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Importance of Dielectric Science in Today's Technology

by Durga Misra

The explosive progress of information technology and 5th generation communication technology enables the introduction of the Internet of Things, where the network of physical objects—devices, vehicles, and buildings embedded with sensors, electronics, software, and network connectivity—permits these physical objects to collect and exchange data. The use of dielectric materials in sensors for a multitude of applications such as self-driving cars has made the dielectric science and technology research even more significant than before. More than seventy years ago, in 1945, it all started with establishing the Electric Insulation Division in ECS to offer an interdisciplinary forum to discuss the science of the materials used for electrical insulation in power transmission. With the advancement of technology, when integrated circuits became popular, the division became the Dielectrics and Insulation Division in 1965. In 1990, it became the Dielectric Science and Technology Division due to extensive growth in electronic manufacturing technology. Today, the division still provides a strong interdisciplinary research environment.

Recently, the division's focus has related to new dielectric devices with applications in sensor technology, devices for new communication technologies, and new materials and processes for nanoelectronics manufacturing. In the earlier days, the division mostly considered topics like electrophysics, electrical properties of plastics, wet electrolytic capacitors, wires and cables, inorganic and organic dielectrics, liquid dielectrics, high temperature insulation, prefabricated circuitry, and chemical aspects of printed wiring. Thirty years ago, the focus was on anodic oxide dielectrics for electrolytic capacitors, silicon nitride, and silicon oxide thin insulating films for electronic applications, plasma processing, chemical vapor deposition, multilevel metallization, diamond and diamond-like carbon films, corrosion and reliability of electronic materials and devices, III-V nitride materials and devices, and rapid thermal processing of dielectrics. Subsequently, with the introduction of new materials and processing technologies the focus of Dielectric Science and Technology Division has changed to post-CMOS devices and dielectrics in nanosystems. The division stimulates and disseminates fundamental research on present and future dielectric materials and their synthesis, characterization, processing, fabrication, manufacturing, and reliability through its symposia and short courses.

In this issue of *Interface* we have focused on some of the current topics that are an integral part of current and future technologies. The first article in this issue, by Chen, reviews the nanoscale hybrid dielectric materials used in humidity sensors. These sensors use a porous α-Al_2O_3(sapphire)/SiO_2 hybrid dielectric capacitive structure. When the humidity level in the environment changes, it results in a change of the dielectric constant of the porous dielectric material because of absorption of water molecules. This leads to a change of the capacitance and impedance of the sensors. This α-alumina(sapphire)/silicon dioxide hybrid dielectric humidity sensor exhibits long-term stability, fast response, and durability at extremely high/low humidity levels. This dielectric sensor finds its way to many applications starting from household appliances, automobiles, health care equipment, to agricultural applications.

In the second article, by Sai, et al., the authors discuss magnetic nanoferrites for radio frequency CMOS technology, where the functional materials, especially magnetic oxides such as ferrites, are used in higher frequency integrated devices for the 5th generation communication systems. A low-temperature CMOS-compatible deposition of ferrite films and its integration as a deposition method into the semiconductor processing technology is definitely required for the success of new devices. Since the hexagonal ferrites and their stoichiometric derivatives can be used as suitable magnetic materials in the frequency bands ranging from a few GHz to several hundreds of GHz, extensive research to attain industry-scale reliability and control over material properties is required for the deposition of these hexaferrite films. The article suggests that microwave-irradiation assisted solution-based nonequilibrium spinel ferrite deposition technique offers promise towards CMOS-compatible and scalable ferrite film deposition. For characterization, highly sensitive permeability measurement systems need to be developed. Magnetic nanoferrites bring an interdisciplinary approach by combining the wisdom of RF engineers, semiconductor technologists, material scientists, physicists, and chemists.

The third article, by Iwai, et al., provides an overview of high dielectric constant materials for nanoscale devices and their possible future applications. A historical perspective is provided by outlining the development of these materials over the last twenty years. Some new understanding of these materials that can have new applications in future nanoscale devices are discussed. The reliability aspect of these materials used in advanced devices is also addressed. Even though some of the technologies have matured, new science finds novel applications for these materials.

A symposium on physics and technology of high-k gate dielectrics, started in 2002, completed its 15th edition at the 232nd meeting of the ECS in National Harbor in 2017. The fifteen volumes of the symposium proceedings represent a unique collection of research publications on the high-k gate stacks, high mobility channel semiconductors, gate electrode metals, and the related topics.

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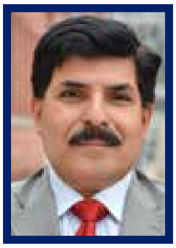
About the Guest Editor



Durga Misra is a professor in the electrical and computer engineering department at the New Jersey Institute of Technology, Newark, NJ. He received an MS (1985) and a PhD (1988) in electrical engineering from University of Waterloo, Waterloo, Canada. He is a past chair of the Dielectric Science and Technology Division of ECS. He is a fellow of ECS and a senior member of the Institute of Electrical and Electronics Engineers. He received the Thomas D. Callinan Award from the DS&T Division and also the winner of the Electronic and Photonic Division Award. His research interests are in the areas of nanoelectronic/optoelectronic devices and circuits especially in the area of high-k gate dielectrics and its reliability. He has published over 250 papers in journals and conferences and edited and co-edited more than 40 proceeding volumes and *ECS Transactions*. He may be reached at dmisra@njit.edu.

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