The TRANSISTOR and Its Many FACETS

by Jerzy Ruzyllo

Because of their ability to amplify and/or switch electrical signals, transistors are by far the most important functional semiconductor devices. They are a basic building block of all integrated circuits (ICs), and hence, progress in transistor design is a key driver of IC technology in terms of computational and storage capabilities. While the role in ICs gives transistors the most exposure, there are a number of other key applications for these devices in a broad array of electronic circuits and systems. Four feature papers presented in this issue of *Interface* are aimed at demonstrating the diversity in the field of transistor engineering, and discussing the trends with regard to the modification of its architecture driven by specific target applications.

Transistors can be realized on the basis of different physical phenomena and using accordingly-adjusted device configurations and material selection, all of which lead to the distinction of several types of transistors. The most fundamental classification uses types of charge carriers involved in transistor action as a criterion. Accordingly, unipolar, or field-effect transistors using only majority carriers, and bipolar transistors using both majority and minority carriers to perform transistor action are distinguished. In the former category, the Metal-Oxide Semiconductor Field Effect Transistor (MOSFET) has been of special interest for over 40 years as the most efficient transistor configuration in performing a vast range of logic functions.

The very idea of a field-effect transistor was first proposed by J. E. Lilienfeld in 1925 while a MOSFET specifically was defined in O. Heil's patent ten years later. It was not until the early 1960s, however, that the first working MOSFETs were demonstrated. In the meantime, a functional transistor was experimentally proven for the first time in 1947 (J. Bardeen, W. Brattain, and W. Shockley) using different than field-effect transistor configuration of bipolar point-contact transistor. This groundbreaking event provided a huge boost to all of semiconductor technology including efforts focused on bringing alternative transistor configurations to life. Since then various transistor designs have emerged, driven by applications in either digital or analog circuits as well performance requirements in terms of frequency of operation and power handling capabilities. The need to meet such diverse requirements made transistor engineering a cornerstone of semiconductor electronics and at the same time a measuring stick of its progress.

Based on its outstanding characteristics, MOSFET in the complimentary pair, or CMOS, configuration has become a device of choice for digital integrated circuits such as microprocessors. However, looking at the evolution of transistors only from the perspective of CMOS electronics does not adequately represent the complexity of current transistor technology. To meet the needs of specific applications, transistor technology includes a range of highly specialized designs both from the device architecture and material selection point-of-views. For instance, while CMOS transistors used in advanced logic and memory applications need to be built using the smallest attainable feature size, other types of transistors are free from minimum feature size constraints. Similar considerations apply to the selection of materials where compound semiconductors make significant inroads into silicon dominated territory.

Acting on behalf of the ECS Electronics and Photonics Division, it is my pleasure to introduce in this issue of *Interface* the four feature articles, the contents of which reflect the diversity of transistor designs.

In the paper "Recent Advances in High Performance CMOS Transistors: From Planar to Non-Planar," Suman Datta reviews some of the recent innovations in CMOS transistors that show how far mainstream logic transistor technology has to depart from an original planar Si-CMOS in order to maintain the historical pace of delivering higher transistor performance with increasing energy efficiency.

With the next paper entitled, "Switching Megawatts with Power Transistors," Krishna Shenai moves the discussion of transistor evolution to the opposite end of the spectrum in terms of its power handling capabilities. The paper discusses various transistor-based power switches and considers material aspects of next generation semiconductor power electronics based on wide-bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN).

The third paper featured in this issue takes the discussion to yet another highly distinct area of transistor applications. In the paper entitled, "Thin Film Transistor Technology—Past, Present, and Future" Yue Kuo discusses a path in transistor evolution that is concerned with thin-film transistor (TFT) technology that is governed by its own set of requirements.

Finally, a paper on "Graphene Transistors and Photodetectors," co-authored by the team of A. V. Klekachev, A. Nourbakhsh, I. Asselberghs, A. L. Stesmans, M. Heyns, and S. De Gendt, gives an overview of the *status quo* in terms of transistor implementation using graphene.

It is my hope that the selection of outstanding contributions presented in this issue of *Interface* will help better highlight the critically important role transistors play in semiconductor electronics and bring about an increased appreciation of the complexity and diversity of the field of transistor engineering.

About the Author

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