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Editorial

Special Issue on “Multifunctional Hybrid Materials Based on Polymers: Design and Performance”

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Hybrids and composite materials offer a synergic combination of polymer and inorganic features. Over the past few decades, hybrid materials based on polymers have gained a lot of attention, not only for their interesting structural characterization, but also for their promising functional applications. Thus, investigations into multifunctional polymeric hybrid materials establish an essential task for polymer science. Tremendous progress in the design and preparation of new hybrid materials based on polymers has created a large number of solutions to the current challenges in many applications such asadsorption, separation, gas storage, catalysis, sensing, electronic devices, etc. Especially, the hybridization of these materials can bring about exceptional superior multifunctions, and thus presents the promise of application in the fields of chemical and biological sensing, heterogeneous catalysis, energy transformation and storage, and atmosphere and human health.

Moreover, polymer hybrid materials can be created via blending of functional polymers with other nanostructured compounds, with the latter displaying size-dependent physical and chemical features. This has become a considerable area for research and technological development due to the significant properties and multifunctionalities emanated from polymers’ nanocomposite/nanohybrid structure. Therefore, scientists are attempting to incorporate different types of nanostructured compounds to adjust structures and enhance the properties of conventional polymers, which will have a tremendous impact in the field of polymer science. Nevertheless, the design and development of multifunctional hybrid nanomaterials also remain challenging, and their introduction into realistic applications is not yet acceptable. Therefore, it is highly advantageous to implemnet a progress on state-of-the-art nanomanufacturing and scale-up nanotechnology so as to design and synthesize progressive multifunctional hybrid nanomaterials with improved efficiency.

In this Special Issue, we introduce an elegant selection of first-rate reviews and original research articles that demonstrate the significance of developing multifunctional hybrid material based on polymers (including nanomaterials) for different applications. Deep understanding and appropriate theoretical calculations for analyzing the behaviors of these materials (involved in the formulations) at their interface have also been achieved through fundamental investigations. The aim of this editorial is to present a short introduction to each published paper, and to highlight their major findings and conclusions. In the following paragraphs, we review all the articles in our Special Issue. We believe that this editorial will hold the attention of the extensive possible section of our readership.

At present, global tendencies towards a cyclical economy, sustainability, a green economy, and nanotechnology propose the use of by-products, biomass, and/or biowastes that have zero environmental fingerprints as raw materials for the design of original, biodegradable, active packaging materials. One of the most promising and extensively used bio-based polymers that has already been commercialized is Poly(L-Lactic Acid) (PLLA).

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A novel process to enhance the mechanical, antioxidant, and barrier features of Poly(L-Lactic Acid)/chitosan films is presented by Karakassides et al. through incorporating essential basil oil extract. The obtained composite films exhibited advanced food packaging properties compared to those films without the addition of basil oil. The authors observed that films with 5%wt and 10%wt chitosan/basil oil loadings displayed improved thermal, mechanical, and barrier behaviors, as well as significant antioxidant activity [1]. Organic–organic biohybrid systems for sustained drug release have also emerged as a flexible approach for the development of optimized formulations and dosage forms. Biohybrid materials are advanced systems that combine the characteristics of organic nanocarriers with the biodegradability of (bio)polymers. In this regard, a smart copolymeric hydrogel for controlled delivery of galantamine hydrobromide has been developed by Elaissari et al. The synthesis of the hydrogel was performed via free radical polymerization using HPMC (hydroxypropyl methylcellulose) and pectin as biocompatible polymers and acrylic acid as a monomer. The authors concluded that the prepared hydrogel showed good swelling and release kinetics, which may help in providing controlled release drug effects, leading to improved compliance for dementia patients [2].

Functionalized nanocomposites of crosslinked polyethylene (XLPE)/SiO2 have been developed by Xuan Wang et al. with the aim of improving the crosslinking efficiency of an ultraviolet-initiated crosslinking technique and ameliorating electrical resistance of XLPE materials. This goal was achieved by chemically grafting an auxiliary crosslinker (trimethylolpropane triacrylate, TMPTA) onto nanosilica surfaces. Introducing polar-groups on the modified nanosilica surfaces through this outstanding work could inhibit electrical-tree growth and simultaneously introduce deep traps that imbed charge injections, thus accounting for remarkable improvements in electrical-tree resistance and dielectric breakdown strength. The authors concluded that this approach could facilitate new design and assembly technologies to obtain significant improvements in crosslinking degree, electrical-tree resistance, and AC electrical breakdown field [3]. Another related research is reported in detail by Jinkie Shim et al., who employed the melt mixing technique with a controlled residence time of 20 min to disperse single-walled carbon nanotubes (SWNTs) into a polypropylene matrix. As for the main findings, an improvement in the electrical conductivity of the SWNTs in the PP matrix was achieved with the novel melt mixing process without further modifications, such as compatibilizers or chemical treatment of CNTs [4]. Related to this subject is the effect of imidazolium-based ionic liquids on the thermo-mechanico-chemical properties of polymer nanocomposites, which was reviewed by Shamsuri et al. According to the authors, this review paper could serve as an initial guide for polymer composite researchers in modifying nanofillers by means of ionic liquids for improving the performance of polymer nanocomposites [5].

From an engineering perspective, the continuously increasing demand for cost reduction, together with high performance product requirements, has led to substantial research developments in new construction materials and tailored hybridization technologies. As stated before, the outcomes of these efforts are hybrid structures in which the characteristics and performance of products are improved via combining the properties and behaviors of each specific material. One of these construction materials is polymer concrete, which contains aggregates and a polymeric binder such as epoxy, polyester, vinyl ester, or normal epoxy mixture. In one of the articles published in this Special Issue, Mohammadyan-Yasouj et al. investigated the effect of basalt fiber (BF) and sodium alginate addition on the compressive strength of polymer concrete. They found that BF and alginate can decrease the compressive strength of polymer concretes at room temperature, but they can also improve resistance against higher temperatures [6]. In another contribution, the same authors reviewed the effect of using nano-alumina (NA) to improve rheological, mechanical parameters, as well as the elevated temperature resistance of self-compacting concrete (SCC). As a summary of this review paper, the authors indicated that the rheological parameters of fresh SCC are significantly affected by the addition of NA due to their high surface-area-to-volume ratio. Moreover, enhanced durability and compressive strength could be achieved only by adding a small amount of NA to SCC. Therefore, the use of NA could enhance the performance of SCC, as the addition of NA to SCC results in a denser microstructure compared to normal SCC [7].

Another type of construction material is polymer–metal hybrid structures, which are used in several engineering applications. Due to strong dissimilarities in physical-chemical properties, hybrids of metals and polymers are challenging, though this is due more to geometrical and design considerations. To overcome some of the limitations of the current state of hybrid joining, a friction riveting (FricRiveting) process has been developed for joining metallic bolts (rivets) with polymeric plates. In this regard, Blaga et al. contributed an article in which they demonstrate the transferability of friction riveting from dedicated laboratory equipment to modified simple drilling machines using a commercially available off-the-shelf motor for achieving relatively high rotational speeds, and thus sufficient energy for rivet tip deformation and anchoring. They showed that this technique can be performed with an easy-to-achieve modification and low-cost machinery [8].

The present Special Issue also benefits from some reports dealing with simulation and modeling studies. In one study, Bassyouni et al. evaluated the effect of functionalized multi-walled carbon nanotubes (MWCNTs) on the performance of glass fiber (GF)-reinforced polypropylene (PP) for wind turbine blades. In this study, simulation and analysis are performed with the Ansys computer package to gain insight into the durability of polypropylene-chopped E-glass for application in turbine blades under aerodynamic, gravitational, and centrifugal loads. The authors found out that adding MWCNTs to glass fiber-reinforced PP composites had a substantial influence on deflection reduction, while that adding them to chopped-polypropylene E-glass had a significant effect on reducing the bias estimated by finite element analysis [9]. In another study, Unal Sen at al. studied the mesoscale morphologies of Nafion/poly(1-vinyl-1,2,4-triazole) (Nafion-PVTri) and Nafion/poly(vinyl phosphonic acid) (Nafion-PVPA) blend membranes through dissipative particle dynamics (DPD) simulation techniques. Simulation results indicated that both blend membranes can form a phase-separated microstructure due to the different hydrophobic and hydrophilic characters of different polymer chains and different segments in the same polymer chain. The authors established a connection between the simulated morphologies and experimental properties [10].

Finally, the last contribution in this Special Issue is a review paper that focuses specifically on the significance and emerging role of surface-functionalized and hybrid nanomaterials as drug delivery systems in combating lung cancer. This spotlight was achieved by Aboudzadeh et al. through citing most recent and representative examples targeted at lung cancer treatment [11].

In view of the above review and discussion, we feel that the present Special Issue investigates the latest research on multifunctional hybrid materials, including fundamental theory and experiments, along with reviews and articles. More efficient approaches and synthesis processes, as well as further insights about the interfacial chemistry of integrated materials in polymeric hybrid systems, are needed.

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