35th EUROPEAN SYMPOSIUM

on Reliability of Electron Devices, Failure Physics and Analysis

ESREF 2024

PROCEEDINGS

September 23-26, 2024
PARMA, Italy

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WELCOME TO ESREF 2024

Dear colleagues,
on behalf of the Scientific and Organizing committees, we are pleased to welcome you to ESREF 2024, the 35th European Symposium on Reliability of Electron Devices, Failure Physics and Analysis. This year the conference takes place in Parma, Italy, from September 23 to 26, 2024. This International Symposium continues its 35-year history of focusing on the latest research developments and future directions in failure analysis, quality, and reliability of materials, devices, and circuits for microelectronics and optoelectronics, power, space, and automotive electronics. ESREF historically provides a European forum to develop all reliability aspects, including management and advanced failure analysis techniques for present and emerging semiconductor applications.
This edition is a special one: in 2024, ESREF will celebrate its return to Italy after 12 years. The Conference is held in the Motor Valley, a very productive region with many automotive brands and great know-how on the latest automotive technologies.
Besides, ESREF 2024 is a unique opportunity to get in contact with Italian universities, with their unequaled background in the reliability of automotive and electronic systems for automation.
Electronics enhance our safety and comfort, playing a crucial role in helping us understand and shape the world we live in. As we confront the challenges before us, we are confident that electronics can and should be integral to the solutions. Reliability is fundamental to improving sustainability, sovereignty, security, and safety.
This year's ESREF Conference has once again attracted exceptional contributions from across the globe. The presentations have been organized in 16 oral sessions and two days of interactive poster sessions, covering Quality and Reliability Assessment Techniques, Semiconductor Failure Mechanisms, Progress in Failure Analysis, Reliability of Microwave Devices, Packaging- and Assembly Reliability, Power Device Reliability, Photonics Reliability, MEMS and Sensors Reliability, Extreme Environments and Radiation. This year, a new track on Automotive and Industrial Electronic Reliability has also been added, to meet the new challenges related to the development of sustainable mobility and smart industry.
On the first day, two tutorials of great interest will open the conference, by discussing timely and relevant topics:

- **GAUDENZIO MENEGHESSO**, University of Padova, Italy, GaN reliability: from technological considerations to failure processes
- **HUAI WANG**, Aalborg University, Denmark, AI-assisted reliability testing, modeling, and condition monitoring for power electronics applications

The program will be enriched by the contribution of four distinguished experts, who joined the conferences as keynote speakers.

Semiconductor Keynotes:

- **HARALD GOSSNER**, Intel Senior Principal Engineer, IEEE Fellow, Intel CCG a Group, Munich, Germany
- **GIANLUCA BOSELLI**, ESD Team Manager and Director of Advanced Technology Development University Research Program, Advanced Technology Development, Texas Instruments, Dallas, Texas, USA

Automotive Keynotes:

- **GIORGIO GULLONE**, Simulation and Control Specialist at Ferrari S.p.A., Italy
- **LUCA ZACHEO**, Benches & Automations Management at Automobili Lamborghini S.p.A., Italy

Moreover, six invited talks will guide the audience into the latest developments in microelectronics and reliability.

In the tradition of the conference, we will also welcome, as invited, speakers who have received best paper awards at our sister conferences IPFA, and ISTFA.

Finally, the conference program includes three workshops on important topics in electronics reliability, which will be discussed by experts from industry and academia:

- **Automotive Electronic Workshop - Driving into the future**
- **Reliability of WBG Power Conversion**
- **Hardware Security Meets Failure Analysis**

This conference has been made possible through the generous contributions of our sponsors, exhibitors, and industrial partners. We extend our gratitude to them. Their belief in our conference and support for the development and execution of our exceptional technical and social program have been invaluable.

Lastly, we would like to extend our heartfelt thanks to the track chairs and to all the reviewers and members of the Scientific Committee, who generously volunteered their time and expertise to review the papers. Their efforts have been instrumental in ensuring that this conference meets the high technical and professional standards we strive for.

We hope all of you will enjoy the conference, the scientific interaction, and the lively discussions!

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B - Semiconductor Failure Mechanisms and Reliability for Si Technologies & Nanoelectronics
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C - Progress in Failure Analysis: Defect Detection and Analysis
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D - Reliability of Microwave Devices and Circuits
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E - Packaging and Assembly Reliability and Failure Analysis
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F1 - Power Devices Reliability: Smart-Power Devices and Silicon Power Devices
GIOVANNI BREGLIO University of Napoli (IT)
ZOUBIR KHATIR Gustave Eiffel University (FR)

F2 - Power Devices Reliability: Wide Bandgap Devices
FARID MEDJDOUB CNRS-IEMN (FR)
MATTEO MENEGHINI University of Padova (IT)

F3 - Power Devices Reliability: Power Electronic Systems
OLIVIER CREPEL Airbus (FR)
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G - Photonics Reliability
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CONFERENCE PROGRAM

Monday, September 23rd

09:00 Tutorials

CHAIR: *Nicola Delmonte*
University of Parma, Italy

09:00 AI-assisted reliability testing, modeling, and condition monitoring for power electronics applications
Huai Wang
Aalborg University, Denmark

11:00 GaN reliability: from technological considerations to failure processes
Gaudenzio Meneghesso
University of Padua, Italy

14:00 Opening session

CHAIR: *Paolo Cova*
University of Parma, Italy

14:40 Session K1: Semiconductors Keynotes

CHAIR: *Francesco Iannuzzo*
Aalborg University, Denmark

14:40 The Reliability Perspective of the Advanced CMOS Roadmap
Harald Gossner
Intel, Germany

15:20 System-Level ESD Design in HV Automotive Applications: Process, IP and System Co-Design Challenges
Gianluca Boselli
Texas Instruments, United States

16:20 Session F1: Power devices reliability: smart-power devices and silicon power

CHAIRS: *Giovanni Breglio*[1] *Zoubir Khatir*[2]
[1]University of Naples Federico II, Italy [2]Gustave Eiffel University, France

16:20 **(Invited)** Out-of-SOA Electrothermal Limitations of Power Semiconductor Devices: Characterization and Modeling
Andrea Irace[1]
[1]University of Napoli "Federico II", Italy

17:00 New Temperature-Independent Aging Indicator for power semiconductor devices – application to IGBTs
Zoubir Khatir[1], *Ali Ibrahim*[1] *Richard Lallemand*[1]
[1]University Gustave Eiffel, France

17:20 Effect of load sequence interaction for low ΔTj's on the reliability of bonded aluminium wires in IGBTs
Ayda Halouani[1], *Zoubir Khatir*[1], *Richard Lallemand*[1], *Ali Ibrahim*[1] *Damien Ingrosso*[1] *Nicolas Degrenne*[2]
[1]University Gustave Eiffel, France; [2]Mitsubishi Electric R&D Centre Europe, France

17:40 Improvement of Sensitivity for Power Cycle Degradation by A New Device Structure
Koki Okame[1], *Yuki Yamakita*[1], *Shin-Ichi Nishizawa*[2], *Wataru Saito*[2]
[1]Interdisciplinary Graduate School of Engineering Science, Japan; 2. Kyushu University, Japan

18:00 Impact of IGBT emitter pad design and front- side ageing on switching stability
Christian Bäumler[1], *Thomas Basler*[1]
[1]Chemnitz University of Technology, Germany

17:00 Session B: Silicon technologies, nanoelectronics and MEMS: from device reliability to back-end reliability

CHAIRS: *Alain Bravaix*[1], *George Papaioannou*[2]
[1]ISEN, France, [2]University of Athens, Greece

17:00 Reading reliability in 1S1R OTS+PCM devices based on Double Patterned Self Aligned structure
Renzo Antonelli, Guillaume Bourgeois, Valentina Meli, Zineb Saghi, Théo Monniez, Simon Martin, Niccolò Castellani, Mathieu Bernard, Leïla Fellouh, Antoine Salvi, Sylvain Gout, François Andrieu, Abdelkader Souifi, Gabriele Navarro
Univ. Grenoble Alpes, France

17:20 Electrical and reliability characterization with optimized extrapolation models of two- and three-dimensional Metal-Insulator-Metal decoupling capacitors with ZrAlxOy high-κ dielectric under BEoL-friendly conditions
Konstantinos Efstathios Falidas[1], Kati Kühnel[1], Matthias Rudolph[1], André Reck[1], Malte Czernohorsky[1], Johannes Heitmann[2]
[1]Fraunhofer IPMS, Germany, [2]Technische Universität Bergakademie Freiberg, Germany

17:40 Vertically Scaled Cu/low-k Interconnect Development for BEOL Reliability Improvement of 12nm DRAM
Jaehyeong Lee, Byoungwook Woo, Yumi Lee, Namhyun Lee, Young-Yun Lee, Yunsung Lee, Seungbum Ko, Sangwoo Pae
Samsung Electronics, South Korea

18:00 Evaluation of the Impact of Body Bias on the Threshold Voltage Drift of SiO2 Transistors
Konstantinos Tselios[1], Theresia Knobloch[1], Dominic Waldhoer[1], Hubert Enichlmair[2], Eleftherios G. Ioannidis[2], Rainer Minixhofer[2], Tibor Grasser[1], Michael Waltl[1]
[1]TU Wien, Austria, [2]ams-OSRAM AG, Austria

18:20 On the electrical properties of ALD HfO2 dielectric films for MEMS capacitive switches.
John Theocharis[1], Paolo Martins[2], Aymen Mahjoub[2] Etienne Eustache[2], Afshin Ziaei[2], George Papaioannou[1]
[1]University of Athens, Greece, [2]Thales Research and Technology, France

Tuesday, September 24th

08:20 Session K2: Automotive Keynotes
CHAIR: *Nicola Delmonte*
University of Parma, Italy

08:20 Battery Diagnostics and Virtual Sensors in Ferrari
Giorgio Gullone
Ferrari S.p.A., Italy

09:00 An approach to Electronic Platform Complexity: the System Integration in Lamborghini
Luca Zacheo
Lamborghini S.p.A., Italy

10:00 Session A-1: Accelerated life tests and design of experiments
CHAIR *Edgar Olthof*
NXP Semiconductors, Netherlands

10:00 Design-of-Experiments and ALT plan for reliability qualification of chip resistors based on mission profile of AIMDs
Fatima-Ezahra Indmeskine[1], Laurent Saintis[1], Abdessamad Kobi[1], Hélène Marceau[2]
[1]University of Angers, France, [2]TAME-COMPONENT (TRONICO), France

10:20 Reliability Assurance in Foldable Displays: Design of Experiment-Based Testing Strategy for Market-Ready Products
Ui Hyo Jeong[1], Seongyong Lim[2], Seung Su Han[1]
[1]Korea Testing Certification, South Korea, [2]Incheon National University, South Korea

10:40 New statistical analysis methodology to forecast the memory cell behavior before reliability test
Sebastien Perrin[1], Vincenzo Della Marca[2], Thibault Kempf[1], Marc Bocquet[2], Loic Welter[1], Jean-Michel Moragues[1], Arnaud Regnier[1], Jean-Michel Portal[2]
[1]STMicroelectronics, France, [2]Aix-Marseille University, France

11:00 Condition Monitoring for Detection of Humidity-Induced Failures in Control Electronics of Power Converters
Frederic Sehr[1], Stefan Wagner[1], Adelja Schulz[1], Alexander Vorwerk[1]
[1]Fraunhofer Institute for Reliability and Microintegration (IZM), Berlin, Germany

10:00 Session L: Automotive and industrial electronic reliability
CHAIRS: *Nicola Trivellin[1], Ulrich Abelein[2], Michael Nelhiebel[3]*
[1]University of Padova, Italy, [2]Infineon Technologies AG, Germany, [3]KAI Kompetenzzentrum Automobil- und Industrieelektronik GmbH, Austria

10:00 Reliability analysis of high power LEDs for automotive: impact of current and temperature
Alessandro Caria, Nicola Trivellin, Riccardo Fraccaroli, Nicola Roccato, Matteo Buffolo, Carlo De Santi, Gaudenzio Meneghesso, Enrico Zanoni, Matteo Meneghini
University of Padova, Italy

10:20 Aging modelling of Li-Ion Battery Systems based on accelerated tests
Andrea Toscani, Mattia Stighezza, Marco Simonazzi, Nicola Delmonte, Paolo Cova, Valentina Bianchi, Ilaria De Munari
University of Parma, Italy

10:40 Development challenges of a one-sided GaN- based high-current density buck converter through multiphysics optimization for electric vehicle applications
Mohamed Belguith[1], Sonia Eloued[2], Moncef Kadi[3], Jaleleddine Ben Hadj Slama[2]
[1]Université de Sousse, Tunisia / Université Rouen Normandie, France, [2]Université de Sousse, Tunisia, [3]Université Rouen Normandie, France

11:00 Performance characterization of lithium-ion battery and ageing under constant stress conditions at low temperature
Ossama Rafik, Armande Capitaine, Olivier Briat, Jean-Michel Vinassa
IMS Bordeaux, France

11:20 SMART Protection Design of Automotive Power Distribution Systems with Temperature-Based Electronic Fuses: Mathematical Background, Design Guidelines and Drawbacks of Energy-Based Methods
Mirko Bernardoni, Robert Illing, Mario Tripolt, Christian Djelassi-Tscheck
Infineon Technologies Austria, Austria

12:00-14:00 Poster Session 1

CHAIR: *Giovanna Mura*
University of Cagliari, Italy

Degradation model for insulation characteristics of tantalum capacitors related to manufacturing parameters and stress
Xue Zhou, Mingxu Zhang, Donghui Li, Chensong Ji, Le Xu, Guofu Zhai
Harbin Institute of Technology, China

Research on The Degradation of Contact Resistance of Wire-Spring Contacts in Different Wear Condition
Le Xu, Yuyao Zhao, Shujuan Wang
Harbin Institute of Technology, China

Reliability Design of GaN Based High-frequency Inverter Optimization
Ya Jing Zhang[1], Xin Yu Ao[1], Hong Li[1], Xiu Teng Wang[2]
[1]Beijing Information Science and Technology University, China, [2]China National Institute of Standardization, China

Correlating time and voltage laws in BTI
Joseph Bernstein[1], Alain Bensoussan[2], Emmanuel Bender[3], Tsuriel Abraham[1]
[1]Ariel University, Israel, [2]ReEExS Reliability, France, [3]MIT, Israel

Evidence of resistive switching in SiNx thin films for MEMS capacitors: the role of metal contacts
John Theocharis, Spiros Gardelis, George Papaioannou
National and Kapodistrian University of Athens, Greece

Recovery and Unrecovered Damage During Interrupted CVS in MFIS FE devices
Tiang Teck Tan[1], Tian-Li Wu[2], Kalya Shubhakar[1], Nagarajan Raghavan[1], Kin Leong Pey[1]
[1]Singapore University of Technology and Design, Singapore, [2]National Yang Ming Chiao Tung University, Taiwan

HTRB effects on threshold instability of 4H-SiC PowerMOSFET with carrots defects
Laura Anoldo[1], Giuseppe Tosto[1], Santina Bevilacqua[1], Erwin Schroer[1], Salvatore Patanè[2], Alfio Russo[1]
[1]STMicroelectronics, Italy, [2]University of Messina, Italy

Thermal layout optimization of electrolytic capacitors considering degradation self- acceleration effect for reliability improvement
Xuerong Ye[1], Qisen Sun[2], Ruyue Zhang[3], Junpeng Gao[1], Haodong Wang[1], Guofu Zhai[1]
[1]Harbin Institute of Technology, China, [2]City University of Hong Kong, Hong Kong, [3]China Jiliang University

Semi-supervised parameter estimation for Synthetic Aperture Focusing in Scanning Acoustic Microscopy for a 3D reconstruction of plastic molded electronic devices
Mario Wolf[1], Peter Hoffrogge[2], Michael Wiedenmann[3], Stefan Oberhoff[3], Christian Kupsch[1], Jörg Krinke[3], Peter Czurratis[2]
[1]TU Bergakademie Freiberg, MSE Lab, Germany, [2]PVA TePla Analytical Systems GmbH, Germany, [3]Robert Bosch GmbH, Germany

Reliability detection and analysis of elliptical holes corresponding to defects in electrothermal environment
He Zhang, Li Wang, Jiwen Cui
Harbin Institute of Technology, China

On the influence of the porosity and homogeneity of sintered die-attach layers on the power cycling performance
Lukas Mikutta, Frederik Otto, Jörg Schadewald
Infineon Technologies AG, Germany

Aging impact of the SiC Mosfet gate dielectric
Tanguy Phulpin, Alexandre Jaffré, Pascal Chrétien, David Alamarguy
GeePs, France

Failure mode competition and long-term reliability in the isothermal aging of sintered Cu joints
Jianbo Xin[1], Xiaochun Lv[2], Yue Gao[3], Le Yang[1], Sushi Liu[1], Ke Li[1], Minghao Zhou[1], William Cai[1], Jing Zhang[3], Yang Liu[1]
[1]Harbin Institute of Technology, China, [2]Harbin Welding Institute Limited Company, China, [3]Heraeus Electronic Technology, Shanghai, China

Investigating the thermal degradation trends for thermal interface materials in the power converter
Ziheng Wang[1], Yi Zhang[1], Huai Wang[1]
[1]Aalborg University, Denmark

PBO Delamination and RDL Corrosion detection on WLCSP Package Products
Klodjan Bidaj[1], Yong Chen[2], Jason Chang[3], Orianne Atance-Loustaunau[3], Francois Braud[1]
[1]STMicroelectronics, France, [2]STMicroelectronics, Singapore, [3]STMicroelectronics, Taiwan

Laser voltage probing and simulation of a flip-flop with undesired quasi-static switching
Angelo Antonio Merassi[1], Tommaso Melis[2]
[1]STMicroelectronics, Italy, [2]STMicroelectronics, France

Multi-sensor Data Fusion for Prediction of Remaining Useful Life of IGBT Power Modules
Martin Votava[1], Karthik Debbadi[1], Gopal Mondal[2], Sebastian Nielebock[2], Yoann Pascal[1], Marco Liserre[1]
[1]Fraunhofer Institute for Silicon Technology ISIT, Germany, [2]Siemens AG, Germany

Effect of Drain Field Plate design and 2DEG density on Dynamic-RON of 650V AlGaN/GaN HEMTs
Marcello Cioni[1], Giovanni Giorgino[1], Alessandro Chini[2], Nicolo Zagni[2], Giacomo Cappellini[1], Santo Principato[1], Cristina Miccoli[1], Tariq Wakrim[3], Maria Eloisa Castagna[1], Aurore Constant[3], Ferdinando Iucolano[1]
[1]STMicroelectronics, Italy, [2]University of Modena and Reggio Emilia, Italy, [3]STMicroelectronics, France

Evolution analysis of mechanical behavior of through-silicon via under thermal cycling load
Kaihong Hou, Zhengwei Fan, Xun Chen, Shufeng Zhang, Yashun Wang, Yu Jiang
National University of Defense Technology, Changsha, China, China

Long-Term Positive and Negative Gate Bias Stress Tests on Parallel Connected SiC MOSFETs at -40°C and 175°C
Arkadeep Deb[1], Mohamed Taha Elsayed Abdelkader[1], Jose Ortiz Gonzalez[1], Phil Mawby[1],Saeed Jahdi[2] Olayiwola Alatise[1]
[1]University of Warwick, UK,[2]University of Bristol, UK

Single Event Irradiation Damage Effect of SiC MOSFETs Based on Degradation of Forward Conduction Characteristic
Pengwei Li[1,2], Liang Zhen[2], Xingji Li[2], Jianqun Yang[2], Hongwei Zhang[1], Yi Sun[1], Qianyuan Wang[1], Qingkui Yu[1], Xuhui Wang[3], Guohe Zhang[3]
[1]China Academy of Space Technology, China, [2]Harbin Institute of Technology, China, [3]Xi'an Jiaotong University, Xi'an, China

Stress comparison of several short-circuit types on SiC MOSFET packaging
Bin Yu[1], Xingjian Shi[2], Hongyi Gao[2], Haoze Luo[2], Wenbo Wang[3], Francesco Iannuzzo[4], Wuhua Li[2]
[1]Nanjing University of Information Science and Technology/Zhejiang University, China, [2]Zhejiang University, China, [3]Harbin Institute of Technology, China, [4]Aalborg University, Denmark

The Drift in Threshold Voltage and On-Resistance of SiC MOSFETs Induced by AC Bias Temperature Instability
Zicheng Wang, Cen Chen, Boya Zhang, Yifan Hu, Hao Chen, Xuerong Ye, Yaokang Lai
Harbin Institute of Technology, China

The failure of CW high-power optical elements due to laser beams characteristics
Xinyu Luo, Peng Yang, Qian Li, Jing Qiu, Guanjun Liu
National University of Defense Technology, China

Low-Voltage Schottky p-GaN HEMT Properties under Extreme Repetitive Short-Circuit Operation Conditions : 2DEG Pinch-off, Stability, Aging, Robustness and Failure-Modes Analysis
Frédéric Richardeau, Lucien Ghizzo, David Tremouilles, Sébastien Vinnac
CNRS, Toulouse, France

Preliminary SiC MOSFET Gate-Cracking Modeling under Short-Circuit Based on Rankine's Damage Energetic Approach Using a Wide Temperature- Range Elastoplastic 2D Simulation
Mustafa Shqair, Emmanuel Sarraute, Frédéric Richardeau
University of Toulouse, France

Impact of drain-source leakage on the dynamic Ron of power HEMTs with p-GaN gate
Simone Longato[1], Davide Favero[1], Arno Stockman[2], Arianna Nardo[2], Piet Vanmeerbeek[2], Marnix Tack[2], Gaudenzio Meneghesso[1], Enrico Zanoni[1], Carlo De Santi[1], Matteo Meneghini[1]
[1]University of Padova, Italy, [2]BelGaN, Oudenaarde, Belgium

Effect of gate oxide thickness on gate latent damage induced by heavy ion in SiC power MOSFETs
Shiwei Zhao[1], Yuzhu Liu[1], Xiaoyu Yan[1], Peipei Hu[1], Xinyu Li[1], Qiyu Chen[1], Pengfei Zhai[1], Teng Zhang[2], Li Cai[1], Yang Jiao[1], Youmei Sun[1], Jie Liu[1]
[1]Institute of Modern Physics, Chinese Academy of Sciences, China,[2]Nanjing Electronic Devices Institute, China aN, Oudenaarde, Belgium

Physics informed Markov chains for remaining useful life prediction of wire bonds in power electronic modules
Mehdi Ghrabli[1], Mounira Bouarroud[2], Ludovic Chamoin[1], Emanuel Aldea[1]
[1]Université Paris Saclay, France, [2]Créteil University, Paris, France

Remaining Useful Life Prediction of DC Contactor Based on LSTM
Yu Wang[1], Yong Xie[2], Huimin Liang[1], Hangyu Ma[1]
[1]Harbin Institute of Technology, China, [2]GA Technologies Co.Ltd., China

Investigation of the long-term dynamic Rds(ON) variation and dynamic high temperature operating life test robustness of Schottky gate and ohmic gate GaN HEMT with comparable stress conditions
Fawad Rauf[1], Muhammad Farhan Tayyab[2], Samir Mouhoubi[2], Marcelo Heldwein[3], Gilberto Curatola[2]
[1]TUM and HUAWEI, Germany, [2]HUAWEI, Germany, [3]TUM, Germany

Study on intermittent fault mechanism of high- density integrated circuits under temperature shock
Wenxiang Yang,Yong Zhang, Kehong Lv, Qiang Guo, Kai Shen, Jing Qiu
National University of Defense Technology, China

Creep tester for quality assessment of solder joints using normal and thermal stress
Jae-Seong Jeong, Young-Ki Ahn
Korea Electronics Technology Institute (KETI), South Korea

Heat-resistant durability of AMB substrates for SiC power devices: AlN and Si3N4, which one is thermally strong?
Yun-Chan Kim[1], Dong-Yurl Yu[1], Shin-il Kim[1], Yong-Mo Kim[2], Dongjin Byun[3], Junghwan Bang[1], Dongjin Kim[1]
[1]Korea Institute of Industrial Technology (KITECH), South Korea, [2]Korea Instrument Co., Ltd., South Korea, [3]Korea University, South Korea

Online Junction Temperature Monitoring of SiC MOSFET Based On The Maximum Drain Current Change Rate During The Process of Opening
Hong Li[1], Yixiang Zhao[1], Xiaofei Hu[1], Qinghao Zhang[2]
[1]Beijing Jiaotong University, China, [2]Tsinghua University, China,

Efficient Long-term Reliability Assessment of Planar InGaAs/InP Avalanche Photodiodes using Accelerated Step-Stress Test
Yunseok Han[1], Sunho Kim[2], Ilgu Yun[1]
[1]Yonsei University, South Korea, [2]Wooriro Co., South Korea

Active Gate Driver for Current Overshoot Suppression of SiC+Si Hybrid Switches with Dynamic gate Current Regulation
Ping Liu[1], Yongjie Liu[1], Qi Cao[1], Biao Xiao[1], Chunming Tu[1], Bin Yu[2,3]
[1]Hunan University, Changsha, China, [2]Nanjing University of Information Science and Technology, China, [3]Zhejiang University, Hangzhou, China

Optimized Semi-Physical EKV Model for Simulation of SiC MOSFETs
Benewende Diane Raïnatou Bonkoungou[1], Romain Gwoziecki[1], Gaetan Perez[1], Leo Sterna[1], Zoubir Khatir[2]
[1]Univ. Grenoble Alpes, France, [2]Univ. Gustave Eiffel, France

A study of UIS ruggedness of mismatched paralleled SiC MOSFETs
Ciro Scognamillo[1], Antonio Pio Catalano[1], Lorenzo Codecasa[2], Alberto Castellazzi[3], Vincenzo D'Alessandro[1]
[1]University of Naples Federico II, Italy, [2]Politecnico di Milano, Italy, [3]Kyoto University of Advanced Science, Japan

The Use of Filtered High-Energy X-rays and 60Co for TID Testing of a 32-Bit 28nm FDSOI DSP
Alejandro Urena-Acuna[1], Julien Favrichon[2], Aurelien Ballier[2], Pierre-Alexis Robin[2], Vincent Gironés[2], Tadec Maraine[2], Frederic Saigné[2], Jerome Boch[2]
[1]Université de Toulouse, France, [2]Univ. Montpellier, France

Comprehensive LED Reliability Assessment through Integrated Real-Time Visualization, Electrical, and Optical Analysis
Hui Teng Tan[1], Wardhana A. Sasangka[1], Yu Gao[1], Kenneth Eng Kian Lee[1], Carl V. Thompson[2], Chee Lip Gan[3]
[1]Singapore-MIT Alliance for Research and Technology, Singapore, Singapore, [2]Massachusetts Institute of Technology, USA, United States, [3]Nanyang Technological University, Singapore, Singapore

Machine learning classification for failure analysis of smart spark plugs
Minh Long Hoang[1], Simone Daniele[2], Nicola Delmonte[1], Massimo Dal Re[2], Paolo Cova[1], Danilo Santoro[1]
[1]University of Parma, Italy, [2]Federal-Mogul Italy s.r.l, Carpi, Italy

Issues of electronic devices in hostile environment
Valeria Trabattoni[1], Alessandro Andreani[1], Massimo Lazzaroni[1], Andrea Riminucci[1], Danilo Santoro[2], Andrea Zani[3]
[1]Università degli Studi di Milano, Italy, [2]University of Parma, Italy, [3]INFN Sezione di Milano, Italy

Methodology to estimate the impact of Single Event Transients in Logic
Saumya Joshi, Rosina Menditto, Karsten Ermisch, Guenther Schindler, Joerg Berthold, Toni Huber, Steffen Rost[1], Katja Waschneck, Wolfgang Gustin, Georg Georgakos
Infineon Technologies, Germany

14:00 Workshop: Reliability of WBG Power Conversion
CHAIRS: *Fabio Coccetti[1], Thomas Harder[2]*
[1]IRT Saint Exupéry, Toulouse, France, [2]ECPE, Nurnberg, Germany

14:20 Session A-2: Reliability and Lifetime predictions focused on power electronics
CHAIR: *Edgar Olthof*
NXP Semiconductors, Netherlands

14:20 Lifetime prediction for power modules in wind-energy converters based on temperature variations in a large area substrate solder connection
Nils Zöllner[1], Oliver Schilling[1], David Übelacker[1], Hans-Günter Eckel[2], Tobias Heise[2],
[1]Infineon Technologies AG, Germany, [2]University of Rostock, Germany

14:40 On the Validity of Rainflow Counting-Based Lifetime Assessment for Power Electronics Assembly
Dawei Zhao, Sebastian Letz, Jürgen Leib, Bernd Eckardt
Fraunhofer-Institute for Integrated Systems and Device Technology, Germany

15:00 Reliability Prediction of Electronic Components based on Physical of Failure with Manufacturing Parameters Fluctuations
Zijian Guo, Hao Chen, Yifan Hu, Xuerong Ye
Harbin Institute of Technology, Harbin, China

15:20 Reliability prediction of multi-level power supply system based on failure precursor parameters
Weiming Liu[1], Cen Chen[1], Wei Zheng[2], Mingtao Feng[2], Xuerong Ye[1], Guofu Zhai[1]
[1]Harbin Institute of Technology, Harbin, China, [2]Beijing Aerospace Automatic Control Research Institute, China

15:40 A New Methodology of Modeling Conducted Emission Behavioural in System-in-Packages (SiP)
Yifei Zheng[1], Jianfei Wu[1], Yanfang Lu[2], Yang Li[2], Hongli Zhang[2], Peiguo Liu[1]
[1]National University of Defense Technology, China, [2]Tianjin Institute of Advanced Technology, China

14:20 Session F3: Power devices reliability: power electronic systems
CHAIR: *Andrea Toscani*
University of Parma, Italy

14:20 Series AC Arc Fault Diagnosis Method Based on Spectrogram and Deep Residual Network
Wenxin Dai. Xue Zhou, Zhigang Sun, Guofu Zhai
Harbin Institute of Technology, Harbin, China

14:40 Condition Monitoring of a DC-Link Capacitor in an Inverter with a front-end diode rectifier under Imbalanced Three-phase Supply Voltage
Takuma Yamasoto, Kazunori Hasegawa
Kyushu Institute of Technology, Japan

15:00 Analysis and experimental verification of current sharing among parallel-connected dc- link capacitors in a fast-switching converter
Kazunori Hasegawa, Sakurako Nasu
Kyushu Institute of Technology, Japan

15:20 Conducted EMI Assessment of Aging Power Si-MOSFET in 3 phase inverter
Mohamed Tlig, Bessem Zitouna, Mahmoud Hammouda, Jaleleddine Ben Hadj Slama
University of Sousse, Tunisia

15:40 High AC load current testing method for power capacitors
Fabian Dresel, Jürgen Leib, Lukas Blamberger, Bernd Eckardt, Martin März
Fraunhofer IISB, Germany

16:20 Session D: Reliability of microwave devices and circuits
CHAIR: *Michael Dammann*
Fraunhofer, Germany

16:20 Reliability and Failure Analysis of AlGaN/GaN HEMT with NiPtAu and PtAu Gate
Michael Dammann[1], Peter Brückner[1], Rachid Driad[1], S. Krausea[1], S.A. Albahrania[1], B. Webera[1], M. Baeumlera[1], H. Konstanzera[1], M. Mikullaa[1], M. Simon-Najasekb[2], S. Hübnerb[2], A. Graffb[2]
[1]Fraunhofer Institute for Applied Solid State Physics, Freiburg, Germany, [2]Fraunhofer Institute for Microstructure of Materials and System, Halle, Germany

16:40 Study of Trapping Mechanisms Affecting AlGaN/GaN HEMTs adopting AlGaN Back- Barriers with Different Aluminum Concentrations
Andrea Carlotto, Fabiana Rampazzo, Marco Saro, Francesco De Pieri, Manuel Fregolent, Carlo De Santi, Gaudenzio Meneghesso, Matteo Meneghini, Enrico Zanoni
University of Padova, Italy

17:00 Nonlinear modelling of AlN/GaN HEMT accounting for Self-biasing effect during RF step stress: analysis and Hard-SOA
Nasri Said[1], Damien Saugnon[2], Kathia Harrouche[3], Farid Medjdoub[3], Nathalie Labat[4], Nathalie Malbert[4], Jean Guy Tartarin[2]
[1]IMS Bordeaux - LAAS Toulouse, France, [2]LAAS Toulouse, France, [3]IEMN Lille, France, [4]IMS Bordeaux, France

17:20 DC and RF aging test of AlGaN/GaN HEMT technology on SiC substrate
Thomas Pallaro[1], Tristan Dubois[1], Magali De Matos[1], Christophe Chang[2], Nathalie Labat[1], Benoit Lambert[2], Nathalie Malbert[1]
[1]University of Bordeaux, France, [2]United Monolithic Semiconductors, France

16:20 Workshop: Automotive Electronic, Driving into the Future
CHAIRS: *Rene Rongen[1], Ulrich Abelein[2], Francesco Leali[3]*
[1]NXP Semiconductors, Netherlands, [2]Infineon Technologies AG, Germany, [3]MUNER, Modena, Italy

Wednesday, September 25th

08:20 Session F2-1: GaN&SiC: reliability and testing methodologies (1)
CHAIR: *Matteo Meneghini*
University of Padova, Italy

08:20 **(Invited)** Advanced Methodology and Understanding of GaN Device Reliability
Manuel Stabentheiner
Infineon Technologies Austria AG, Austria

09:00 Gate voltage modulation for power cycling tests of SiC MOSFETs and its influence on temperature distribution
Lukas R. Farnbacher[1], Jürgen Leib[1], Fabian Dresel[1], Andreas Schletz[1], Bernd Eckardt[1], Jörg Schulze[2]
[1]Fraunhofer Institute IISB, Germany, [2]Friedrich-Alexander-University of Erlangen-Nürnberg, Germany

09:20 Test Methodology for Short-Circuit Assessment Applied to Power SiC MOSFETs
Joao Oliveira[1], Jean-Michel Reynes[1], Hervé Morel[2], Pascal Frey[1], Olivier Perrotin[3], Michel Piton[4], Fabio Coccetti[1]
[1]IRT Saint Exupéry, France, [2]INSA/Ampère, France, [3]Alter Technology, France, [4]Alstom, France

09:40 A Screening Test of GaN-HEMTs for Improvement of Breakdown Voltage Uniformity
Wataru Saito, Shin-Ichi Nishizawa
Kyushu University, Japan

10:00 Dependence between the drain current saturation and short-circuit robustness of p- GaN HEMTs
Mohamed Lemine Dedew[1], Stéphane Lefebvre[1], Tien Anh Nguyen[1], Thanh Long Le[2], Valeria Rustichelli[3], Joao Oliveira[3], Maroun Alam[3], Fabio Coccetti[3]
[1]SATIE, Cnam, CNRS, ENS Paris-Saclay, France, [2]SAFRAN TECH, France, [3]IRT Saint-Exupéry, France

09:00 Session BPA: Best papers ISTFA 2023 and IPFA 2024
CHAIRS: *Matteo Medda[1], Frank Altmann[2]*
[1]ST Microelectronics, Italy, [2]Fraunhofer, Germany

09:00 **(ISTFA 2023 Best Paper)** Finite Element Analysis (FEA) and Fractography: Complementary Methods in Understanding the Factors Resulting to Hairline Die Crack on Chip-On-Lead (COL) Devices
Melanie S. Cajita
Analog Devices, Inc., Philippines

09:20 **(IPFA 2024 Best Paper)** Reliability of Reconfigurable Field Effect Transistors: Early Analysis of Bias Temperature Instability
Giulio Galderisi
NaMLab GmbH, Germany

09:40 Session C: Progress in Failure Analysis: Defect detection and Analysis
CHAIRS: *Matteo Medda[1], Frank Altmann[2]*
[1]ST Microelectronics, Italy, [2]Fraunhofer, Germany

09:40 **(Invited)** Physical Assurance for Advanced Packaging
Navid Asadi[1]
[1]University of Florida, United States

10:40 Localization enhancement in quantitative thermal lock-in analysis using spatial phase evaluation
Sebastian Brand[1], *Michael Kögel*[1], *Christian Grosse*[1], *Frank Altmann*[1], *Hemachandar Tanukonda Devarajulu*[2], *Francisco M Benito*[2], *Deepak Goyal*[2], *Mario Pacheco*[2]
[1]Fraunhofer IMWS, Germany, [2]Intel Corporation Inc., United States

11:00 Fast high-resolution X-ray nano tomography for failure analysis in advanced packaging
Till Dreier, *Daniel Nilsson*, *Julius Hållstedt*
Excillum AB, Sweden

11:20 Failure Analysis of Gold-plated Fuzz Button Contacts in Elevated Temperature
Lei Zhang[1], *Shujuan Wang*[2], *Xueyong Chen*[3], *Jianshe Guo*[3], *Le Xu*[2], *Sanqiang Ling*[3], *Xiaojuan Zhang*[3]
[1]Harbin Institute of Technology, China Aviation Optical-Electrical Technology Co., Ltd., China, [2]Harbin Institute of Technology, China, [3]China Aviation Optical-Electrical Technology Co., Ltd., China

11:40 Improved 2D charge carrier quantification workflow for scanning spreading resistance microscopy
Thomas Adlmaier[1], *Stefan Doering*[1], *Boris Binder*[1], *Daniel K. Simon*[1], *Lukas M. Eng*[2], *Thomas Mikolajick*[3]
[1]Infineon Technologies Dresden GmbH, Germany, [2]Institute of Applied Physics, University of Technology Dresden, Germany, [3]University of Technology Dresden, Germany

10:40 Session F2-2: GaN&SiC: reliability and testing methodologies (2)
CHAIR: *Matteo Meneghini*
University of Padova, Italy

10:40 Analyzing the role of hole injection on the short circuit performance of p-GaN gate power HEMTs
Dominik Wieland[1], *Boris Butej*[2], *Manuel Stabentheiner*[1], *Christian Koller*[3], *Dionyz Pogany*[4], *Clemens Ostermaier*[3]
[1]TU Vienna, Infineon Technologies Austria AG,[2]TU Vienna, KAI, Austria, [3]Infineon Technologies Austria AG, [4]TU Vienna, Austria

11:00 Advanced Power Cycling Test Strategies on Discrete SiC MOSFETs in Different Operating Modes and the Impact on Life-time
Lukas Hein, *Patrick Heimler*, *Tobias Lentzsch*, *Josef Lutz*, *Thomas Basler*
Chemnitz University of Technology, Germany

11:20 Gate lifetime investigation at low temperature for p-GaN HEMT
Maroun Alam[1], *Valeria Rustichelli*[1], *Moustafa Zerarka*[1], *Christophe Banc*[2], *Jean-Francois Pieprzyk*[3], *Olivier Perrotin*[4], *Romain Ceccarelli*[4], *David Tremouilles*[5], *Mohamed Matmat*[1], *Fabio Coccetti*[1]
[1]IRT Saint Exupéry, Toulouse, France, [2]Safran Electronics & Defense, France, [3]STMicroelectronics, Toulouse, France, [4]Alter Technology, Toulouse, France, [5]LAAS-CNRS, Université de Toulouse, CNRS, Toulouse, France

11:40 Reliability of Discrete SiC MOSFETs under Temperature-Shock and Power Cycling Tests
Patrick Heimler, *Sandro Richter*, *Josef Lutz*, *Thomas Basler*
University of Chemnitz, Germany

12:00-14:00 Poster Session 2
CHAIR: *Giovanna Mura*
University of Cagliari, Italy

Spacecraft Sensor Reliability Improvement Based On Temporal Digital Twin Model
Yingqi Wang, *Yuchen Song*, *Runze Yu*, *Shengwei Meng*, *Yu Peng*, *Datong Liu*
Harbin Institute of Technology, China

A Floquet Theory-Based Stability Analysis Method for PV-Storage Independent DC Microgrid
Hong Li, *Kuang Zhang*, *Jinchang Pan*, *Mingbo Wei* ,*Yuanye Lu*
School of Electrical Engineering, Beijing Jiaotong University, Beijing, China

Machine learning-based surrogate models for finned heatsink optimization
Ziheng Wang, *Yi Zhang*, *Huai Wang*
Aalborg University, Denmark

Electronics authentication using electrical measurements and machine learning
Simone Carta[1], *Alessandro Urru*[2], *Michela Musa*[2], *Pietro Andronico*[2], *Giovanna Mura*[1]
[1]University of Cagliari, Italy, [2]Nurjana Technologies srl, Italy

Charging effects in alumina layers deposited with different precursors for microelectronic applications
Vladimir Kolkovsky, *Ronald Stübner*
Fraunhofer IPMS, Germany

Enhancing AC Degradation Modeling by Considering the Degradation Profile in SiON pMOSFETs
Yujin Kim, *Yeohyeok Yun*
School of Electrical, Electronics and Communication Engineering, KOREATECH, South Korea

The effects of NBT stressing on later operation of power VDMOS transistors under normal conditions
Sandra Veljković[1], Nikola Mitrović[1], Vojkan Davidović[1], Albena Paskaleva[2], Dencho Spassov[2], Igor Jovanović[1], Emilija Živanović[1], Goran Ristić[1], Danijel Danković[1]
[1]University of Nis, Serbia, [2]Bulgarian Academy of Sciences, Sofia, Bulgaria

Sorption getter characterization under wafer-level packaging (WLP) conditions
Hélène Duchemin, David Bouchu
Univ. Grenoble Alpes, France

Fast Reverse Engineering of Chips using Lasers, Focused Ion Beams, and Confocal and Scanning Electron Microscopy
Matthew Maniscalco, Hongbin Choi, Adrian Phoulady, Alexander Blagojevic, Toni Moore, Mohammad Taghi Mohammadi Anaei, Parisa Mahyari, Nicholas May, Sina Shahbazmohamadi, Pouya Tavousi
UConn, United States

Solid failure analysis flow for the detection of the leakage current in MEMS gyroscope resonant system
Domenico De Rosa
STMicroelectronics, Italy

GaN defect detection and analysis using electrical probing, EBAC, EBIC and EBIRCH
Andreas Rummel[1], Andrew Smith[1], Greg Johnson[2], Heiko Stegmann[3]
[1]Kleindiek Nanotechnik GmbH, Germany, [2]ZEISS Research Microscopy Solutions, United States, [3]Carl Zeiss Microscopy GmbH, Germany

Failure investigation on an embedded Schottky Barrier Diode due to an inhomogeneous silicide formation
Francis Nikolai Lupena[1], Timo Mohamed El Khawaga
Renesas Design Germany GmbH, Germany

Power devices Failure Analysis Use Cases Using High voltage OBIRCh and EMMI workflows
Elisa Vitanza[1], Chiara Realmuto[1], Antoine Reverdy[2], Paolo Dalla Ricca[3]
[1]ST Microelectronics Catania, Italy, [2]Sector technologies, France, [3]ThermoFisher Scientific, United States

A Submodule Capacitor Degradation Balancing Control with Capacitor Parameter Monitoring of a Modular Multilevel Converter for a Battery Energy Storage System
Takumi Yasuda[1], Kazunori Hasegawa[2], Jun-Ichi Itoh[3]
[1]Mitsubishi Electric, Japan, [2]Kyushu Institute of Technology, Japan, [3]Nagaoka University of Technology, Japan

Assembly reliability of ceramic small outline packaged devices
Wenyan Wang
China Academy of Space Technology, China

FEM-based development of novel 3D-printable plastic direct coolers for power semiconductor modules
Nicola Delmonte, Davide Spaggiari, Corrado Sciancalepore, Roberto Menozzi, Paolo Cova
University of Parma, Italy

System in package: Advanced FA Techniques to Minimize Analysis Time and Cost
Katalin Szász, Denise Luca
Renesas Electronics, Germany

Evaluation with FEM Analysis of peak case non- rupture current for power devices working at very high current
Davide Spaggiari[1], Paolo Cova[1], Federico Portesine[2], Marco Aschero[2], Nicola Delmonte[1]
[1]University of Parma, Italy, [2]Poseico S.p.A., Genova, Italy

Microstructure-based fatigue analysis of SiC power module with sintered silver die attach
Zhihao Guo[1], Shuibao Liang[1], Saran Ramachandran[2], Han Jiang[3], Yaohua Xu[3], Zhihong Zhong[1]
[1]Hefei University of Technology, China, [2]University of Strathclyde, UK, [3]Anhui University, China

Understanding improved pitting corrosion resistance under high temperature application leading to a newly developed palladium coated copper wire
Noritoshi Araki[1], Motoki Eto[1], Teruo Haibara[1], Takashi Yamada[1], Robert Klengel[2], Sandy Klengel[2]
[1]Nippon Micrometal Corporation NMC, Japan
[2]Fraunhofer IMWS, Germany

Impact of Device Encapsulation on the Time- Dependent Dielectric Breakdown in Polymeric Dielectrics for Galvanic Isolation
Matteo Greatti[1], Jurij Lorenzo Mazzola[1], Lorenzo Cantù[1], Christian Monzio Compagnoni[1], Alessandro Spinelli[1], Dario Paci[2], Fabrizio Speroni[2], Michele Lauria[2], Vincenzo Marano[2], Gerardo Malavena[1]
[1]Politecnico di Milano, Italy, [2]STMicroelectronics, Italy

Solder Stop as a Reliable Insulation Layer on Printed Circuit Boards – Different Layouts and Materials under Humidity and High Voltage
Michael Vogt[1], Alexander Brunko[1], Markus Meier[2], Helmut Schweigart[2], Lothar Henneken[3], Michael Schleicher[4], Detlev Schucht[5], Nando Kaminski[1]
[1]University of Bremen, Germany, [2]Zestron Europe, Dr. O.K. Wack Chemie GmbH, Germany, [3]Robert Bosch GmbH, Germany, [4]Semikron-Danfoss, Semikron Elektronik GmbH & Co. KG, Germany, [5]Lackwerke Peters GmbH & Co. KG, Germany

The Effect of Trench Depth on Single-Event Burnout Hardening of Split-Gate-Trench MOSFET
Shuo Liu, Fengkai Liu, Zhongli Liu, Lei Wu, Jianqun Yang, Xingji Li
Harbin Institute of Technology, China

Thermal Impedance and Local Thermal Runaway during Surge Events in Power Rectifiers
Ole Bergmann[1], Tim Böttcher[2], Hoan Vu[2], Hoc Khiem Trieu[3]
[1]Delft University of Technology, Netherlands, [2]Nexperia Germany GmbH, Germany, [3]Hamburg University of Technology, Germany

Separate Investigation of Performance Degradation for the Si and GaN parts in Cascode GaN devices under Repetitive Short Circuits
Zhebie Lu, Francesco Iannuzzo
Aalborg University, Denmark

Investigation of Trade-off between Switching Loss and Gate Overshoot in SiC MOSFETs by Driving Waveform Modification
Bang-Ren Chen[1], Cheng Sung[1], Yu-Sheng Hsiao[1], Wei-Chen Yu Yu[2], Yi-Jun Dong[1], Wei-Cheng Lin[1], Surya Elangovan[2], Yi-Kai Hsiao[2], Hao-Chung Kuo[2], Chang-Ching Tu[3], Tian-Li Wu[1]
[1]National Yang Ming Chiao Tung University, Taiwan, [2]Hon Hai Research Institute, Taiwan, [3]National Central University, Taiwan

Power Cycling Results of Cascode GaN Devices – Separate Analysis of Performance Degradation for Si/GaN parts and Lifetime Model
Zhebie Lu, Francesco Iannuzzo
Aalborg University, Denmark

Numerical simulation of current uniformity in Ga2O3 planar diodes and its effect on temperature field and device reliability
Lorenzo Perini, Payam Rajabi Kalvani, Antonella Parisini, Roberto Fornari, Giovanna Sozzi
University of Parma, Italy

Aging Effects on Short-Circuit Peak Current Through Gate-oxide Degradation in SiC MOSFET
Farzad Hosseinabadi, Sajib Chakraborty, Omar Hegazy
Vrije Universiteit Brussel, Belgium

Hail damage investigation in heterojunction silicon photovoltaic modules: a real word case study
Marco Nicoletto[1], Davide Panizzon[1], Alessandro Caria[1], Nicola Trivellin[1], Carlo De Santi[2], Matteo Buffolo[1], Gaudenzio Meneghesso[1], Enrico Zanoni[1], Matteo Meneghini[1]
[1]University of Padova, Italy, [2]University of Padova & National Interuniversity Consortium for Nanoelectronics, Italy

A Geometry-Scalable Electrothermal Compact Circuit Model of SiC MPS Diodes Accounting for the Snapback Mechanism: Application to Current Surge Events
Alessandro Borghese, Vincenzo Terracciano, Marco Boccarossa, Andrea Irace, Vincenzo D'Alessandro
University of Naples Federico II, Italy

Long-term (8000 h) reliability and failures of high- power LEDs for outdoor lighting stressed at high ambient temperatures
Alessandro Caria[1], Riccardo Fraccaroli[1], Giulia Pierobon[1], Thomas Castellaro[1], Ambrogio Huang[1], Julien Magnien[2], Joerdis Rosc[2], Gyula Lipák[3], Gusztáv Hantos[3], János Hegedüs[3], Carlo De Santi[1], Matteo Buffolo[1], Nicola Trivellin[1], Enrico Zanoni[1], András Poppe[3], Gaudenzio Meneghesso[1], Matteo Meneghini[1]
[1]University of Padova, Italy, [2]Materials Center Leoben Forschung GmbH, Austria, [3]Budapest University of Technology and Economics, Hungary

Selective Hardening of RISCV Soft-Processors for Space Applications
Giorgio Cora, Corrado De Sio, Sarah Azimi, Luca Sterpone
Politecnico di Torino, Italy

Impact of Constant and Pulsed Active Balancing Current Patterns on the Aging of Lithium-ion Batteries
Muhammad Aitezaz Hussain, Alessandro Soldati, Giovanna Sozzi
[1]University of Parma, Italy

Characterization and Analysis of Single-Event Effects in 16 nm FinFET FPGAs Based on On-Orbit Data
Zhi Chao Wei[1,2], Ran Zheng[2], Yi Sun[1], Hongwei Zhang[1], Bo Mei[1], Yinghui Liu[1]
[1]China Academy of Space Technology, China, [2]Northwestern Polytechnical University

Empirical reliability model of GaN HEMT devices
Tsuriel Avraham, Joseph Bernstein
Ariel University, Israel

Reliability Assessment of SiC Power MOSFETs in Dynamic Reverse Bias Test
Alessandro Sitta, Giuseppe Mauromicale, Michele Fiore, Michele Calabretta
STMicroelectronics, Italy

Mechanical Characterization of Silicon Carbide- Coated Carbon Nanotube Composites via High-Temperature Compressive Testing for Hyper- interconnect Applications
Leiming Du[1], Gerald Schaffar[2], Jiarui Mo[1], Verena Maier-Kiener[2], Daniel Kiener[2], Guoqi Zhang[1]
[1]Delft University of Technology, Netherlands, [2]Montanuniversität Leoben, Austria

Degradation of SiC-MOSFETs Utilized in Bidirectional Switch for Grid Applications Under Over Current Stress
Tomoyuki Mannen
University of Tsukuba, Japan

Thermal Performance Comparison of Wide Bandgap Power Modules by Simulation
Guesuk Lee, Jemin Kim, Byongjin Ma
Korea Electronics Technology Institute, South Korea

Peak detection for current balancing of parallel- connected SiC power devices using PCB sensors
Ravi Nath Tripathi, Ichiro Omura
Kyushu Institute of Technology, Japan

ESD Human Body Model step stress distributions of GaN HEMTs and the correlation with one level test results
Roelof van der Berg[1], Edwin Jellema[2]
[1]Ampleon, Netherlands, [2]Eurofins | Maser, Netherlands

Improving Large-Area Sintering Reliability of Power Module Systems Using Copper Paste/Film
Ke Li[1], Xiaochun Lv[1,2], Jun You[1], Minghao Zhou[1], William Cai[1], Jianbo Xin[1], Jicun Lu[2], Yang Liu[3]
[1]Harbin University of Science and Technology, China, [2]Harbin Welding Institute Limited Company, Harbin, China, [3]Zhuhai Fudan Innovation Research Institute, China

Development of Life Prediction Model based on Physics-of-Failure for Negative Temperature Coefficient Thermistor
Hyoungseuk Choi
Korea Institute of Ceramic Engineering and Technology, South Korea

Synergistic Effect of Total Ionizing Dose and Electromagnetic Interference in SRAM using 22nm FDSOI technology
Yinyin Shang[1], Chenhe Gao[1], Xing Zhao[1], Binhong Li[1], Jianzhong Li[2], Jianfei Wu[3], Hongli Zhang[3], Yang Li[3], Jun Luo[1], Tianchun Ye[1]
[1]Korea Institute of Microelectronics of the Chinese Academy of Sciences, China, [2]Guangdong Greater Bay Area Institute of Integrated Circuit and System, China, [3]Tianjin Advanced Technology Institutes, China

14:00 Session F2-3: GaN&SiC: reliability and testing methodologies (3)
CHAIR: *Matteo Meneghini*
University of Padova, Italy

14:00 The impact of mold compound on power cycling capability of SiC MOSFETs in double sided cooled modules
Tobias Lentzsch, Josef Lutz, Thomas Basler
University of Chemnitz, Germany

14:20 Toward understanding the impacts of dynamic Ron on the efficiency in GaN-based AC-DC flyback converter
Chih-Yao Chang[1], Hsing-Hua Hsieh[1], Huang-Pin Hsu[1], Cheng-Tsung Ho[1], Tsung-Hsiu Wu[1], Han-Wei Chen[1], Ming-Chang Tsou[1], Chih-Wen Hsiung[1], Ming-Nan Chuang[1], Tian-Li Wu[2]
[1]Leadtrend Technology Corporation, Taiwan, [2]National Yang Ming Chiao Tung University, Taiwan

14:40 OFF-state Breakdown and Threshold Voltage Stability of Vertical GaN-on-Si Trench MOSFETs
Manuel Fregolent[1], Francesco Bergamin[1], Davide Favero[1], Carlo De Santi[1], Christian Huber[2], Gaudenzio Meneghesso[1], Enrico Zanoni[1], Matteo Meneghini[1]
[1]University of Padova & National Interuniversity Consortium for Nanoelectronics, Italy, [2]Robert Bosch GmbH, Renningen, Germany

15:00 Improved CV characterization technique for interface state evaluation in Si3N4/n-GaN MIS Capacitors
Anton Marco Hofer[1], Christian Koller[2], Nicola Modolo[2], Dionyz Pogany[3], Clemens Ostermaier[2]
[1]TU Wien, Infineon Technologies Austria AG, Austria, [2]Infineon Technologies Austria AG, Austria, [3]TU Wien, Austria

14:00 Workshop: Hardware Security Meets Failure Analysis
CHAIRS: *Navid Asadi[1], Frank Altmann[2]*
[1]University of Florida, United States, [2]Fraunhofer, Germany

15:40 Session F2-4: GaN&SiC: discrete device stability and reliability
CHAIR: *Matteo Meneghini*
University of Padova, Italy

15:40 Evidence for double degradation regime in off-state stressed 100 V GaN transistors: from dielectric failure to subthreshold current increase
Riccardo Fraccaroli[1], Manuel Fregolent[1], Mirco Boito[1], Carlo De Santi[1], Eleonora Canato[2], Isabella Rossetto[2], Maria Eloisa Castagna[3], Ferdinando Iucolano[3], Cristina Miccoli[3], Alfio Russo[3], Giansalvo Pizzo[4], Gaudenzio Meneghesso[1], Enrico Zanoni[1], Matteo Meneghini[1]
[1]University of Padova, Italy, [2]STMicroelectronics, Agrate Brianza, Italy, [3]STMicroelectronics, Catania, Italy, [4]STMicroelectronics, Cornaredo, Italy

16:00 Interface-related VTH Shift of SiC MOSFETs during Constant Current Stress extracted from Charge Pumping measurements
Alberto Marcuzzi[1], Marina Avramenko[2], Carlo De Santi[1], Peter Moens[2], Gaudenzio Meneghesso[1], Enrico Zanoni[1], Matteo Meneghini[1]
[1]University of Padova, Italy, [2]Onsemi, Belgium

16:20 Threshold Voltage Hysteresis Investigation of SiC MOSFETs with Different Structures under Various Measurement Conditions
Dong Xie, Patrick Heimler Roman Boldyrjew-Mast, Mohamed Alaluss, Sven Thiele, Josef Lutz, Thomas Basler
University of Chemnitz, Germany

16:40 Ultra-Fast recovery transients in GaN MIS- ĒHEMT submitted to OFF State stress
Alberto Cavaliere[1], Nicola Modolo[2], Carlo De Santi[1], Gaudenzio Meneghesso[1], Enrico Zanoni[1], Matteo Meneghini
[1]University of Padova, Italy, [2]Infineon Technologies, Villach, Austria

Thursday, September 26th

08:20 Session E-1: Reliability of packages for power devices and sensors
CHAIR: *Nicola Delmonte*
University of Parma, Italy

08:20 **(Invited)** Virtual prototyping in power electronics: the role of simulation in developing reliable products
Mirko Bernardoni[1]
[1]Infineon Technologies Austria, Automotive Product Development, Austria

09:00 Numerical study of critical filler particle to chip interaction on an automotive Hall sensor
Falk Naumann[1], Michél Simon-Najasek[1], Bernd Wiesenberger[2], Achim Lindner[2], Frank Altmann[1]
[1]Fraunhofer Institute IMWS, Germany, [2]TDK-Micronas GmbH, Germany

09:20 Risk of CuxO phase penetration between the Ag plating layer and Cu during high- temperature reliability testing of interfaces bonded to cold sintered Ag nano-porous sheets on direct Ag-plated Cu substrates
Yehri Kim[1], Eunjin Jo[1], Byeong Kwon Ju[2],Yoongul Lee[3], Jaeup Kim[3], Kijoon Ahn[3], Seungjun Noh[4], Dongjin Kim[1]
[1]Korea Institute of Industrial Technology (KITECH), South Korea, [2]Korea University, South Korea, [3]SP semiconductor, South Korea, [4]Hyundai Mobis, Co., Ltd., South Korea

09:40 Evaluation and thermal ageing of power semiconductor die attachment based on porous film electrodeposition
Goulven Janod[1], Lucas Chachay[1], Jonathan Schoenleber[2], Yvan Avenas[1], Didier Bouvard[1], Remi Daudin[1], Jean-Michel Missiaen[1], Marie-Pierre Gigandet[2], Jean-Yves Hihn[1], Rabih Khazaka[3]
[1]Grenoble-INP/UGA, France, [2]UTINAM, France, [3]SAFRAN-Tech, France

10:00 Enhancing Long-Term Thermal Reliability of Sintered Joints through the Use of Silver-Coated Copper Particles
Dajung Kim[1], Mi So Won[1], Hyunseung Yang[1], Chulmin Oh[1]
[1]Korea Electronics Technology Institute (KETI), South Korea

08:20 Session G: Photonics reliability
CHAIRS: *Matteo Buffolo[1], Yannick Deshayes[2]*
[1]University of Padova, Italy, [2]IMS Laboratory, France

08:20 **(Invited)** LED Reliability for Lighting Applications and Beyond
Grigory Onushkin
Signify Research, Eindhoven, Netherlands

09:00 Changes in the extraction and collection efficiency of GaN-based MQW solar cells under optical step-stress
Marco Nicoletto, Alessandro Caria, Nicola Roccato, Carlo De Santi, Matteo Buffolo, Gaudenzio Meneghesso, Enrico Zanoni, Matteo Meneghini
University of Padova, Italy

09:20 Evidence for Optically-Induced Degradation in CIGS Solar Cells
Claudia Casu[1], Matteo Buffolo[1], Alessandro Caria[1], Carlo De Santi[2] Nicola Trivellin[1], Stefano Rampino[3], Matteo Bronzoni[3], Massimo Mazzer[3], Gaudenzio Meneghesso[1], Enrico Zanoni[2] Matteo Meneghini[1]
[1]University of Padova, Italy, [2]University of Padova & National Interuniversity Consortium for Nanoelectronics, Italy, [3]CNR-IMEM Parma, Italy

09:40 About the influence of temperature operation and packaging stress on the threshold for catastrophic optical damage in laser diodes
Jorge Souto, José Luis Pura, Julian Anaya, Juan Jimenez
University of Valladolid, Spain

10:00 Degradation Modeling of InGaAs/InP Avalanche Photodiodes using Calibrated Technology Computer-aided Design
Heewon Bang[1], Yunseok Han[1], Sunho Kim[2], Ilgu Yun[1]
[1]Yonsei University, South Korea, [2]Wooriro Co., South Korea

10:40 Session E-2: Bond wire reliability

CHAIRS: *Olaf Wittler[1], René Rongen[2]*

[1]Fraunhofer, Germany, [2]NXP Semiconductors, Netherlands

10:40 Wire bonding failure characterization of an IGBT based power module through impedance analysis

Paul-Etienne Vidal[1], Stéphane Baffreau[1], Guillaume Viné[1], Anusha Gopishetti[2], Than-Le Long[3]

[1]Université de Technologie de Tarbes, Toulouse University, France, [2]Deep Concept, France, [3]Safran, France

11:00 Degradation mode analysis of Cu bond wires on Cu plated SiC power semiconductors stressed by active power cycling

Rasched Sankari[1], Ulrich Keßler[2], Martin Rittner[2], Borja Kilian[2], Youssef Maniar[2], Olaf Wittler[3], Martin Schneider-Ramelow[4]

[1]Robert Bosch GmbH, Germany - Technical University Berlin, Germany, [2]Robert Bosch GmbH, Germany, [3]Fraunhofer-Institute, Germany, [4]Technical University Berlin, Germany - Fraunhofer-Institute, Germany

11:20 Thermal ageing monitoring in Cu-Al intermetallic joints through electrical resistance drift: comparative study of lifetime potential in pure and alloyed copper wires

Roberta Carluccio[1], Alberto Mancaleoni[1], Gabriele Losacco[1], Riccardo Villa[1], Andrea Serafini[1], Lucrezia Guarino[1], David Dellasega[2]

[1]STMicroelectronics, Italy, [2]Politecnico di Milano, Italy

11:40 Lifetime model for wire bond degradation in power semiconductors based on accelerated mechanical testing and power cycling

Bernhard Czerny[1], Golta Khatibi[2], He Du[3], Francesco Iannuzzo[4]

[1]University of Applied Sciences Burgenland, Austria, [2]TU Wien, Austria, [3]Kyushu Institute of Technology, Japan, [4]Aalborg University, Denmark

12:00 Crack propagation in ultrasonic-bonded copper wires investigated by power cycling and accelerated mechanical fatigue interconnection test methods

Liz Karanja[1], Pierre-Yves Pichon[2], Marc Legros[1]

[1]CEMES-CNRS, France, [2]Mitsubishi Electric R&D Centre Europe, France

10:40 Session I: Extreme environments and Radiation

CHAIRS: *Marta Bagatin[1], Francesco Pintacuda[2]*

[1]University of Padova, Italy, [2]STMicroelectronics, Italy

10:40 **(Invited)** Non-volatile Memories for the Space Environment: Ionizing Radiation Effects

Simone Gerardin

University of Padova, Italy

11:20 C-SMART: A preprocessor for neural network performance and reliability under radiation

Anuj Justus Rajappa[1], Philippe Reiter[1], Paolo Rech[2], Siegfried Mercelis[1], Jeroen Famaey[1]

[1]Imec- IDLab, Universiteit Antwerpen, Belgium, [2]University of Trento, Italy

11:40 The behavior of 350V GaN HEMTs during heavy ion irradiations

Francesco Velardi[1], Giovanni Canale Parola[1], Simone Palazzo[1], Emanuele Martano[1], Annunziata Sanseverino[1], Luca Silvestrin[2], Carmine Abbate[3], Giovanni Busatto[1]

[1]University of Cassino, Italy, [2]University of Padova, Italy, [3]DAC Engineering and Research srl, Italy

12:00 Optimization of the drain-side configuration in ESD-protection SCR-LDMOS for high holding- voltage applications

Laura Zunarelli[1], Simone Rotorato[1], Elena Gnani[1], Susanna Reggiani[1], Raj Sankaralingam[2], Mariano Dissegna[2], Gianluca Boselli[2]

[1]University of Bologna, Italy, [2]University Texas Instruments, United States

12:20 Closing Session

CHAIR: *Paolo Cova*

University of Parma, Italy

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Issues of electronic devices in hostile environment

A. Andreani[a], M. Lazzaroni[a,b], A. Riminucci[a],
D. Santoro[b,c], V. Trabattoni[a,b], A. Zani[b]

[a] *Department of Physics, Università degli Studi di Milano, Milano, Italy*
[b] *Sezione di Milano, INFN, Milano, Italy*
[c] *Department of Engineering and Architecture, Università degli Studi di Parma, Parma, Italy*

Abstract

The operation of electronic devices in hostile environment has been investigated. Issues due to Extremely Low Temperature (i.e., Cryogenic temperature) and operation in cryogenics liquids (liquid argon, LAr, or liquid nitrogen, LN_2) are presented and discussed. Both passive and active electronics components have been considered and their troubles at cryogenics temperature have been presented.

1. Introduction

In the last few years, the interest in characterizing electronic devices operating in hostile environments has been growing due to the progress achieved in applied particle physics, involving the presence of cryogenic scintillators and cryogenic setups to optimize detection rates. Operation in cryogenic environment aims at improving the intrinsic efficiency of detectors used in astrophysics, particle physics and nuclear physics: in these conditions, it is possible to reduce signal-to-noise ratios (SNR), but usually one must minimize the mass of power electronics and front-end readout circuits, aiming at minimum power dissipation required.

A new challenge has been presented for modern liquid argon-based neutrino experiments (LAr-TPCs) which exploit photon detectors (PhotoMultiplier Tubes, PMTs, and Silicon PhotoMultipliers, SiPMs) immersed in liquid argon (LAr), acting as scintillating medium. This is the case for experiments like ICARUS, MicroBooNE, and more recently DUNE and its Prototypes at CERN. In these experiments, electronics must survive at 87 K, for extended periods of time (data-taking spans many years), and it must have a minimal power dissipation, as even a small amount of bubbling in the liquid can disrupt the operation of the detectors. Furthermore, recently R&D led to the idea of placing photon detectors on (very) high voltage surfaces (up to -300 kV, in DUNE), thus making it impossible to feed bias to the devices, and extract signals, via standard copper cables. For this reason, power through optical fibers, implementing a Power over Fiber (PoF) technology at cryogenic temperatures, can be proposed and are investigated.

The low temperature, combined with the high voltage environment, requires an accurate preliminary study of the commercial electronic devices and their performances in such hostile set-up. Although some electronic components can operate at cryogenic temperature, every commercial technology must be tested and characterized beforehand, since the lack of suitable models to simulate the circuit behaviour makes the design very difficult, as performance estimated with commercial tools is unreliable and, in any case, limited to relatively high temperatures (i.e., 50 °C). Therefore, the behaviour of electronics components at cryogenic temperature is still open to investigation.

It is very important to underline that the focus should be pointed on the Dependability and not restricted to reliability (which is, obviously, the most important aspect). Dependability means RAMS: Reliability, Availability, Maintainability and, Safety. In high complexity experiments the Reliability is of paramount importance because maintenance can be operated only in well-defined periods, typically named shutdown period or shutdown time. In the case of LAr-based neutrino detectors, the condition is even more restrictive, as it will not be possible to intervene on the electronics during data taking. A failure

occurred during the operation (data taking) cannot be addressed, therefore component mortality and ageing issues must be addressed beforehand with intensive characterization campaigns and repeated thermal cycling.

Safety, not further developed in this paper, is also a very important aspect of the dependability.

The presence of radiation or magnetic fields, which also significantly affect electronics operations, are not of concern for most LAr-based neutrino experiments of the present generation, but dedicated studies should be performed, in view of next-generation programs.

In this manuscript, some considerations about the reliability of the devices (but also of the electronic systems) will be discussed taking into account opeations at Extremely Low Temperature (i.e., Cryogenic temperature).

The paper is organized in the following manner. After some preliminary considerations in Section 2, Section 3 of the manuscript is devoted to passive electronic devices whereas in the following Section 4 active components have been taken into account. Conclusions are, finally, given in Section 5.

2. Some preliminary considerations

In the late 30 years, many studies were made to characterize the behaviour of electronic components in hostile environments. In particularly, here we focus on the use of electronics at cryogenic temperature (below -75 °C) for different applications, such as modern detectors in applied particle physics.

In the following, the discussion is confined components characterization. However, it should be noted that issues arise also at interfaces, e.g. between components and Printed Circuit Boards (PCBs). This is particularly true for repeated temperature cycles: PCBs could undergo tiny deformations, leading to tension on the soldering, ruptures, unsteady contacts. These issues may arise both on the leads of passive components and on the pins of integrated circuits. The same issues may appear also on surface-mounted components.

3. Passive components

In this section, passive components such as resistors, inductors and capacitors were investigated and discussed.

3.1. Resistors

Resistors are passive two-terminal electrical components characterized by a resistance nominal value.

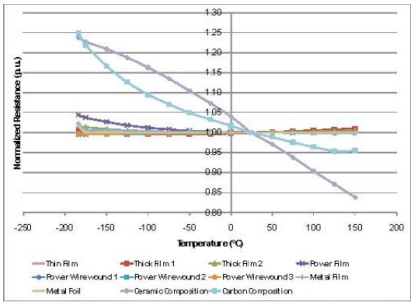


Fig. 1 Trend of resistance value, normalized to nominal value, as a function of temperature.

A primary categorization of resistors can be based on their assembly type. They can be either Pin Through Hole (PTH) or Surface Mount Device (SMD) resistors.

In literature, there are no studies exclusively dedicated to the behaviour of resistors at cryogenic temperatures. However, several papers that address this issue can be found for different applications. In general, resistor properties remain stable even at low temperatures (see Fig. 1). However, exceptions are observed for certain resistor types, specifically thick-film resistors, metal oxide resistors, and ceramic and carbon composition resistors. These particular devices exhibit a slight deviation in resistance values after undergoing a cooling cycle, rendering them less suitable for use in cryogenic conditions.

3.2. Capacitors

Capacitors are passive two-terminal electrical components enabling the accumulation of charges, making them valuable for energy storage within circuits. Capacitors are frequently employed as filters or for decoupling direct and alternating components of a signal, as they impede the passage of direct current. The capacitance value of a capacitor is influenced by the dielectric material used and its geometry. Similar to resistors, capacitors can also be categorized as SMD or PTH. Various types of capacitors, all Surface Mount Device, have been examined in the literature, in particular ceramic and polymer capacitors.

Capacitor characterization comes in different flavours: in some instances, measurements were conducted at well-defined temperatures, such as 300 K and 77 K, or at 300 K, 77 K, and 4K. In other cases, capacitance as a function of temperature was studied.

In all cases, measurements were performed at room temperature after cooling, to ensure survival after the cycle. The measurements were taken at various frequencies to analyse the behaviour of capacitance and current losses across different frequency ranges. Specifically, the frequencies investigated consistently

fell within the range of 50 Hz to 100 kHz.

These studies reveal that for certain capacitor types, including polymer capacitors (polypropylene, polyester, PPS, polycarbonate), NPO ceramic capacitors, and mica capacitors, the capacitance values remain relatively constant, with only small variations of 10% or less as detailed in the finale paper. Additionally, these capacitors exhibit low ohmic losses and low dissipation, which either remain constant or decrease as the temperature decreases.

In the only study carried out at temperatures below 77 K, polymer capacitors exhibited a decrease in capacitance values at 4 K, whereas the capacitance value for NPO capacitors remained approximately constant. On the other hand, various other ceramic capacitors display a stronger dependence on temperature, with variations exceeding 50% in capacitance values. Tantalum capacitors not only exhibit variations of 20% or more but also demonstrate a pronounced dependency on operating frequency.

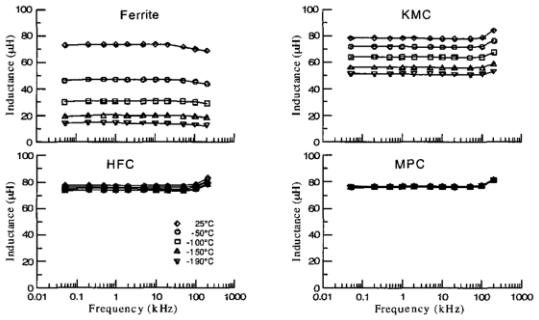
Capacitor selection therefore is fundamental and must match the range of cryogenic temperatures and required frequency at which power electronics and read-out circuits must operate during the experiment.

3.3. Inductors

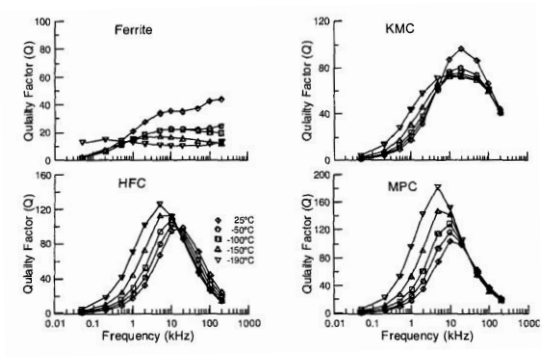
Inductors are passive two-terminal devices characterized by a high inductance value.
Inductors are often employed to store electrical energy through magnetic fields or as filters, given their high inductance that tends to obstruct the passage of signals at high frequencies. They are constructed as windings of conductive wires around ferromagnetic cores. The inductance value is contingent on the materials employed, the geometry and the number of turns in the winding around the core of the device itself.

Studies on inductors at cryogenic temperatures have primarily focused on investigating the structure of the magnetic core and the winding. A study conducted on copper wires discovered that as the temperature decreases, more windings are necessary to achieve the same inductance value. In contrast, other groups examined the windings' response while utilizing superconductors. Once again, tests are either carried out at fixed temperature values, or as a function of slowly varying temperature.

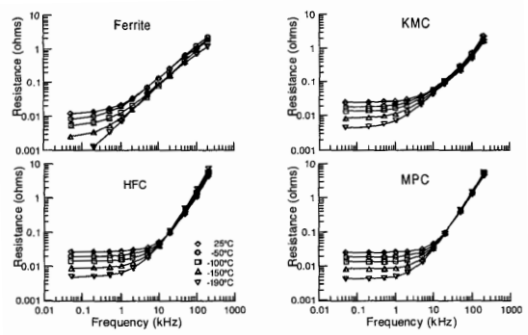
As a result, nanocrystalline materials stand out as the best choice for magnetic cores of inductors (see Fig. 3): these materials exhibit limited degradation in their characteristics at low temperatures compared to other materials, despite having the highest cost.



(a) Variation of inductance as a function of temperature and frequency.



(b) Variation of quality factor as a function of temperature and frequency.



(c) Variation of resistance as a function of temperature and frequency.

Fig. 2 Comparison of ferrite and powder cores.

On the other hand, the best compromise between performance and cost is achieved with ferrite cores.

4. Semiconductor devices

In general, research on semiconductors has revealed that they exhibit improved electronic, electrical, and thermal properties at lower temperatures, extending down to the temperature of liquid nitrogen. This improvement is attributed to increased carrier mobility and saturation rates, enabling higher

operating speeds. Lower temperatures also lead to significant enhancements in the thermal conductivity of device materials and substrates, simplifying thermal management and enhancing overall reliability. Additionally, at cryogenic temperatures, both conduction losses and switching losses of power devices decrease, leading to increased power conversion efficiency. A table summarising the behaviour of semiconductor devices at different temperatures will be added in the final paper.

4.1 Diodes

Diodes are non-linear passive components made from doped semiconductors, providing them with the capability to conduct current in only one direction. Operating with a threshold mechanism, diodes, to a first approximation, prevent current flow until the applied voltage at their ends surpasses a specific value. Once this threshold is exceeded, they can facilitate current flow without any restriction. This characteristic makes diodes ideal components for constructing rectifier circuits.

The study conducted on diodes examined how their characteristics, including junction voltage, breakdown voltage, and reverse current losses, change with temperature variations. Specifically, breakdown voltage and reverse current losses decrease with temperature, whereas junction voltage increases. All these observed phenomena can be attributed to the freezing effect of charges at low temperatures.

Germanium diodes exhibit favourable behaviour at cryogenic temperatures. A diode that enhanced its characteristics at low temperatures, specifically at 4 K has been developed. Studies were focused on Schottky diodes in GaAs. These diodes possess interesting characteristics such as a low threshold voltage, low resistance in the active region, and strong rectification performance. The study encompassed a temperature range from 20 K to 300 K.

4.2 Transistor

Transistors are three-pole electronic components, typically crafted from doped semiconductors. Their versatile structure, which can vary significantly based on construction methods, makes them capable of operating under different conditions, making them fundamental components for computational operations. Transistors play a crucial role in Resistor Transistor Logic (RTL) and are used for logic gates in digital electronics.

In particular, one study investigated MOS-FETs parameters between 300 and 77 K, focusing on: on-state resistance (R_{ON}), drain-source breakdown voltages (V_{dsmax}), and initial turn-on voltages through their integrated reverse diodes (V_{diode}).

It is apparent that R_{ON} exhibits a minimum which occurs when the maximum electron mobility coincides with the minimum freezing effect of the charge carriers. As for V_{dsmax} and V_{diode}, they demonstrate linear correlations with temperature, particularly with directly and inversely proportional trends, respectively.

An investigation was conducted on R_{ON} at a fixed temperature (77K) while varying the drain current (I_D). In this case as well, a minimum value is observed at high currents, attributed to internal heating of the transistor resulting from current flow.

These performance findings give rise to two fundamental boundary conditions: the practical operating voltage must be within the reduced V_{dsmax} at cryogenic temperature, and the use of power diodes is generally not recommended at cryogenic temperature. Furthermore, despite the observed increase in on-state resistance at temperatures below 130 K, the study of the relationship between R_{ON} and I_D suggests that MOS-FET transistors can be effectively utilized at low temperatures while enhancing their performance, especially for high-current applications.

Antimony-based High Electron Mobility Transistors (HEMTs) were also examined in literature, comparing their properties at room temperature and at 77 K.

Additionally, dedicated studies on HEMTs in GaN and MOS-FETs in SiC have been conducted, investigating the characteristics of these devices under varying temperature conditions.

In the final paper, the performances of semiconductor components in cryogenic environments will be deeply discussed.

4.3 Systems

Among the various systems examined, there are oscillator, Pulse Width Modulated controllers and DC- DC converters and so on. Due to space constrain, these aspects will be discussed in the finale paper.

5. Conclusions

The operation of electronic devices in hostile environment has been discussed in this manuscript highlighting how low temperature influences the behaviour of electronic devices.

References

References will be added in the final paper.