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Antibacterial Applications of Biodegradable Polymer Matrix Composites with Graphene-Related Materials: A Critical Analysis

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Abstract

For the first time, the development, processing methods, mechanical properties, and antibacterial activity of biodegradable polymer matrix composites containing graphene-related materials (GRMs) for antibacterial applications are discussed in this review. Chitosan is the most widely used biodegradable polymer for the production of antibacterial GRM-containing composites due to its suitable biological properties and processability. The majority of biodegradable polymers, such as those made from cellulose, gelatin, PVA, PCL, and PHA, have little to no antibacterial properties on their own; However, when combined with GRMs, they exhibit significant antibacterial activity (>70 percent). In vitro and in vivo examinations demonstrate that GRMs functionalization with biodegradable polymers likewise lessens potential GRM cytotoxicity.

Keywords: Biodegradable Polymer; Graphene; Antibacterial applications

Introduction

Polymers are widely used in a variety of medical applications, including wound dressings, implants, mobility aids, cleanroom supplies, and medical device packaging. Their use as biomaterials has had a significant impact on modern medicine. The global market for medical polymers was valued at USD 18.4 billion in 2021, according to a recent report . From 2022 to 2030, the market is expected to grow at an annual rate of 8%. Biodegradable polymers, in particular, have the advantage of being able to be broken down and removed after their intended use has been accomplished. Each year, approximately 300 million tons of polymer-based materials are produced, half of which are used in single-use products and emit significant carbon dioxide and environmental pollution when. As a result, non-biodegradable polymers have been gradually being replaced by biodegradable, renewable, and non-toxic polymers. With a global biodegradable polymer production capacity of 1.2 million tons in 2020 that is anticipated to rapidly increase, biodegradable polymers are one of the fastest-growing segments of the global plastics industry. In this review paper, we focus on the antibacterial properties of biodegradable polymers and biodegradable polymer matrix/GRM composites and present an overview of their current state [1].

GRMs for use in the medical field

GRMs, which include GR, GO, FLG, GNP, and rGO, are versatile reinforcements that can be used to create high-performance polymer composites with a variety of applications in industry and medicine. Due to its oxygen-containing functional groups, GO has particularly high mechanical properties and excellent interfacial adhesion with polymers; these can bind to oxygen-containing functional groups in aliphatic polymers, allowing the polymer matrix and GRMs to interact effectively. The development of composites with superior process ability, good electrical conductivity, relatively high mechanical properties, and most importantly, as discussed in the present review article, a broad-spectrum bactericidal activity has been documented by the exponential increase in the number of studies on GO and GR reinforced composites over the past few years. By incorporating GRMs into various bulk polymers, excellent antibacterial properties and relatively high mechanical properties like fracture strength and modulus can be maintained for biomedical and filtration applications. Nonetheless, the ebb and flow writing for the most part comprises of unique exploration articles inspecting antibacterial movement and seldom mechanical properties of biodegradable polymer/GRM composites; Consequently, a comprehensive critical review paper that discusses and contrasts the findings of the extensive available literature is required. The authors are aware of only a few review papers focusing on coatings and GO reinforced polymer nanocomposites. Examples of GRM-reinforced polymer matrix composites (mostly PLA, PVA, PLA, and polymathic methacrylate composites) can be found in these examples. However, they only briefly discuss a small number of composite systems' antimicrobial activity without going into detail about their mechanical properties or processing methods [2, 3, 4, 5].

As a result, we believe that GRMs reinforced biodegradable polymer composites for antibacterial applications require a comprehensive critical review. As a result, the recent difficulties associated with the processing and creation of such composites specifically for clinical applications are the subject of this review's critical evaluation of the relevant literature [6]. The antibacterial activity of biodegradable polymer-based GRMs composites under various in vivo and in vitro conditions is the primary focus. In order to produce biodegradable polymer/GRM composites for antibacterial applications, polysaccharide-based (CS, Cel, and alginate), protein-based (Gel and Col), synthetic-based (PLA, PVA, and PCL), and microbial-based (PHA) polymers have been among the most widely considered biomaterials. As a result, the current review provides a comprehensive overview of the current state of the art in relation to the aforementioned polymers GRMs used in biomedical applications are also briefly discussed, their antibacterial functionalization is discussed, and the proposed antibacterial mechanisms are summarized. Based

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on the classification of these polymers that was provided earlier, the antibacterial properties of biodegradable polymer/GRM composites, as well as their microstructural, mechanical, surface, and biological characteristics, are discussed. A brief overview of the investigated processing paths for the creation of these composites is provided. Each composite system's future research directions shed light on how to overcome composite performance challenges like long-term health effects, time-dependent mechanical properties, toxicity, and durability [7, 8].

Discussion

PLA is a thermoplastic engineered polymer and an alluring biopolymer given its inexhaustibility, biodegradability and somewhat minimal expense. It has some drawbacks, despite its widespread use in tissue engineering, drug delivery, and food packaging [196]: lack of intrinsic bioactivity, slow crystallization rate, low barrier to oxygen, excessive brittleness, and poor mechanical behaviour [9].

Conclusion

The following are some of the (mostly) GR and GO reinforced biodegradable polymer composites' antibacterial uses that have been critically examined in this article: (1) polysaccharide-based polymers, such as CS, Cel, and alginate; 2) protein-based polymers, such as Gel and Col; 3) synthetic polymers, such as PLA, PVA, and PCL; and 4) microbial polymers made from renewable resources (PHA). The development, processing methods, mechanical properties, and specifically the antibacterial activity of these composites are all discussed in the paper [10].

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Conflict of Interest

The authors declare that they do not have any known personal relationships or competing financial interests that could have appeared to have influenced the work reported in this paper.

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