MIRELAI

MIcroelectronics RELiability driven by Artificial Intelligence

Issue 1, July 2024

DC NEWSLETTER

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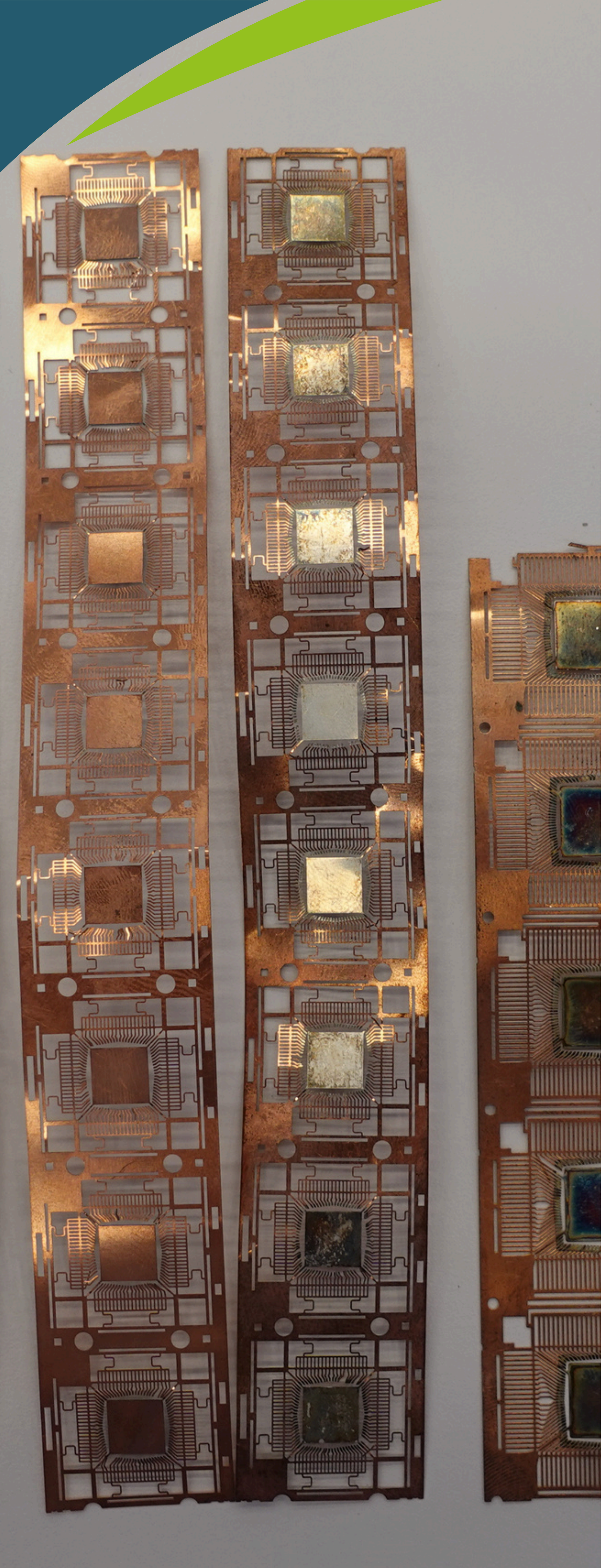

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We are thrilled to launch the first edition of our MIRELAI Newsletter, a special series designed to keep you informed about the work and collaborative efforts happening within the MIRELAI network. Our mission is to elevate the standards of microelectronics reliability through the innovative use of artificial intelligence, physics-based modelling, and multi-scale simulation techniques.

In this edition, we kick off with an insightful introduction to MIRELAI Here we eloquently discuss the critical need for advancements in microelectronics reliability, fuelled by both the demands of modern technology and the potential of AI integration.

Following this introduction, we highlight This newsletter organizing will dive into all the workshops. These workshops focus on microelectronics reliability, machine learning applications, and science communication, enhancing the training and development of doctoral candidates. Musadiq's dedication to these initiatives underscores the importance of collaborative learning and practical application in advancing microelectronics reliability.

Further, we feature insights into the enhancement of defect detection in power modules using AI-integrated lock-in thermography. Her findings, crucial for industrial applications, are showcased in this newsletter. Here we also presented the contribution of AI-driven research on optimising microelectronic package substrates. The collaboration with industry partners showcased here underlines the practical impact of AI in microelectronics.

Insights on working on probe card reliability using AI and machine learning models. This research, featured in this edition, focuses on employing advanced AI techniques to enhance design and testing processes, significantly cutting down on development time and costs.
Make sure to subscribe and join us on this transformative journey as we push the boundaries of technology and reliability in microelectronics.

Why MIRELAI?

Understanding the Quest for Raising Reliability Standards

TWO SECONDS! Within a mere two seconds, a modern hyper-car can reach speeds beyond the realm of any mammal to have ever existed. These mechanical beasts, often seen tearing down the glorious German Autobahn, exemplify the pinnacle of automotive engineering. Equipped with engines that outperform many conventional machines and bearing price tags akin to luxury real estate, these cars share a surprising commonality with everyday hatchbacks or family SUVs – i.e., being equipped with tens of thousands of microelectronic components.

Each component is uniquely built to serve a common purpose - to enhance the overall driving experience in every scenario imaginable. However, should even a single microelectronic component degrade before its rated life, the entire car may come to a halt. This a problem not exclusive to cars, but every electronic gadget or machine that functionally relies on microelectronic devices; be it the devil's calculator in every pocket to the 200 tonne aluminium shells cruising at 6-mile altitudes.

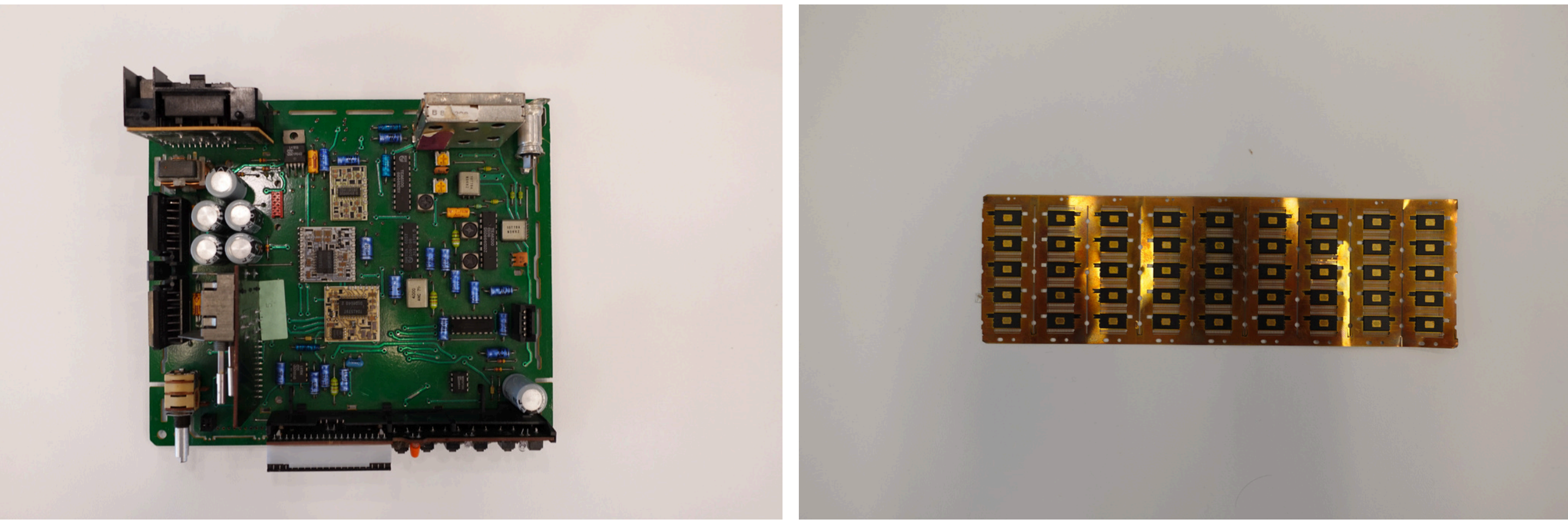

Figure 1. Examples of microelectronics components: Printed circuit board (left); Stack of IC packages (right)

Every component shall degrade, for none escapes the relentless march of time!

It then becomes imperative to precisely assess the lifespan of each critical microelectronic component installed and validate its survivability in operating conditions and beyond. Traditionally, this has been done by employing reliability standards and measures proposed by organisations like JEDEC and ASTM. However, it has been identified that these reliability assessments take up more than two-thirds of product development time. Some reliability tests take months or even years to complete, and a single mistake in the setup may call for a restart from the beginning. This means that the success rate of a product reaching the market is not solely dependent on technological development but rather on the reliability testing and validation process.

One could rightfully assume that machines capable of making man a galaxy-conquering force can be developed within a year, however, their testing and validation may take decades, if not centuries.

Can MIRELAI accelerate the testing and validation process?

Launched in October 2022, MIRELAI – MIcroelectronics RELiability driven by Artificial Intelligence – is a doctoral network aiming to revolutionise the fusty field of microelectronics reliability, by integrating advanced physics-based models with the power of artificial intelligence.

As part of the MIRELAI network (See Fig. 2), thirteen doctoral candidates (DCs) are dedicated to advancing the microelectronics reliability industry. Guided by a consortium of industrial and academic leaders from seven European countries, our research aims to accelerate Europe's innovation capacity and enhance competitiveness in the global Electronic Components and Systems (ECS) market.

Our scientific approach rests on three pillars: Physics of Degradation, Multi-Scale Modelling, and AI-based Reliability. Every DC's individual work aligns with one or more of these pillars but has one collective goal: to collaboratively contribute to the development of AI-based reliability assessment tools capable of advanced reliability and enhanced predictability of ECS.

While the challenges posed are formidable, but our resolve to overcome them is unwavering. Soon, the impactful work of our DC network will shine across all the leading journals and conferences of the electronics industry. The advancements made will ripple through the industry, driving innovation, enhancing product reliability, and ultimately progressing technological evolution.
To witness this transformative journey and stay updated on our research, we invite our readers to subscribe to this newly established newsletter for MIRELAI. Every six months, we will bring updates from a few of our DCs, while also discussing certain concepts of the microelectronics industry, in an easy-to-digest format.

Figure 2. Photo of the MIRELAI network at the MIRELAI 2nd annual meeting held in Leoben, Austria

A Year of Growth:

MIRELAI's First Year of Expert-Led Workshops

In its first operational year, MIRELAI organised three workshops tailored for the scientific and professional development of its doctoral candidates. Professors, researchers, and technical experts from different partner institutions of the MIRELAI consortium participated, sharing their insights on the following topics:

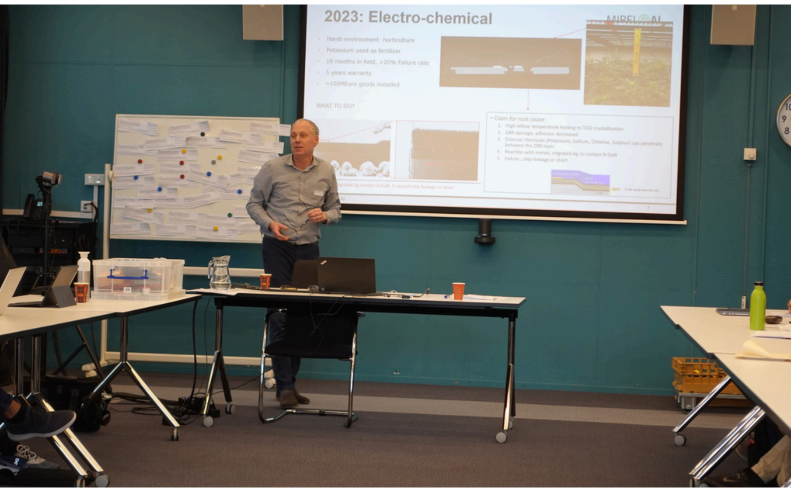

Figure 3. Willem Dirk van Driel during the reliability of microelectronics workshop

Reliability of Microelectronics

Willem Dirk van Driel (See Fig. 3), a professor from TU Delft and a Fellow scientist at Signify, led the reliability workshop during the first annual meeting of the MIRELAI consortium. He introduced the importance of reliability in microelectronics with real-life examples and explained the factors and mechanisms leading to device failure. He emphasised the significance of failure modes analysis techniques like FMEA (Failure Modes and Effects Analysis) and 8D (Eight Disciplines) for addressing issues in chips, packages, and board-level devices. He also discussed design for reliability, guiding researchers on improving device longevity during the design stage.

Romuald Roucou from NXP Semiconductors shared his expertise, highlighting the importance of reliability in telecommunications, consumer electronics, and automotive sectors. He covered factors like environmental stress, thermal stress, and ageing effects that lead to device failure, and explained industry standards, failure analysis techniques, and reliability testing methods to ensure long-term reliability.
Rene Poelma from Nexperia discussed challenges and approaches in semiconductor reliability. He covered material science, package technology, and finite element analysis (FEA) tools to analyse material behaviour under stress, and explained principles of microelectronics reliability, such as degradation processes and failure mechanisms.

Reliability of Microelectronics

Stoyan Stoyanov from University of Greenwich presented "Deep Learning Modelling for Composite Properties of PCB Conductive Layers," discussing how deep learning techniques can enhance and predict the properties of conductive layers in printed circuit boards (PCBs). He highlighted how advanced modelling can improve material performance, reduce manufacturing defects, and boost PCB reliability and efficiency.
Roberta Corti from Technorobe spoke on "Machine Learning Applied to Computer Vision." She explained how machine learning algorithms can improve image recognition, object detection, and quality control, especially in high-precision environments. She highlighted the transformative potential of machine learning in visual data analysis and automation.

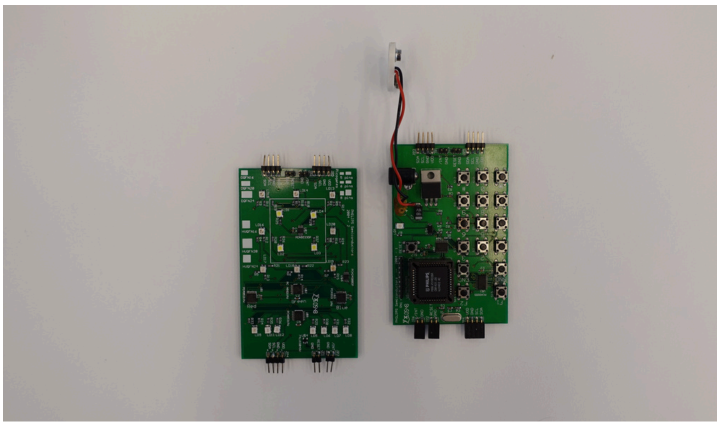

Figure 4. Example of a microelectronics component

Angelika Hable and Dieter P. Gruber from PCCL gave a practical lecture on “Hands-on Classification Example with PyTorch Framework.” They demonstrated how to construct and assess neural networks using PyTorch, equipping participants with skills to tackle various machine-learning problems.

Bart Vandervelde from IMEC discussed “BGA Solder Strain Prediction using an Artificial Neural Network Regressor.” He explained how predictive modelling with neural networks can enhance the reliability of electronic components by identifying potential failure points and improving solder joint design.

Simon Hirlander from IDA Lab talked about “Reinforcement Learning and the Real World.” He discussed the application of reinforcement learning algorithms in real-world scenarios, highlighting successes in autonomous systems, robotics, and decision-making processes, and emphasizing the practical implications of these technologies.

Mathias Verbeke from KU Leuven lectured on “Physics-Informed Neural Networks (PINNs),” showing how integrating physical laws into neural network models can solve complex scientific and engineering problems. He highlighted the accuracy and efficiency of simulations in fluid dynamics and material science using PINNs.

Onur Atak and Gwendal Jouan from SISW presented “An Industrial Perspective on Machine Learning for Simulation and Digital Twin.” They explained how machine learning can improve simulation methods and digital twin technology in manufacturing, enhancing performance, predicting maintenance needs, and increasing overall system effectiveness.

Science Communication

Dr Emily Rose and Mario Ceccarelli led a workshop (See Fig. 5), explaining the difference between science communication and scientific communication for different audiences. They provided tips on how to describe projects to the general public, avoiding technical jargon. They also covered the European Commission's guidelines on project communication and shared advice on writing news pieces or blogs and using motion graphics on social media to convey messages effectively.

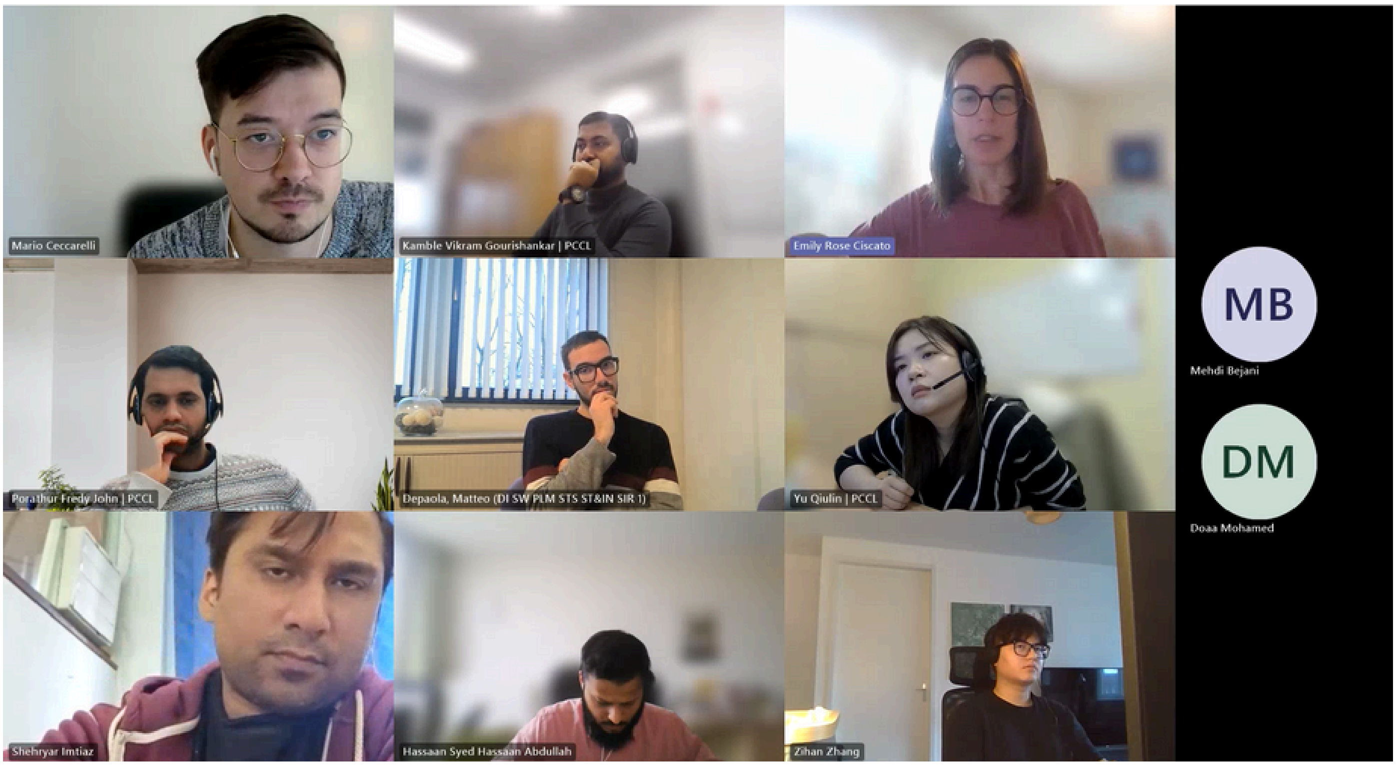

Figure 5. Screenshot from the Science Communication workshop held as part of the MIRELAI network.

From Theory to Application

Fredy’s Journey at PCCL

Fredy’s (See Fig. 6) academic background laid a solid foundation for scientific research. However, his PhD experience at the Polymer Competence Center Leoben (PCCL), a leading institution in polymer research, has propelled him into the dynamic world of applied science, specifically within the field of microelectronic packaging.

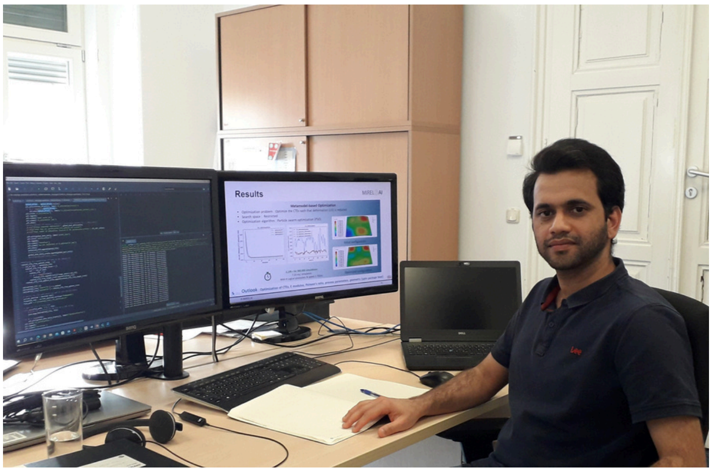

Figure 6. Fredy John Porathur (PCCL)

At PCCL, research thrives on collaboration, serving as an ever-flowing fountain of knowledge. Teams across various projects synergise, cultivating an intellectually stimulating atmosphere. This collaborative ethos extends beyond PCCL; he is engaged in a project deeply intertwined with ams OSRAM, a key player in the microelectronics sector. Their collective efforts contribute to the MIRELAI project, which pioneers microelectronics reliability powered by AI. Partnering with experienced researchers and industry stalwarts forms the bedrock of these endeavours, which involve PhD students from diverse academic background.

ds collaborating with industrial partners. This collective endeavour exposes him to myriad perspectives and state-of-the-art problem-solving methodologies, fostering exponential growth. Not only has he honed technical prowess in polymer science, but he has also nurtured indispensable communication and teamwork acumen.

Fredy asserts that his involvement in the MIRELAI project has remarkably enriched his PhD expedition. It provided him with the opportunity to participate in a fully funded "Deep Learning" course, a valuable addition to his skillset in machine learning. Additionally, he actively participated in the first annual MIRELAI project meeting, attending courses like “Microelectronics Reliability.” This project also facilitated his participation in the EUROSIME 2024 conference, covering all expenses. Furthermore, he had the opportunity to present his first review paper, titled “Warpage optimisation of package substrates using metamodels - A review,” at this prestigious conference.

A pivotal facet of his PhD journey is also spearheading the nascent research phases. While experimentation looms on the horizon, his current focus is on developing innovative AI-driven simulations to optimise microelectronic package substrates. Specifically, his project aims to develop metamodels corresponding to Finite Element Method (FEM) simulation models, bolstering the prediction efficiency of warpage and paving the path for more reliable microelectronic packages.

His PhD exposure at PCCL extends far beyond technical expertise; it underscores the importance of soft skills like time management, self-motivation, and the ability to adapt to new situations. More importantly, it instils in him a passion for research that transcends theoretical realms, striving to fashion pragmatic solutions with tangible impacts.

Looking forward, Fredy mentions that he is enthusiastic about continuing to learn and collaborate at PCCL. This experience is shaping him into a well-rounded researcher equipped to tackle intricate microelectronics challenges with innovative, AI-driven solutions, all underscored by the transformative potential of polymers.

Technical read

Intelligent Inline Failure Analysis

Revolutionising Defect Detection with AI and Lock-In Thermography

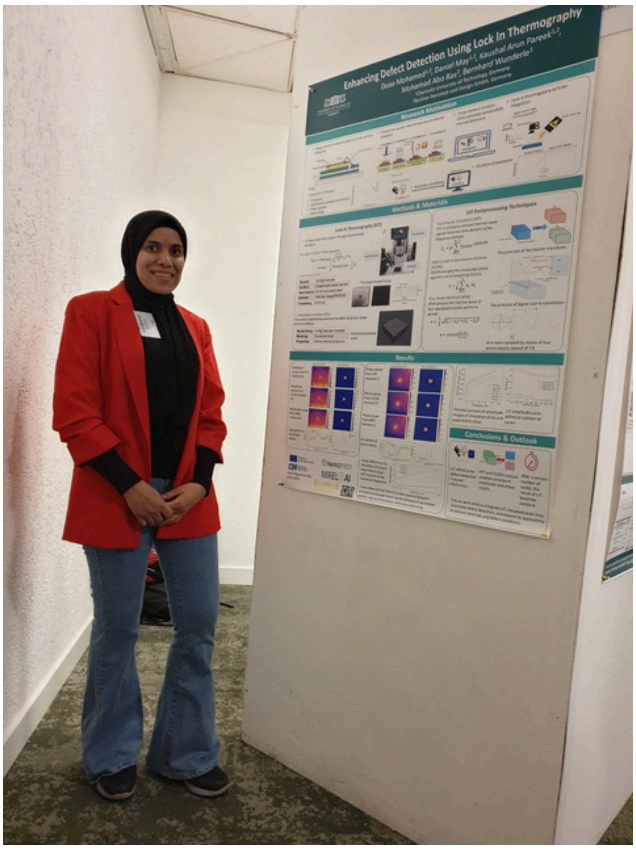

Figure 7. Doaa Mohamed (Nanotest)

As a member of the MIRELAI doctoral network, Doaa's (Fig. 7) research focuses on advancing the reliability of manufacturing processes through the integration of lock-in thermography (LIT) and artificial intelligence (AI) for inline failure analysis, particularly in the sintering layer of power modules. This innovative approach aims to enhance real-time defect detection with unparalleled accuracy and speed, thereby improving the overall quality and reliability of production processes.

Traditionally, defect detection in manufacturing has relied on manual inspections and time-consuming methods. However, the limitations of these traditional approaches, such as their labour-intensive nature and the potential for human error, necessitate a shift towards more automated and reliable solutions.

LIT, an infrared thermography technique, offers a powerful alternative by extracting phase and amplitude data from thermal images to detect defects. This process is facilitated by advanced techniques such as the Fast Fourier Transform (FFT) and the Digital Lock-In Correlation Method (DLCM), which have been identified as the most effective for achieving high precision and reliability in defect analysis.

The integration of AI further enhances this process by automating defect detection, thus eliminating the need for manual inspections and significantly speeding up the analysis. Finite Element Method (FEM) simulations play a crucial role in this integration by generating extensive data that is used to train AI models, leading to more accurate defect predictions.

One of the key findings of this research is the effectiveness of the U-Net segmentation algorithm in analysing phase and amplitude data in LIT. U-Net has outperformed other algorithms like SegNet and DeepLabV3+, making it particularly suitable for industrial applications where precise defect detection is critical.

The capability of LIT to identify defects not only in steady-state conditions but also in transient states further expands its utility in fast-paced production environments, making it an invaluable tool for inline quality assessments.

In summary, Doaa's research endeavours to transform defect detection in manufacturing by leveraging the synergistic potential of LIT and AI. This approach promises to streamline processes, reduce costs, and enhance the reliability and quality of production, marking a significant advancement in the field of intelligent inline failure analysis.

Reflections on EuroSimE

Insights and Innovations in the Microelectronics field

Attending the EuroSimE 2024 in Catania, Sicily was an incredibly exciting opportunity for anyone involved in the fields of thermal, mechanical, and multi-physics simulation and experiments in microelectronics and microsystems. This conference, now in its 25th edition has established itself as a premier event for researchers, engineers, and industry professionals.

One of the aspects that make EuroSimE particularly appealing is its multidisciplinary nature. The convergence of thermal, mechanical, and multi-physics domains provides a comprehensive platform for discussing cutting-edge research and advancements. The synergy between these fields is crucial for the development of innovative solutions in microelectronics and microsystems, areas that are crucial to the advancement of modern technology.

Catania, with its rich history and vibrant culture, adds an extra layer of allure to the event. The picturesque setting of Sicily not only provides a beautiful backdrop but also offers a unique opportunity to experience the local culture, cuisine, and hospitality. The blend of professional development and cultural immersion makes attending this conference a truly enriching experience.

Figure 8. MIRELAI DCs and their supervisors at the 2024 EuroSimE conference

Moreover, EuroSimE's commitment to fostering collaboration and knowledge exchange cannot be overstated. The conference's agenda, which typically includes a mix of keynote speeches, technical sessions, and poster presentations, is designed to facilitate the dissemination of interesting research and the sharing of best practices. Networking opportunities abound, allowing attendees to connect with leading experts and peers from around the world, potentially leading to future collaborations and innovations.

However, the hope for the future EuroSimE conferences is that it will include more topics focused on artificial intelligence.

Given the rapid advancements in AI and its growing applications in simulation and other fields, expanding the discussion on AI-related themes would not only enrich the conference content but also attract more researchers and professionals interested in AI.

In total, EuroSimE 2024 gave an invaluable experience for anyone in the relevant fields. The combination of high-quality technical content, the chance to engage with a diverse and knowledgeable community, and the enchanting location of Catania made this conference the best.

Looking ahead to next year, DCs (Fig. 8) aim to build upon this experience, present new findings, and continue to engage with the audience. Gaining further insights from industry experts is essential for fostering innovation and advancing our field. This engagement will be a key component in driving forward my research and contributing to the broader community.

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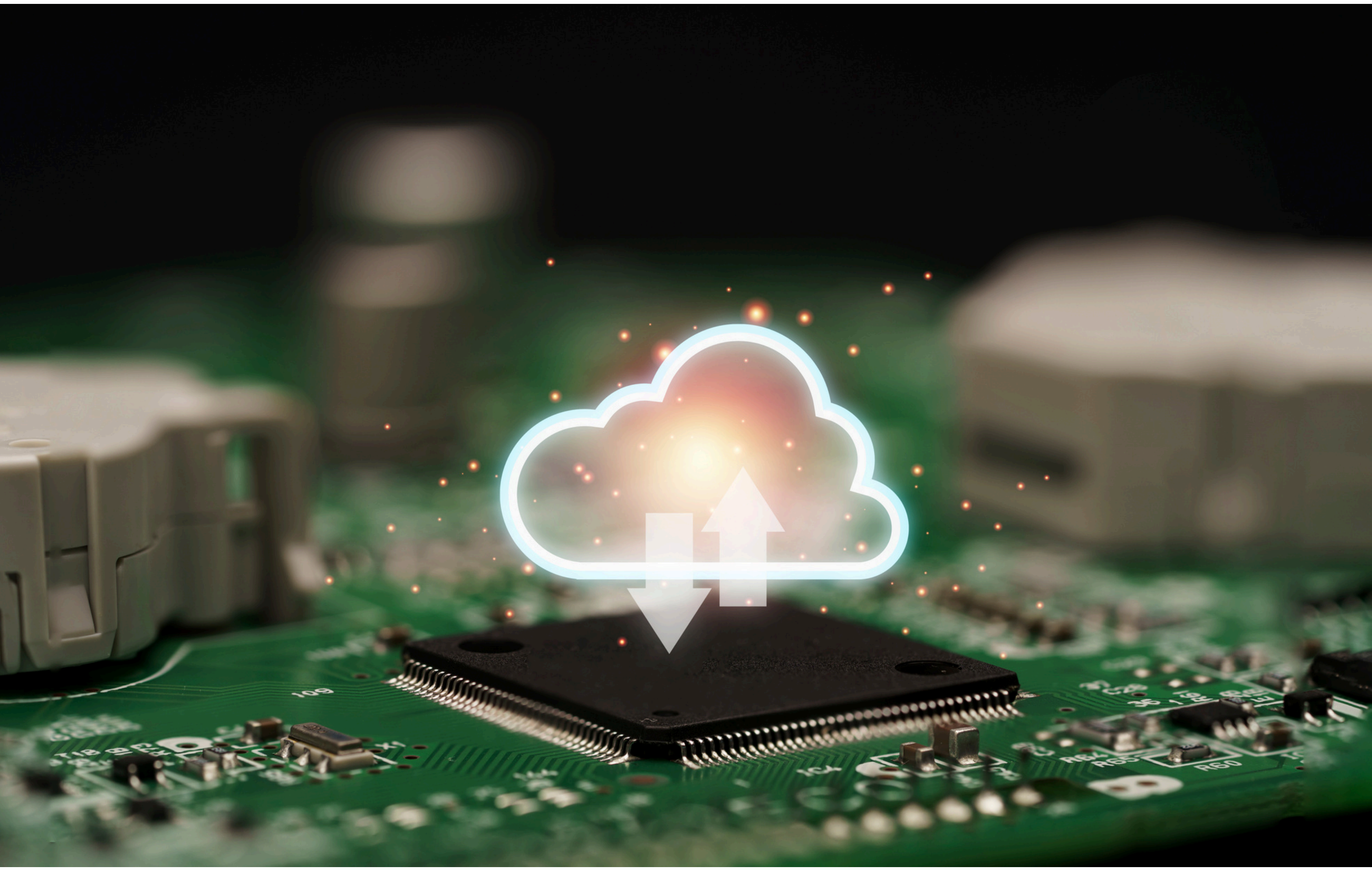

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