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Review

Potential of Polymer/Graphene Nanocomposite in Electronics

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Abstract:
This review covers potentially significant nanocomposite materials for electronics industry. Polymer-based electronics is an emerging technology focusing the development of electronic devices incorporating polymers and electrically conductive materials. Graphene is an imperative type of nanomaterial used in nanocomposite. Polymer/graphene nanocomposites are made up of polymer matrices and graphene to be employed as advanced materials. Incorporating nanometric graphene may improve the electrical, electronic, thermal, and mechanical properties of polymer/graphene nanocomposites. Conducting polymers have been found more effective in electronics compared with the non-conducting thermoplastics and thermosets. Such nanomaterials have been employed in number of growing electronic technologies such as electronic circuits, display devices, sensors, detectors, conductors, transistors, transparent electrodes, batteries, solar cells, biomolecular electronics, telecommunication, storage systems, etc.

Keywords: Graphene; polymer; electronics; sensors

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1. Introduction

Field of nanocomposite is exceptionally miscellaneous and multidisciplinary field ranging from automotive to biomedical application. In electronics, polymers are commonly employed components. Polymers have advantages of lightweight, processability, durability, ease of fabrication, and low cost. Polymer-based electronics are often referred as organic electronics. Some remarkable conducting and semiconducting polymers have been designed and used having fine properties providing basis for novel next generation electronics. Design, synthesis, characterization, and application of polymer-based electronics have been explored for desirable electronic properties such as conductivity. However, their use in electronics is limited because of low electrical and other electronics desired properties [1, 2]. In this regard, nanocarbon such as graphene is the commonly used nanofiller. Graphene is two-dimensional carbon nanosheet with sp^2-hybridized carbon atoms [3]. To improve the characteristics of polymers, graphene has been used as an effective reinforcement. Theproperties and applications of polymer/graphene nanocomposite have been enhanced owing to exclusive enhanced mechanical, and thermal features [4-8]. Moreover, other attractive characteristic properties such as high electron mobility, superior thermal conductivity, and optical transmittance have also been observed. Polymer/graphene nanocomposites have been fabricated using different methods such as solution mixing, melt processing, *in situ* polymerization, etc. For electronic applications, film casting, spin-coating, dip-coating, and imprinting techniques have been employed. The most successful electronic applications of polymer/graphene are in electronic circuits, batteries, sensors, detectors, capacitors, displays, etc. [9, 10]. This review covers essential aspects of polymer/graphene nanocomposite especially focusing their electronic applications.Extensive knowledge of polymer/graphene materials is essential to define material specification and overcome challenges for electrical devices and electronic industry.

2. Graphene

Graphene is a single nanosheet with sp^2 hybridized carbon atoms (Fig. 1). Graphene has intrinsic mobility of 200,000 $cm^2\ v^{-1}\ s^{-1}$, specific surface area of 2630 m^2g^{-1}, thermal conductivity of ~5000 $Wm^{-1}K^{-1}$, and Young's modulus of ~1.0 TPa. It also possess optical transmittance of 97%. Oxidized graphene nanosheet is referred as graphene oxide (GO). It typically contains pseudo-two-dimensional lamellae and superior structural properties. It has been prepared by the oxidation of natural graphite flakes. Owing to outstanding features, graphene and its derivatives have been used as nanofiller for polymer nanocomposite [11-13]. Superior thermal conductivity, mechanical properties, and electronic transport properties of nanocomposite have been considered for several electronics and device applications. Mainly distinctive electrical conductivity, thermal conductivity, and optical propertiesrender polymer/graphene nanocomposites useful for electronic circuits, sensors, batteries, and current protectors.

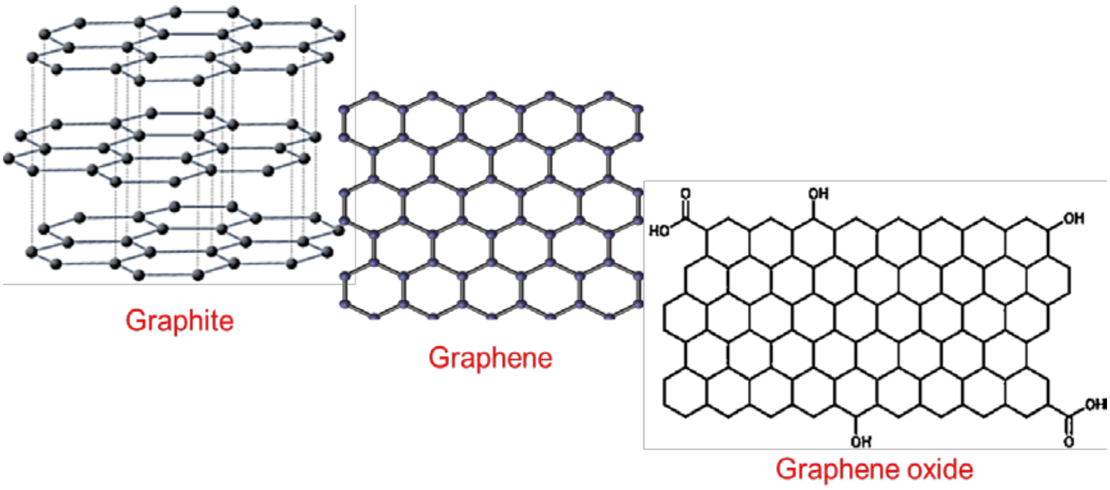

Fig. 1 Graphite, graphene,and graphene oxide nanosheet.

3. Polymer/graphene nanocomposite

Polymeric nanocomposite is an important application of graphene and graphene-derived nanomaterials. Graphene is an appositenanofiller for physical and mechanical property improvement of nanocomposite. Graphene nanofiller dispersion may improve the characteristics of polymer matrices. Polymer/graphene nanocomposites has gained immense research attention owing to superior mechanical, thermal, electrical, and barrier properties [14-18]. Polymer/graphene nanocomposite has been prepared using various techniques involving solution/melt processing and *in situ* polymerization techniques (Fig. 2) [19].

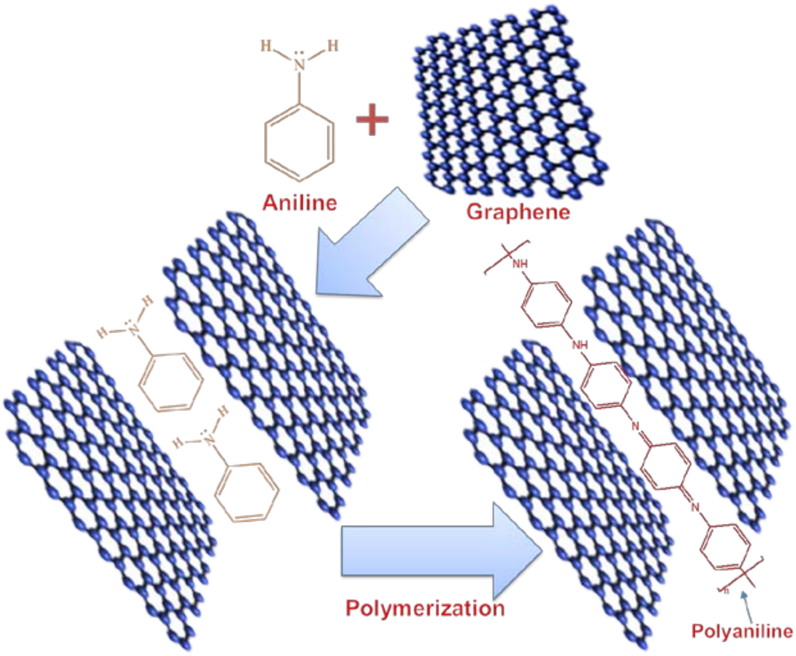

Fig. 2*In situ* polymer/graphene formation.

Conjugated polymers such as polyaniline (PANI) has been in situ polymerized. The PANI doped graphene nanocomposite has been used as building blocks for electronics. The deposition of range of conjugated polymers in electronic devices have been achieved by this simple technique followed by printing. Fig. 3 shows the formation of a graphene dispersed polymer nanocomposite. Solution dispersion of graphene in polymers followed by filtration and vacuum drying is the commonly employed technique [20-25]. Solvent blending process has found to significantly improve the nanofiller dispersion. Such nanocomposite has shown enhancement in mechanical properties, electrical conductivity, and gas barrier properties. Optical, thermal, and magnetic properties of solution processed polymer/graphene nanocomposite have also been enhanced [26-28]. Deeper understanding of fabrication methodologies and properties of these materials is essential to design high performance materials with desired properties.

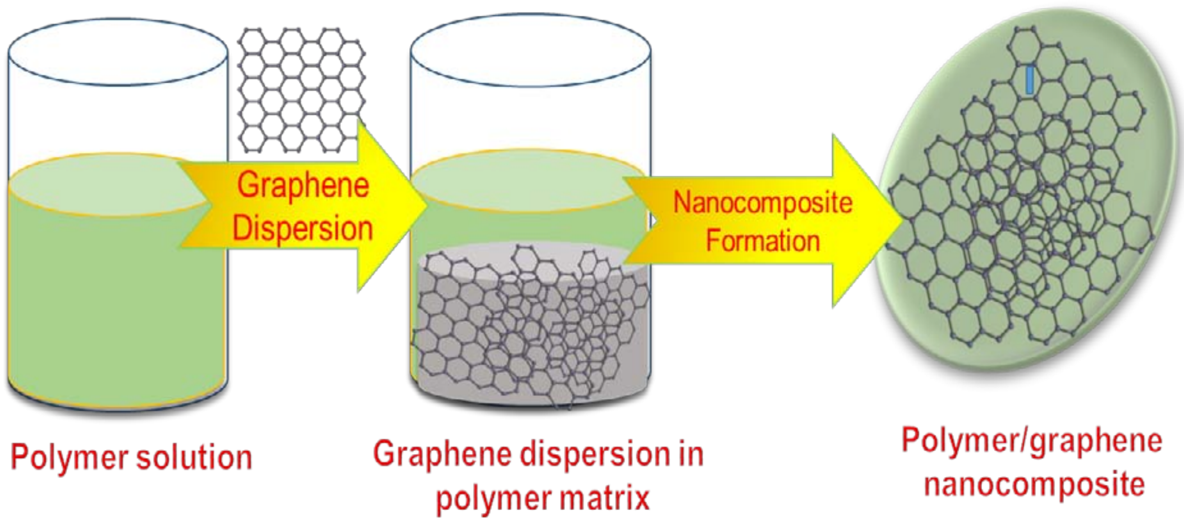

Fig. 3 Polymer/graphene nanocomposite from solution route.

4. Electronic applications

Nanocomposites have evolved significant relevance for electronic applications. Emerging curiosity in graphene has replaced the use of carbon nanotube in electronics. Consequently, design of advanced devices and systems using polymer/graphene nanocomposite has gained noteworthy research interest (Fig. 4). The utility of graphene-based nanocomposite in electronics is rather diverse depending upon the end use [29].

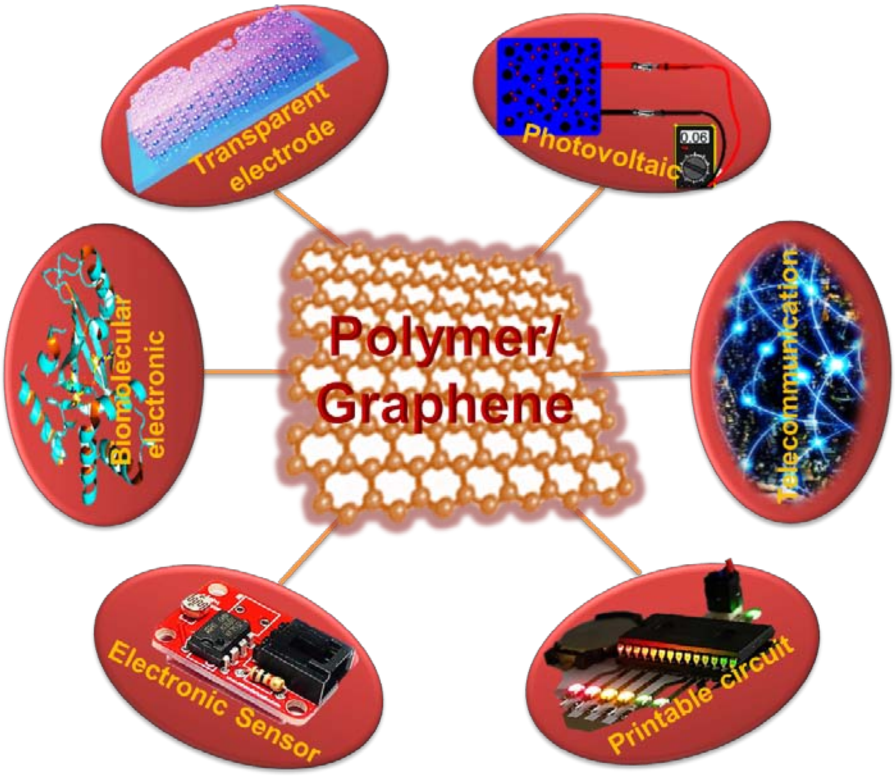

Fig. 4 Polymer/graphene nanocomposite in electronic industry.

Polymer/graphene nanocomposite have been developed using polymers such as polyethylene, polystyrene, polyamide, poly(methylmethacrylate), poly(vinyl alcohol), poly(vinyl chloride), etc. Percolation threshold and electrical conductivity are interconnected properties of prime interest in electronic applications. In these nanocomposites, non-linear enhancement in electrical conductivity vs. filler content has been observed. At certain critical concentration, percolation threshold may be achieved to form matrix-nanofiller network, so enhancing the electrical conductivity of nanocomposite. Usually, very low conducting nanoparticle content may develop effectual conducting paths. In several devices, graphene nanosheet has been used to replace silicon. Thus, polymer/graphene nanocomposite has been focused for resulting electronic applications in printable conductors, electroluminescent devices, batteries, memory devices, light emitting diodes (LED), and transistors [30, 31]. The potential electronic applications also include actuators, electrodes, and sensors (gas sensors, biosensors, chemical sensors)-based on polymer and graphene [32-38]. Mainly conjugated polymer/graphene nanocomposite has found success for sensor applications. Polymer/graphene has also been focused to construct large flexible panels in solar cells and also in fuel cell structure [39-45]. These hybrid materials has also shown fabrication possibilities for supercapacitors, optical displays, printing circuits, electrical devices, photo- and superconductor devices [46-50]. An essential use of polymer/graphene has also been observed in thermal management of electronics or electronic devices such as cell phones, laptops, LEDs, etc. In short, polymer/graphene nanocomposite has opened a new era of research and countless possibilities for electronic devices and systems and overall electronic industry.

5. Conclusions

Polymers, owing to ease of processing, low-cost, light-weight, and structural, have been employed in technical devices. Graphene possess added advantage to improve the properties of advanced polymer/graphene nanocomposite. This review focused on polymer/graphene nanocomposites and their application in electronic industry. Essential features of graphene and graphene-based nanocomposite have gained considerable research attention to attain feasible performance in numerous devices. Better graphene dispersion and fabrication techniques are also focused to attain fine properties for electronic relevance such as electrical conductivity, thermal conductivity, and thermal and mechanical robustness. Future efforts on polymer/graphene nanocomposite may result in remarkable nanomaterials for miniaturization of high performance electronic devices and systems.

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