ISSN (O): 2393-8609
International Journal of Aerospace and Mechanical Engineering
Volume 7 – No.1, March 2020

GRAPHENE

THE QUEST FOR SUPERCARBON IN AVIATION

Mahima Soota
Amity Institute of Space Science and Technology
Amity University, Noida
mhmsoota@gmail.com

ABSTRACT
Graphene has been one of the latest wonder materials which can be used to enhance the functioning of today's modern world. The paper review has been compiled to disseminate the findings and possible era of applications of graphene in the field of aerospace and aviation, to identify Graphene, so that it can be incorporated into present day life structures, aeronautic systems and even propulsion systems. The paper will therefore seek to accelerate the maturation of these graphene technology opportunities alongside helping the formation of suitable technology projects that address the key requirements, Material Research, Industrialization and Impact on Aerospace Industry.

1. INRODUCTION
Back in 1947, Canadian physicist Philip Wallace wrote a pioneering paper about the electronic behavior of graphite that sparked considerable interest in the field. Nobel-Prize winning chemist Linus Pauling was speculating about how flat, single layers of carbon atoms would behave as long ago as 1960. In 1962, such materials were named "graphene" by German chemist **Hans-Peter Boehm**, who had spotted them under his electron microscope the year before.

Graphene is a hexagonal lattice of monolayer carbon atoms that has been called a wonder material due to intriguing combination of characteristics. Due to its lattice structure, graphene is highly flexible, but also interestingly has great strength, in a way stronger than diamond. Being a low-density material, it exhibits high electrical and thermal conductivity because of highly mobile electrons which enable ultra-fast switching. It is due these attributes, that Graphene has been labelled as Super Carbon. This paper reviews the properties of graphene, its sustainability in aerospace and space craft systems.

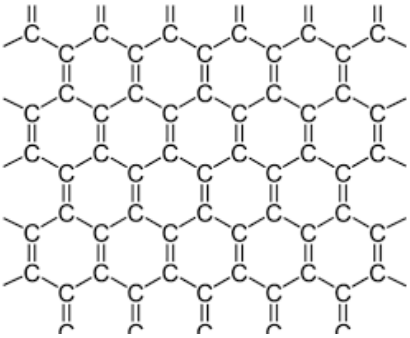

Fig 1. Graphene Structure

2. THE SUPER CARBON - GRAPHENE
The term Super Carbon has been coined to refer to carbon structures that exhibit extra-ordinary properties in terms of strength, conductivity, flexibility and/or structural stability [1]. Graphene has been hailed to be a wonder material ever since it was isolated in the year 2004 [2]. The structure has an intriguing combination of characteristics, being impossibly light yet incredibly strong and flexible.

Graphene is an excellent conductor of heat and electricity. Properties of graphene, as measured on the nanoscale are:

- **Optical Absorption -** Graphene is so thin that it absorbs only 2% of the light that passes through it [3]. This means it's almost completely invisible to the naked eye.
- **Flexibility and Elasticity** - Since Graphene is only one atom thick, this makes it very flexible.[4] Just like a rubber or elastic band, if graphene is stretched to 20% more of its original length, then it shows great applications in different types of wearable technology.[5]
- **Thermal Conductivity -** Graphene has one of the highest thermal conductivity of all materials known to man, that is$> \mathbf{3000}\, \boldsymbol{WmK^{-1}}$. We can harness this by making a composite for various purposes [6]. Graphene electronic circuits can also run faster because they can conduct the heat away from themselves. [7]
- **Electrical Property** - Graphene exhibits extraordinary physical and electrical properties [8]. One outstanding electrical property of graphene is its mobility, $\mathbf{2.5} \times \mathbf{10^5}\, \boldsymbol{cm^2V^{-1}s^{-1}}$, to be very suitable for ultra-fast switching.

However, one of the key challenges within the Graphene research community is how to translate these and other superlative properties, as measured on the nanoscale, into real components. [9-11]

3. GRAPHENE IN AEROSPACE SYSTEMS
The aerospace industry still has a long way to go. Several systems can be improvised or developed in an efficient and lighter way with the help of graphene. [12]

COST EFFECTIVE AIRCRAFTS: The cost of travel by air is related to the fuel consumption and on the all up weight of aircraft. The expensive flights make it difficult for most of the people to prefer air travel. This expense is majorly due to excessive fuel usage. Not only does this increase flight expenses, but also contributes to the depletion of fuel on a large scale. In the recent years, aviation industry has seen many accidents due to insensitive sensors. Lightning protection and de-icing process are another two problems majorly faced by these industries.

ISSN (O): 2393-8609
International Journal of Aerospace and Mechanical Engineering
Volume 7 – No.1, March 2020

AIRCRAFT MATERIAL: Graphene exhibits extra-ordinary thermal and electrical properties. With so many properties combined within a single material, its possible use in multi-functional components introduces the industry to a variety of applications. Graphene can be designed to produce smart structures like integrated structural wiring looms and sensors, hence reducing, major assembly and final assembly equipping times. A larger number of multi-functional components would mean lower parts count and thus, reduced production costs.

EFFICIENT USE OF CFRP AND ADVANCED MATERIALS: CFRP (Carbon Fiber Re-Enforced Plastics) has been proposed as a crucial part of future aircraft due to its high specific strength and stiffness, when compared to the conventional materials, and the ability to re-shape and tailor their structure to form aerodynamically efficient configurations. Graphene enhanced structure might result in increased or at least equivalent performance at lower mass, which again result in lower fuel consumption and environmental damages. Use of graphene for interior polymers is expected for re-enforcement and fire redundancy.

ADVANCED AIRCRAFT FUEL SYSTEMS Use of Graphene Oxide membranes in fuel tank can easily separate water from oils in the fuel tank, hence resulting in advanced and efficient fuel systems. Printed Graphene sensors have already been demonstrated to detect the fuel level using a metal, hence building corrosion-free systems.

3.1 ELECTRONICS

NOVEL HEAT MANAGEMENT Compressed sheets of graphene or its addition to a polymer or rubber could make ideal heat spreaders that minimize heat spots particularly for batteries and electronics at a minimal weight.

ADVANCED COCKPIT AVIONICS Two dimensional materials like graphene, boron nitride and tungsten di-sulphide can behave as ideal electronic devices just a few atoms thick. This means that the electronic circuits laid will be transparent and can be simply embedded onto the cockpit's windscreen to provide a new generation of head up displays.

ROBUST INTEGRATED ELECTRONICS SYSTEMS High mobility of graphene enable ultra-fast switching electronics due to which they can be extensively used in high frequency antennae. These antennas will be required to connect evolving network of sensors throughout an aircraft, and can be easily printed or screened onto the component. Antennae hence produced can be further developed into sensors such that environmental conditions can change their dielectric properties.

NOVEL ENERGY HARVESTING The evolution of smart sensors would eventually lead to demand for passive sensors and energy harvesters for locally powering the aircraft. In near future, use of graphene oxide with thermoelectric materials which increases the thermal operating window and figure of merit, would lead to high usage of this new cheaper, lighter and less toxic generation of materials that operate over a high temperature range, which is quite required for airplanes.

3.2 AEROSTRUCTURES

ADVANCED USE OF CFRP AND HYBRID MATERIALS

Graphene can be used as a coating to strengthen existing structures by providing corrosion resistance. Due to its atomic structure, it can reduce drag, and with its thermal and electrical conductivity, it can further be used in de-icing and lightening protection. The usability of many other CFRP structures can be increased by reducing the chances of fiber/matrix de-bonding (a low energy absorbing damage mode). Use of graphene by matching the properties of interphase region, can restrict the propagation of fiber break, hence, enhancing strength and impact resistance. An optimized performance can be expected from pre-graphene-coated fiber, improving reliability and positive modification of safety factors.

MULTIFUNCTIONAL MATERIALS

Graphene battery technology can be progressed to create multifunctional materials capable of storing energy and self-sensing. Flexible manufacturing methods and use of graphene reinforced CFRP materials opens the door to possibility of creation of novel structural forms, like schemes for active vibration and noise control and large shape changes, hence eliminating any requirement of secondary control surfaces on aero-structures or discrete actuators on propeller rotor hubs. This will reduce the manufacturing as well as operational costs of the aircraft.

DAMAGE RESISTANT STRUCTURES MADE FROM NEW MATERIAL CFRP has poor damage tolerance due to which aero-structures undergo a major mass driving effect. Graphene Related Materials (GRMs) can possibly boost the damage tolerant. Graphene lattices exhibit self-healing properties.

3.3 PROPULSION SYSTEMS

ULTRA HIGH BYPASS RATIO TURBOFAN

The propulsion system, the turbo fan engine, nacelle and linked pylon support structure, are the major elements for weight reduction which will represent an efficient overall aircraft weight reduction approach besides increasing aerodynamic efficiency of various aircraft components and achievement of very demanding cost and efficiency targets.

Graphene powered CFRP is anticipated to find use in aero-engine fan blade and other relevant static structure like fan case, bearing support structure etc., as well as components like the intake, fan cowl doors and parts of the thrust reverser and pylon, which could result in substantial weight reduction. Additionally, the Graphene powered CFRP will lead to thinner fan blades, permitting further aerodynamic and therefore engine performance improvements.

NEW TURBOPROP DESIGN

Development of CFRP propellers is one of the greatest challenges posed in development of turboprop platforms. CFRP propellers are unable to withstand impact from foreign objects, for example, bird strikes or hail. But with Graphene powered CFRP, improved

impact resistance can be achieved, allowing lighter and potentially more aerodynamically efficient propellers. These updated platforms will enhance passenger experience and improve environmental and operational performance, keeping the aircrafts competitive.

ELECTRICALLY PROPELLED AIRCRAFT

An electrically propelled aircraft would require an electrical power source and an efficient electrical power storage device. Graphene serves as an ideal prospect for use in electrochemical forms of power and storage due to its high aspect ratio, surface area and electrical conductivity. It has already been developed as high-power supercapacitors, limited to laboratories and is yet to be formulated for a larger scale use. Furthermore, graphene can potentially be used as Nafion replacement, or at least an additive which can be used for an efficient use of Hydrogen as a fuel since Graphene has been found to be impermeable to all species except for protons.

3.4 EMI SHIELDING

Graphene can potentially be used as an EMI shielding to the packaging whilst reducing weight as compared to the traditional metals used as of now. This is done by spreading of heat on a larger surface area. Also, graphene's anti-static dissipation capability, possible chemical barrier resistance in addition to fire redundancy properties could along with use of CFRP, help in development of low weight fuel tanks.

4. MILESTONES ACHIEVED

Composite materials are among the first ways to commercially use graphene, which can bestow beneficial properties upon them like lightness of weight, flexibility, mechanical strength and more. Graphene-enhanced composite materials have started to appear commercially in the field of sports gear.

In the beginning of 2013, HEAD announced their new range of graphene tennis rackets (YouTek Graphene Speed series). These rackets supposedly use graphene to make the shaft stronger and lighter, and HEAD says that the graphene helps distribute the weight better and creates a stronger and better controlled racket. [13]

In 2014, HEAD launched a line of graphene-enhanced skis for women, called Joy, which are meant to be lightweight and durable. The line includes several models, and is currently about 20% more expensive than traditional skis.

In 2014, A Spanish Company called Catlike launched a line of cycling helmets called Mixino 2014, enhanced with graphene. These helmets are said to be light and strong, and offer major improvements in the field of safety and impact absorption.

Catlike also launched a line of graphene-enhanced cycling shoes to hit the market around Christmas 2014-2015. The line is called whisper and combines different kinds of cycling shoes (for road, mountain and triathlon biking). The shoes are supposed to provide superior performance by being light and durable.

In November 2016, a graphene oxide (GO) sensor co-developed by the ICN2 Nano bioelectronics and Biosensors group was added to the list products offered by Biolin Scientific, a prestigious instrumentation company devoted to the production of analytical devices. The Q-Sense GO sensor enables interaction studies of GO with various analytes (measured substances) of interest and may open the door to various applications with interest for diagnostics, safety/security and environmental monitoring.

Anker's audio brand, Zolo, sells its Liberty graphene-enhanced fully wireless earphones. The Zolo Liberty earphones that these are wireless and offer a whole-day battery life. It also comes with AI for smart assistance and is sweat-proof (and so suitable for use in fitness activities). The ZOLO promises super clear and immersive sound quality and the graphene-enhanced technology reportedly results in impressive treble and clarity.

5. A LONG WAY TO GO

As rightly quoted by Sir Richard Branson, "The potential for graphene to solve enduring challenges within the aerospace sector presents real opportunities for the material to become disruptive, and a key enabler in future aircraft technology. We need to accelerate the opportunity for the world to realize the benefits from graphene by creating a portfolio of graphene related research and technology projects which if undertaken would lead to real impact in our aerospace industry."

One of the key challenges involved in the application of this wonder material is transformation of properties that have been observed on a Nano scale to an actual scale.

The author would like to acknowledge support of AISST and Prof M S Prasad in making of this paper.

6. REFERENCES

[1] Mark Peplow, "Graphene- The Quest for Supercarbon" Nature 503, 327-329 (21 November 2013) doi:10.1038/503327a

[2] Steve Connor, "The Graphene story: how Andrei Geim and Kostya Novoselov hit on a scientific breakthrough that changed the world… by playing with sticky tape" Independent News, @SteveAConnor (18 March 2013)

[3] S.P. Apell, G.W. Hanson and C. Hägglund, "High Optical Absorption in Graphene", arXiv https://arxiv.org/ftp/arxiv/papers/1201/1201.3071.pdf

[4] Edmund Han, Jaehyung Yu, Emil Annevelink, Jangyup Son, Dongyun A. Kang, Kenji Watanabe, Takashi Taniguchi, Elif Ertekin, Pinshane Y. Huang, Arend M. van der Zande "Ultrasoft slip-mediated bending in a few-layer graphene", Nat. Mater. 19, 305–309 (2020). https://doi.org/10.1038/s41563-019-0529-7

[5] Garima M, Kyong Y R. Role of Graphene in Flexible Electronics. COJ Elec Communicat. 1(2). COJEC.000509. 2018. DOI: 10.31031/COJEC.2018.01.000509

[6] Wonjun Park, Jiuning Hu, Luis A. Jauregui, Xiulin Ruan, and Yong P. Chen, "Electrical and thermal conductivities of reduced graphene oxide/polystyrene composites, arXiv https://arxiv.org/ftp/arxiv/papers/1403/1403.2467.pdf

[7] S. Ghosh, I. Calizo, D. Teweldebrhan, E.P. Pokatilov, D.L. Nika, A.A. Balandin, W.Bao, F.Miao and C.N. Lau, "Extremely high thermal conductivity of graphene: Prospects for thermal management applications in nanoelectric circuits", 2008 American Institute of Physics. DOI: 10.1063/1.2907977

[8] Yong-Jin Kim, Yuna Kim, Konstantin Novoselov, Byung Hee Hong, 1 December 2015, "Engineering Electrical

Properties of Graphene: Chemical Approaches" 2015 IOP Publishing Ltd. https://iopscience.iop.org/article/10.1088/2053-1583/2/4/042001

[9] Rich McEachran, 5 Jan 2018, "Graphene – the not-so wonder material?" Engineering News, Institution of Mechanical Engineers

[10] Lin, L., Peng, H. & Liu, Z. Synthesis challenges for graphene industry. Nat. Mater. 18, 520–524 (2019). https://doi.org/10.1038/s41563-019-0341-4

[11] Liam Critchley, April 13, 2019, "Why are there Challenges with Graphene Manufacturing?", Opinion, Business, Nano Magazine, Nano Media Group https://nano-magazine.com/news/2019/4/13/why-are-there-challenges-with-graphene-manufacturing

[12] Aerospace Technology Institute, University of Manchester, "Graphene Exploitation-Material applications in aerospace", INSIGHT_06, March 2018

[13] RCHEAD-HG3605S 1. https://www.tennis-warehouse.com/descpageRCHEAD-HG360S