ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering
(IJARMATE)
Vol. 7, Issue 4, April 2021

Synthesis Of Graphene Resemblant Carbon Structure From Bio-Waste: A Review

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Abstract:

Carbonaceous materials like carbon nanotubes (CNTs), graphene, graphene oxide (GO), and activated carbon (AC) have received significant attention recently due to its diversity of potential applications. Among them, graphene is unanimously called as 21st-century wonder materials having superior mechanical, electrical, and thermal properties. In recent years, the biomass waste has become a new source for producing graphene. In addition, bio-waste materials are abundant and proper disposal method is needed. Hence, preparation of graphene from waste and biomass precursors is a new approach which can avoid the use of hazardous and toxic reagents. This review focuses on the discussing the different methodology for synthesis of graphene resemblant carbon structure and their application. This graphene like carbon structure have been used filler in graphene-based composite as it has similar properties of graphene, and would only have a marginal effect in the performance of the product/application.

Keywords: Bio-waste management, Graphene Resemblant Carbon, Porous Carbon, Energy Storage

1.Introduction:

Graphene is a two-dimensional, single-layer sheet of sp^2 hybridized carbon atoms and has arrested enormous attention and research motives for its versatile properties. Graphene, in its monolayer form, is an appealing two-dimensional (2D) material with an atomically thick hexagonal packed structure. In sp^2 hybridized bond, the in-plane σ_{C-C} bond is one of the

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strongest bonds in materials and the out-of-plane is π bond, which imparts to a delocalized network or array of electrons resulting electron conduction by providing weak interaction among graphene layers or between graphene and substrate. The graphene material shows unique properties such as theoretical surface area, excellent electrical conductivity, extraordinary mechanical flexibility, and good thermal conductivity, graphene has very promising applications in nanoelectronic components and nanocomposites including high-powered ultracapacitors, transistors, solar cells, molecular sensors, lithium ion batteries, and highly conducting and sturdy materials. The distinctive properties of graphene have led researchers/academicians to use it for wide range of applications, including semiconductors, energy devices, diffusion barriers, heat spreaders, and protective overcoats[1-3].

The graphene oxide was first synthesized in the late 1950s by Hummers[4]. Boehm et al[5] reported chemical reduced grapehene oxide. In fact the interest on the large scale production of graphene oxide received industrial and academic interest after the authors Geim, and Novoselov[6] were awarded the Nobel Prize for their pioneering work regarding on graphene. In fact the graphene was first synthesized by mechanical exfoliation from graphite in the year 2004. This technique has been widely endorsed for the exponential interest in graphene applications. The industrial applications that take advantage of graphene's unique properties in conductive properties require structurally coherent graphene on a large scale. Graphene and few-layer graphene (FLG) have been grown by chemical vapor deposition (CVD). A number of researchers have investigated on numerous numbers of biomass as precursor in graphitic carbon synthesis. To date, various approaches have also been utilized to synthesizing synthetic graphite such as laser ablation, arc discharge, chemical vapor decomposition, thermal heating, microwave heating and Joule heating. After all, not every method is suitable to be implementing in biomass feedstock[7,8]. In recent years, the production of synthetic graphite has attracted tremendous interest due to its enhanced industrial applications. Further, biomass waste has been identified as potential precursor for graphite production due to its ecofriendly and low cost. The biomass enjoys the merits of abundant availability, clean and low cost high utilization potential. The key aspect of graphite production is using high carbon content material as feedstock. Recent research is focused on converting nonedible biomass to produce valuable material. Biomass consists of three main structural unit cellulose, hemicellulose, and lignin. The usage of biomass in green and effective way will definitely give significant impact on environment.

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Biomass-derived carbon is different from other natural occurring carbons such as charcoal, graphite and diamond. The application of biomass derived carbon is gaining increased attention among the researchers and academicians due to its unique properties such as low cost and sustainability. In biomass derived carbon, the natural products such plats, biomass waste is converted into carbon by thermal carbonization or activation[9]. Biomass waste will be defined here as any organic materials and wastes generated from agriculture. The discovery of converting biomass wastes into graphene is a successful route for recovering sources. The yield of biomass derived carbon is highly dependent on mass fraction of cellulose, lignin and hemicellulose. The process of increasing the carbon content by removing other elements through thermal treatment is called carbonization; the process of arranging the carbon structures to produce a graphitic- like structure is called graphitization. It should be noted that the carbonization process often produces amorphous carbon rather than a graphite-like structure. Amorphous carbon consists of hard carbon and soft carbon, where the hard carbon is tough to graphitize even at very high temperatures given its chaotic structure. The amount of amorphous carbon correlates to that of exceeding the reaction time and an excessive amount of carbon sample during the thermal treatment. It is reported that nearly 1×10^{10} tones of biomass waste generated annually across globally. Generally, the organic material wastes can be branched out to crop waste, food processing waste, paper industries waste, and many other things that are recyclable. There is potential in producing graphene using biomass wastes as it is sustainable, renewable, and abundant[10-11].

2. Preparation Of Synthetic Graphene From Bio Waste:

It is known fact that glucose, also known as sugar molecule is abundant and renewable feedstock for carbon source. Recently, researchers have started using glucose as feedstock for graphene preparation. Zhang and coworkers reported on graphene sheet preparation from glucose via carbonization. The authors reported D-band, G-band and 2D-band[12,13]. G-band indicates the existence of sp^2-hybridized carbon atom. The authors also reported that the quality of the graphite material is disappointing without the addition of activating agent. Chen et al. reported an electrical conductivity of 768 S/cm for bio based graphene which in far with conventional CVD based graphene synthesis. Chitosan is found to be the second most abundant biopolymer in nature and it has been used in a broad range of applications such as biomedical,

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pharmaceutical and industrial applications because of its good biocompatibility and biodegradability[14,15]. Yin et al.[16] reported on synthesis of graphene nanomaterial from Chitosan. Xu et al[17] produced graphene from corn stalk. Corn stalk core (CSC) is primarily hemicellulose and lignin and cellulose, naturally porous with large surface area, which is an excellent electron transfer properties.

2.1 Plastic Waste-Based Graphene:

Plastic is one of the abundant wastes that found on the earth, includes plastic bottles, plastic bags and plastic sheets, which can cause a serious waste of resource and environmental pollution. For example polyethylene terephthalate (PET) contains high amount of carbon and promising feedstock for graphene synthesis[19].The graphene produced shows highly amorphous. On the other hand, Sharma[20] and colleagues have produced a high quality single crystal graphene on polycrystalline Cu foil using solid waste plastic as carbon source in an ambient pressure (AP) chemical vapor deposition (CVD) process They claimed that, graphene obtained via this method provides much Arifin et al Chui and coworkers reported that they have prepared graphene foil (GF) via solid-state CVD. Based on the characterization, Raman spectrum shows that the G-band of the material is intense and narrow, indicating a good crystallinity and high graphitization. On the other hand, low ID/IG shows that the defect on the sample is relatively less. The XRD analysis further supports the Raman results where peak at 2θ = 26.7o reveals a high graphitization of graphene.

2.2Chitosan-based Graphene:

Chitosan is found to be the second most abundant biopolymer available in nature. Chitosan has been used in wide range of applications such as biomedical, pharmaceutical and industrial applications due to its unique properties such as biocompatibility, biodegradability with multiple functional groups of amino (NH2). Further, chitosan is a natural nitrogen containing biopolymer which able to produce graphene that is suitable for industrial applications, which greatly enhance their electronic bands and become semiconductor[21]. Cobos et al[22]. Studied the effect of nanofiller (graphene and plasticizer (glycerol)) on chitosan (CS) matrix and reported that NH3+ band is shifted from 1552 cm-1 to 1539 cm^{-1} as compared to pristine plasticized CS. This is because, when graphene is introduced into the matrix, there is an electrostatic interaction between negatively-charged surfaces of graphene with positively-charged chitosan.

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Corn stalk is one of the ample agricultural wastes that is made up of a cortex and a core. The cortex is made up of cellulose and lignin while corn stalk core (CSC) is primarily hemicellulose and lignin and cellulose. CSC is naturally porous, which can form a large surface area of carbon, which is an excellent property for electron transfer and easier for ion diffusion in carbon matrix.

2.3 Graphene from Cellulose Biomass:

The disposable paper plates/cups are made of wood, mainly composed of lignin and hemicelluloses. The disposable paper cup is an extraneous material; however a research team perceived disposable paper cups differently. Hong Zhao et al. made a novel endeavor by using the disposable paper cups as a precursor for graphene preparation with the aid of iron catalyst. The activation treatment of paper cup using KOH, K^+ ions gets adsorbed into the structure of paper pulp. Introducing Fe catalyst eventually results in the exchange of Fe^{2+} ions and K^+ ion. Finally, Fe_3C layers are formed when heated at high temperature in a fashion similar to graphitization process. Good catalytic activity is exhibited for ORR (oxygen reduction in a fuel cell). Graphene preparation from a disposable paper cup is a suitable economical approach since it uses a cheap starting material. Further, the method seems to be good due to high yielding. Graphene preparation using a disposable paper cup is a pioneer work, so further optimization is essential[23].

3.CONCLUSIONS

Graphene and its derivatives are novel materials that have yet to reach their peak in technology fields. Although there has been much discussion related to this structure, there are still barriers that need to be overcome to reach the goal of easily available material. Graphene technology is limited by graphene production. Thus, graphene production is expensive, even though it is produced from cheap and abundantly available material, graphite. The utilization of biomass waste can alleviate this problem while reducing the associated pollution. Graphene can be produced from biomass waste by removing volatile compounds and increasing the carbon content in the structure. This mechanism can be achieved by using a thermal treatment, which is already used for bio-materials production. High-temperature pyrolysis incorporating metal pre-cursors mixed with the biomass has been chosen by many researchers. The high temperature ensures the decomposition of the biomass structure, while the metal catalyst provides a surface for volatile carbon materials released from the biomass to deposit. Moving forward, low- temperature thermal treatment will be necessary, as the time required for heating and cooling is added to total reaction time. Bio-based graphene might not surpass the quality one can get through the graphite route. However, the development of graphene using the green synthesis route can be considered as one step forward in graphene technology. One thing to take from this route is the possibility of producing a massive amount of multi-layer graphene, GO and RGO. Even though quality-wise, bio-based graphene is lacking, it is still usable for most current graphene-based applications.

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