

Literature Review of Graphene Composites

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ABSTRACT: Graphene is the thinnest material known to man at one atom thick, and also incredibly strong - about 200 times stronger than steel. On top of that, graphene is an excellent conductor of heat and electricity and has interesting light absorption abilities. It is truly a material that could change the world, with unlimited potential for integration in almost any industry. Graphene can also be added to metals, polymers and ceramics to create composites that are conductive and resistant to heat and pressure. Graphene composites have many potential applications, with much research going on to create unique and innovative materials. The potential of graphene composites includes medical implants, engineering materials for aerospace and renewables and much more. In this paper literature review is done to know various techniques to produce graphene composites and its properties for various applications.

KEYWORDS: Graphene, Graphene composites, 3D printing

I. INTRODUCTION

Graphene is a one-atom-thick layer of carbon atoms arranged in a hexagonal lattice. It is the building-block of Graphite (which is used, among others things, in pencil tips), but graphene is a remarkable substance on its own - with a multitude of astonishing properties which repeatedly earn it the title "wonder material". Graphene is the thinnest material known to man at one atom thick, and also incredibly strong - about 200 times stronger than steel. On top of that, graphene is an excellent conductor of heat and electricity and has interesting light absorption abilities. It is truly a material that could change the world, with unlimited potential for integration in almost any industry. Graphene is an extremely diverse material, and can be combined with other elements (including gases and metals) to produce different materials with various superior properties. Researchers all over the world continue to constantly investigate and patent graphene to learn its various properties and possible applications.

Composite materials (also referred to as composition materials, or simply composites) are materials formed by combining two or more materials with different properties to produce an end material with unique characteristics. These materials do not blend or dissolve together but remain distinct within the final composite structure. Composite materials can be made to be stronger, lighter or more durable than traditional materials due to properties they gain from combining their different components.

Graphene and composite materials

As was stated before, graphene has a myriad of unprecedented attributes, any number of which could potentially be used to make extraordinary composites. The presence of graphene can enhance the conductivity and strength of bulk materials and help create composites with superior qualities. Graphene can also be added to metals, polymers and ceramics to create composites that are conductive and resistant to heat and pressure. Graphene composites have many potential applications, with much research going on to create unique and innovative materials. The applications seem endless, as one graphene-polymer proves to be light, flexible and an excellent electrical conductor, while another dioxide-graphene composite was found to be of interesting photocatalytic efficiencies, with many other possible coupling of materials to someday make all kinds of composites. The potential of graphene composites includes medical implants, engineering materials for aerospace and renewables and much more.

II.LITERATURE REVIEW

N. Decordea, R.C.T. Howea, F. Tomarchioa, C. Pauknerb, J. Joaugb, K. Koziolb, T. Hasana, A.C[1] demonstrated 3d printing of a graphene-polymer filament by FMD. Graphene powder produced from methane plasma cracking is blended with PLA using two different routes: wet mixing in chloroform and dry mixing at 250°C. The composite is then extruded at 160°C into a solid filament and 3d printed by FMD. Figs.1d,e show pure polymer and graphene composite 3d-printed objects. The electrical and mechanical properties of the 3d printed structures are investigated by conductivity and tensile strength measurements.

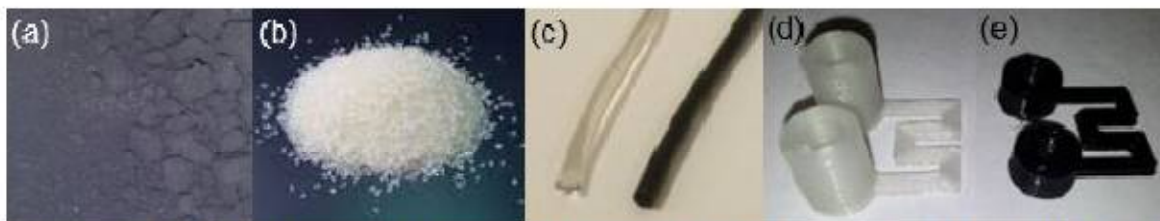


Figure 1: (a) Graphene Powder, (b) PLA pellets (c) Filament of PLA (White) and Graphene-PLA (Black), (d) Printed structure with pure PLA and (e) graphene-PLA composite.

Michael Satches[2] in his research sought to create a graphene reinforced, polymer matrix nano-composite that is viable in commercial 3D printer technology, study the effects of ultra-high loading percentages of graphene in polymer matrices, and determine the functional upper limit for loading. Loadings varied from 5 wt. % to 50 wt. % graphene nanopowder loaded in Acrylonitrile Butadiene Styrene (ABS) matrices. Loaded sample were characterized for their mechanical properties using three point bending, tensile tests, as well as dynamic mechanical analysis. Results of this work showed that it is possible to synthesize graphene ABS nano-composites in loadings up to 50 wt. % utilizing thermal extrusion techniques to produce raw stock material designed for a commercial fused deposition modeling (FDM) 3D printer. This research showed that with a non-specialized commercial 3D printer it is possible to print up to 10 wt. % parts with high quality. Proper customization to the current print head design will enable printing parts up to 50 weight percent. With the current 3D printer setup, 5 wt. % percent graphene is found to be the best choice for increasing print stiffness. 5 wt. % graphene 3D printed parts show an increase of Young's Modulus of 146%, along with a decrease of yield strength of 24% and a reduction of the percent elongation by 44%. This study proves the feasibility of printing parts with graphene as a filler and opens the door for future designer materials to expand the 3D print technology capability.

This work has shown that it is currently possible to synthesize high weight percent graphene/ABS nano-composite materials that are compatible with commercial off-the-shelf 3D printers. This work has shown that nano-composite materials have functionality in a 3D printer and that even in ultra-high concentrations can be made into viable composites. A greater than 300% increase in tensile modulus has been realized as well as approximately 400% increase in flexural modulus with a 50 weight percent addition of graphene. Although the graphene/ABS nano-composites did not show the increases in strength that were hypothesized to occur, large increases in material stiffness can still have a function for 3D printed parts where these stiff components can serve as reinforcing material to traditional ABS or other print materials.

Jordan Girdis1, Matthew McCaffrey1, Gwénaëlle Proust[3] In their paper, the effects of the addition of short carbon fibres (SCF) and graphene into acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) polymers to create composite filaments for fused deposition modelling (FDM) were investigated. After creating carbon polymer composite filaments, using a commercial 3D printer, samples were reprinted and tested for mechanical and electrical properties. The measured values for these composites were compared to those obtained for pure ABS and pure PLA. It was found that by using only 2% SCF it was possible to achieve a 22% increase in tensile strength with no significant impact on printability. With addition of graphene, PLA was made to be conductive. These results show the feasibility of developing new materials for 3D printing that will create structurally sound and conductive designs.

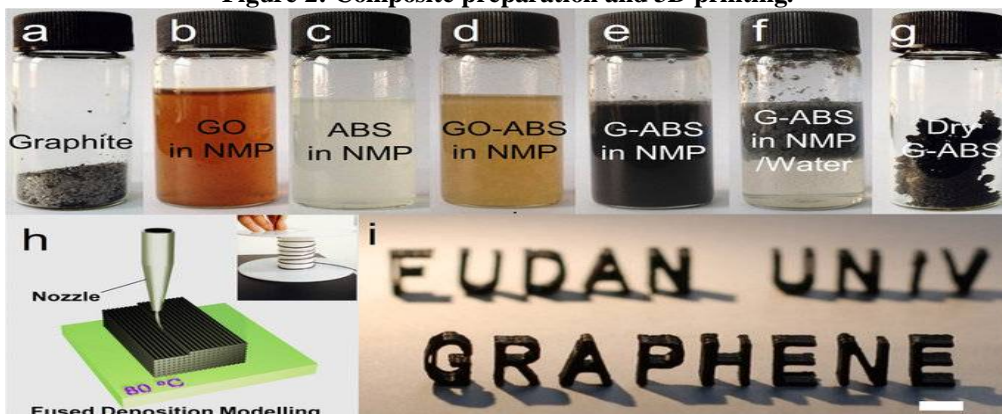
The investigation involved analysis of structural and electrical properties of 3Dprinted carbon polymer composite components. To achieve this, short carbon fibres of 212µm were mixed with commercially available ABS pellets in a single screw Filabot filament extruder in specified ratios. These filaments were then extruded at approximately 178°C and printed into tensile test coupons. The 3D printer used was a commercially available Leapfrog 3D Creatr. The printing parameters used were a print temperature of 230°C with a bed temperature of 80 °C. Test coupons were then analysed for conductivity using a high accuracy ohm meter and in tension until failure using a MTS Criterion loading frame. Pure ABS, 1wt% SCF/ABS, 2wt% SCF/ABS, PLA and PLA/Graphene coupons were subject to this test regime.

Table 1 – Comparison of average maximum tensile stresses

Sample	Average tensile Strength (MPa)	Theoretical tensile strength at 100% infill (MPa)	% Increase compared with Pure Material
PLA	30.2	43.77	N/A
PLA-Graphene	13.78	19.97	-54%
ABS	22.24	32.23	N/A
ABS-1wt% SCF	22.54	32.67	1%
ABS-2wt% SCF	27.23	39.46	22%

Xiaojun Wei [4] demonstrated for the first time, a graphene composite, with a graphene loading up to 5.6 wt%, can be 3D printable into computer-designed models. The composite's linear thermal coefficient is below 75 ppm·°C⁻¹ from room temperature to its glass transition temperature (T_g), which is crucial to build minute thermal stress during the printing process. Demonstrate a series of images related to the process flow to prepare the 3D printable graphene-ABS (G-ABS) composite. Large graphite flakes were first oxidized into GO using an optimized method reported before. Fully exfoliated GO sheets were dispersed in N-Methylpyrrolidone (NMP) medium which is also compatible with the ABS polymer. The two solutions (GO in NMP and ABS in NMP) were mixed using a homogenizer at 15000 r.p.m. for 1 hour, allowing a thorough mixing of GO sheets and the ABS. Figure 2d shows a homogeneous GO-ABS dispersion obtained through homogenizer mixing. Through chemical reduction of GO with hydrazine hydrate, black reduced G-ABS dispersion was *in-situ* formed without obvious phase separation. To fractionally precipitate G-ABS composites from NMP, the dispersion was added into water. The precipitated G-ABS composite is shown in Fig. 2f. The top layer is the G-ABS coagulations, while the bottom is the water phase. These composites were subsequently centrifuge-separated, washed and further dried in a vacuum oven. The high-speed homogenizer is essential to yield homogeneous G-ABS composites. Phase separation between graphene and ABS polymers was observed without using the homogenizer during the synthetic process. A series of the composites with various graphene loadings were prepared using the above method. The reduced graphene oxide loading were 0.4, 0.8, 1.6, 2.3, 3.8, 5.6 and 7.4 wt%, respectively. A sample of 0.8 wt% graphene-PLA (G-PLA) composites was also prepared using the same strategy.

Figure 2: Composite preparation and 3D printing.



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a, Picture of graphite flakes. **b,c**, Dispersions of GO and ABS in NMP solvent. **d,e**, Pictures showing a homogeneous mixture of GO-ABS in NMP before and after chemical reduction by hydrazine hydrate at 95 °C for 1 h. Brownish GO-ABS turned into black G-ABS suspension during chemical reduction. **f**, G-ABS coagulations obtained after isolation (**e**) with water. **g**, G-ABS composite powder after washing and drying. **h**, Schematic illustration of fused deposition modelling 3D printing process. Inset is the graphene-based filament winding on a roller. The filament was deposited through a nozzle onto a heated building plated, whose temperature was set at 80 °C. **i**, A typical 3D printed model using 3.8 wt% G-ABS composite filament, scale bar: 1 cm.

Ray Gibbs Chief Executive Officer Haydale Ltd[5] told in this interview for AZO network about the scope of graphene composites is that one of the first applications is, bizarrely, to develop electrically conductive epoxy resins which can significantly increase the electrical conductivity of the carbon composite materials used in the construction of fuselages to such a level that it would hopefully negate the need to utilise copper mesh which is employed for the prevention of damage caused from lightning strikes. The aircraft industry relies heavily on composite materials and lightning strikes pose a big risk as composites tend to be inert and electricity wishes to find an earth. Aircraft are generally extremely insulating. Therefore the aircraft is likely to be subject to a number of potential lightning strikes during operation, so it's essential to have a good conductor. It can take up to ten years to qualify new materials in the aerospace industry, particularly if it's in the framework of the aircraft – and rightly so. However, there are reproducible parts within the aircraft itself that wear out and need replacing. They're often made from composites materials. For example, trays, overhead storage lockers, toilet fixtures etc. could all be made from graphene composite materials and reducing weight which is the constant goal of the aircraft industry, without compromising safety.

Graphene Laboratories Inc., USA[6] had recently announced that it was successfully in developing a state-of-the-art graphene composite material under the trade name of G6-Impact™. This graphene composite material will be intended for industrial users in the automotive, robotics, drone aerospace and military sectors. Graphene composite materials are prepared using multiple components which are processed together to enhance existing properties. G6-Impact™ composite material is developed based on a mixture of High Impact Polystyrene (HIPS) resin, Carbon Fibers and Graphene Nanoplatelets. The G6-Impact™ impressive properties are ensured by the Company's proprietary formulation and micro-mixing technique. Across industries, mechanical parts and complex electronic devices are increasingly subjected to shock, friction, vibrations, and harshness. G6-Impact™ holds a combination of excellent stiffness, toughness as well as impact and vibration absorption. G6-Impact™ will be an optimal material for applications where vibration damping is required on firm surfaces that could include sporting gear, power tools handles, automotive parts, and aerospace components.

III.CONCLUSION

Graphene is an extremely diverse material, and can be combined with other elements (including gases and metals) to produce different materials with various superior properties. Graphene composite materials are prepared using multiple components which are processed together to enhance existing properties. Literature review shows that, it can be possible 3d printing of a graphene-polymer composites, Grapheme reinforced, polymer matrix nano-composite using commercial 3D printer technology. Addition of graphene shows an increase of Young's Modulus, along with a decrease of yield strength and a reduction of the percent elongation. Feasibility of printing parts with graphene as a filler and opens the door for future designer materials to expand the 3D print technology capability. Grapheme composite material will have large scope for industrial users in the automotive, robotics, drone aerospace and military sectors.

REFERENCES

- [1] N. Decordea, R.C.T. Howea, F. Tomarchioa, C. Pauknerb, J. Joaugb, K. Koziolb, T. Hasana, A.C. Ferraria, F. Torrisia "3d printing of graphene-polymer composites"- a Cambridge Graphene Centre, University of Cambridge, Cambridge CB3 0FA, UK b Cambridge Nanosystems, Cambridge CB5 8HY, UK
- [2] Michael Satches "Nano-Composite Material Development for 3-D Printers", B.S.M.E.A Thesis In Mechanical Engineering Submitted to the Graduate Faculty of Texas Tech University in Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE
- [3] Jordan Girdis1, Matthew McCaffrey1, Gwénaëlle Proust" Additive Manufacturing of Carbon Fiber and Graphene – Polymer Composites using the technique of Fused Deposition Modelling." School of Civil Engineering, The University of Sydney, NSW 2006 Australia
- [4] Xiaojun Wei1"3D Printable Graphene Composite" Scientific Reports5, Article number: 11181 (2015)
- [5] Graphene Composites for Aerospace Applications: An Interview with Ray Gibbs
- [6] Elena Polyakova "Advanced graphene composites for 3D printing and other high end applications,"(Graphene Laboratories Inc., USA)