Study of Specific Capacitance, Electrical Conductivity and Mechanical Strength of Polyaniline–(Derivatives Of) Graphene Nanocomposites

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Abstract:

In this review we highlighted the importance of graphene and present an overview of applications of Polyaniline–graphene nanocomposites. Graphene and its derivatives are being studied in nearly every field of science and engineering. Recent progress has shown that the graphene-based materials can have a profound impact on electronic and optoelectronic devices, chemical sensors, nanocomposites and energy storage. The aim of this review article is to provide a comprehensive scientific progress of graphene to date and evaluate its future perspective. The reinforcement of graphene and GO in polymer matrices has shown very exciting results in improving electrical conductivity at a very low percolation threshold, increase in strength and elastic modulus, high thermal conductivity and stability, and reduced permeation of gas molecules. All of these results open a new avenue for developing high strength light weight structural polymer composites for innumerable applications.

Keywords: polyaniline; conducting polymers; carbon nanotubes; composites; graphene.

INTRODUCTION:

Graphene is a two-dimensional one-atom-thick planar sheet of **sp2** bonded carbon atoms [1–2,4,5], which is considered as the fundamental foundation for all fullerene allotropic dimensionalities. In addition to its planar state graphene can be 'wrapped' into zero-dimensional spherical bucky balls, 'rolled' into one-dimensional CNTs – further categorized into single- or multi- walled depending on the number of graphene layers present (SWCNTs/MWCNTs respectively), or can be 'stacked' into three-dimensional graphite – generally consisting of more than ten graphene layers [1,2,3,6]. Consequently graphene can be considered the 'mother of all carbon forms' – as a building block. A variation on graphene are nano-platelets which are characterized by stacks consisting of between two and ten graphene sheets, with another graphene existing in the form of graphene oxide (GO) – where the graphene has been oxidized within the employed fabrication process or spontaneously by contact with air, however, this form is usually chemically or electrochemically reduced before use [3]. It is important to clarify that a single graphene nanosheet (GNS) refers to graphene as its standard form – that is a single layer of graphene.

The development of a nanolevel dispersion of grapheme particles in a polymer matrix has opened a new and interesting area in materials science in recent years. These nanohybrid materials show considerable improvement in properties that cannot normally be achieved using conventional composites or virgin polymers. The extent of the improvement is related directly to the degree of dispersion of the nanofillers in the polymer matrix. The most important aspect of these nanocomposites is that all these improvements are obtained at a very low filler loading in the polymer matrix [7-15]. Different types of nano graphite forms, such as expanded graphite and exfoliated graphite, have also been used to produce conducting nanocomposites with improved physicochemical properties

Specific Capacitance: The general specific capacitance of graphene is not as high as expected, and thus it is notable that many researchers have turned to the incorporation and fabrication of graphene based hybrid materials in the pursuit for improved capacitance performance. In one notable example Wang et al. [17] report a novel high performance electrode material based upon polyaniline (PANI) doped with graphene oxide sheets. The authors obtained a nanocomposite with a mass ratio of PANI/graphene, 100:1, which exhibited a high specific capacitance of 531 Fg^{-1}, obtained by charge-discharge analysis, PANI/graphene of 50:50 weight% exhibited a high specific capacitance of 408 Fg^{-1}, obtained by microwave solvothermal, PANI/graphene obtained by in situ anodic polymerization of PANI film on graphene paper exhibited a high specific capacitance of 233 Fg^{-1}, and when compared to individual PANI (216 Fg^{-1}) it was clear that doping (and the ratio of graphene oxide) has a profound effect on the electrochemical capacitance performance of nanocomposites; graphene exhibits great potential for application in super-capacitors and other power source systems of the future. Further work was conducted by Yan et al. [18] reporting that a GNS/PANI composite synthesized using in situ polymerization could obtain a high specific capacitance of 1046 Fg^{-1} which compared to 115 Fg^{-1} for pure PANI, 463 Fg^{-1} for SWCNT/PANI, and 500 Fg^{-1} for MWCNT/PANI; additionally, the energy density of the GNS/PANI composite could reach 39$Whkg^{-1}$ at a power density of 70$kWkg^{-1}$. It is apparent that GNS/PANI modifications offer a highly conductive support material where the well-dispersed depositions of nanoscale PANI particles are attributable to the GNSs large surface area and flexibility. Similar work has carried out by Yan et al. [19] and investigated the effect of a GNS/CNT/PANI composite, claiming responses similar to the composites mentioned above, and that after 1000 cycles the capacitance decreased by only 6% of the initial (compared to 52 and 67% for GNS/PANI and CNST/PANI respectively), demonstrating that a hybrid-graphene material may exhibit the ultimately desired properties required for superior energy related devices to be realized [19,20].

Electrical conductivity: The electrical conductivity of pure graphene was 277.2 Sm^{-1}, which is close to pristine graphite. In contrast, the electrical conductivity of GO, PANI, PANI/GO, and PANI/graphene were reported to be 0.2, 10.6, 231.2, and 168.7 Sm^{-1}, respectively. The conductivity of the

PANI/graphene composites were slightly lower than that of the PANI/GO composites, probably due to a decrease in the degree of doping in PANI and a change in the morphology of the composites during the reduction, reoxidation and reprotonation processes. The composites had high specific capacitance and good cycling stability with the PANI/graphene composites showing the highest specific capacitance of 480 $F g^{-1}$ at a current density of 0.1 Ag^{-1}.

Mechanical strength: Graphite, diamond and carbon nanotubes have each set their own record in terms of mechanical robustness, be it hardness or Young's modulus. Graphene is no exception although its mechanical behavior has been much less investigated than its electronic or optical properties. The reported stiffness of graphene is of the order of 300–400 N/m, with a breaking strength of ca. 42 N/m, represents the intrinsic strength of a defect-free sheet [23]. The estimates of the Young's modulus yielded approximately 0.5–1.0 TPa which is very close to the accepted value for bulk graphite [23,24]. Interestingly, in spite of their defect, suspended graphene oxide sheets retained almost intact mechanical performances with a Young's modulus of 0.25 TPa [25]. These values combined with the relative low cost of thin graphite and the ease of blending graphene oxide into matrices [22] makes these materials ideal candidates for mechanical reinforcement [26–28]. On the other hand, with such a high sustainable tension in a single sheet, graphene bears tremendous potential as the ultimately thin material for NEMS applications such as pressure sensors and resonators. Mechanically exfoliated single and multilayer graphene sheets placed over trenches in a SiO_2 substrate were contacted to produce graphene-based nano-electromechanical systems. Fundamental resonant frequencies, which can be triggered either optically or electrically, were experimentally observed in the 50–200 MHz range with a room temperature charge sensitivity as low and a quality factor in vacuum ($<10^{-6}$ torr) of 80. Direct imaging of the driven oscillating modes by a non-conventional AFM technique revealed that non-uniformity of the initial stress upon depositing the graphene sheet results in exotic nanoscale vibration eigen modes with maximal amplitude on the graphene sheet edges. Suspended graphene being under tension and impermeable provides the optimized atomically thin supporting membrane for sensitive gas sensing [29].

CONCLUSIONS:

In summary, the specific capacitance of PANI/GNS increases with increase in %weight of GNS. Also, the specific capacitance is higher for PANI/GNS as compared to pure PANI, PANI/SWCNT, PANI/MWCNT. The electrical conductivity of GO, PANI, PANI/GO, and PANI/grapheme have been calculated and observed that the conductivity of the PANI/graphene composites were slightly lower than that of the PANI/GO composites. The stiffness of graphene which is defect free is very high.

REFERENCES:

[1] A.K. Geim, K.S. Novoselov, Nat. Mater. 6 (2007) 183.

[2] M. Pumera, Chem. Rec. 9 (2009) 211.

[3] D.A.C. Brownson, C.E. Banks, Analyst 135 (2010) 2768.

[4] W. Yang, K.R. Ratinac, S.P. Ringer, P. Thordason, J.J. Gooding, F. Braet, Angew. Chem. 49 (2010) 2114.

[5] R.L. McCreery, Chem. Rev. 108 (2008) 2646.

[6] G.G. Wallace, J. Chen, D. Li, S.E. Moulton, J.M. Razal, J. Mater. Chem. 20 (2010) 3553.

[7] Stankovich S, Dikin DA, Dommett GHB, Kohlhaas KM, Zimney EJ, Stach EA, et al. Graphene-based composite materials. Nature (2006),442:282–6.

[8] Ansari S, Giannelis EP. Functionalized graphene sheetpoly(vinylidene fluoride) conductive nanocomposites. J Polym Sci Part B Polym Phys (2009),47:888–97.

[9] Ramanathan T, Abdala AA, Stankovich S, Dikin DA, Alonso MH, Piner RD, et al. Functionalized graphene sheets for polymer nanocomposites. Nat Nanotechnol (2008),3:327–31.

[10] Lee YR, Raghu AV, Jeong HM, Kim BK. Properties of waterborne polyurethane/functionalized graphene sheet nanocomposites prepared by an in situ method. Macromol Chem Phys.(2009), 210:1247–54.

[11] Xu Y, Wang Y, Jiajie L, Huang Y,MaY,WanX, et al. A hybrid material of graphene and poly(3,4-ethyldioxythiophene) with high conductivity, flexibility, and transparency. Nano Res (2009), 2:343–8.

[12] Quan H, Zhang B, Zhao Q, Yuen RKK, Li RKY. Facile preparation and thermal degradation studies of graphite nanoplatelets (GNPs) filled thermoplastic polyurethane (TPU) nanocomposites. Compos Part A (2009), 40:1506–13.

[13] Eda G, Chhowalla M. Graphene-based composite thin films for electronics.

Nano Lett. (2009), 9:814–8.

[14] Liang J, Xu Y, Huang Y, Zhang L, Wang Y, Ma Y, et al. Infrared triggered actuators from graphene-based nanocomposites. J Phys Chem (2009), 113:9921–7.

[15] Kim H, Macosko CW. Processing–property relationships of polycarbonate/graphene nanocomposites. Polymer (2009), 50:3797–809.

[16] Dikin AK, Stankovich S, Zimney EJ, Piner RD, Dommett GHB, Evmenenko G, et al. Preparation and characterization of graphene oxide paper. Nature (2007), 448:457–60.

[17] H. Wang, Q. Hao, X. Yang, L. Lu, X. Wang, Electrochem. Commun. 11 (2009), 1158.

[18] J. Yan, T. Wei, B. Shao, Z. Fan, W. Qian, M. Zhang, F. Wei, Carbon 48 (2010), 487.

[19] J. Yan, T. Wei, Z. Fan, W. Qian, M. Zhang, X. Shen, F. Wei, J. Power Sources 195 (2010), 3041.

[20] K. Zhang, L.L. Zhang, X.S. Zhao, J. Wu, Chem. Mater. 22 (2010), 1392.

[21] Tapas Kuilla a, Sambhu Bhadrab, Dahu Yaoa, Nam Hoon Kimc, Saswata Bosed, Joong Hee Leea,d, Progress in Polymer Science 35 (2010), 1350–1375.

[22] Stankovich S, Dikin DA, Dommett GHB, asurement of the elastic properties and intrinsic strength of monolayer graphene. Science 9(2008Kohlhaas KM, Zimney EJ, Stach EA, et al. Graphene-based composite materials. Nature (2006),442(7100):282–6.

[23] Lee C, Wei X, Kysar JW, Hone J. Me), 321(5887):385–8.

[24] Frank IW, Tanenbaum DM, Van der Zande AM, McEuen PL. Mechanical properties of suspended graphene sheets. In: 51st International conference on electron, ion, and photon beam technology and nanofabrication. Denver, CO: AVS Amer Inst Physics; May 29–June 01, (2007), p. 2558–61.

[25] Gomez-Navarro C, Burghard M, Kern K. Elastic properties of chemically derived single graphene sheets. Nano Letters (2008), 8(7):2045–9.

[26] Cai D, Yusoh K, Song M. The mechanical properties and morphology of a graphite oxide nanoplatelet/polyurethane composite. Nanotechnology (2009) 20(8):085712.