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Editorial

Editorial for the Special Issue on Robust Microelectronic Devices

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Integrated electronic circuits have influenced our society in recent decades and become an indispensable part of our daily lives. To maintain this development and to ensure the benefits therefrom for decades to come, continuous further development of electronic chips is necessary. These developments include improving their performance and universality as well as exploiting the full potential of microelectronic technologies. It is also noteworthy that with the increasing number of applications for microelectronic systems, the associated demands on the individual components are also growing. A few challenges facing semiconductor industry research are the continuous optimization of integrated circuits towards higher operating frequencies and increasing the number of devices per chip area, while reducing power consumption. In addition to the abovementioned improvements, integrated electronic chips must also function robustly and reliably under various operating conditions, such as at low (cryogenic) or high temperatures, humidity, and many more.

The robustness, i.e., the high performance and reliable function, of microelectronic devices is the key for long-term failure-safe and stable operation of complex electrical circuits and applications. In recent decades, the performance and geometry of integrated devices have been continuously updated to improve performance, leading to new challenges that must be addressed. For instance, MOS transistors suffer from imperfections at the atomic level, which can emerge as electrically active sites—so-called defects. On the one hand, these defects are unavoidably introduced during device fabrication, and on the other hand, new defects can form during device operation at nominal bias conditions. The impact of these defects on the device performance itself manifests as a drift in the performance of the MOS transistors over time. In this context, the so-called bias temperature instability (BTI), which emerges as a drift of the threshold voltage of a transistor, is an essential criterion for determining the reliability of devices. Although significant emphasis has been placed on understanding this phenomenon and developing suitable models to explain the observed device performance degradation, the detailed physical mechanisms behind BTI are still controversial and debated.

In principle, BTI can be analyzed in two fundamentally different ways. The first is the investigation of large-area devices where continuous drifts of the threshold voltage, resulting from the superposition of the contributions of many defects, can be studied. This enables the calibration of analytical and compact models, essential for efficient circuit simulation. The second approach is to analyze the random telegraph noise (RTN) and investigate single defects by employing nanoscale devices. In doing so, the charge-trapping kinetics of single defects can be studied, which is vital for the development of physical defect models that further enable an accurate lifetime estimation under various operating conditions.

A continuous improvement of our understanding of BTI is not only essential for further optimization of silicon transistors, but also for the improvement of the performance of emerging technologies such as devices based on wide bandgap materials such as SiC or GaN, as well as for novel 2D transistors employing graphene, MoS_2, and many other 2D materials. In addition to the evolving challenges for the physical understanding of these observations, the study of novel material systems also poses a major challenge for suitable characterization techniques and measurement instruments, e.g., the requirement of high-speed measurement techniques (fast IDVG or fast CV methods), but also the need for ultra-low-noise systems, which allow us to investigate trap-assisted tunneling.

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The publications published in this Special Issue are just as diverse as the field of research itself. In [1], the authors study the impact of BTI on the performance of logic inverter circuits using different SiC transistor technologies. As has been mentioned before, BTI is a severe reliability issue for all kinds of material systems, and thus, also for power electronics fabricated on SiC substrates. The authors report that defects in the structure of the SiC transistor can lead to a considerable change in signal propagation delay, which might become an issue at high operating frequencies. In [2], a photoexcited switchable THz metamaterial (MTM) polarization converter/absorber based on the incorporation of photoconductive silicon is designed and demonstrated. A key achievement with the discussed design is opening up a new field towards active switches and polarization manipulation with high performance in the THz regime. Potential applications of this novel structure compromise biological imaging, THz scanning, sensors, and more. The subsequent work in [3] studies the synthesis, structural characterization, and electrical behavior of $AgSn[Bi_{1-x}Sb_x]Se_3$, a candidate for thermoelectric materials. In [4], stable and efficient Ge Schottky contacts, based on low-cost carbon paste interlayers, are investigated. Schottky contacts are of particular importance for high-speed devices. Another important class of devices is discussed in [5]—i.e., SiC MOSFETs—and the impact of interfacial layer charge trapping on the device stability. In turn, the stability of a certain technology is vital for the reproducibility of measurements, and the authors report that experimental results strongly depend on the measurement scheme and the precise timing on a microsecond scale. Finally, two review papers have also been submitted to the special issue. In [6], the limitations and advances of simulating ammonothermal growth of bulk GaN is discussed. GaN is an important material system exhibiting a wide bandgap, making it attractive for powered electronic devices. The second review paper [7] outlines the robustness of GaN metal–insulator–semiconductor (MIS) transistors when used in power switching applications. It is noted that both negative BTI (NBTI) and positive (PBTI) are serious reliability concerns for this technology and require careful consideration when designing circuits and applications.

The Guest Editor would like to take the opportunity to thank all the researchers who contributed to this Special Issue by sharing their latest results and achievements. Furthermore, a special thank you goes to the reviewers for their time spent providing constructive feedback to the authors and helping to improve the quality of the published papers considerably. Finally, the Guest Editor wants to point out that there are a wide variety of further robustness issues of modern microelectronics devices and materials that are currently not fully understood. Therefore, it is essential to carefully look into these aspects if we are to ensure further improvements of integrated electronic applications for many years to come.

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