CQB
1 <sup>st</sup>	SSM Scientific Colloquia (16)	0.3	Prof. Mattia Frasca	University of Catania	SSM
1 <sup>st</sup>	IEEE Authorship and Open Access Symposium Tips and Best Practices to Get Published from IEEE Editors	0.3	Rachel Berrington	IEEE	IEEE
1 <sup>st</sup>	Potential and challenges of next generation railway signaling systems: Moving	0.2	Eng. Joelle Aoun	Delft University of Technology	ITEE

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXVII Cycle

PhD candidate: Marco Boccarossa

	Block and Virtual Coupling				
1 <sup>st</sup>	Explainable Natural Language Inference	0.3	Dr. Marco Valentino	University of Manchester	ITEE
1 <sup>st</sup>	Using delays for control	0.2	Prof. Emilia Fridman	Tel Aviv University - Israel	ITEE
1 <sup>st</sup>	Population and medical genomics applications to human traits and diseases	0.2	Dr. Nicole Soranzo	Soranzo Group	ITEE
1 <sup>st</sup>	SSM Scientific Colloquia (24)	0.2	Prof. Tiziano De Angelis	University of Torino	SSM
1 <sup>st</sup>	Symbiotic Control of Wearable Soft Suits for human motion assistance and augmentation	0.4	Prof. Lorenzo Masia	Heidelberg University	ITEE
2 <sup>nd</sup>	SSM Scientific Colloquia (1)	0.2	Prof. Alioscia Hama	University of Naples Federico II	SSM
2 <sup>nd</sup>	SSM Scientific Colloquia (2)	0.2	Prof. Pietro De Lellis	University of Naples Federico II	SSM
2 <sup>nd</sup>	From Cyber Situational Awareness to Adaptive Cyber Defense: Leveling the Cyber Playing Field	0.4	Prof. Massimiliano Albanese	George Mason University - USA	ITEE
2 <sup>nd</sup>	SSM Scientific Colloquia (5)	0.2	Dr. Olivier Minazzoli	Observatory of Côte d'Azur in Nice	SSM
2 <sup>nd</sup>	SSM Scientific Colloquia (6)	0.4	Prof. Valerio Cozzani	University of Bologna	SSM
2 <sup>nd</sup>	Open Digital Framework – Crash Course	0.6	Alberto Curcio, Valeria Crimaldi	Capgemini	5G Academy
2 <sup>nd</sup>	Industry 4.0 Fundamentals in Bosch Applications	2	Eng. Martino Bruni	Bosch	National Doctoral program in Autonomous Systems
2 <sup>nd</sup>	ITIL – Crash Course	0.6	Alberto Curcio, Valeria Crimaldi	Capgemini	5G Academy
2 <sup>nd</sup>	Principi Architeturali - TOGAF I	0.6	Alberto Curcio, Pietro Boscolo	Capgemini	5G Academy
2 <sup>nd</sup>	Fulbrighters Fredericiani a Ingegneria	0.4	Prof. Giuseppe Ruello	UNINA	Fulbright
3 <sup>rd</sup>	Ensuring Electronic Reliability Against CERN's Radiation Environment	0.2	Dr. Salvatore Danzeca	CERN	ITEE

## Research activities

Marco Boccarossa participated in the research on power semiconductor devices, focusing on their design through TCAD simulations to enhance in- and out-of-SOA performance. His primary research involved the use of ferroelectric materials in power semiconductor devices to improve the reliability of silicon carbide (SiC) MOSFETs, in collaboration with the *Ca' Foscari University of Venice (IT)*. Specifically, the temperature dependence of the dielectric constant of ferroelectric materials can counterbalance the current increase due to temperature during short-circuit events, enhancing device reliability. He also collaborated in collaboration with the company *Hitachi Energy Semiconductors (CH)* on innovative SiC MOSFETs designs, including gate-all-around structures. Throughout the PhD, Marco Boccarossa maintained an ongoing collaboration with the company *Vishay Semiconductors (IT)*, contributing on the design of active areas and terminations of both silicon (Si) and SiC diodes. During his time abroad at the *University of Warwick (UK)*, Marco Boccarossa had the opportunity to work on developing a novel approach to semi-superjunction SiC MOSFETs, including a process of trench etching and sidewall implantations with a tilted trench to simplify the implantation process. He has presented five contributions at international conferences, including Wipda22, ISPSD23, ISPS23, ICSCRM23, and ISPSD24.

## Tutoring and supplementary teaching activities

- Co-supervision of MSc thesis “*Analysis of the Impact of the Design of the Active Area on the Electrical Characteristics of a SiC Power Diode*” of the student Vincenzo Terracciano.
- 50-hour tutorship assistance to the 2<sup>nd</sup> year course “*Metodi Matematici per l’Ingegneria*”.

## Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	21	5.8	33.2	/
2 <sup>nd</sup>	11	5.6	43.4	/
3 <sup>rd</sup>	4	0.2	55.8	/

## Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
3 <sup>rd</sup>	University of Warwick, Coventry, UK	Marina Antoniou, Associate Professor - Reader	09/03/24-09/08/24	Research on Semi-superjunction (SSJ) SiC MOSFETs. Designing of SSJ MOSFETs through TCAD simulations. Joint scientific papers preparation (1 conference and 1 journal).

### PhD Thesis

In the PhD Thesis, Marco Boccarossa presents novel designs aimed at improving the in- and out-of-SOA (Safe Operating Area) performance of Silicon Carbide (SiC) Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs). The Thesis begins with an introduction to the working principles of SiC MOSFETs and a review of the current state-of-the-art in terms of in- and out-of-SOA performance. Then, it presents the fundamentals of Technology Computer-Aided Design (TCAD) simulations work and the governing equations behind their operation.

After this introduction, Marco Boccarossa presents his research result. To enhance the on- and off-state performance of 3.3 kV SiC MOSFETs, he introduces a semi-superjunction (SSJ) MOSFET design. A detailed numerical analysis is conducted to compare the performance in terms of breakdown voltage (BV) and on-state resistance ( $R_{DS-ON}$ ) of both planar and trench SSJ designs against a standard planar device. The analysis highlights the significant performance improvements of the proposed SSJ designs over standard planar device, without introducing the fabrication complexity typically associated with standard superjunction devices.

Regarding the out-of-SOA performance, the thesis addresses the critical issue of short-circuit (SC) capability in SiC MOSFETs. Specifically, it examines how ferroelectric materials can enhance the SC capability of 1.2 kV SiC MOSFETs, particularly focusing on the use doped hafnium oxide ( $HfO_2$ ), a CMOS-compatible ferroelectric material. The thesis introduces a novel MOSFET design that incorporates a ferroelectric-silicon dioxide stack as the gate dielectric in a SiC power MOSFET. This innovative approach leverages the temperature-dependent dielectric constant of the ferroelectric material to mitigate the temperature rise during SC events, improving device reliability without affecting its performance under normal operating conditions.

### Research products

Research results appear in 14 contributions to international conferences and 2 papers are currently under review in international journals.

### List of scientific publications

#### International journal papers

**M. Boccarossa**, L. Maresca, A. Borghese, M. Riccio, G. Breglio, A. Irace, and G. A. Salvatore,  
The Ferro-Power MOSFET: Enhancing Short-circuit Robustness in Power Switches with a Ferroelectric Gate Stack,  
*IEEE Transactions on Power Electronics (Submitted)*

**M. Boccarossa**, K. Melnyk, A. B. Renz, P. M. Gammon, V. Kotagama, V. A. Shah, L. Maresca, A. Irace, and M. Antoniou,  
The 3.3 kV SiC Semi-superjunction MOSFET with Trench Sidewall Implantations,  
*IEEE Transactions on Electron Devices (Submitted)*

### International conference papers

K. Melnyk, **M. Boccarossa**, A. B. Renz, Q. Cao, P. M. Gammon, V. A. Shah, L. Maresca, A. Irace, and M. Antoniou,

Cost-Effective Design and Optimization of a 3300-V Semi-Superjunction 4H-SiC MOSFET Device,  
*International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Raleigh (NC), USA, Oct. 2024.

C. Scognamillo, A. Borghese, K. Melnyk, I. Nistor, V. d'Alessandro, **M. Boccarossa**, V. Terracciano, M. Riccio, A. P. Catalano, G. Breglio, N. Lophitis, M. Antoniou, M. T. Rahimo, A. Irace, and Luca Maresca,  
Out-of-SOA Performance of 3.3 kV SiC MOSFETs: Comparison between Planar and Quasi-Planar Trench,  
*International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Raleigh (NC), USA, Oct. 2024.

L. Maresca, V. Terracciano, A. Borghese, **M. Boccarossa**, M. Riccio, G. Breglio, S. Wirths, and A. Irace,  
Evaluation of Switching Performances and Short Circuit Capability of a 1.2 kV SiC GAA MOSFET through  
TCAD Simulations,  
*International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Raleigh (NC), USA, Oct. 2024.

**M. Boccarossa**, L. Maresca, A. Borghese, M. Riccio, G. Breglio, A. Irace, G. A. Salvatore,  
Substantial Improvement of the Short-circuit Capability of a 1.2 kV SiC MOSFET by a HfO<sub>2</sub>/SiO<sub>2</sub> Ferroelectric  
Gate Stack,  
*36th International Symposium on Power Semiconductor Devices and ICs (ISPSD)*,  
Bremen, Germany, Jun. 2024, pp. 88-91, DOI: 10.1109/ISPSD59661.2024.10579678.

**M. Boccarossa**, L. Maresca, A. Borghese, M. Riccio, G. Breglio, A. Irace, and G. A. Salvatore,  
Non-Linear Gate Stack Effect on the Short Circuit Performance of a 1.2-kV SiC MOSFET,  
*International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Sorrento (NA), Italy, Sep. 2023, <https://doi.org/10.4028/p-50ZNaN>.

A. Borghese, S. Angora, **M. Boccarossa**, M. Riccio, L. Maresca, V. R. Marrazzo, G. Breglio, and A. Irace,  
Analysis of Electrothermal Imbalance of Hard-Switched Parallel SiC MOSFETs through Infrared  
*Thermography*, *International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Sorrento (NA), Italy, Sep. 2023, <https://doi.org/10.4028/p-2uwgqf>.

V. Terracciano, A. Borghese, **M. Boccarossa**, V. d'Alessandro, and A. Irace,  
A Geometry-Scalable Physically-Based SPICE Compact Model for SiC MPS Diodes Including the Snapback  
Mechanism,  
*International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Sorrento (NA), Italy, Sep. 2023, <https://doi.org/10.4028/p-b9ImzL>.

L. Maresca, V. Terracciano, A. Borghese, **M. Boccarossa**, M. Riccio, G. Breglio, A. Mihaila, G. Romano, S.  
Wirths, L. Knoll, and A. Irace,  
SiC GAA MOSFET Concept for High Power Electronics Performance Evaluation through Advanced TCAD  
Simulations,  
*International Conference on Silicon Carbide and Related Materials (ICSCRM)*,  
Sorrento (NA), Italy, Sep. 2023, <https://doi.org/10.4028/p-lhRi4M>.



V. d’Alessandro, V. Terracciano, A. Borghese, **M. Boccarossa**, and A. Irace,  
A Simple Electrothermal Compact Model for SiC MPS Diodes Including the Snapback Mechanism,  
*29th International Workshop on Thermal Investigations of ICs and Systems (THERMINIC)*,  
Budapest, Hungary, 2023, pp. 1-5, doi: 10.1109/THERMINIC60375.2023.10325871.

**M. Boccarossa**, L. Maresca, A. Borghese, M. Riccio, G. Breglio, A. Irace, and G. A. Salvatore,  
Threshold Voltage Temperature Dependence for a 1.2 kV SiC MOSFET with Non-Linear Gate Stack,  
*International Seminar on Power Semiconductors (ISPS)*,  
Czech Technical University in Prague, Czech Republic, 2023.

**M. Boccarossa**, L. Maresca, A. Borghese, M. Riccio, G. Breglio, A. Irace, G. A. Salvatore,  
Short-Circuit Rugged 1.2 kV SiC MOSFET with a Non-Linear Dielectric Gate Stack,  
*35th International Symposium on Power Semiconductor Devices and ICs (ISPSD)*,  
Hong Kong, 2023, pp. 354-357, doi: 10.1109/ISPSD57135.2023.10147604.

A. Borghese, **M. Boccarossa**, M. Riccio, L. Maresca, G. Breglio and A. Irace,  
Short-circuit and Avalanche Robustness of SiC Power MOSFETs for Aerospace Power Converters,  
*IEEE Aerospace Conference (AEROCONF)*,  
Big Sky, MT, USA, 2023, pp. 1-8, doi: 10.1109/AERO55745.2023.10115580.

**M. Boccarossa**, A. Borghese, L. Maresca, M. Riccio, G. Breglio, and 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)*,  
Davos, Switzerland, Sep. 2022, <https://doi.org/10.4028/p-mlkxy8>.

**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,  
*IEEE Workshop on Wide Bandgap Power Devices and Applications in Europe (WiPDA Europe)*,  
Coventry, United Kingdom, 2022, pp. 1-5, doi: 10.1109/WiPDAEurope55971.2022.9936079.

## Awards and Prizes


Winner of the **Borsa Califano** Award from *Fondazione Roma Sapienza* for research in the field of “Innovative materials, technologies, and components for Electronics” in 2023.

Date 15/10/2024

PhD student signature



Supervisor signature



Co-supervisor signature

