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A REVIEW ON GRAPHENE BASED POLYMER COMPOSITES

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ABSTRACT

Graphene is the thinnest know material in the universe and the strongest ever measured. It has excellent performance in the field mechanical electrical, electronic and thermal applications. In this paper preparation and properties of graphene/epoxy composites are reviewed. And also focused on different processing methods of graphene and graphene/epoxy composites.

KeyWords: Graphene, epoxy, nanocomposites.

I. INTRODUCTION

Graphene is the single layer strongest material discovered in 2004[1]. It has rapidly attracted both academic interest and industrial interest.

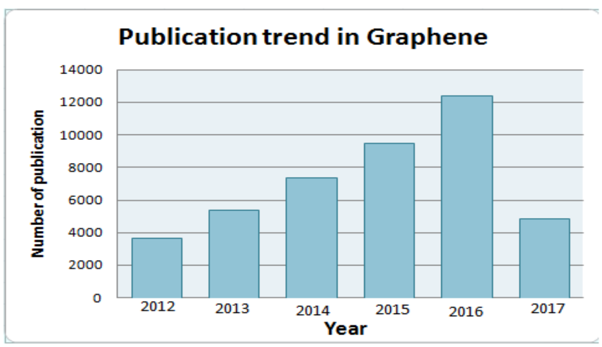

Fig 1: Number of publications retrieved using 'Graphene' as keyword searched in title in web of science (by 10/02/2017)

Fig.1 shows the quantity of research publication in one of science website by using keyword as graphene. In the year of 2012 total 3651research articles have been published and in the year 2013 total 5343 research articles have been published. In the year 2017 till 10th February 4847 articles have been published. Total 53015 research articles have been retrieved from science website. It is observed that research by using graphene has been dramatically increasing every year.

Graphene exhibits a very high young's modulus of 1TPa, ultimate strength of 130GPa and excellent thermal conductivity of 5000w/m^{3}k, larger surface area of 2630 m^2/g[2]. the different methods of graphene synthesis are Mechanical exfoliation, chemical vapor deposition, Epitaxial growth, Oxidation and reduction, Liquid-phase exfoliation of graphite[3].

Epoxy is the one of the most adaptable and universal high performance material. It is used widely because of its superlative mechanical properties, thermal stability, and excellent resistance to corrosion dimensional stability and adhesion properties, the resins has high viscosity, so that they are usually moulded at temperature in the region of 50-100^{0}c. Some of the application of epoxy and its nanocomposites includes aerospace, automotive, marine, construction, sports material, structures, electronic and electrical system, and coatings, biomedical.

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Graphene/epoxy composite exhibits excellent thermal and mechanical properties which can replace steel in the structure of aircraft, but graphene/epoxy cannot be mixed by simple mixing process because of graphene's pronounced tendency to re aggregate in the matrix due to the strong Van der waals force and pi stacking between separately dispersed graphene sheets. So in order to get superior Graphene/epoxy material property, Graphene must be homogenously dispersed in the matrix material [4].

II. PROCESSING OF GRAPHENE BASED EPOXY AND THEIR MECHANICAL PROPERTIES

Chang-uk et al. [5] in this study carbon nanotube/carbon fiber reinforced plastic composite were manufactured by varying the carbon nanotube weight ratio as 2% and 3% and graphene nano platelet/ carbon fiber reinforced plastic composite were manufactured by varying the graphene nano platelet weight ratio as 0.5% and 1%. These two types of composites were manufactured by 3 roll mill method.3 roll mill is the machine that uses the shear force created by three horizontally positioned rolls rotating in opposite direction and different speed relative to each other, in order to mix, refine disperse materials fed into it. After manufacturing composites tensile wear and impact test were performed according to ASTM standard. It was observed that increasing the carbon nanotube weight ratio improves the mechanical properties.

Shivan Ismael et al. [6] in this study graphene oxide was prepared by modified Hummers method using sulfuric acid and potassium permanganate as oxidizing agent.then the product was purified by washing with HCL followed by H_2O. An hour of ultra-sonication was used to exfoliate the product. The graphene oxide dispersion was finally accomplished. Grapnene oxide/epoxy composites were prepared with different content of volume percentage (0, 1.5, 3, 4.5, and 6) using casting method under room temperature. It was observed that enhancement of mechanical properties of graphene oxide/epoxy composites i e experimental results shows that improvement in the youngs modulus hardness and tensile strength but impact strength of grapnene oxide/epoxy composites was decreased due to increase in brittleness.microstructure analysis is carried out using X-ray diffraction (XRD) and scanning electron microscope (SEM). It was observed that how graphene oxide impeded the propagation of crack in the composite.

David A et al.[7] in this study neat epoxy, graphene/epoxy, carbon/epoxy and carbon-graphene/epoxy were manufactured for fracture toughness testing. graphene/epoxy nanocomposites samples were produced by mechanical mixing the graphene nano powder with acetone then graphene acetone solution is sonicated for 30min then epoxy resin combined with the graphene acetone solution by mechanical mixing graphene-epoxy-acetone solution sonicated for 60 minutes. graphene-epoxy-acetone solution subjected to constant heating (60°C) and constant magnetic stirring until acetone is removed from solution then curing agent combined with graphene-epoxy solution and mixed via high shear mixing for 2 minutes then graphene-epoxy solution poured onto glass mold and allowed to cure for 24 hours at room temperature.then the specimen is prepared and subjected to bending. The result shows that significant improvement in fracture toughness of both graphene/epoxy and carbon-graphene/epoxy nano composites in comparison to neat epoxy and carbon epoxy composites.

Jiacheng Wei et al. [4] In this paper, graphene bundles dispersed in two-component epoxy system by bath sonication, dispersion state, and reaggregation behavior of graphene in this system have been studied. Graphene was purchased from Graphene Laboratories. The graphene nanoplatelets have a specific surface area of 80 m2/g. The average lateral size 4.5 µm and thickness are 12 nm. For studying the influence of sonication time on the dispersibility 0.005 wt% dispersions were sonicated for different durations ranging from 6 mins to 60 mins at 20°C. All samples had been degassed at −0.1 MPa to remove the entrapped air. To prepare epoxy/graphene nanocomposites, graphene was first dispersed in hardener by bath sonication for 30 mins at room temperature. Then the suspensions were mixed with liquid epoxy by the ratio of EP : HD of 2 : 1. Following thorough hand mixing for 10 mins, vacuum degassing was carried out to remove the entrapped air. The mixtures were then mould cast and cured at room temperature for 6 h followed by post curing at 80°C for 6 h. With the incorporation of 0.3 wt% graphene, the tensile strength of nanocomposites increased from 57.2 MPa to 64.4 MPa and the storage modulus increased from 1.66 GPa to 2.16 GPa. The results showed that the dispersion state depends on the function of sonication time and temperature, and graphene has a significant reinforcement effect on epoxy.

Tkalya, E [3] described preparation of the polystyrene nanocomposites based on graphene prepared via oxidation of graphite with subsequent exfoliation and chemical reduction of graphite oxide. and discusses the main approaches recently used to produce CNTs/graphene dispersions and conductive CNTs/graphene-based polymer composites with the help of surfactants. The main focus is given to water-based systems. the effect of the dispersion state of graphene as a factor influencing the electrical percolation threshold of graphene/polystyrene nanocomposites. compares the ability of some conventional surfactants such as sodium dodecylbenzene sulfonate (SDBS), sodium cholate (SC), sodium poly (styrene sulfonate) (PSS) and Tween-80 to disperse graphene in water. Percolation thresholds and ultimate conductivity values of the composites based on graphene dispersed in the presence of these surfactants are compared. An influence of utilizing conductive surfactants for graphene dispersion in water on percolation threshold and conductivity of the corresponding nanocomposites is discussed

Thuc vo at al.[8] In this paper graphene nanocomposites are reviewed in general .Graphene has recently attracted significant academic and industrial interest because of its excellent performance in mechanical, electrical and thermal applications. Graphene can significantly improve physical properties of epoxy at extremely small loading when incorporated appropriately. The modification of graphene and the utilization of these materials in the fabrication of nanocomposites with different processing methods have been explored. This review has been focused on the processing methods and mechanical, electrical, thermal, and fire retardant properties of the nanocomposites. The synergic effects of graphene and other fillers in epoxy matrix have been summarized as well.

Zhan shi et al. [9] In this paper, theoretical calculations were conducted to determine the coefficient of thermal expansion (CTE) based on the effective medium approach using Green's function method. The influences of microstructural features were investigated, including volume fraction, aspect ratio, and the orientation of graphene fillers. Calculated results demonstrated strong anisotropy of CTE when all graphene sheets in the composite were aligned in the in-plane direction due to the large difference between the elastic moduli of the graphene and epoxy. The in-plane CTE in the graphene/epoxy composite can be effectively reduced with small additions of graphene additive. Orientation dispersion among the graphene fillers significantly decreases the anisotropy of CTE. Accounting for the influences of all microstructural features, simulation results closely align with current experimental results. This work will provide a general guideline and a solid foundation for the optimal design and preparation of graphene/polymer composites.

Sung et al. [10] This study aims to investigate the thermal and mechanical properties of graphene/epoxy nanocomposites using molecular dynamics (MD) simulation. Three different formats of graphene: graphene flakes, intercalated graphene and intercalated graphene oxide, were incorporated respectively in an epoxy matrix to form the graphene/epoxy nanocomposites. The mechanical properties of the graphene/epoxy nanocomposites, including Young's modulus (E), glass transition temperature (Tg) and coefficient of thermal expansion (CTE), in terms of three different formats of graphene, were characterized in this study. In addition to the mechanical properties, the influences of graphene on the density distribution of epoxy polymers in the nanocomposites were also examined. The results showed that the local density in the vicinity of the graphene is relatively high, and then progressively decreases to the bulk value in regions further away from the interface. The interacted graphene oxide provides the best reinforcement of the three systems of nanocomposites. Based on the calculation of interaction energy, it appears that the oxide modification of the graphene surface can effectively lead to the high interaction energy, such that the graphene oxide can demonstrate a relatively high reinforcing efficiency.

Swetha et al. [11] Epoxy based polymer nano-composite was prepared by dispersing graphite nano-platelets (GNPs) using three-roll mill (3RM) and sonication combined with high speed shear mixing. The influence of addition of GNPs on the electrical and thermal conductivity, fracture toughness and storage modulus of the nano-composite was investigated. The GNP/epoxy prepared by 3RM technique showed a maximum electrical conductivity of 1.8×10^{-03} S/m for 1.0 wt% .The percentage of increase in thermal conductivity was only 11% for 1.0 wt% and 14% for 2.0 wt% filler loading. Dynamic mechanical analysis results showed 16% increase in storage modulus for 0.5 wt%, although the Tg did not show any significant increase. Single edge notch bending (SENB) fracture toughens (K_{IC}) measurements were carried out for different weight percentage of the filler content. The toughening effect of GNP was most significant at 1.0 wt% loading, where a 43% increase in K_{IC} was observed. Among the two different dispersion techniques, 3RM process gives the optimum dispersion where both electrical and mechanical properties are better

S Chatterjee et al.[12] Influence of reinforcements on mechanical and thermal properties of graphene nanoplatelets/epoxy composites is investigated. Amine functionalized expanded graphene nanoplatelets (EGNPs) were dispersed within epoxy resins using high-pressure processor followed by three roll milling. Bending and nano-mechanical testing was performed on the composites. Incorporation of EGNPs improved the flexural modulus and hardness of the composite and increased fracture toughness by up to 60%. Marked improvement was observed in thermal conductivity of the composites reaching 36% at 2 wt.% loading. Functionalized EGNPs exhibited significant improvements indicating favorable interaction at EGNPs/polymer interface

Long-cheng Tang et al. [13] In this paper the effect of dispersion state of graphene on mechanical properties of graphene/epoxy composites was investigated. The graphene sheets were exfoliated from graphite oxide (GO) via thermal reduction. Different dispersions of (Reduced Graphene oxide) RGO sheets were prepared with and without ball mill mixing. It was found that the composites with highly dispersed RGO showed higher glass transition temperature and strength than those with poorly dispersed RGO, although no significant differences in both the tensile and flexural moduli are caused by the different dispersion levels. In particular, the glass transition temperature was increased by nearly 11 °C with the addition of 0.2 wt.% well dispersed RGO to epoxy. As expected, the highly dispersed RGO also produced one or two orders of magnitude higher electrical conductivity than the corresponding poorly dispersed RGO.

B Ahmadi et al. [14] This study introduces a new strategy for functionalizing graphene nanoplatelets (GNPs) by bonding a silane agent to its structure. epoxy resin specimens reinforced with silane modified GNPs (G-Si) are prepared at different weight contents of nanoparticles along with three other types of GNPs (unmodified GNP, graphene oxide GNP [GO], and amino functionalized GNP [G-NH2]). The nanocomposites' mechanical properties, such as the elastic modulus, ultimate strength, modulus of toughness and fracture toughness are evaluated and compared for different types of functionalization. The results show that nanocomposites containing G-Si and G-NH2 provide the best results for most of the mentioned properties. The functionalization of GNPs gives the most promising results for fracture toughness of epoxy, showing an 82% increase, and scanning electron microscopy (SEM) micrographs and XRD analysis reveal that an improved dispersion status is obtained by GNP functionalization.

III. CONCLUSION

Graphene has significant potential for epoxy based composites excellent properties can be achieved subjected to homogenous dispersion and strong interfacial interaction.

Mechanical properties, thermal properties, electrical conductivity, flame retardant properties are generally increased with the incorporation of graphene.

Graphene/epoxy composites have excellent property which can replace the steel structure in automobile and aerospace industry.

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