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Editorial

Advancing the Frontiers of Electronic Materials Through Functional Design, Processing Innovation, and Device Integration

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The collection of research articles and reviews presented in this editorial highlights the exciting and rapid development of electronic materials research. As an open-access, peer-reviewed platform dedicated to fundamental science, engineering, and practical applications, *Electronic Materials* continues to foster interdisciplinary advances spanning semiconductors, device physics, processing technologies, and emerging electronics. The works gathered in this editorial exemplify how the field is progressing toward novel electronic materials, functional integration, and device fabrication, which are key aspects for next-generation electronics.

One strategy in development is the careful design of electronic materials to achieve specific electronic and optoelectronic functions. Cecilia Guillén studied the band gap energies in doped ZnO and SnO_2 thin films with a focus on controlling crystallinity and doping to tune optical and electronic characteristics [1]. The films revealed various crystallite sizes, absorption coefficients, and free carrier concentrations depending on the material and the annealing temperature. It was found that the expression for amorphous materials underestimates the band gap value, and the unified method overestimates the value. On the other hand, the equations for perfect or heavily doped crystals provide band gap energies more consistent with the doping level, regardless of the crystalline quality of the films. This study demonstrates the broader need for precise structure–property relationships in electronic materials critical for applications in photovoltaics, sensors, and transparent electronics.

Beyond materials design and processing, the integration of advanced materials into functional device architectures is important as addressed in the article by Rafi et al. [2]. The authors applied numerical simulations to optimize a C60-layered copper zinc tin sulfide-based solar cell structure in which the C60 served as an electron transport and buffer layer, improving charge separation and reducing recombination losses. The influence of critical parameters such as the acceptor thickness and concentration was investigated regarding the defect density and the auger hole/electron capture coefficient to identify optimal performance conditions. Under optimized parameters with an acceptor thickness of 3 µm and a concentration of 6×10^{18} cm^{-3}, the device achieved simulated power conversion efficiency of 30.18%, along with high open-circuit voltage and fill factor. The work highlights challenges arising from optimization of the solar cell structure on the performance.

Darwish and Pohl have published another notable article about functional device architectures [3]. The authors explored resistive random access memory (ReRAM) crossbar memory arrays integrated with an insulator–metal transition-based selector to overcome scaling challenges in memory technologies. The authors focused on the architecture of crossbar arrays, where memristive devices were positioned at intersecting metal wires.

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The resistive switching mechanisms of memristors and the challenges of sneak path currents were discussed for the one-selector one-resistor architecture with an insulator–metal transition-based selector. Simulations were used to study an array with vanadium dioxide selectors and titanium dioxide film memristors to understand the influence of ambient temperature and critical insulator–metal transition temperatures on performance. Such selector devices are essential for mitigating sneak currents and enabling high-density data storage, a basis of modern computing.

Electronic devices, circuits and especially modern microchips require efficient cooling systems to ensure reliability and safety for a longer life. Cooling becomes more crucial as microchip dimensions decrease and become more powerful, resulting in increased heat flux generation. Ghani et al. discuss microchannel heat sink (MCHS) technology in their review, which has been developed to meet the recent cooling requirements of microchips [4]. The MCHS system is particularly efficient due to its high surface area to volume ratio. The authors summarize design, material selection, and performance parameters of the MCHSs, including limitations and challenges of the different techniques. A broad range of device parameters are addressed to describe the heat sink characteristics such as thermal enhancement factor, Nusselt number, and pressure drop at different Reynold numbers in passive techniques. This review outlines current trends and offers guidelines for designing more efficient MCHSs to meet the increasing cooling demands of power electronics.

Besides the device architecture and cooling system, the entire packaging design of power devices is crucial for long-term reliable operation. In their review, Gao et al. discuss the power cycling test (PCT) for a reliability evaluation of low-thermal-resistance packaging design structures for SiC devices [5]. The reviewed packaging designs comprise planar packaging with dual heat dissipation, press-pack packaging, three-dimensional packaging, and hybrid packaging. The authors present control strategies of the PCT methods and failure mechanisms of SiC devices under the tests with various electrical and temperature-sensitive parameters. Additionally, the lifetimes of the various packaging designs for the tested SiC devices under PCTs are compared. This review provides a broad overview of the current challenges and main trends in PCTs for SiC devices.

Simple and sustainable processing of electronic materials becomes a critical factor for their integration into devices. Inkjet printing materials into devices enables scalable and environmentally friendly fabrication. Bai et al. inkjet printed a poly(4-vinylphenol) gate insulator into an organic field effect transistor [6]. The authors systematically studied different parameters, including the molecular weight of the polymer, printing direction, printing voltage, and drop frequency. The highest transistor performance was observed for a small molecular weight of the polymer, a printing direction parallel to the channel, a printing voltage of 18 V, and a drop frequency of 10 kHz. This approach establishes a solution-based fabrication toward fully inkjet-printed field-effect transistors.

In the context of printed electronics, Rubio and Bolduc have provided an overview article about screen printing and analyzed the role of ink viscosity, mesh selection, and squeegee dynamics on film uniformity, pattern resolution, and device performance [7]. A broad range of conducting ink formulations are discussed including carbon allotropes, such as graphene and carbon nanotubes, metal nanostructures, and MXene. Another essential aspect is the right choice of the flexible substrate, typically based on a polymer or elastomer, whereby environmentally friendly materials receive increased attention. The authors also evaluated screen-printed energy storage layers and functional electronics for wearable, medical and industrial applications.

Wang et al. reviewed conductive hydrogels as novel electronic materials which are attractive for flexible electronics since they combine characteristics of hydrogels and conductors [8]. The softness and biocompatibility of hydrogels allow them to adapt to uneven

biological surfaces without compromising electrical conductivity. The authors demonstrate that conductive hydrogels can be used as conductive pathways and electrodes in flexible electronics for sensors and tissue engineering applications. Moreover, the discussion covers functional materials, strategies for enhancing performance, and applications in wearable technologies related to the human body.

Another important class of electronic materials is conductive polymer composites. In their review, Shamsuri et al. discuss the role of ionic liquids in polymer composites mostly in combination with conductive fillers on electrical conductivity [9]. They explain that ionic liquids improve filler dispersion and favor the formation of three-dimensional conductive networks which result in conduction improvement of the polymer composites. These insights disclose pathways toward next-generation conductive materials for electronics.

Polyimide is an attractive dielectric material for electronics due to its high-temperature capacitive energy storage. The polymer shows high thermal stability and high breakdown strength, together with pronounced mechanical properties. Liu et al. provide an overview of polyimide and its application in electronics [10]. Furthermore, the authors discuss recent developments and modifications of polyimide-based polymers. Correlations are established between molecular compositions, spatial configurations and key properties such as dielectric constant, breakdown strength, discharged energy density, and charge–discharge efficiency. Finally, current challenges and future development directions of PI-based high-temperature energy storage dielectric materials are outlined.

This collection of contributions exemplifies the dynamic and multifaceted nature of electronic materials research. By advancing both fundamental understanding and applied technologies, these articles and reviews collectively reinforce the central role of materials innovation in shaping the future of electronics. As *Electronic Materials* continues to serve as a platform for high-quality research across disciplines, it plays a crucial role in driving scientific progress and technological breakthroughs.

Conflicts of Interest: The author declares no conflicts of interest.

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