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Editorial

Low Dimension Elemental and van der Waals Hetetostructures Materials including C Nanostructures and Perovskites

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The field of nanostructures, today, is the one that best covers all domains of knowledge, trying to discover more and more clearly the physical-chemical properties that are hidden in the world at a nanometric scale. Knowing and resolving problems inherent to the structure of "real matter" is its own nature ranging from those of the environment up to health, involving science and scientists in ever increasing challenges. This vast field of research, both fundamental and applied, has interest and increasingly aggregates interest in favor of pure knowledge, curiosity, and potential applicability, given that the world smaller than the visible often reserves surprising results. In recent years, low dimensional structures, including 2D layered materials, nanowires, and nanocrystals, have received remarkable attention due to their unique properties, novel functionality, and potential applications in several areas of photonics, nanoelectronics, sensing, and photovoltaics [1–4]. Notably, low-dimensional systems and devices are already featured in several emerging technologies and advanced applications.

This editorial article highlights the research works published in the journal Nanomaterials and Nanotechnology within the Special Collection on "Low Dimension Elemental and van der Waals Heterostructures Materials including C Nanostructures and Perovskites." This Special Collection showcases original research and includes seven articles presenting remarkable results obtained in the field with a worldwide participation of authors from India, Italy, Ireland, Estonia, France, Norway, China, Egypt, Pakistan, and Saudi Arabia.

In relation to the considerable attention reserved to the field of low dimensional materials and their amazing applications, due mention must be made to the seven articles published within this Special Collection, which can be categorized in two broad topics: (i) carbon-based materials, such as carbon nanocrystals [5] and carbon nanotubes [6–8], and (ii) 2D materials [9] and nanostructures, such as bimetallic oxides [10] and nanocomposites [11].

Carbon materials are crucial for a widespread range of technological applications, such as electrodes for batteries, super capacitors, catalysis and fuel cells, gas storage, and water cleaning, along with biomedical applications related to the carbon biocompatibility. For this reason, C-based materials are extensively studied in each of their forms, from bulk to nanoscale, along with their methods of preparation and modeling [12].

The family of carbon materials include structures such as carbon fullerenes, carbon nanofibers, carbon nanotubes, and carbon nanospheres. In recent years, among the others, the spherical-shaped carbons nanocrystals (NCs) have gained increasing interest for a variety of amazing applications. As an example, the C nanostructures are used to virtually permanently stop the Acid Orange-7 dye employed for coloring in the textile industry, as shown by B. Krishnappa et al. [5]. In this paper, the removal efficacy of spherical-shaped nanocarbons was investigated as a function of contact period by varying their dose, pH, and initial AO-7 concentration. Interestingly, the oil palm leaves–based carbon nanospheres removed acid dye with an efficiency of about 99%.

In the field of C-based materials, carbon nanotubes (CNTs) have attracted much attention for their numerous technological applications. Their functionalization allows for addressing low dispersion and solubilization of CNTs in many solvents or polymers [13]. Moreover, different materials have shown enhancements in physical, chemical, and structural properties when combined with CNTs. Among the other materials, ZnO continues to gather considerable interest for a wide range of its applications in the form of both thin films [14] and nanostructures [15]. Especially for making a variety of short-wavelength devices, such as light-emitting diodes and photodetectors, different kinds of ZnO-based nanostructures have been widely studied [16]. In these UV devices, the surface states are responsible for the reduction of the emission. The combination of the as-synthesized ZnO nanoparticles with CNTs allows in reducing the residual ZnO surface states to obtain a notable enhancement in the UV emission, as shown in the article by K. Nagpal et al. [6] within the present Special Collection. In this article, through an effective passivating mechanism of the surface states of ZnO nanoparticles, the latter manifested an intense near band-edge (NBE) UV emission and a negligible surface related defect level emission (DLE). Therefore, by combining ZnO NPs with CNTs, the DLE was suppressed and the NBE was blue-shifted and further amplified to about 5-fold.

Furthermore, CNTs have been widely used in various fields due to their excellent physical and chemical properties, such as an excellent electrical conductivity and large specific surface areas, establishing them as a good candidate to provide a pathway for preventing the aggregation of nanoparticles and accelerating the electron transfer. Moreover, metallophthalocyanine (MPcs) loaded on carbon-based materials is suitable for the electron transfer to improve the catalytic activity. In their work G. Zhang et al. [7] use dinuclear metallophthalocyanines $Fe_2Pc_2(CP)_4$, containing carboxyl substitutes wrapped with amino-functionalized carbon nanotubes (MWCNTs-NH_2) to improve electrocatalytic activity for oxygen reduction reactions using a facile "*in situ*" amidation reaction. The results obtained showed that the π–π interactions between the $Fe_2Pc_2(CP)_4$ and MWCNTs-NH_2 dramatically increased the π electron density in such conjugated structures, and thus the oxygen is reduced much more easily.

Staying within the topic of C-based materials, V. Sivamaran et al. reported on CNTs, carbon nanorings, and carbon nanospheres, using the chemical vapor deposition (CVD) process, in a comprehensive review paper [8]. In this article, the effect of CVD parameters on carbon nanomaterials morphology, such as diameter, yield, and quality is presented. The mechanism of CVD formation and growth of carbon nanomaterials is also reviewed. Summarizing the results reported in literature, in this review article, Sivamaran et al. also point out that, compared with CNTs, spheres and rings—although there is less intensive research in their synthesis—they are able, in some aspects, to perform better than CNT structures in energy storage and sensing.

The second topic of the special collection includes the 2D layered materials. These structures exhibit several interesting behaviors such as strong light–matter interactions, tunable band gaps, many-body effects, and novel excitonic effects at room temperature. Furthermore, they can be considered as the building blocks from which tailored van der Waals heterostructures with control at the monolayer level can be realized. This offers unprecedented opportunities for their bandgap engineering to achieve new achievements on both fundamental science and promising applications.

Among these materials, transition metal dicalcogenides (TMDCs), such as MoS2, MoSe2, WS2, WSe2, and so on, have been of the utmost interest due to their properties of finite bandgap, flexibiltiy, ultrathinness, and a wide variety of electronic properties ranging from metallic to semi-metallic to semiconducting. These superior properties make TMDCs a promising new material for innovative sensors, optoelectronic devices, highly sensitive photodetection, quantum communication devices, and so on [17, 18]. Within the research on these materials, two-dimentional SnS has attracted widespread interest because of its unique properties such as adjustable direct band gap, high carrier mobility, and in-plane anisotropy. D. Yu et al. applied density functional theory combined with the nonequilibrium Green's function method to study the photogalvanic effect of monolayer SnS at a small bias voltage under perpendicular irradiation [9]. The photocurrent was generated over the entire visible light range, and it was saturated at a small bias voltage for several photon energies of 2.4, 2.6, 3.2, and 3.4 eV. The photocurrent showed cosine dependence of the polarization angle, attributed to the second-order response to the photoelectric field, providing, interestingly, a deeper interpretation of the photogalvanic properties of these fascinating 2D SnS nanosheet-based devices.

The part of the Special Collections devoted to nanostructures includes the paper on bimetallic oxide nanostructure as a high performance electrode material for supercapacitors, authored by V. Adimule et al. [10]. Recently, Sr-based bimetal oxides (Srx My Oz) where M is any metal (for example, $SrTiO_3$, Fe: Sr $(OH)_2$) have been demonstrated to have diversified physical properties and are excellent materials for supercapacitor electrodes. Also, $SrTiO_3$ nanoparticles (NPs) with cubic structure synthesized by using the sol-gel technique have recently demonstrated high specific capacitance, cyclic retention, and excellent cyclic stability. In the article of V. Adimule and coworkers [10], the authors synthesized stable bimetallic oxide, SrO 0.5 : MnO 0.5 nanostructures, as electrode material for energy storage applications by the facile coprecipitation method using surfactants and reducing agents. This work shows significant results concerning the realization of supercapacitor electrodes based on SrO 0.5 : MnO 0.5 nanostructures, which have shown the best electrochemical properties obtained up to now, among others, possessing a specific capacitance of 392.8 F/g.

Within the topic of nanostructures, the last paper of this Special Collection by G. Jabar et al. [11] focuses the attention on novel nanocomposites such as graphitic carbon nitride materials for green oxidative desulfurization of fuel oil. The catalysts utilized for oxidative desulfurization, such as $CoWO_4$ and Bi_2WO_6 with graphitic carbon nitride (g-C_3N_4)

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as a support, were successfully synthesized by the one-pot hydrothermal method. The oxidative desulfurization reaction was found to be a pseudo-first-order process, where the thermodynamic study revealed that the reaction is endothermic and spontaneous in nature. The catalytic efficiency for sulfur removal is more than 90% in the presence of support (g-C_3N_4) to obtain sulfur-free fuel [11].

As guest editors we sincerely hope that the publication of the abovementioned seven scientific papers inside this special collection would give to the readers an opportunity for getting a brief view of some of the most recent results in the field of nanomaterials and nanostructures. We wish the readers a fruitful and pleasant reading.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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