Nanotechnology in Automotive Industry: The Potential of Graphene

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***Abstract- This paper has presented nanotechnology in automotive industry based on the potential of graphene. With the increasing application of composite materials in advancing the nanotechnology platform, an appreciable development has been achieved in transportation sector. The study reviewed the applications of nanotechnology in transportation sector with focus on automotive industry. The potential of graphene in achieving more efficient, stronger, lighter weight and ensure safety has made it to be widely accepted as a promising technology in automobile industries. The rising trends considering some commercial automobile companies were presented. It is believed that grapheme will be the face of nanotechnology application in automobile industries in the near future*.

Indexed Terms- Automotive industry, Composite materials, Graphene, Nanotechnology, Transportation sector

I. INTRODUCTION

Since its discovery as a single-layered atom-thick flatbed structure, graphene has changed the concept of nanotechnology platform [1] [2]. There are several attempts that have been made to date that are geared towards synthesizing graphene in such an extent as to meeting the needs of various industries, especially the composite industry, which has used graphene to impressively transform the global market for the production of state of the art composite materials [1]. Also, graphene has been extensively employed for research in developing electrodes, sensors, energy storing devices, solar cells and so on. The improvement of electrical and mechanical properties of composite materials can be made possible by using graphene sheets or platelets as fillers due to their size and relatively large surface area [3].
Graphene is known to have the following physical properties: transparent, very thin, lightweight, and a hundred times stronger than steel [4] [5]. Its other characteristics are: a good conductor of electricity and heat, large surface area (2630m^2/g), high electrical properties (6000s/cm), high thermal properties (5000W/mK), fine mechanical strength (130GPa), and young modulus (1TPa) [4][6]. Nevertheless, graphene, in recent decades, has found wide applications in areas where the use of composite materials is of great importance due to its excellent and outstanding properties [4].

Many methods have been used in the production of graphene such as top-down technique and bottom-up technique [. During top-down process, grapheme [4] [7] sheets or modified graphene are produced by isolation or exfoliation of graphite or derivatives of graphite such as graphite oxide (GO) and graphite fluoride. This processor approach of producing graphene is most suitable and important for the application of polymer composites [4]. This production process produces graphene on large scale. For the bottom-up technique, the production of graphene is either Chemical Vapor Deposition (CVD), epitaxial growth, micromechanical exfoliation, unzipping of carbon nanotubes (CNTs), reduction of graphene oxide, and arc discharge method. There are advantages and disadvantages offer by each process. However, the CVD approach has been discovered to be more appropriate for the synthesis of graphene [8].

With the increasing application of composite materials in advancing the nanotechnology platform, an appreciable development has been achieved in transportation sector. Transportation industries have exploited all the benefits of nanocomposite materials in the development of a safe, environment friendly, comfortable and superior transportation systems [9]. Nanocomposite materials have been used in automotive and aircraft industry due to lightweight, low density, low cost, high strength, modulus, stiffness, and corrosion [10]. The used of nanocomposites in automobiles is evident in various parts such as the interior parts of car, different type of sensors, tyres, panels, electronics, and other mechanical parts [10].

The movement of people and goods is basic and indispensable necessity to the contemporary society. It was estimated by the United Nations that vehicle fleet will double from 750 million today to approximately 1.5 billion worldwide by 2030 [9] [11]. There is also the concern for the safety of passengers, intelligent traffic guidance systems, reduction of pollutant and efficient recycling approach to save limited resources.In this paper, the objective is to review the application of nanocomposite materials in the automotive industry considering the potential of graphene with a view of studying recent trends. The remaining parts of this paper are divided into four sections: nanotechnology in automotive industry, the need for graphene, recent trends, and conclusion.

II. NANOTECHNOLOGY IN AUTOMOTIVE

Mathew et al [9] examined the recent applications of nanotechnology in automobiles and other transport sectors. The authors outlined the most important advancement of various sector of transportations in nanotechnology. They stated that comfort, safety and economy are three factors that are considered while choosing a transport and nanotechnology. According to the authors, incorporating the various nanotechnology and nanoparticles in automobiles improves the functionality and durability of paint coating, body parts, engines, tyres and compartments (see Figure 1 for the various parts with nanotechnology application).

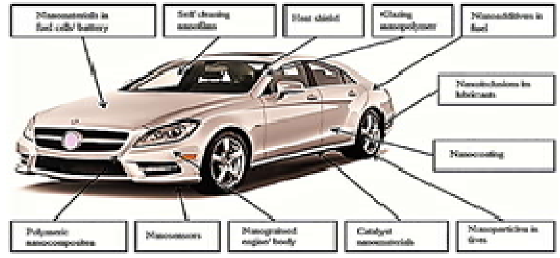

Fig.1. Different parts of automobile using nanotechnology (not actual vehicle) [9] [12]

Coelho et al [13] studied the progress of nanotechnology applications based on safety features of latest vehicle models and fuel efficiency, importance of sustainable development of these technologies and material analysis. According to the authors, nanotechnology would ensure a more efficient use of materials, energy and reduced waste and pollution. Area of improvement in automotive industry is shown in Figure 2.

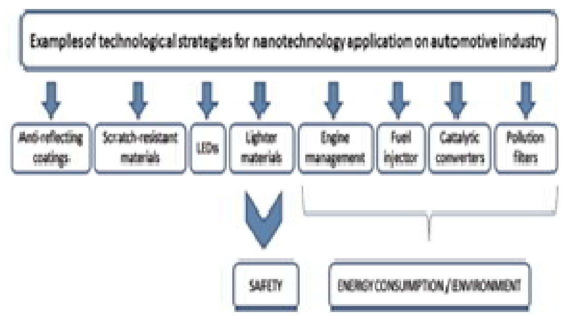

Fig.2. Areas of application fields of nanotechnology in the automotive industry [13]

Martorana et al [14] provided an overview of Graphene Related materials (GRM) applications in automotive industry and examined effective ways to add Graphene as polymer reinforcements within composite materials for energy-efficient and safe vehicles (EESVs). The authors stated that this was based on the Concept-oriented multifunctional lightweight design directed towards the combination of light structures with novel multifunctional materials. As a result of this, GRM were studied in terms of the challenging factors such as the large scale production of Graphene or the non-existence of constitutive material models for high performance structural applications like crashworthiness. For that reason, the authors maintained that accurate material should be developed to support simulation of structural design for these vehicles. Attention was given to the hierarchical modeling of GRM. Emphasis on the multiscale constitutive behaviours of each material phase was elaborated in the context of the Graphene Flagship for better understanding of such shortcomings for a full Graphene application.

Felix and Sivakumar [15] studied nanoparticles in automobiles and examined the advancement presently made in the use of nanoparticles in tyres. According to the authors, to achieve different requirement profiles for tyres (like summer and winter tyres, green or high-performance tyres) and various tyre components (tread, side wall, carcass, etc.), different Nanoprene grades can be used in accordance with their glass transition temperature. The authors stated that Lanxess recently began commercial production of the material with Toyo Tyre and Rubber being its first customer to use it in winter tyres. They outlined other level of usage of nanoparticles in tyres:

a. Nano base: It is a Nano-molecular structure at the bottom of the tyre strong cap. It is used for improving grip and steering properties, and at the same time ensuring heat emission reduction as well as rolling resistance. It is applied in the Nokian WR A3 tyre.

b. Nanostructure-Oriented Properties Control Technology (NanoPro-Tech: It is used as a Nano coating in tyre tread for reducing heat generation; and is applied in the new Ecopiatyre range of Bridgestone.

c. Carbon nanotubes (CNT) enhanced tyres: These tyres have improved mechanical properties like tensile strength of almost 600%, tear strength of almost 250%, and composites' hardness of almost 70% compared to those of the pure styrene-butadiene rubber (SBR) composites.

d. Nanoclay containing brominated isobutylene- co-para-methylstyrene elastomer: This nanoparticle was developed and commercialized by ExxonMobil. It revealed increased air retention properties of about 50% more than halobutyl rubbers.

e. Lamellar nanomaterial organoclays: Example is the Montmorillonite (MMT) Clay developed by Pirelli. It offers an equal performance in vertical and horizontal directions (isotropic behaviour) and compensates between handling and comfort, while showing higher stiffness, improved thermoplastic stability and reduced decay.

f. Other nanoparticles used in tyres are: Polyhedral Oligomeric Silsesquioxanes (POSS); Nano Oxides (Silica, Alumina); Carbon Nano Fibres (CNF); Graphene (delaminated Graphite); and Poly (alkylbenzene)-Poly (diene) (PAB-PDM) nanoparticles (polymer Nano-strings).

Malani et al. [16] examined the application of nanotechnology in automotive industry. The evolution of Nano-engineered automobiles was presented and provided an update overview of the current and evolving state of the art automotive technologies. The authors maintained that nanotechnology is going to bridge the space between performance and cost fluctuation in vehicles with superior technicality.

Goyal et al. [17] examined the application of nanotechnology in automotive industry and outlined the following as the most favorable: Provides better materials with CNTs, grapheme and other nanoparticles/structures;enhanced mechanical, thermal, and appearance properties for plastics;coatings and encapsulates for wear and corrosion resistance, permeation barriers, and appearance;cooling fluids with better thermal performance; fitting together interfaces for improved thermal cycle and crack resistance; providing metal alloys with greater mechanical strength; provision of metal matrix and ceramics with improved mechanical properties; provision of solder materials with crack resistance or lower processing temperature; lower cost and higher performance displays; improved energy capacity of batteries for electric vehicles and fuel cells, automotive sensors with Nano-sensing elements, nanostructures and Nano machines; hybrid electric vehicles using electrical interconnects for high-frequency and high power applications; electrical switching including CNT transistors, quantum transistors, Nano-electromechanical, switches, electron emission amplification, and more efficient solar cells; Self-assembly using fluid carriers.

Elmarakbi et al [18] presented a summary overview on Graphene Related Materials (GRM) applications in automotive industry and examined ways to efficiently combine graphene as polymer reinforcement within composite materials for energy-efficient and safe vehicles (EESVs). The authors discussed Nano-scale production through the graphene elaboration by experiments meso/macro-scale by continuum mechanics modelling considering certain limiting factors based on the large scale production, interfacial performance, wrinkling amount and network arrangement. It was stated that no application of graphene-based materials is marketed in the automotive sector. The automotive sector was encouraged to look forward to innovation activities to realize the potential use of graphene-based technology.

III. THE NEED FOR GAPHENE

Automotive industry worldwide is faced with the challenges of carbon oxides emissions reduction, safety and energy efficiency. For this reason, there is urgent need to apply a new innovation that will ensure greener and safer automobiles. This gives room to the possibility of graphene to be the appropriate solution.

It is believed that graphene will play a major role in the automotive industry soonest. Certainly, the application of graphene super-capacitors and batteries for instance will considerably encourage and improve general performance and efficiency of vehicle, and reduce power consumption, due to superior heat resistance and enhanced recharging efficiency [19]. Fig. 3 is a diagram showing the graphene market. An aspect of the graphene market end-user is the automotive industry.

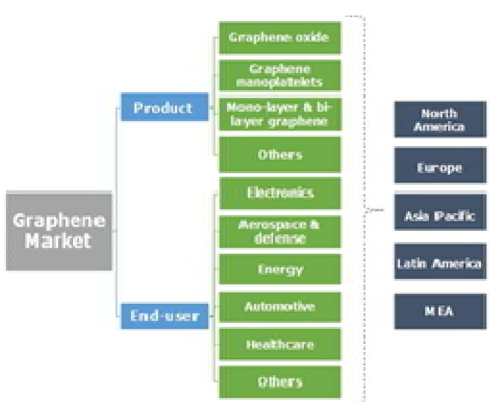

Fig. 3 Graphene market [20]

The application of graphene in the automotive manufacturing process can ensure:

i. Production of lighter and stronger vehicles: The integration of graphene in composites and coating in the making of safe vehicles of lightweight and at the same time strong and even safer, will have enormous impact in automotive sector. Since graphene is stronger than steel (estimate of over 200 times). It can be used to replace the components of carbon fibre, steel, and aluminium. In addition, there will guaranteed improve vehicles dimensional stability.
ii. Improve vehicle's interior: Since self-cleaning and heat conducting polymers can offer comfortable car interior for everybody, the application of graphene enhanced heated vehicle seats with no high energy waste is feasible.
iii. Production of energy-efficient batteries: An important area of research in the application of composites material is the energy storage. Research is on-going in improving the performance capacity of lithium ion battery using the graphene technology. This provides much high storage capacity. It also offers much better lasting and charging rate lithium ion battery. In addition, it will ensure that the proper innovation that will make batteries smaller, low cost and more essentially economic and environmental friendly is in place.

In this paper, the approach adopted is based on information gathering from recent application of graphene in automotive industry. This is achieved by considering report from automotive companies that have applied or are considering using graphene for their vehicle manufacturing processes.

IV. RECENT TRENDS

a) Briggs Automotive Company (BAC): The BAC Mono according to Pelletieri [21] is the maker of the world's only road legal, single seater supper car. It is stated that BAC intends to explore the advantages of using graphene composite body panels. In 2016, BAC became the first car manufacturer in the world to develop a graphene-panelled car; and creating graphene-enhanced carbon fiber composite rear-wheel arches for Mono [21]. The project is aimed at achieving benefits based on weight reduction, carbon (IV) oxide emissions and manufacturing cycle times. Body panels are to be installed and tested on the Mono super car during the project duration, with the goal of achieving 10% weight reduction and more than 25% cycle's times reduction [21].

b) Ford: While acknowledging the challenges of graphene manufacturing and use for large scale items like cars, Ford has found a way to apply graphene reinforcement in some components to make them stronger and reduce their weight as well as noise [22]. It has entered into partnership with Eagle Industries and XG Sciences. As far as 2014, Ford and its partners have tested graphene-reinforced foam covers for noisy components like the fuel rail, pumps, and belt-driven pulleys or chain driven gears on front of engines. This results to parts with 17% lower noise, 20% stronger, and 30.7% more heat resistance [22]. In celebrating National Nanotechnology Day, Ford declared that it will become the first automotive company to apply graphene parts in its vehicles, starting with Mustang and F-150 by the end of 2018 [22].
c) Composites Manufacturing Magazine: A prototype of the world's first graphene composite component for an automotive application was produced by Ahmed Elmarakbi [23]. Sunderland working with a consortium of five research partners from Italy, Spain and Germany, has carried out a series of tests aided by Centro Ricerche CRF of Fiat Chrysler Automobiles to find out how graphene composites behaves when applied to enhance the advance composite materials in vehicle manufacturing.
d) In a report on the website of Automotive World by Isaiah [24], it stated that the market for graphene being in its early stages is expected to be driven over the coming years due to increasing number of suppliers. With North America currently dominating the graphene, a report by Visiongain suggested Asia Pacific will be the fastest for the adoption of graphene for this materials.

According to a report by MarketWatch [25], the market size of graphene is expected to exceed USD 200 million by 2024. The growing trend in the use of graphene in aerospace and automotive industries will drive the market in years to come. Graphene has been extensively accepted in fiber laminates production, which serves as an alternative for the traditional automotive material. The trend representing graphene market size by various sectors using graphene product in the U.S. economy from 2013-2024 is shown in Fig. 4. It is projected that the use of graphene in automotive industry will rise from 2013-2024.

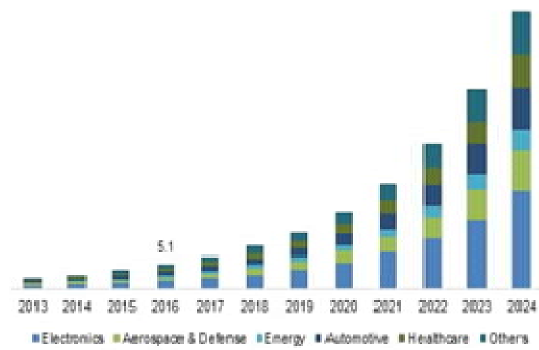

Fig. 4 Projected trend of U.S. Graphene Market size [20]

V. CONCLUSION

The paper has presented review of nanotechnology in automotive industry, the potential of graphene. Nanoparticles are becoming increasingly adopted in the production of lightweight and strong body parts for vehicles. Many automotive industries are accepting graphene to improve their car production even more with stronger and lighter weight. It is believed that with application of graphene in the automotive industry, cars that offer improved thermal comfort, efficiency and safety will become customers (or end-users) choice. However, despite the numerous advantages that graphene will offer to the automotive industries, the growth of graphene market will be likely hindered due to the high cost of manufacturing.

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