Fabrication of Concussion Resistant Nanocomposites

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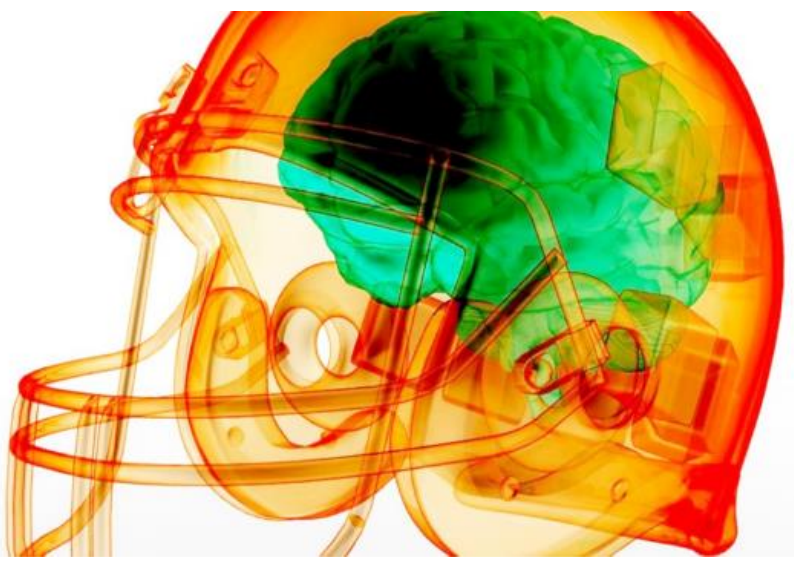
Introduction

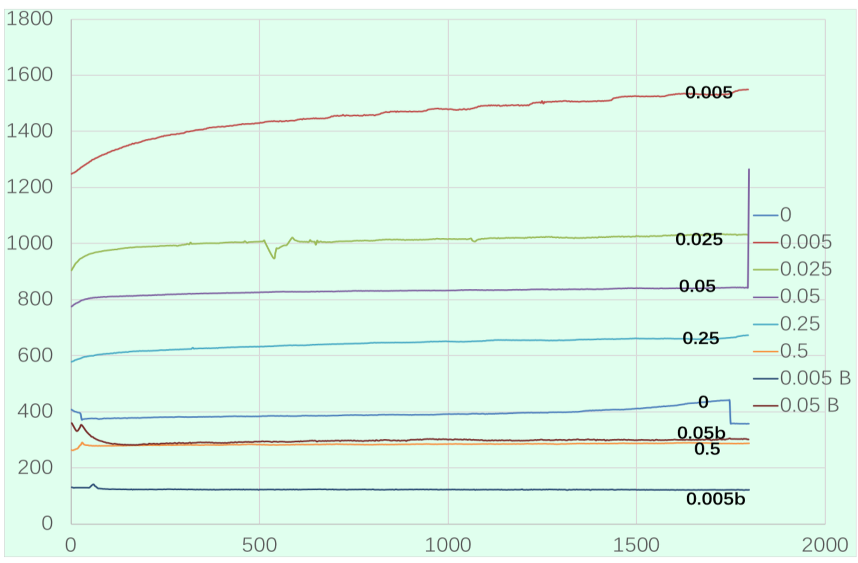
Studying concussions is of paramount importance. Concussions occurring in sports and sudden other accidental cases are causing major injuries to people often times it leads to CTE and eventual death. Chronic Traumatic Encephalopathy (CTE) is one type of degenerative brain disease that can be found in athletes, military veterans, and other people who have repetitive brain trauma. CTE is usually caused by repetitive hits to the head sustained over a period of years, most people diagnosed with CTE suffered hundreds or thousands of head impacts over the course of many years, such as playing contact sports or serving in the military. PDMS-based nanomaterials are gaining widespread attention in this regard. We report the use PDMS polymer and graphene oxide/graphene as nanoparticle reinforcement to produce the vibration-absorbing PDMS-graphene nanocomposite. The stiffness of PDMS and graphene-PDMS nanocomposites were measured using dynamic mechanical analyzer.

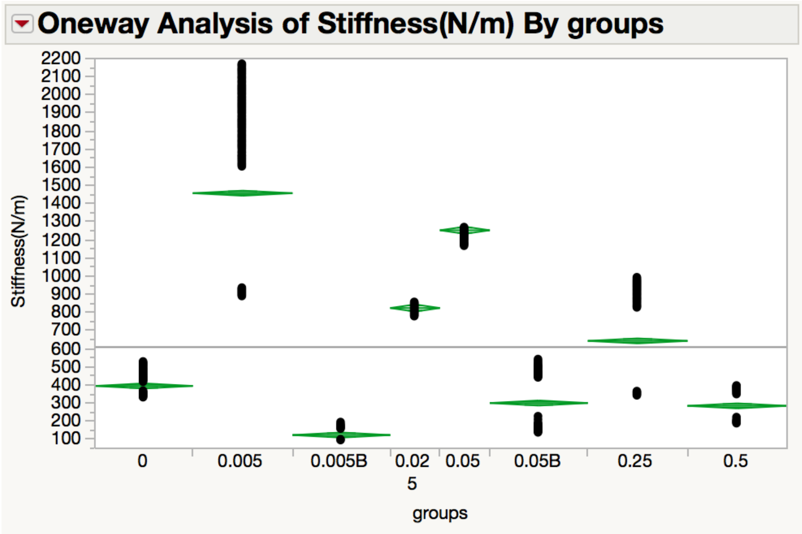
We prepared a well-controlled pore containing PDMS-graphene nanocomposites that exhibited significant improvement in impact absorption properties as a function of porosity. Visual Molecular Dynamics (VMD) was used to compute the physical interactions between graphene and PDMS.



Dynamic Mechanical Analyzer

The modulus of elasticity is often one of the primary properties considered when selecting a material. A high modulus of elasticity is sought when deflection is undesirable, while a low modulus of elasticity is required when flexibility is needed.





Oneway Anova

Summary of Fit

Rsquare	0.77023
Adj Rsquare	0.770036
Root Mean Square Error	247.7221
Mean of Response	608.3891
Observations (or Sum Wgts)	8320

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
groups	7	1709864677	244266382	3980.468	<.0001*
Error	8312	510076230	61366.245		
C. Total	8319	2219940907			

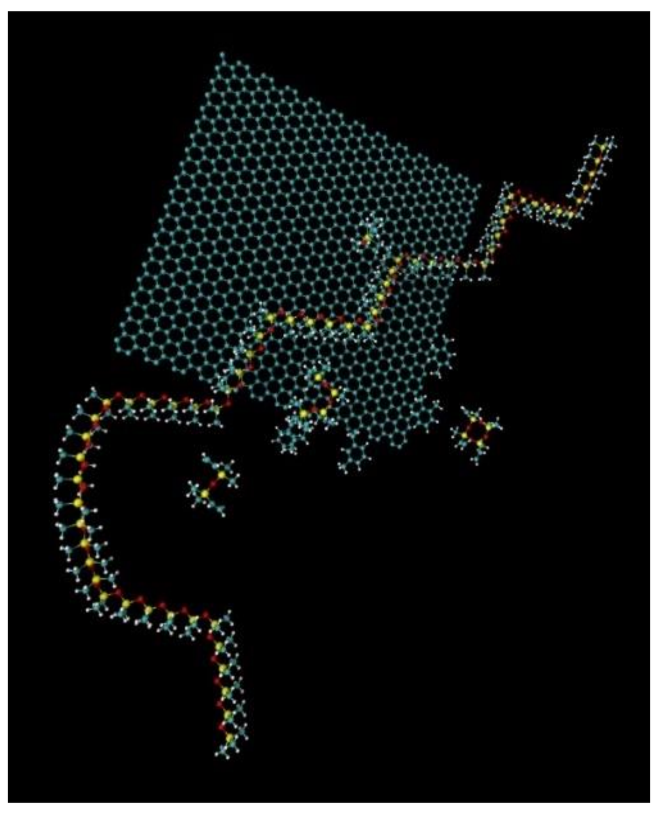
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
0	1177	394.20	7.221	380.0	408.4
0.005	1198	1457.28	7.157	1443.3	1471.3
0.005B	1175	123.32	7.227	109.2	137.5
0.025	597	824.00	10.139	804.1	843.9
0.05	600	1252.83	10.113	1233.0	1272.6
0.05B	1178	299.98	7.218	285.8	314.1
0.25	1198	642.56	7.157	628.5	656.6
0.5	1197	284.30	7.160	270.3	298.3

Visual Molecular Dynamics

Visual Molecular Dynamics (VMD) is a molecular visualization to displaying, animating, and analyzing the molecular system.

In here, it uses the VMD to analysis the interface and the micro force between PDMS and Graphene. Protein Data Bank (PDB) files get from the PubChem or building by software. PSF files build by the Automatic PSF builder of VMD. And, it was using the VEGA ZZ to build the solvent box for the non-water solvent. The molecular dynamic analysis will generate by NAMD. After all those work, it will show the result of the hydrogen bond, molecular energy, Timeline and other data in Nano level

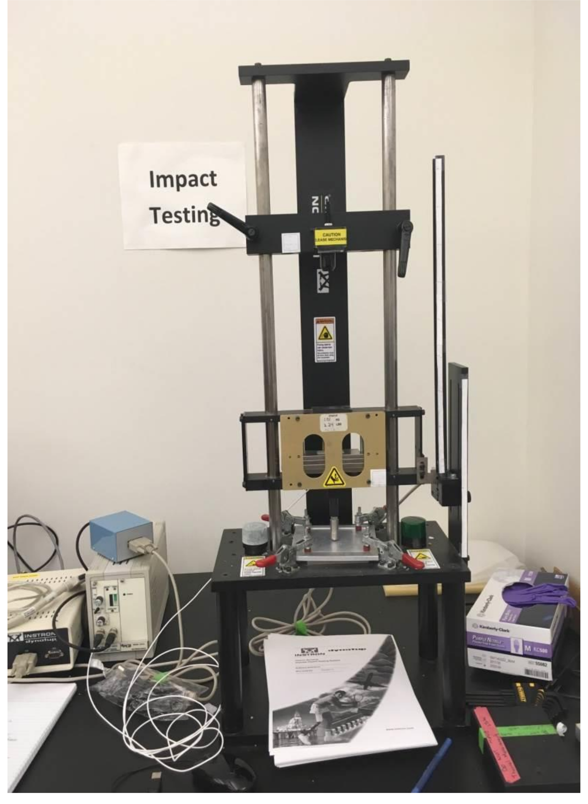


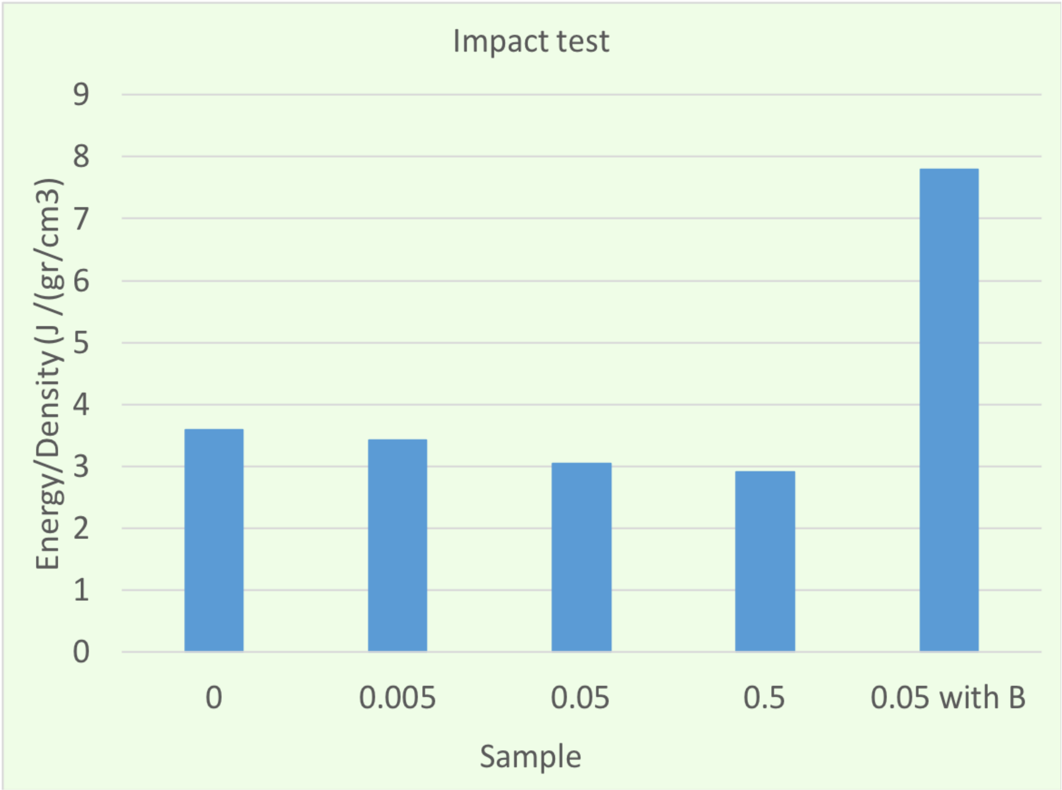
Materials and Methods

PDMS based nanocomposite was fabricated by swelling the PDMS in chloroform/TEOS (4:1 ratio) mixture followed by ultrasonication of the graphene oxide and graphene nanoplatelets in the same solvent that swells the polymer. Various factors, such as temperature, curing agent (Sylgard 184 kit and PHMS), nanoparticle size, solvent and filler concentrations that influence the nanoparticle-polymer interface has been studied in the experiment. Different size of the nanocomposite was also being fabricated include thin film and Round cake could support different type of tests.

Impact testing

The impact test show the energy absorption of the materials. All of the samples are under the same weight impact of the object. Increase the object height to increase the energy until the sample is broken. Result shows that the sample will absorb more energy by increasing the amount of the graphene nanoplatelets. The bubble group has a significant increase of energy absorption than other groups.





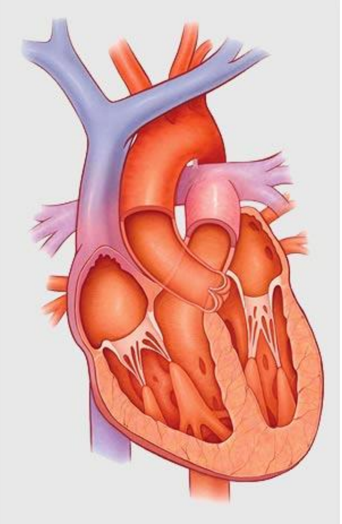
Discussion and Conclusion

Graphene nanoplatelets could make composite harder than Graphene oxide(GO), GO plays a role of both filler and curing agent. More filler added into composite, higher elasticity and crisp properties could be achieve. Either pure Chloroform or TEOS are not suitable solvent, due to less solubility and stability, mix Chloroform and TEOS to 4 ： 1 ratio could solve this problem. PMHS have faster curing time than Dow Corning kit. However, faster time usually come with Inhomogeneous situation which means bubbles. Decrease curing agent percentage will need longer time to finish curing process but could produce more "soft" material. Nanocomposite with uniform bubble structure have twice impact absorb properties than usual.

Ultrasonication is necessary for uniform dispersion the filler into solvent. Microwave give more energy to the composite but easier to make filler cluster together and hard to dispersion. High temperature could rush the curing process but also make the material more "hard".

Application and Future Work

The detailed understanding of dynamic stiffness along with loss and storage modulus of the nanocomposites will enable its potential use as concussion resistant materials. Resulting nanocomposite may find its application as compliant heart valve mimicking biomaterials.



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