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Editorial

Advanced Technologies in Graphene-Based Materials

Justina Gaidukevic * and Jurgis Barkauskas

Institute of Chemistry, Faculty of Chemistry and Geosciences, Vilnius University, Naugarduko Str. 24, LT-03225 Vilnius, Lithuania; jurgis.barkauskas@chf.vu.lt

* Correspondence: justina.gaidukevic@chf.vu.lt

Graphene-based materials, including single layer graphene, laser-induced graphene, carbon nanotubes, graphene oxide, and reduced graphene oxide, have become cornerstones of modern materials science due to their exceptional properties and wide range of potential applications. These materials are driving innovation in many fields, such as electronics, catalysis, biosensors, and biomedicine, etc. To unlock the full potential of these materials, the continuous development of new synthesis methods, functionalization techniques and comprehensive characterization approaches is crucial. This Special Issue on “Advanced Technologies in Graphene-Based Materials” presents a collection of groundbreaking studies that explore the multifaceted nature of graphene and its derivatives, and contains a mixture of review articles and original contributions.

The latest research on the preparation of graphene and its application in biomedicine has been reviewed by Klaudia Malisz and Beata Świeczko-Żurek [1]. Their review article highlights graphene’s unique physiochemical, mechanical, and biological properties, which have sparked significant interest in its use for various applications, including sensors, implantology, gene and drug delivery, tissue engineering, anticancer therapies, and antimicrobial agents. It emphasizes the importance of the biocompatibility of graphene, making it suitable for use in regenerative medicine and drug delivery systems. Additionally, it discusses the most popular methods of graphene production, particularly chemical vapor deposition. The role of graphene as a support for metal hydrides in energy storage applications is comprehensively reviewed by Cezar Comanescu [2]. The article examines recent advances in graphene-supported metal hydrides, focusing on how these composite systems utilize the unique properties of graphene to enhance the performance of metal hydrides in energy storage. Additionally, it provides a brief overview of the applications of these graphene-supported metal hydride nanocomposites, emphasizing their energy storage properties and potential practical benefits.

Several contributions explored the impact of graphene on the mechanical properties of composite materials. José D. Ríos et al. [3] investigated how variations in the concentration of graphene oxide (GO) and the intensity of ultrasonication influenced the fracture behavior of nano-reinforced cement pastes. Their study demonstrated that the incorporation of GO sheets into cement matrices significantly altered their mechanical and fracture characteristics, with outcomes depending on factors such as the pore size and the dimensions of the GO particles. This research highlighted the potential of GO to improve the durability and structural integrity of construction materials. S. M. Nourin Sultana et al. [4] investigated the effects of few-layer graphene (FLG) on electrical conductivity, mechanical reinforcement, and resistance to photodegradation in polyolefin blends. Their findings showed substantial improvements in electrical conductivity and UV protection due to FLG. As little as 1 wt.% of FLG was sufficient to retard the degradation of the polyolefin composites by UV light. Additionally, the incorporation of FLG helped maintain the mechanical properties of the materials under UV exposure, demonstrating its potential as a multifunctional additive in polymer composites. In a related study, S. M. Nourin Sultana and colleagues [5] explored the impact of FLG on the properties of mixed polyolefin waste streams. The study concluded that FLG enhances the mechanical properties of polyolefin waste composites while

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maintaining processability. Also, they found that adding FLG up to 10 wt.% did not affect the melt flow index, effective torque during extrusion, or the viscosity of the composites.

The ability to tailor the electronic properties of graphene is crucial for its integration into advanced electronic devices. Isaac Appiah Otoo and colleagues [6] explored how different dielectric materials could modulate the carrier concentration in graphene, offering a method to fine-tune its electronic properties for specific applications. Their findings revealed that the sheet resistance of graphene was significantly influenced by the dielectric substrate, while the carrier scattering time remained unchanged. This insight could open new avenues for designing graphene-based electronics with customized electronic characteristics.

Further expanding the versatile applications of graphene, Andrés Serna-Gutiérrez and Nicolás A. Cordero [7] provided computational insights into the mechanical properties of quasi-square graphene nanoflakes. By challenging conventional assumptions about the mechanical behavior of these nanosystems, the authors proposed new models for understanding the strain-induced electronic modifications in graphene, contributing to the emerging field of straintronics. Stefan A. Pitsch and R. Radhakrishnan Sumathi [8] examined the effect of polar faces of SiC on the epitaxial growth of graphene. Their study revealed how different SiC crystallographic faces influenced the growth mechanism and electrical properties of graphene, providing important insights into optimizing the fabrication of high-quality graphene layers.

The unique surface properties of graphene-based materials also make them an excellent candidate for a variety of functionalization strategies aimed at improving its performance in a wide range of applications. Aya Jezzini et al. [9] investigated the stabilization of reduced graphene oxide (rGO) sheets with copper cations in ethanol and revealed promising photocatalytic activity for dye degradation under visible light. This study demonstrated the potential of rGO–copper systems for environmental remediation and chemical sensing applications. Meanwhile, Hanna Bandarenka and her team [10] demonstrated that graphene-coated Ag/ZrO_2 substrates significantly enhanced their surface-enhanced Raman scattering (SERS) activity. They showed that while UV exposure typically suppressed SERS signals due to zirconia's photocatalytic activity, the presence of graphene effectively counteracted this suppression, resulting in an increased SERS signal. By optimizing the UV treatment conditions, they further increased the sensitivity of these substrates for detecting low concentrations of analytes, such as rhodamine 6G molecules, highlighting the role of graphene in advancing SERS-based sensing technologies.

Innovative theoretical studies also featured prominently in this Issue. Mikhail A. Kalinin et al. [11] presented "graphocrown", a novel two-dimensional oxocarbon material. Through computational analysis, the authors revealed the structural stability and potential electronic applications of graphocrown, suggesting that it could serve as a more effective alternative to traditional graphene in certain contexts. This theoretical work paved the way for future experimental investigations and the development of new graphene-like materials with enhanced properties. The study by Lunwei Yang et al. [12] investigated the adsorption and sensing properties of formaldehyde on chemically modified graphene surfaces. By systematically analyzing the effects of different dopants (B, N, O, P, S, Mg, and Al), the authors provided a theoretical basis for the design of superior graphene-based sensors. They also highlighted the importance of chemical modification in tailoring graphene properties for specific sensing applications.

This Special Issue includes several papers that present new approaches to the synthesis of graphene-based materials. Dongyang Wang et al. [13] prepared polydopamine films on SiO_2 substrates under various conditions, focusing on the effects of pH and dopamine solution concentration on the deposition process. They then carbonized and graphitized these films at high temperatures (800 °C or 1000 °C) to produce a graphene-like material. Raman spectroscopy revealed that the resulting graphene-like film exhibited fewer structural defects compared to previous studies, and X-ray photoelectron spectroscopy showed that most of the carbon atoms were incorporated into a cross-linked honeycomb lattice structure. Additionally, the graphene-like material demonstrated high electrical conductivity and satisfactory mechanical elasticity. Aivaras Sartanavičius et al. [14] used a picosecond laser to convert polyimide (PI) into a conductive graphene network. They confirmed this by Raman spectroscopy and sheet resistance measurements. In addition, they investigated the use of laser-induced graphene (LIG) in PI for high-frequency antenna applications. In particular, they focused on the development of a 2.45 GHz patch antenna, which is commonly used for WiFi frequencies. The study showed that, due to their flexibility and conductivity, LIG-PI composites could be effectively used in antenna applications. By varying the laser parameters, they controlled the quality of the LIG and achieved a minimum sheet resistance of 36.6 ohms/sq. The resulting LIG-PI patch antenna showed a wide operating frequency band and comparable performance to conventional materials, although the conductivity needed to be improved for optimal efficiency. They concluded that LIG-PI composites held great promise for creating flexible and sustainable electronic devices, including antennas. However, future research should focus on optimizing the LIG production process and exploring additional substrates to improve performance.

Taken together, the papers in this Special Issue highlight the ongoing progress in the field of graphene-based materials and their potential to transform a wide range of technologies. The studies presented provide a strong foundation for future research and development, with a focus on expanding the capabilities and applications of these remarkable materials.

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