Nano-Composite Material Development for 3-D Printers

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Abstract

The research objective is to demonstrate the ability to create ultra-high weight percent graphene composite materials to determine how their material properties compare to their pure counterparts, and to demonstrate the ability to 3-D print these materials. This will be accomplished in two parts. First samples will be created using casting methods to assess material properties and determine effective concentrations. Then these materials will be used in a 3-D printer to demonstrate the ability to print high strength parts from commercially available printing technology. This project focuses on a material set that is readily available and is compatible with many 3-D printers commercially available today. Materials to be tested are ABS, Polycarbonate, and PLA, and all composite materials will use 8nm functionalized reduced graphene oxide(RGO). To date testing is ongoing to determine a functional upper limit of RGO loading in polymer matrices to obtain the best mechanical properties while retaining workability for rapid prototyping.

Introduction

Graphene has been the source of much scientific research in recent years due to its excellent combination of mechanical, thermal, and electrical properties. It has been demonstrated that graphene polymer composites show superior strength to pure polymer materials, and can increase mechanical properties at lower loading levels than with traditional methods like carbon fibers.[1] For this reason composite materials which use graphene have seen considerable interest and could be used to create inexpensive high strength parts for use in many applications. 3-D printing has seen vast improvements in recent years that have allowed many companies and individuals to create rapid prototypes for much less money. For this reason the combination of high strength composites and 3-D printing seems a natural progression that could have potential for use in defense or commercial markets. In this research the goal is to create a 3-D printer capable material that possess high strength good thermal properties, and low weight which could be used in a variety of applications. In this study RGO has been selected as it is easy to obtain and relatively inexpensive, which will make the process simpler to scale up to production levels. This work seeks to determine if a graphene polymer composite material set can possess similar or better mechanical properties to an alloy or ceramic material, and still possess the ability of rapid prototyping and production. The Hypothesis made is that RGO will have a marked impact on the strength of the polymer, and that it is possible to achieve much higher loadings than what has currently been published.

Methods

For the first phase of this research material properties are to be determined. To accomplish this 8nm RGO is added to the chosen solvent at the desired weight percentage of the polymer being used. The solvent/RGO mixture is horn sonicated for a given length and power to disperse the RGO effectively. The polymer is then added, at which time the mixture is heated and stirred vigorously until there is a complete dissolution of the polymer. This mixture is then poured into molds and allowed to degas.
The second stage of this project involves demonstrating that this material set can be rapidly prototyped using a commercial off the shelf 3-D printer. A 3-D printer was purchased from Airwolf Technologies[2], and will be used to create material parts for testing. To accomplish printing with this 3-D printer material must be fed to the print head using a 3mm diameter filament. This requires the composite materials be cast or extruded into wire form for printing. To accomplish this a mold was designed to allow the material to be cast directly into wire.

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Results

Tensile Data Here

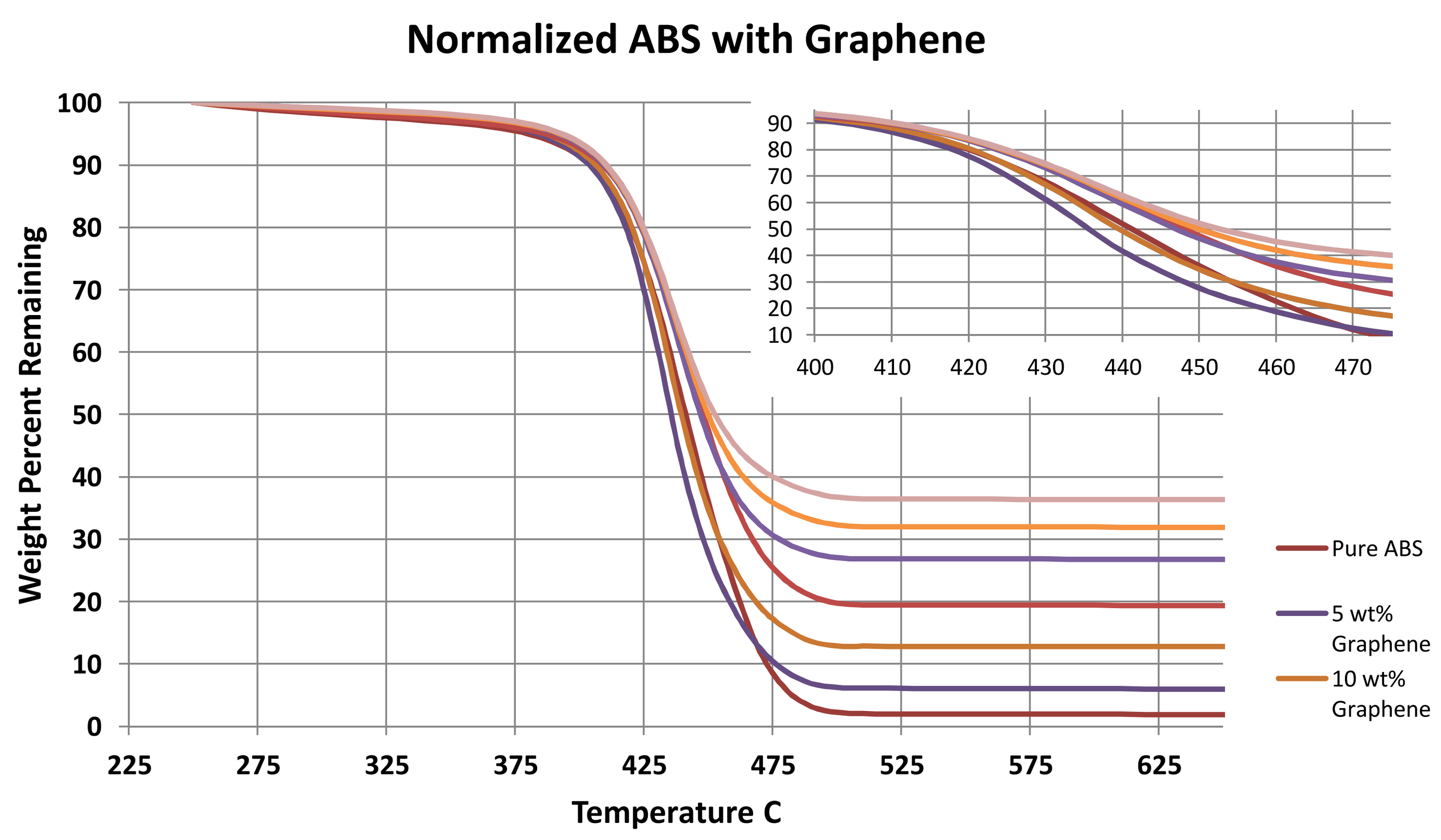

Fig. 1 Depicting Thermo Gravimetric Analysis for ABS doped with RGO

Discussion

Through testing to date it has been shown that it is possible to add very high weight percentages RGO to ABS polymers and still maintain a high degree of workability of the material. Before continuing with this work, the procedure must be improved to create higher quality parts. This will include the investigation of different solvents and methods to degas the samples. Testing that will be performed in the future will allow a determination as to a fundamental limit where increased loading will have a negative effect on the material properties. Future Testing will include non-destructive LDV testing, rheometry, continued tensile testing of printed parts, shear testing, and torsional testing. These tests will allow a determination of how increased loading affects the material properties for each material set.

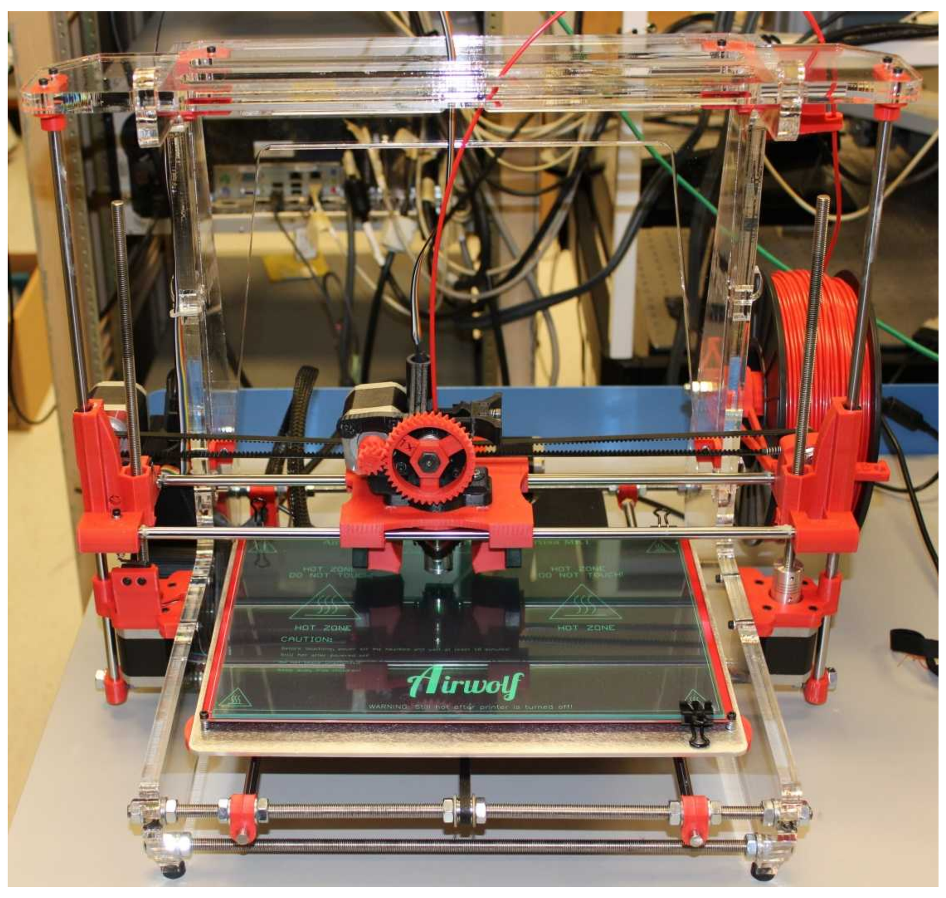

Fig. 2 depicting commercially available 3D printer used in these experiments

Future Work

Cast or extrude composite material sets into wire form. 3-D print these materials and preform mechanical and dynamic experiments to determine material properties.

Conclusions

Further testing is required to show whether high loaded graphene composites possess the strength and functionality for use with 3D printing techniques

References

1. Kim, Hyunwoo, and Christopher W. Macosko. "Processing-property Relationships of Polycarbonate/graphene Composites." *Polymer* 50.15 (2009): 3797-809.
2. "Airwolf 3d - High Performance 3D Printers." *Airwolf 3d*.

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