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Editorial

Special Issue—Polymer Composites: Materials and Processes for Challenging Applications

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Despite the availability of numerous neat polymers, polymer composites offer a wide range of advantages over traditional materials such as metals, ceramics, and neat polymers. Polymer (matrix) composites consist of a base polymeric material and another material with different properties such as mechanical strength. Traditionally, polymer composites were developed to enhance mechanical functions. A prime example is fiber-reinforced plastic or polymer (FRP) [1] which has a polymer matrix with fibrous minor components such as fiberglass, carbon fibers, fibers made of engineering plastics, or other natural fibers. It is used in applications that require enhanced mechanical strength such as helmets, tennis rackets, and fishing rods.

With the increasing need for new demands to address the challenges that we face, polymer composites offer a vast number of potential solutions. Composites can be developed by compounding polymers with minor components with various properties, including size (macro [2], micro [2,3], or nano [4,5]), shape (fiber [1], sheet, chunk [3], or changing shape [6]), phase (gas [7], supercritical fluid [8], liquid [9], or solid [3]), rheology [3,8], rigidity [2] (flexible, soft, or hard), mechanical strengths [2] (toughness, abrasion, ductility, or yielding), surface properties [10] (surface tension, attraction, or repulsion), optics [11] (polarization, transparency or color), thermal stability [12,13] (flammability, thermal decomposition [3], or molecular weight change), biocompatibility/biodegradability [14], phase behavior (crystallization, melting, sol–gel transition, or glass transition), density, electrical properties [15,16] (resistance, dielectric [7], conductive, or capacitance [7]), magnetism [11], and chemical properties [17] (corrosion, reaction, or modification). By combining various candidate materials using different processes, composites can offer a huge number of functions, making them a versatile solution to many challenges.

The challenges we face today include climate change, greenhouse gas emissions, plastic pollution, accumulated waste, a lack of enough energy or resources, unfavorable conditions for farming or fishing, new virus outbreaks, space exploration, and other various human needs. Developing new materials and processes that provide desired functions while spending less time and consuming fewer resources of materials and energy is critical in addressing these challenges. Thus, the development of polymer composites provides a viable and sustainable solution to these challenges.

The following are examples of the uses of polymer composites for challenging applications. In the aerospace industry [18,19], they are used to create lightweight, high-strength components such as wings, fuselages, engine parts, and space suits that must withstand extreme temperatures and pressures and radiation yet show durability or/and flexibility. The automotive industry [20] uses composites to produce body panels, bumpers, and interior components with reduced weight, improved fuel efficiency, enhanced safety, and sustainability. Energy applications [21] such as wind turbine blades, solar panels, and fuel cells require composites that can handle high mechanical stresses and chemical attacks while improving efficiency and durability. In the automotive/energy industry, developing a composite to construct fuel tanks [22] for fuel cell vehicles, which can withstand high pressure and remain light, is a challenging task. Marine applications [23] require corrosion-resistant composites such for boat hulls, decks, and masts that should resist chemical attacks from ions and marine organism growth but be environmentally benign. Medical applications [24] use composites to create biocompatible implants, prosthetics, and surgical instruments that require strength, flexibility, and biocompatibility/biodegradability. In sports and recreation [25], composites are used to create lightweight and durable components such as skis, tennis rackets, and bicycle frames that can handle high temperature fluctuations, mechanical imparts, and wear and tear. Polymer composites also play an essential role in electronic displays [26], including transparent displays that are made of polymeric films and circuits. These displays require high resolutions, and circuits must be hidden by employing nanowires or transparent electrodes. This reduces the amount of material required to fabricate electronic displays compared with traditional liquid crystal display (LCD) or organic light emitting diode (OLED) displays. The industry of foams benefits from polymer composites as well. Physical foaming plastics with smart (active) polymeric fibers improve foamability [27], which enhances insulation and reduces heating energy. Composites can also be developed to address plastic pollution [28] by compounding biodegradable plastics, where one serves as the matrix, and the other has a spherical [29] or fibrous [30] structure that improves mechanical strength.

In recent years, the field of polymer composites has shown significant advancements. New types of raw materials have been discovered, and researchers have developed methods to compound different materials, to shape them into new forms, to fabricate composites using novel processes, and to characterize new materials. These advancements have led to the development of composites with advanced functions, capable of addressing the challenges that we face in the early 21st century. This Special Issue aimed to provide an up-to-date overview of those recent advances in polymer composites. Furthermore, the papers in this Special Issue highlight the importance of sustainability in the development of polymer composites. Advances in sustainability will be critical to ensuring that polymer composites can continue to address the challenges of the 21st century in a way that is responsible and sustainable.

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

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