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Editorial on “Hybrid clay materials” Special Issue

The present Special Issue reports recent advancements in hybrid materials obtained by the combination of biocompatible compounds (e.g. polymers, clay nanoparticles and natural wastes) that can be perspective for biomedical and technological applications. The blending of inorganic fillers and organic macromolecules into natural or synthetic clays represents a powerful tool to fabricate green composites with tunable mesoscopic properties depending on their structure and surface characteristics leading to the development of a framework of functional materials. These materials offer cost-effective and eco-friendly solutions across various industries, including environmental remediation, catalysis, and energy storage, making them valuable for addressing real-world challenges.

This Special Issue is composed of 16 research articles published between December 2022 and June 2025. Regarding the specific applications of the composite materials, the articles can be classified in the following fields: delivery systems for biomedicine, devices for biotechnological purposes and geopolymers for construction.

As concerns the biomedical applications, Garousi et al. [1] report that water-in-oil-in-water (W/O/W) emulsification is an appropriate procedure to fabricate nanohydrogel systems containing agarose, polyvinyl alcohol, halloysite clay nanotubes (HNTs) and 5-fluorouracil. This hybrid nanohydrogel is promising for the treatment of breast cancer. Hydrogel systems for wound dressing and moxifloxacin drug delivery were prepared by graft copolymerization reaction of poly (2-(methacryloyloxy) ethyl trimethylammonium chloride) [poly (METAC)] onto aloe vera (AV) and sterculia gum (SG) polymers [2]. Ternary hybrid hydrogels formed by polymers (polyvinyl pyrrolidone and polyethylene glycol) and montmorillonite clay can be employed as pH-sensitive nanocarriers for curcumin [3]. Copolymer hydrogels formed by grafting of methacrylamide (MAAm) and vinyl sulphonic acid (VSA) onto psyllium are efficient to control the release of vancomycin drug [4]. Polysaccharide xanthan gum (XG) was used to synthesize copolymer network hydrogels with antioxidant activity as demonstrated by the DPPH scavenging method [5]. Caruso et al. [6] proved that the vacuum-cyclic assisted procedure is efficient for the loading of antisense oligonucleotide (ASO1) and a DNA aptamer (D12) inside the cavity of HNTs. The encapsulation of photosensitive pharmaceutical ingredients (α-lipoic acid and moxifloxacin hydrochloride) within halloysite clay represents a proper tool to obtain UV-resistant tablets [7]. The morphological characteristics of Hydroxyapatite (HAp)/Polyethylene glycol (PEG) composites are affected by the synthesis temperature. The optimum conditions can be achieved at 70 °C, where the synthesis produces needle and cubic HAp-PEG composites with excellent thermal resistance useful for bone implant applications [8]. Composite hydrogels with antimicrobial activity can be obtained by mixing natural polysaccharides, such as gum acacia and tragacanth gum [9]. Moreover, tragacanth gum is a suitable polysaccharide for fabrication of hydrogel wound dressing containing citocoline, which is a nerve regenerating agent [10]. Wound dressings were prepared through encapsulation of ofloxacin (antibiotic drug) within hybrid hydrogels formed by moringa gum (MG) and poly (METAC) [11].

Regarding the development of advanced devices, Sánchez-Tizapa et al. proved the suitability of epoxy based nanocomposites as sensing devices for environmental purposes [12], while Sengwa evidenced that hybrid films based on poly (vinylidene fluoride) (PVDF), poly (ethylene oxide) (PEO) and silica nanoparticles can be employed as insulator and dielectric substrate materials for flexible radioelectronics and energy storage applications [13]. It was demonstrated that ultrasonic pulse velocity controls the physico-chemical properties (water absorption, apparent porosity and density) of hybrid systems reinforced by different microparticles [14].

Finally, geopolymeric materials prepared by mixing metakaolin, fly ash, ground granulated blast furnace slag and rice husk ash exhibited optimal mechanical performances, superior sorptivity, fast chloride permeability and acid attack resistance [15]. The combination of borax and recycled brick waste (RBW) was successful in producing geopolymers with excellent compressive resistance [16].

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