Experimental Investigation of SWNT based Bio-Composite and Their Applications in Automobiles

P. Kaviyarasu,
Assistant Professor,
Aeronautical Engineering,
MAM School of Engineering,
Trichy, India.

Maniamramasamy. S,
Assistant Professor,
Mechanical Engineering,
MAM School of Engineering,
Trichy, India.

Dr. P.V. K. Perumal
Professor,
Aeronautical Engineering,
MAM School of Engineering,
Trichy, India.

***Abstract*— In this paper, a technique is presented for developing a composite system with single walled carbon nanotubes (SWNT) and natural rubber. Considerable growth has been seen in the use of bio-composites over the past decades. The dispersion of nanotubes in natural rubber has been investigated as a means of deriving new and advanced engineering materials namely bio-composites. This experimental investigation results establish the importance of composites in automobile industry. Carbon nanotubes are promising new materials for blending with polymers and having potential to obtain low weight nano composites of extraordinary mechanical, electrical, thermal and multifunctional properties. The size scale, aspect ratio and properties of nanotubes provide advantages in a variety of applications including advanced materials with combined stiffness, strength and impact for aerospace or sporting goods. Our objective is to develop a composite using carbon nanotubes and natural rubber, analyse the morphology and thermal stability using Atomic force microscopy, Thermogravimetry and to check the feasibility of using them in automobiles.**

Keywords: Single walled carbon nanotubes, Atomic force microscopy, Thermogravimetry etc…

I. INTRODUCTION

Instead of using steel or some other heavy metals, composite materials made a big trend in automotive construction. These are being considered to make lighter, safer and more fuel efficient vehicles. Using of composite materials results non rust, light weight, better in terms of stiffness and strength etc… reduce of weight results more fuel efficient. The reputed automobile industries like Mercedes-benz, BMW, jaguar are using advanced techniques for improving their design and manufacturing. Although the composites are widely used but limited parts only can be constructed. Many materials and techniques are used in preparing of composites, among that Bio-composite is eco friendly and bio-degradable. A CNT is a tube-shaped material, made of carbon, having a diameter measuring on the nanometer scale. A nanometer is one-billionth of a meter, or about one ten-thousandth of the thickness of a human hair. The graphite layer appears somewhat like a rolled-up chicken wire with a continuous unbroken hexagonal mesh and carbon molecules at the apexes of the hexagons.

CNTs have many structures, differing in length, thickness, and in the type of helicity and number of layers. Although they are formed from essentially the same graphite sheet, their electrical characteristics differ depending on those variations, active either as metals are as semi-conductors. Carbon nanotubes can be categorized by their structures as (i) Single wall nano tubes, (ii) Multi wall nano tubes. CNTs have many extraordinary intrinsic properties. The experimental and theoretical studies have demonstrated that individual multiwall carbon nanotubes (MWNTs) show extremely high Young's modulus, good stiffness, and flexibility.

CNTs show high electrical and thermal conductivity along the axial direction, which could be used as a variety of micro-electronic components or super excellent heat-transfer devices. To obtain materials with high electrical conductivity, high loading of conductive filler is generally needed. This could increase the final cost of the material, and often impair the mechanical properties of the materials. For these reason, the CNTs are considered to be a good candidate as one of the functional electrical conductive fillers.

II. LITERATURE REVIEW

Alastair F.Johnson et al.,[1] in his paper "Impact and crash modeling of composite structures: a challenge for damage mechanics" describes recent progress on the materials modeling and numerical simulation of the impact and crash response of fiber reinforced composite structures. The work is based on the application of explicit finite element (FE) analysis codes to composite aircraft structures under both low velocity impact conditions, detailed results are presented for the crash response o helicopter subfloor box structures using a strain based damage and failure criterion for fabric reinforced composites. In order to obtain better agreement with measured impact response, an improved composites damage mechanics model with damage parameters as internal state variable is presented.

The authors G. Andrei et al.,[2], describe that carbon fibers/polymer matrix composites tend to be used more widely instead of aluminum structures in the aircraft and aerospace industry. There are many reasons that explain the increasing interest for this class of composites due to the lightweight, high strength, high stiffness, good fatigue life, excellent corrosion resistance and low cost manufacturing.

Authors X.Zhang et al.,[3], say that the real structural carbon fiber composites always contain carbon fiber reinforcements where fibers run continuously through the composite matrix. With the recent optimization in aligned nanotube growth, samples of nanotubes in macroscopic lengths have become available, and this allows the creation of composites that are similar to the continuous fiber composites with individual nanotubes running continuously through the composite body.

Y.Marchal et al.,[4] describes that Al-, Zn-, and Cu-based matrix composites reinforced with continuous fibers of carbon, Sic, A1203, or steel have been processed by squeeze casting or powder metallurgy. Interface reactions can be controlled by alloying additions in the matrix. Interface adhesion has been characterized from the distributions of fiber pull-out lengths on fracture surfaces. Thermal expansion curves reveal the magnitude of the stress transfer at interfaces. In the case of low melting point matrices, ductile steel fibers offer the best combination of fracture toughness and creep resistance.

John E.Fischer et al.,[5] conveys that a coagulation method provides a better dispersion of 0single-walled carbon nanotubes (SWNTs) in a polymer matrix was used to produce SWNT/poly (methyl methacrylate) (PMMA) composites. Optical microscopy and scanning electron microscopy showed an improved dispersion of SWNTs in the PMMA matrix, a key factor in composite performance.

E.J.Garcia et al.,[6] (2006) says that the interaction, or wetting, of long aligned carbon nanotube (CNT) forests with off-the-shelf (no solvent added) commercial thermo set polymers is investigated experimentally. A technique for creating vertically aligned CNT composite microstructures of various shapes is presented (Wise K.E et al, 2003). The effective wetting of the forests, as evidenced by a lack of voids, by three polymers with widely varying viscosities supports the feasibility of using CNT forests in large-scale hybrid advanced composite architectures.

III. FABRICATION

The following raw materials are used for fabrication of SWNT based composite materials

1.Single walled carbon nanotubes
2. Natural rubber (Latex)
3. Toluene

A. *Single walled carbon nanotubes*

As shown in Figure.1 SWNT have diameter less than 1 nm with a tube length that can be many millions of times longer. They are formed by wrapping a one-atom-thick layer of graphite called graphene into a seamless cylinder.

Fig .1. Single walled carbon nanotubes

1. Properties of SWNT

a) Electrical Conductivity

- The resistivity of the SWNT ropes was in the order of 10–4 ohm-cm at 27°C. This means that SWNT ropes are the most conductive carbon fibers known.
- WNTs can route electrical signals at high speeds (up to 10 GHz) when used as interconnects on semi-conducting devices.

b) Strength and Elasticity

- The basal-plane elastic modulus of graphite is one of the largest of any known material. For this reason, CNTs are expected to be the ultimate high-strength fibers.
- SWNTs are stiffer than steel, and are very resistant to damage from physical forces.
- Pressing on the tip of a nanotube will cause it to bend, but without damage to the tip. When the force is removed, the tip returns to its original state. This property makes CNTs very useful as probe tips for very high-resolution scanning probe microscopy.
- The current Young's modulus value of SWNTs is about 1 TeraPascal, but this value has been disputed, and a value as high as 1.8 Tpa has been reported.

c) Thermal Conductivity and Expansion

- CNTs may be the best heat-conducting material man has ever known.
- The strong in-plane graphitic C-C bonds make them exceptionally strong and stiff against axial strains.

B. *Natural rubber*

As shown in Figure.2 Rubber is an elastomeric- a polymer that has the ability to regain its original shape after being deformed. It is an elastic material obtained from the latex sap of trees that can be vulcanized and finished into a variety of products.

Fig.2. Natural rubber (Latex)

1. Properties of Natural rubber

a. Water repellent,
b. Resistant to alkalies and weak acids,
c. Less build up of heat from flexing,
d. Greater resistance to tearing when hot,
e. Resilience over a wider temperature range.

ISSN: 2278-0181
Vol. 4 Issue 12, December-2015

C. Toluene

As Shown in Figure.3 Toluene (C7H8), aromatic hydrocarbon used extensively as starting material for the manufacture of industrial chemicals. It comprises 15–20 percent of coal-tar light oil and is a minor constituent of petroleum. The compound is used in the synthesis of trinitrotoluene (TNT) benzoic acid etc. It is also used as a solvent and antiknock additive for aviation gasoline.

Fig.3. Toluene

1. Properties of toluene

Pure toluene (melting point, -95° C [-139° F]; boiling point, 110.6° C [231.1° F]) is a colorless, flammable, toxic liquid, insoluble in water but soluble in all common organic solvents.

D. Specimen preparation

- 0.1 g of SWCNT is taken in a spatula and measured in a physical balance.
- 10 ml of toluene is pipetted out in a beaker and 0.1 g of SWCNT is added to it.
- The beaker is then placed over a magnetic stirrer as shown in Figure.4 and the contents while heating using magnetic pallets with 100% of heat available.
- The stirred components are then subjected to an ultrasonic probe sonicator as shown in Figure.5 for particle dispersion (i.e) dispersion of carbon nanotubes into natural rubber.
- 500 ml of toluene is taken in a measuring jar and poured into a 100 ml beaker.
- 10 ml of latex is taken in a measuring jar and mixed well with the 500 ml toluene using magnetic stirrer while heating.
- The materials prepared in points 1-6 were directly mixed in a petridish.
- Petridish is placed in a furnace and a constant temperature of 700 C was maintained for about 2 hrs in order to obtain a semisolid form as shown in Figure.6.
- The heated petridish is then cooled for around 12 hrs at room temperature.
- As shown in Figure.7 Final sample is obtained by stripping off the contents from the cooled petridish.

Fig.4. Magnetic Stirrer

Fig.5. Sonicator

Fig.6. Semisolid Form

Fig.7. Final Sample

IV. LISTS OF TESTS TO BE CONDUCTED

The following tests were performed with the obtained sample to analyze the thermal stability and morphology of the composite

- AFM (Atomic Force Microscopy)
- Thermo gravimetric Analysis

A. AFM (Atomic Force Microscopy)

Atomic Force Microscopy is a technique for analyzing the surface of a rigid material all the way down to the level of the atom. It uses a mechanical probe to magnify surface features up to 100,000,000 times and it produces 3-D images of the surface. AFM is being used to understand material problems in many areas including data storage, telecommunications, biomedicine, chemistry and aerospace.

Fig.8. Atomic Force Microscopy

ISSN: 2278-0181
Vol. 4 Issue 12, December-2015

B. Thermo gravimetric Analysis

It is based on continuous recording of mass changes of a sample of material, as a function of a combination of temperature with time, and additionally of pressure and gas composition. A sample of material (ranging from 1 mg to 100 mg, but sometimes as large as 100 g) is placed on an arm of a recording microbalance, also called thermo balance where that arm and the sample are placed in a furnace.

Fig.9. Thermogravimetry

The furnace temperature is controlled in a pre-programmed temperature/time profile, or in the rate-controlled mode, commonly investigated processes are: thermal stability and decomposition, dehydration, oxidation, determination of volatile content and other compositional analysis, binder-burnout, high-temperature gas corrosion etc...

V. Results and Discussions

A. Atomic force microscopy

AFM is performed over the sample to check whether the sample is of nanosize or not and hence the following images and results were obtained

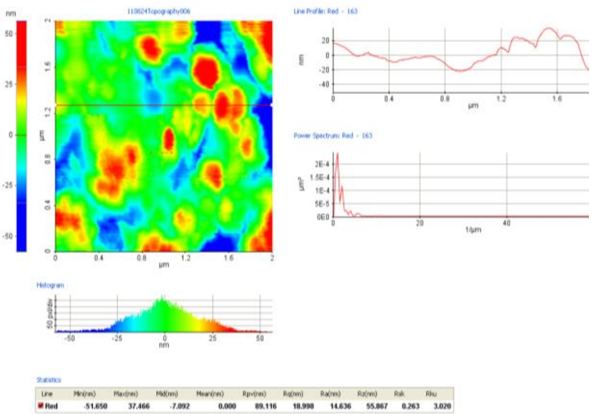

Fig.10. Topographical image of sample

Figure.10. shows the topographical image wherein the red spectrum in the sample is dealt in detail whose maximum wavelength is 37.466 nm and minimum wavelength is -51.650nm.

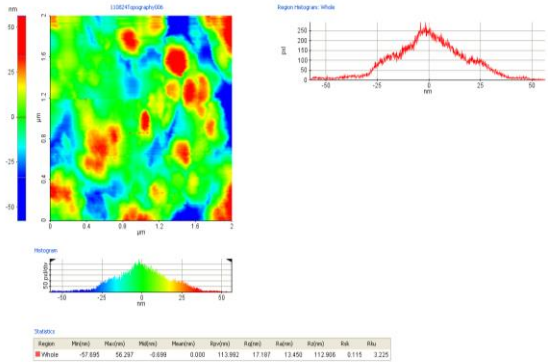

Fig.11. Histogram of the whole region

Figure.11. shows a histogram of the whole region wherein all the spectrum concerned with the entire region were taken into consideration and the maximum and minimum wavelength are 56.297 nm and -57.895 nm respectively.

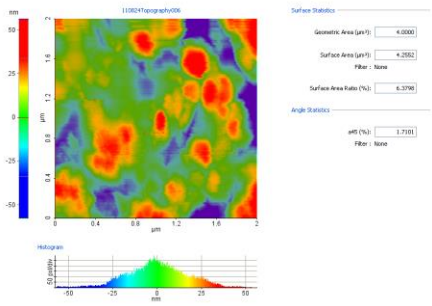

Fig.12. Surface statistics and angle statistics

Figure.12. shows the surface statistics and angle statistics from which the following specifications about the sample were obtained

- Geometric area-4micrometer square
- Surface area-4.2252 micrometer square
- Surface area ratio-6.3798%

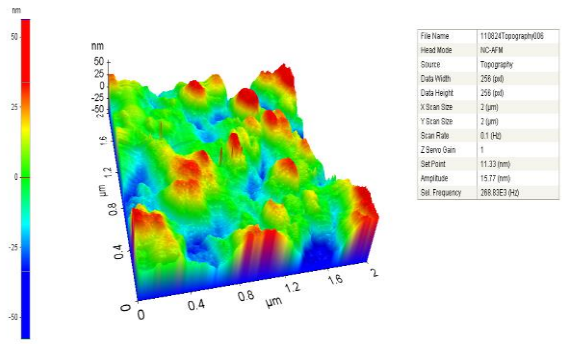

Fig.13. Complete projection of the specimen

Figure.13. is a complete projection of the specimen which shows the ups and downs (i.e.) peaks and flat surfaces over the specimen and the amplitude was measured as 15.77 nm selecting the frequency as 268.83E3 Hz

B. TGDTA (Thermo gravimetric Analysis)

Based on the values obtained from thermo gravimetry analysis using air as the operating medium, a graph is plotted between temperature and temperature difference as a function of weight as below and the weight specifications are provided in table I.

TABLE I. TABLE FOR THERMO GRAVIMETRIC ANALYSIS

S.No	Temperature (Degree Celsius)	DTA-Temperature Difference	TG-Weight (mg)
1.	100.0033	6.407337	4752.027
2.	200.0725	13.30651	4679.373
3.	300.0272	21.76205	4210.346
4.	400.0023	29.23413	1164.73
5.	500.0665	21.16115	77.48413
6.	600.0388	14.4956	12.83643
7.	700.0242	11.91011	-16.6436
8.	800.0688	10.90849	-26.0487

Sample Weight: 4.790 mg
Reference Name: Alumina
Reference Weight: 4.213 mg

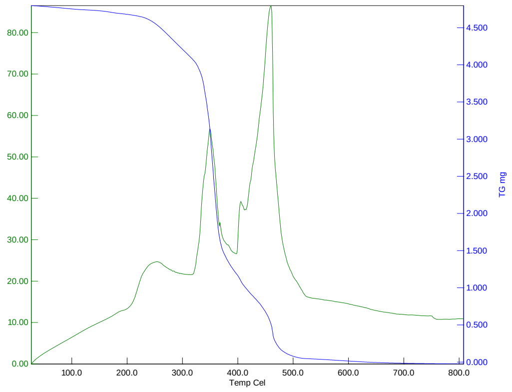

Fig .14. Graph obtained between temperature and temperature difference, weight in TGDTA

After performing thermo gravimetric analysis on the nano sized sample, we infer that they can de efficiently used in Automobile applications since they can bear a temperature up to 800^0 C.

VI. CONCLUSION

The nano composite we have developed can withstand temperatures upto about 800^0 C. The test programs to find out the dynamic properties and failure behavior of composites of complex materials are expensive for automobile industry. In order to overcome the above, we can go for composites which could be of great favor to the automotive industry. Also, by our analysis we conclude that the new nano composite could be used efficiently in aircraft structures, since they have the advantages of nano size, less weight and hence less fuel consumption.

REFERENCES

[1] Alastair F.Johnson, Anthony K. Pickett , 'Impact and crash modeling of composite structures: a challenge for damage mechanics', Structural Crash-worthiness and Failure, Vol.43, No.2, pp.1-12, 1993.
[2] Andrei.G, Dima.D 'Lightweight magnetic composites for aircraft applications', Journal of Optoelectronics and Materials, Vol.8, No.2, pp.726-730, 2006.
[3] L.Ci, J.Suhr, V.Pushparaj, X.Zhang, P.M.Ajayan 'Continuous Carbon Nanotube Reinforced Composites', Science, Vol.35, No.2, pp-11-16, 1991.
[4] E.Delannay, C. Colin, Y.Marchal, L. Tao, F. Boland, P Cobzaru, B. Lips, M.-A. Dellis 'Processing and properties of metal matrix composites reinforced with Continuous fibers for the control of thermal expansion creep Resistance and fracture toughness', Journal DE Physique, Vol.3, No.3, pp.1675-1684, 1993.
[5] Fangming DU, John E. Fischer, Karen I. Winey 'Coagulation Method for Preparing Single-Walled Carbon Nanotube/Poly (methyl methacrylate) Composites and Their Modulus, Electrical Conductivity, and Thermal Stability', Journal of Polymer Science, Vol.41, No.2, pp.3333-3338, 2003.
[6] E.J.Garcıa, A.J.Hart, BL.Wardle, A H Slocum 'Fabrication of composite microstructures by capillarity-driven wetting of aligned carbon nanotubes with polymers', Nanotechnology, Vol.18, No.5, pp.1-11, 2007.
[7] Kwang J Kim, Mohsen Shahinpoor , 'Ionic Polymer-Metal Composites', Smart Materials and Structures, Vol.12, No.9, pp.65-79, 2003.
[8] Lawrence T.Drazal, A.K. Mohan, M.Misra 'Bio – composite materials as alternatives to petroleum – based composites for automotive applications', Modern Plastics, Vol.29, No.3, pp.89-96, 2002.
[9] Mai L.P.Ha, Brain P. Grady, Giulio Lolli, Daniel E. Resasco 'Warren T.Ford, Composites of Single-Walled Carbon Nanotubes and styrene-isoprene Copolymer plastics', Macromolecular Chemistry and Physics, Vol.208, No.17, pp.446-456, 2007.
[10] Ramesh S Sharma Dr.V.P.Raghupathy Sai Sashankh Rao Shubhanga P 'Review of recent trends & developments in biocomposites', Materia Science, Vol.35, No.1, pp.556-564, 1992.
[11] R A Singh, R K Gupta, S K Singh 'Preparation and characterization of polymer composites based on charge-transfer complex of phenothiazine-iodine in polystyrene' Material Science, Vol.28, No.5, pp.423-429, 2003.
[12] Chen BQand Evans JRG 'Thermoplastic starch–clay nanocomposites and their characteristics', Carbohydration Polymer, Vol.61, pp.455–463, 2005.
[13] Follain N, Joly C, Dole P and Bliard C 'Mechanical properties of starch-based materials-Short review and complementary experimental analysis', Journal of Applied Polymer Science, Vol.97, pp.1783–1794, 2005.
[14] Antony P, De SK and van Duin M 'Self-crosslinking rubber/ rubber and rubber/thermoplastic blends: a review', Rubber Chemistry and Technology, Vol.74, pp.376–408, 2001.
[15] M. Taya, S. Hayashi, A. S. Kobayashi 'Toughening of a Particulate Ceramic-Matrix Composite by Thermal Residual Stress', Journal of American Ceramic Society, Vol.73, pp.1382–1391, 1990.