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Inorganic-Organic Hybrid Nanocomposite for Biomedical Applications

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Introduction

Recently, inorganic-organic hybrid nanocomposites (IOHNs) have drawn special attention for their extraordinary properties and wide spread applications in diverse fields such as cell imaging, drug delivery, photothermal therapy, bio-sensing, catalysis, energy storage and conversion, gas sensing, etc. [1-3]. In hybrid nanocomposite, the term 'hybrid' refers to the combination of inorganic and organic components that form a single material called nanocomposite with improved/unique properties than the individual components [4]. Origin of the properties of an IOHN can found dependent upon its particle morphology in addition to the extent of interfacial/chemical interactions existed between the components [5]. An IOHN can be more advantageous than the ordinary mixture of components for several advanced applications [1-3] but some important physicochemical characteristics of IOHNS like size, composition, surface-to-volume ratio, aggregation, stability, solubility in body fluid etc. need to study before considering the materials for biomedical applications [6].

Among varieties of organic component for IOHNs, graphene is mostly recognized as one of the potential biocompatible materials because living cells can adhere and proliferate well on graphene sheets [7]. In this context, graphene oxide (GO), a compound of graphene, is highly toxic due to the presence of large numbers of oxygen functional groups which may create more toxic effect on living cells by enhancing [8] mitochondrial respiration rate through donating its available electrons and creates reactive oxygen species (ROS) but chemically converted graphene (CCG) or reduced graphene (rGO) with less ROS is biocompatible. The large surface area, unique physiochemical properties, easy functionalization with several organics like poly(ethylene glycol), chitosan, poly(propylene glycol), poly(3-hydroxybutyrate) and inorganic counterparts makes CCG/rGO an ideal candidate for biomedical applications [7,9]. The graphene can adsorb plenty of aromatic biomolecules, makes them ideal for biosensing applications [10]. It is noted that the interaction of rGO based nanocomposite with protein can also be utilized for detection of glucose, cholesterol, haemoglobin, etc. [10].

Among the inorganic component, silica from silane chemistry is a popular material for drug/gene delivery due to its low cytotoxicity and existence of well-established bio-conjugation mechanism [11]. The porous hollow silica nanoparticles have been employed as a carrier to control the release behavior of a model drug [11]. The hollow nanospheres of Fe_3O_4 and α-Fe_2O_3 can also be used as drug carrier [12]. Besides silica, hierarchical porous titania modified with ZnO nanorods can also be employed for biomedical applications [13]. However, the metal oxide nanoparticles are not always biocompatible. ZnO nanomaterials are widely used in sunscreens lotions and cosmetics due to its non-toxicity to human skin and health. Thus, ZnO is known to be a biocompatible material but due to its particle dissolution, the metal oxide in tissue culture medium, can show toxic effects on living cells [7]. In the process of particle dissolution, Zn2+ ions shedding can damage lysosomes, perturbs mitochondria and generates ROS. The toxicity of ZnO can arise due to release of Zn2+ ions and one possible way to resist the dissolution is the functionalization by biocompatible organics such as graphene (CCG/rGO), formation of core shell structures with other metal oxide or suitable doping into the crystal lattice [7]. It is also reported that the dissolution can be prevented by polyethylene glycol capping or Fe doping [10,14]. The toxicity of the nanoparticles can also be mitigated [17] through their proper surface modification with graphene. Even, highly toxic nanoparticles (such as CdSe/ZnS quantum dots) can also tag [15] with rGO for making them potential biocompatible materials. Hu et al. [7] reported that quantum-dots (CdSe/ZnS) tagged reduced graphene oxide nanocomposites are useful for in-situ monitored bright fluorescence imaging and photothermal therapy of living cells. We also explored the biocompatible luminescent europium incorporated ZnO–CCG based nanocomposite synthesized by low temperature solution process for human breast cancer cells (MCF7) imaging [7]. The graphene based hybrid nanocomposites can also show excellent antibacterial property. In this respect, researchers already investigated graphene based IOHNs for antibacterial application [14]. We also [14] reported Ag incorporated ZnO-graphene nanocomposite for efficient antibacterial application at 6.25μg/ml concentration of the nanocomposite. Thus, it is believed that the advancement of research on IOHNs is enormous but their real-life biomedical applications need special attention on precise control of their chemical and physical properties.

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