applied sciences

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Editorial

Design, Synthesis and Characterization of Hybrid Composite Materials

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Citation: Blanco, I. Design, Synthesis and Characterization of Hybrid Composite Materials. *Appl. Sci.* **2023**, *13*, 3443. https://doi.org/10.3390/app13063443

Received: 25 February 2023
Revised: 2 March 2023
Accepted: 7 March 2023
Published: 8 March 2023

Polymer composites represent the platform materials of the 21st century, and they make up an important slice of the market for the production of modern materials [1,2]. This trend is expected to grow further in the coming years due to the fact that composites are compatible with eco and sustainable design; in addition, they represent the best option in manufacturing equipment for the planned energy transition [3,4]. Their design is based on adding a second component to a polymer matrix to enhance its properties. Among the various possible composites, organic–inorganic hybrid materials offer advantageous performance relative to their non-hybrid counterparts [5]. In fact, the rapid development of technology in the present age requires ever better performing materials capable of responding to the financial needs of customers and not impacting the environment. To meet all of these requirements, scientists, especially materials engineers, have looked to nature, which has always been a source of inspiration for the greatest discoveries. They have realized that nature has always mixed multiple components to obtain superior properties, compared with their pure counterparts. In particular, if this combination takes place between two organic and inorganic counterparts, the best results are generally obtained, thus hybrid composite materials are born.

Nine articles and one review, by various materials scientists, constitute the architecture of this Special Issue, which aims to highlight new findings in the design, synthesis, and characterization of hybrid composite materials.

Seo and Kim studied the possibility of preparing a TiO_2-incorporated ultra-high-performance concrete (UHPC) mix for its use in transparent plastic bar reinforced concrete [6]. The Korean researchers aimed to produce a visible-light-reactive photocatalyst, whose process takes place through calcination at high temperature, using the advantages offered by transparent plastic bar reinforced concrete (TPBRC) in NOx removal performance. They observed an increase in the removal efficiency up to about 25% when it was applied with TPBRC. Furthermore, the prepared hybrid composite confirmed the possibility that the harm caused by harmful substances in indoor spaces can be mitigated due to photocatalytic reactions under visible light when considering the light transmittance and the exposed area on the concrete surface.

Choi and coworkers developed a natural matrix hybrid hydrogel patch and evaluated its effectiveness against atopic dermatitis (AD) [7]. Since there is no cure for AD, and the available topical patch for AD treatment minimizes skin irritation but does not sufficiently adhere and absorb to specific areas, the aforementioned researchers designed and prepared a new hydrogel formulation that can effectively control the release of therapeutic agents to specific local areas with minimal skin irritation. They found that a 0.4 wt% Centella asiatica extract (CAE) loaded with a hyaluronic acid–dextran (HA-Dex) hybrid hydrogel patch produced the most stable release profile and the highest level of cellular activity, thus providing moisture and releasing CAE over an extended period of time, making them ideal for relieving atopic itching.

Considering the fact that the development of hybrid metal/polymer filaments opens up the possibility to expand metal 3D printing with investment costs accessible to small and medium enterprises, Cicala et al. proposed the 3D printing of metal parts with the same approach used for desktop 3D printing. Using fused filament fabrication (FFF), they studied two commercial hybrid metal/polymer filaments for manufacturing metal parts without using the expensive and complex equipment typically associated with standard additive manufacturing (AM) techniques for metals [8]. The results of the mechanical characterization revealed that considerable gaps still exist compared to metals produced by standard metal AM techniques. However, it was demonstrated by cost modelling referring to a single mold prototype that the use of hybrid metal/polymer filaments processed by FFF has a strong potential to facilitate the printing of metal parts at lower cost.

Olarte-Paredes and his collaborators prepared a hybrid composite based on polyvinyl alcohol–chitosan (PVA-Chi) and reinforced it with conductive fillers such as polypyrrole (PPy), Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT: PSS), carbon black (CB), and a multi-wall carbon nanotube (MWCNT) for engineering applications [9]. The obtained hybrid materials showed higher electrical conductivity in the OH's presence and NH_2 groups, which means that they could have possible applications in biopolymer electrodes.

Samal et al. investigated the dispersion and interfacial adhesion of both isotropic and anisotropic fillers in based polymer composites [10]. They highlighted the key role of the particles in the filler distribution. Specifically, they observed how non-isotropic particles created eddies in the matrix, resulting in some porosity within the volume, but enhancing filler adhesion with the polymer. On the contrary, isotropic particles showed uniform distribution within the polymer matrix. The mechanism of the filler particles' movement within the matrix was explained in terms of simulation and surface images.

Through the sol–gel method, Catauro and coworkers designed and synthesized iron (II)-based hybrid materials with silica and polyethylene glycol (PEG) for drug delivery employment [11]. The release kinetics in a simulated body fluid (SBF) were investigated, and the amount of Fe^{2+} released was detected via ultraviolet–visible spectroscopy (UV-Vis). They also evaluated the bioactivity of the synthesized hybrid materials and the potential antibacterial properties of seven different materials against two different bacteria—*E. coli* and *S. aureus*. Continuing their studies on the hybrid materials employed in medical applications, the Italian research group focused their work on the failure of medical devices, such as bones prosthesis, which is generally the result of inflammatory and infectious phenomena. Since entrapping anti-inflammatory and anti-microbial agents inside the biomaterial matrix could avoid these phenomena, they prepared, consistently through sol–gel synthesis, inorganic/organic silica (S)/polyethylene glycol (P)/caffeic acid (A) hybrid systems with different weight percentages of P and A [12]. They verified the formation of a hydroxyapatite layer on hybrid surfaces, and through antimicrobial activity measurements, they evaluated the caffeic acid kinetic release in simulated body fluid (SBF) at 37 °C.

Mija and her research group were engaged in developing eco-friendly bio-composites through the copolymerization of a vegetable-oil-based epoxy and epoxidized linseed oil (ELO) with dodecenyl succinic anhydride (DDSA) [13]. The polymer matrix and the natural filler were then characterized showing improvements to the mechanical properties of the composites, fulfilling multiple roles: (i) spruce bark powder (SB) with its hydrochar (HC) acts as a co-reactant in the copolymerization mechanism; (ii) HC acts as reinforcement, consolidating the network and providing stiffness and rigidity; and (iii) SB acts as a plasticizer for reducing the brittle character of the epoxy resins.

Zhu et al. prepared composites by incorporating APDMS-modified carbon felt (A-CF) into an epoxy resin (EP) and a fluorinated ethylene propylene (FEP) mixed resin with the aim of obtaining hydrophobic, wear-resistant, and thermally conductive multifunctional composites [14]. They highlighted how the synergy among the epoxy resin, FEP, and the A-CF filler plays an important role in constructing hydrophobic surfaces and improving wear resistance and thermal conductivity. In particular, the obtained results showed that EP enhances adhesion, the FEP supplies low surface energy, and the A-CF framework improves the wear resistance of A-CF/EP/FEP composites.

Finally, in a detailed review, Gencel et al. described the fresh, hardened, and physical properties of foam concrete [15]. The properties of materials such as the cement, aggregate, foam, and fiber used in foam concrete production were detailed and their effects on microstructures were discussed. The purpose of the authors' work was to show the current level of cement-based foam concrete and their shortcomings, which requires more investigations, namely investigations into the effect of fibers on the characteristics of foam concrete and the acoustic characteristics of foam concrete.

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

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