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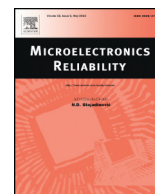


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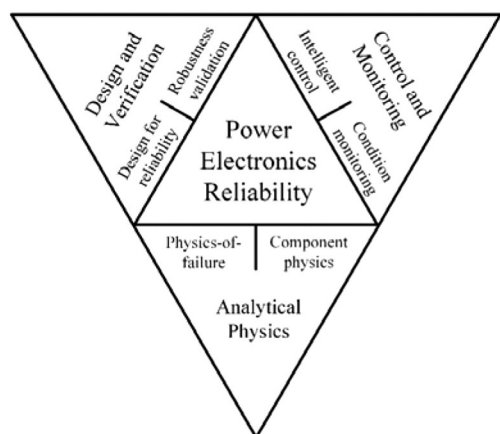
## Microelectronics Reliability

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## Guest Editorial

## Reliability issues in power electronics

Nowadays, seventy percent of the overall electrical power is managed by semiconductor power devices. Applications like automotive, aerospace and railway transportation are facing more and more stringent reliability constraints coming from the increased lifetime expectation and safety requirements. The industrial and energy sectors are also following the same trend, so that strong efforts are made to improve the reliability of power electronic systems with cost-effective and sustainable solutions. In the meanwhile, Wide Band Gap semiconductor devices (WBG) are capturing increasingly new power applications, as they are quite promising in terms of switching speed, efficiency, thermal management and high voltage capability, even if their reliability performance is still far to be demonstrated.



In the depicted scenario, reliability of semiconductor power devices has become a primary challenge. In fact, it is generally recognized that electronic systems are stressed by many factors, including temperature, humidity, vibration, cosmic rays, and so on, which lead to the degradation of the components. Therefore, in order to meet the expected lifetime of a product (and keep the failure rate within the specified expected range), the next paradigm in power electronics must include a thorough strategy for built-in reliability, wherein many new disciplines are taken into account, as illustrated by the triangle in the figure. Here *Analytical Physics*, *Design and Verification* and *Control and Monitoring* are the main pillars. Physics-based modeling, physics of failure, modern design methodologies – like design for reliability and robustness validation (e.g. mission profile simulators) – are a must, especially looking at new concepts of power topologies and systems to be necessarily approached in multi-physics domains. Fault-tolerant design, intelligent control, condition monitoring, prognostics and health

management are also fundamental to further improve the lifetime expectation of power devices.

This special issue on Reliability in Power Electronics copes with the above challenges, collecting state-of-the-art contributions from industry and academia in almost all the hot topics in the field. For the sake of clarity, seven invited papers and twenty contributed submissions have been subdivided in five sections titled Power Device Modeling, Failure Mechanisms, Reliability Modeling and Testing, Strategies for Reliability Management, and Wide Band Gap Devices and Processes.

## Power device modeling

The invited paper by Chimento et al. proposes an analytical modeling approach to study thermal evolution of power MOSFET devices under unclamped inductive switching. Then, a paper from industry and academia by Suzuki et al. deals with electro-thermal simulation of current sharing during short circuit in Si- and SiC-based power modules. Three more physics-oriented papers directly coping with reliability of power devices conclude the topic, namely: the one from Mirone et al., on termination ruggedness of IGBTs, the one from industry by Efthymiou et al., on oxide reliability of trench-gate MOSFETs and finally with a co-operation by industry and academia, Kikuchi et al. discuss a model for threshold voltage instabilities in SiC MOSFETs.

## Failure mechanisms

Two invited papers – one by G. Soelkner and the second one by Rahimo et al. (both from industry) – introduce two different crucial aspects of modern power device reliability, namely cosmic rays and termination discharges due to impurities, respectively. The topic is completed by three papers on bond-wire reliability, namely the ones from Popok et al. and Czerny et al. on bond wire interfaces, and the last one from Saritas et al. on dynamic analysis of bond wires, all three from academia.

## Reliability modeling and testing

The invited academic paper by Herold et al. discusses important principles for lifetime cycling of power devices. The topic is continued by Ghimire et al. with a paper on a technique for reliability growth for megawatt applications, De Leon et al., with a paper on reliability prediction of photovoltaic systems and A. Bensoussan, with a contribution on long term multiple stress operation on normally-off GaN devices, all three of them are co-operations from academia and research centers.

## Strategies for reliability management

The first paper by Wang et al. introduces some new strategies for adaptive cooling. The second paper authored by Andresen et al. deals with active thermal control to improve the reliability tradeoff with efficiency. The third contribution is proposed by Chiozzi et al. and proposes to improve reliability by thermal analysis of printed circuits boards. The fourth one is from Gagrica et al. and copes with active power curtailment methods for PV micro-inverters. Finally, an overview paper by Luo et al., discusses the present gate driving strategies to improve IGBT reliability. All five papers are from academia.

## WBG devices and process

Confirming the increasing relevance of wide-bandgap devices, eight papers have been submitted specifically on this topic. The first three ones are invited contributions by Meneghesso et al., from academia, dealing with trapping phenomena in GaN metal-insulator-semiconductor HEMTs, Kusumoto et al., from industry, discussing reliability of Diode-Integrated SiC Power MOSFETs, and Castellazzi et al., from academia, with an extended study on the state of the art of SiC MOSFETs. Following, five regular papers by Meneghini et al. (academia) discuss the degradation mechanisms of Normally-off GaN-HEMTs with p-type gate, Sato et al. (academia) the concave formations by dielectric breakdown in SiC, Peng et al. (academia) reliability issues of interfaces and oxide in 4H-SiC, Smith et al. (industry) lifetime test design for 600-V GaN-on-Si and, finally, Ibrahim et al. (research center) high-temperature power cycling of modern SiC MOSFETs.

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We warmly hope you will enjoy your reading!

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