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REVIEW

Design, development, and drug delivery applications of graphene polymeric nanocomposites and bionanocomposites

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Abstract
Recently, nanotechnology has significantly influenced nanomedicine and drug development, and conveyance. From the polymeric nanoarchitectural and bionanoarchitectural perspective, nanomedicine entails the application of emerging science and technology of these nanomaterials (NM) for diagnosis, treatment, and inhibition of diseases while attaining excellent health care. Graphene (GN) has undergone versatile studies as drug delivery system because of their inherent outstanding attributes and relatively minimal/zero-toxic dispositions in biologically affiliated systems. In previous decades, significant efforts have focused on smart drug delivery feasibilities of graphene and graphene-oriented materials. Thus, this elucidation elaborates newly emerging applications of graphene-based polymeric nanoarchitectural and bionanoarchitectural materials for pharmaceutical applications especially in targeted drugs conveyance effective for cardiovascular, anti-cancer, anti-microbial, anti-inflammatory, and anti-diabetic applications. Furthermore, future perspectives and challenges are also elucidated.

Keywords Polymeric nanobioarchitectures · Polymeric nanoarchitectures · Drug delivery · Graphene · Graphene oxide · Graphene nanoribbons · Reduced graphene oxide

1 Introduction

Graphene (GN), is a 2-D, flattened free standing-layer of carbon atoms, closely aligned in a hexagonally geometrically inclined honeycomb architecture [1]. GN is the building block of prevailing 0-D (graphene quantum dots (GQD), fullerene), 1-D (CNTs), and 3-D (Graphite) carbon derivatives as depicted in Scheme 1.

In GN, an atom of carbon is in attachment to three carbon atoms through tri-hybridization of sp^2 bonding whereas a single out-of-plane p-orbital offers electron delocalization. Inherent outstanding GN attributes including superior mechanical strength, elevated electrically, thermally and magnetically affiliated properties, along with exceptionally optically inclined properties which have presented GN as ideal material for application in versatile engineering fields [2]. Moreover, the unique biocompatibility, extremely broad surface areas, superior optically inclined properties in addition to simplified bio-functionalization of GN, and inherent derivatives such as graphene oxide (GO) as well as reduced graphene oxide (rGO)) have captivated global research for use of these nanomaterials (NM) in the biomedical engineering field (drug/gene conveying as well as tissue engineering, TE) [3].

Nanoscale graphene-based materials have also been extensively used for designing targeted and stimuli- responsive drug delivery systems through either external stimulus (such as temperature, light, ultrasound waves, magnetic and electric fields), internal stimulus (such as pH, redox, and enzymes), or multi-stimuli-responsive drug delivery systems bringing a controlled smart drug delivery with higher bioactivity and better temporal and spatial control at lower dosages of therapeutic agents, together with decreased toxicity and other adverse side effects [4]. Composites are mixtures of two differing materials where one is the reinforcement phase constituted of particulates, fibers, and sheets, in embedment within the other phase referred as the matrix phase. Nanoarchitectures or nanocomposites are referred as architectures where at least a single phase amongst the other phases exhibits dimensions within the nanometric range (1 nm = 10^{-9} m) which undergo further embedment in a polymeric, metallic, or ceramic matrix as depicted in Fig. 1 [5].

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