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Mini Review

Graphene with East Taste in Herbal Nanomedicine

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Abstract

Graphene with a carbon-based structure can be considered as one of the most biocompatible nanomaterials synthesized in the laboratories. In this regard, green synthesis of graphene by herb and their extracts/ingredients has been drawn many attentions. Furthermore, potential applications of herbal-functionalized graphene nanomaterials in upcoming nanomedicine is known as one of the hot topics in recent years. Here, we have briefly reviewed green synthesis of graphene by some traditional east herbs and the unique features of herbal-functionalized graphene in some important biomedical/biological fields including anti-pathogen, cancer therapy, and tissue engineering purposes.

Keywords: Graphene Oxide; Nanomaterials; Green Synthesis; Antibacterial/Anticancer Drugs; Tissue Engineering

Introduction

Graphene is known as one of the unique two-dimensional nanomaterials with fascinating physicochemical properties highlighted in nanomedicine [1]. Interestingly, it is constructed by carbon atoms which are the basic elements of life in the Universe. Hence, graphene has been extensively applied in various biological as well as biomedical applications including, antibacterial [2], antifungal [3], antiparasitical [4] antiviral [5] purposes, various tissue engineering from cartilage [6] to vascular [7], bone [8], cardiac [9] and neuronal [10] tissue regenerations, drug/gene delivery [11], cancer detection/imaging [12], targeting [13] and therapy [14], DNA/RNA extraction [15], genetic biosensing [16] applicable in early detection of harmful gene expressions in blood [17], treatment of various diseases from viral-induced diseases [18] to Parkinson/Alzheimer [19] and recently fabrication of antiviral drugs [20] and vaccine [21]. In this work, we have reviewed green reduction of graphene oxide by some traditional east herbs and some special applications of herbal-functionalized graphene in upcoming biomedicine.

Green reduction of graphene oxide by traditional east herbs

Ingredients and/or extracts of various traditional east herbs (originated from China and India to Persian) have been widely utilized for green synthesis and green functionalization of graphene materials applicable in various biological/biomedical purposes. For instance, Polyphenols of green tea [22], Aloe vera [23], *Spinacia oleracea* [24], Allicin of garlic [25], *Ocimum sanctum* [26], Curcumin [27], Inulin [28], *Lycium barbarum* [29], Chrysanthemum [30], *Hibiscus sabdariffa* L. [31], *Salvadora persica* L. [32], Clove essential oil [33], and Rose water [34] have been used for green reduction/deoxygenation of graphene oxide.

Herbal-functionalized graphene in biomedicine

The green reduced graphene oxide sheets functionalized by herbal molecules/ingredients/drugs have been used in versatile biological/biomedical applications. For example, ginseng-reduced graphene oxide sheets were utilized as a two-dimensional scaffolds in proliferation/differentiation of human neural stem cells into neurons [35]. The reduced graphene oxide synthesized by

Chenopodium album [36] and *Lantana camara* [37] was suggested as effective biomediated nanomaterials for antimicrobial and anticancer purposes. Allicin-loaded graphene was used in antibacterial purposes [38]. Chang., *et al*. [39] reported the effect of reduced graphene oxide/Amaranth extract/Au nanocomposite hydrogel for localized and multiple synergistic cancer therapy. Curcumin-reduced graphene oxide was also applied in cancer cell destruction [40]. Green tea polyphenols-reduced graphene oxide sheets showed high attachment to cancerous cells [41], as similarly observed for glucose-reduced graphene oxide sheets [42]. In another work, Lentinan-modified graphene oxide sheets could facilitate antigen uptake in macrophages and improved/modulated the performance of antigens involved in adaptive immunity [43]. Laminaran of brown algae (with antioxidant and anti-infalammotry activities) was incorporated with three-dimensional graphene foam and the coposision was used as a three-dimensional scaffold to increase the toughness of the scaffold and modelate the behavior of starting stem cells [44]. Konjac glucomannan/sodium alginate/GO hydrogels (in which konjac glucomannan was extracted from Amorphophallus konjac) was prepared and utilized as an anticancer drug with pH-dependent release of anticancer drug [45]. The β-carotene of *Abelmoschus esculentus* L. was incorporated by graphene oxide for further regulation of Nrf2 in order to trigger protection against diethylnitrosamine-induced hepatic fibrosis [46].

Conclusion

These data indicate that graphene, as one of the most biocompatible and/or low-risk nanomaterials in the world (due to its carbon-based structure), can present high potentials for developing the current nanomedicine, especially in the frame of traditional herbal medicine having low side-effects on human body and living environment. This strategy is not against the modern medicine for the required cases and so can help it for further completion and effectiveness of the preventions/treatments.

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