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CERTIFICATION OF APPROVAL

DISPERSION OF MULTIWALLED CARBON NANOTUBES BY ADDING A HYDROXYL GROUP

by

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Title **Dispersion of Multiwall Carbon nanotubes into Polar Solvents by adding a functionalized hydroxyl Group to its aided with sonication**

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1.0. Abstract

The objective of the project is to prevent the agglomeration known in Carbon nanotubes in order to utilize its exceptional properties. In order to achieve this, it was decided to find a method to dissolve the carbon nanotubes into polar solvents by adding a hydroxyl group (-OH) that would prevent the agglomeration as well as improve the dispersion significantly into Polar Solvents. In this project, a method is proposed to add a hydroxyl group to the Long chain of the Multi Wall carbon nanotubes which will make it disperse into polar and non-polar solvents using Tetra-hydro- furan (THF) and sodium Zincate solution as an electrophilic agents, we added a hydroxyl group to the CNT chain which by reaction of sodium Zincate with the walls of the carbon nano tubes under stable sonication for nearly 12 hours. The product was characterized under Trans-mission electron microscope which showed significant de-agglomeration which proves that add-ing a hydroxyl group to the chains of MWCNTs reduce agglomeration significantly as well as improve its dispersion properties. Moreover, after characterizing the sample under the FT-IR spectroscopy, the results have shown bonds between C-OH which proves the attachment of the hydroxyl group that caused the de-agglomeration.

Key words: MWCNTs, properties, Hydroxyl groups,Dispersion,THF,Sodium ZincateUltra-sonication, Dispersion, Antifoam, , Antifoam agents, Ionic Liquids, Water, characterization of carbon nanotube.

2.0. (INTRODUCTION)

2.1. Background Study

As Carbon Nanotubes have Strong test-tube van der Waals forces which cause them to agglomerate together. It became a challenging task since the invention of the synthesized nanotubes to fully utilize its exceptional Properties.[1]

Elemental carbon in the sp2 hybridization can form a variety of amazing structures. Apart from the well-known graphite which was the most known and existent carbon allotropy, carbon can build closed and open cages with honeycomb atomic arrangement. The first such structure was discovered with a C60 molecule observed by Iijima . The remarkable properties of this element gathered the attention of scientists as it promises to revolutionize several fields in material science. Its unique electrical, thermal and mechanical properties showed that CNTs[1] have extremely low electrical resistance, high stiffness and axial strength as well as the highest thermal conductivity recorded. Before CNT discovery diamonds were known to be the most thermal conductive materials. CNTs showed at least twice the thermal conductivity of diamond.[1]

It is rare for a single technology to have power to dramatically influence almost every major industry in the world. CNTs offer fundamental new capabilities to architect a broad way of new materials, composites and structures which are lighter, stronger, and more durable and offer much more untraditional properties. [1]

A huge amount of research and development activity has been devoted to CNT technology in the recent years. However, several critical issues have to be solved to achieve the full potential of CNTs in the metal matrix composites as an example. Therefore, it is still a challenge to develop suitable processing techniques with the ability to induce homogenous distribution of CNTs and good interface bonding in various mixtures.

By improving the dispersion of nanotubes, polymers can be made more resistant against temperatures, harsh chemicals, corrosive environments, extreme pressures and abrasion. There are two categories of carbon nanotubes: Single-wall nanotubes (SWNT) and multi-wall nanotubes (MWNT). In this project we will use MWNT as it is more common and practical.

In this project, a method is proposed to modify the structure of carbon nanotubes modified with hydroxyl groups changing its characteristic to electrophilic and allowing it to be dispersed with various reagents.

According to the journal published in the " The open Materials Science Journal, 2011,5,242-247", Adding a functional group sited on the multi-wall Carbon Nanotube surface has a lot of infinite advantages. First of all, it eases the homogenous dispersion of CNTs which is very diff-icult to achieve using pristine CNTs. As Carbon nanotubes tend to form long bundles, surface functionalization of CNTs improves the solubility and dispersion of the nanotubes in aqueous solutions as well as designing hybrid materials. Besides, such functional groups are found to be responsible for the various physicochemical and catalytic properties of the matter.

In our project we will try and anchor an OH group bond with the carbon molecules on the CNT bundle which will help in agglomeration reduction, solubility in polar and non-polar solvents.

2.2. Problem statement

2.2.1. Problem Identification

In order to fully utilize the properties of CNTs we have to find a method to disperse them with a uniform distribution without affecting the intrinsic sp2 hybridized network which account for the exceptional CNT properties.

A major problem for processing and manipulation of MWNTs is the inherent insolubility of the tubes in common organic solvents and water. Ultra-sonication is a common and effective technique applied to disperse carbon nanotubes (CNTs) in. This is due to two main factors that account for the Insolubility of CNTs:

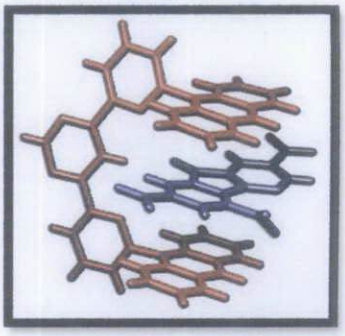


Figure 1 - pi - pi stacking in aromatic rings

- Strong test-tube van der Waals forces.
- Π - Π stacking , which refers to attractive, non-covalent interactions between aromatic rings

2.2.2. Significance of the Project

The proposed method disperse Carbon nanotubes effectively in Ethanol and various Ionic and non–ionic Liquids which would allow the Carbon nanotubes to be added and used for reinforce-ement purposes

On the right, we could see an Image captured of dispersed Carbon nanotubes in a Solution which shows the significance of the proposed Experiment.

Figure 3 – MWCNT sample before Treatment.

Figure 2 - Image captured at UTP lab of Dispersed MWCNTs after Step 3 (Refer to Methodology)

This will allow CNTs to be alloyed with other elements thus improving their thermal, mechanical and electrical properties. It was reported that CNTs can increase the roughness and toughness when mixed with polymers as well as in metal alloys and composites. Its unique properties can improve almost any material by adding a small percentage of CNTs. Therefore, effects of effective and inexpensive methods to disperse MWCNTs would be beneficial for utilizing such great carbon allotropy.

2.3.1. Objectives of the Project

The main objective of the experiment is to achieve the following:

- Preserve the intrinsic structure and properties of CNTs after Dispersion. (Using TEM – Transmission electron Microscope to verify that the structure of the CNTs are not damaged before and after the Experiment)
- Samples of CNT(before and after) were scanned under the TEM (Transmission Electron Microscope) at Centralized Laboratory at UTP to confirm that the Chemical Treatment didn't affect the Structure of CNT under the Microscope). *Please Check Results and Discussion for more elaborated Details*
- Allow CNTs to be dispersed into various reagents and liquids.
- Using the Transmission Electron Microscope, Images should verify that CNTs are well dispersion and no agglomeration occurs.

2.3.2. Scope of Study

Dispersing Multi Walled carbon Nanotubes using common chemicals found at UTP Laboratory with Aided Ultra sonication.

In our Experiment we added a Hydroxyl group to the Structure of the Carbon Nanotubes which allow the CNT to be Electrophilic and avoid agglomeration. Also adding a hydroxyl group will utilize the CNTs which could be used in material selection as well as other industrial applications.

Figure 5 - Structure of CNT

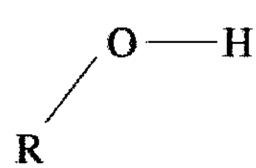


Figure 4- Hydroxyl Group

3.0. Literature Review

3.1. CNTs structure and dispersion properties

Elemental carbon in the sp2 hybridization can form a variety of amazing structures. Apart from the well-known graphite, carbon can build open and closed cages with honeycomb atomic arrangements. The first such structure to be discovered was a C60 molecule by Iijima observed for the first time tubular carbon structures. The nanotube contained up to 10 of graphite shells called multi-walled carbon nanotubes with diameters up to 1nm and high length/diameter ratio.[1]

There are two main types of Carbon nanotubes which are Single walled carbon nanotubes consists of single graphite wrapped into a cylindrical tube. While multiwall CNTs comprise an array of such nanotubes that are nested like ring of a tree trunk.

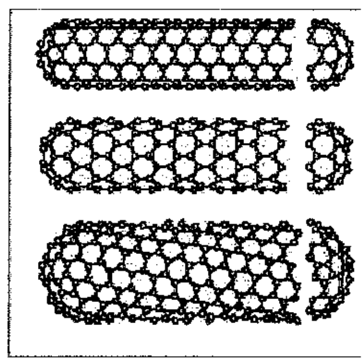


Figure 6-SWCNT Aromatic Structure

However, the strong Vander vaals forces between the CNT molecules limit its dispersion in organic and aqueous solvents which limits its applications.

In this project, a safe method at Atmospheric Pressure and Temperature to Add a Hydroxyl group is achieved which would still maintain the intrinsic characteristics and properties of CNT but would allow it to be dispersed into various polar and non-polar solvents[4]

3.2. Adding a Hydroxyl Group to the Intrinsic Structure of the MWCNTs

According to the research made, adding a hydroxyl group to the Carbon nanotubes will maintain the intrinsic structure of the MWCNTs and maintain the materials unique properties. Added to that beside mechanical stability and permanent procedure, the MWCNTs can also handle further modifications which are usually required in Chemical processes. [8]

According to research made at Rice University, Houston Texas, hydroxyl nanotubes form stable suspension solutions in polar solvents, such as water, and ethanol which facilitate their improved processing in copolymers and nanofabrication fields and thus allow us to utilize the exceptional functions of the Multi Walled carbon nanotubes.[6]

It is therefore important for the nanotubes to be attached with organic functional group which can provide high binding affinity and selectivity through covalent or hydrogen bond formation.

3.3. Stabilization after adding a Hydroxyl Group

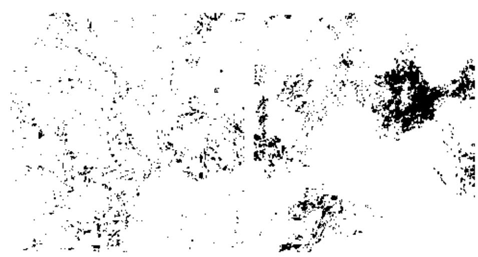
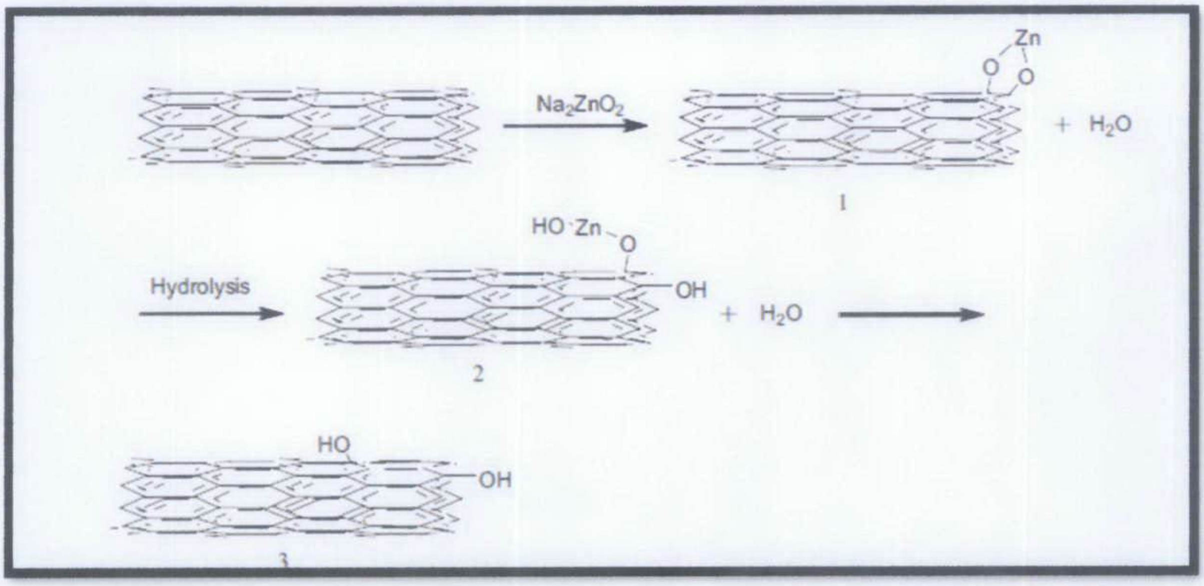


Figure 7 - Agglomerated CNTs before (left) ar After Ultrasonication (Right)

From the research made at Nano Lab Company headquartered in Waltham, Massachusetts it was identified that nanotubes will interact with each other's hydrodynamic radius at any appreciable concentration. This would result in entanglement and the creation of large agglomerates, if there was no repulsive force to keep them from aggregating. This is exactly what was observed from dispersing CNTs worldwide. When pristine nanotubes are suspended in water, they will aggregate and form loose sediment on the container bottom, with a clear supernatant. To provide a repulsive force, nanotubes are electrically charged, so that it repels each other and keep agglomeration from occurring. This may not completely stop gravity induced settling, but any sediment will then be made up of individual particles, not agglomerates. [8]

We can create electrical repulsive charges on the carbon nanotubes in several ways. Chemical functionalization of the nanotubes will create ionizable groups on the nanotube sidewall. The carboxyl group, COOH, will lose its hydrogen and become COO- at any pH <8-9. A carboxylate nanotube will ionize in suspension and the repulsive forces between COO- groups will hold the nanotubes apart, preventing agglomeration. To evaluate the concentration of COOH groups, a titration could be used. Typical carboxyl concentrations run ~5-7wt%. The zeta potential is another good measure of the charge on our carboxylate nanotubes



3.4. TETRAHYDROFURAN (THF) AS A SOLVENT.

According to a research made at the Department of Material Science, University of Patra, Greece [10], the affinity of the Carbon Nanotubes increase after being dissolved in Tetrahydrofuran due to its properties.

It was reported that THF improve dispersion and accessibility of the Nano composites. SEM and optical Microscopy revealed a good dispersion of nanotubes in THF solvent suspensions. This would definitely help in the Reaction of adding a hydroxyl group to the CNT structure.

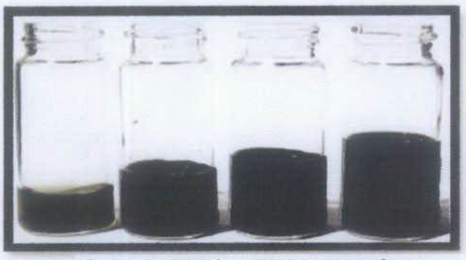


Figure 8- CNT in a THF suspension

3.5. Importance of Ultra-sonication in Dispersion of CNTs

During research, the effective methods of ultra-sonication were narrowed down of ultrasonication which are up-to-date. This part will illustrate the possible effective ultra-sonication techniques which could help us achieve effective dispersion of MWCNT into THF as well as the sodium Zincate Solution [10]

Using Sonication for Easier Dispersion [3]

During the use of surfactants while Dispersing CNTs using ultra sonication, air layers and gas bubbles tend to be trapped in the CNT surfaces thus dispersion might not be effective. In order to ensure effective Sonication, we have to ensure that the Water is stable as well as the Experimental Set. Because the incoming ultrasonic wave is reflected at the air-liquid surface, these air layers prevent the wave from reaching the CNT surfaces thus affecting the dispersion. [5]

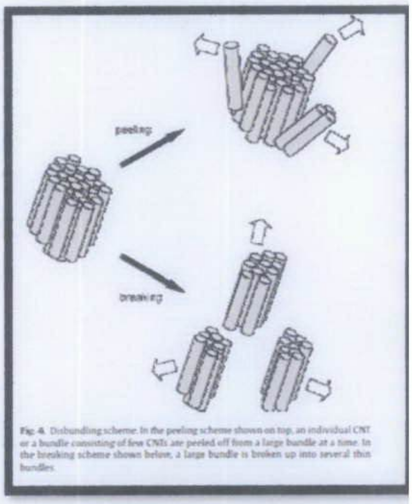


Figure 9- Antifoam Agent Dispersion Disbundling scheme

3.5.1. Using double sonication source

Using a double sonic source was found to dramatically increase dispersion efficiency of CNTs. It was found that double sonic source causes intermittency chaos which result into a dramatic increase of Dispersion.

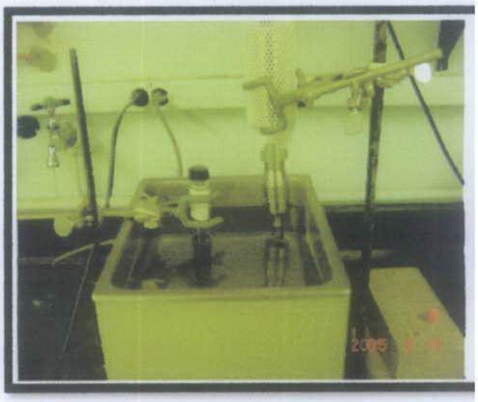


Figure 10 – Sonication Bath tube

This could be a proposed Method If additional Ultrasonication is needed.

It was found out that double ultrasonic source (bath and probe) has been shown to efficiently disperse carbon nanotubes in liquids compared to using just one sonic source. Acoustic energy analysis based on wave superposition principle shown to be inconsistent with such a dramatic increase in dispersion performance. Resonance effects in the form of intermittency chaos have been proposed as the likely theoretical reason for these behaviors, which has actually been shown to occur in systems with two interlocking waves such as this case.

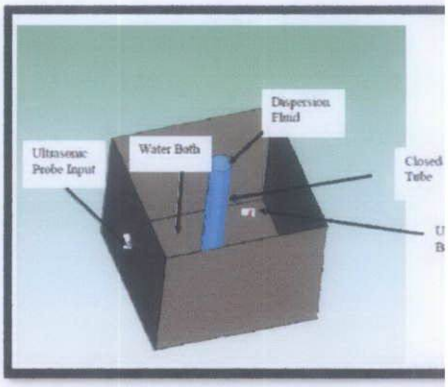


Figure 11 – Bath tub Components

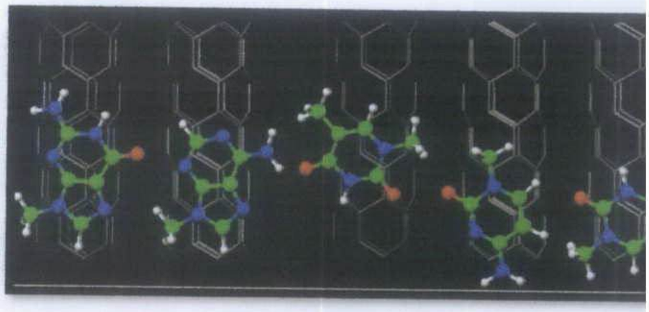
3.6. Transmission Electron Microscopy Measurements

Transmission electron microscopy observations (TEM) will be used to investigate the effect of Dispersion and the whole proposed experiment on the Intrinsic Structure of the Multi-walled Carbon nanotubes by the beta-potential measurement of surfactant adsorbed CNTs which will give us a quantitative measurement of the effectiveness of the dispersion of MWCNTs

The morphology of the MWCNTs-OHs is observed with the TEM. This allowed us to analyze the length of the carbon nanotubes that it is well preserved as well as show the MWCNTs-OHs. We were able to notice that MWCNTs –OHs are not totally entangled and some are well dispersed individual nanotubes can be found. The results even indicated that the MWCNTs with hydroxyl group used in our method can efficiently prevent MWCNTs from the disruption of their tubular structure and display a considerable de-bundling effect. Two TEM samples were analyzed before and after the dispersion in order to investigate the results of our treatment.

3.7. Agglomeration tendency

Due to the extremely attractive forces of CNTs, the establishment of a reliable method for CNT dispersions without agglomeration is still a challenge to engineers and scientists due to the scientific phenomena of strong Van der Vaal forces that make it tedious to separate CNTs without agglomeration.



CNTs agglomeration due to VDW forces

4.0. Methodology

After analyzing the possible choices that could lead to effective dispersion of MWCNTs from updated journals we have initially decided to follow the following methodology and experimental plan using the following Carbon Nanotubes.

The methodology aims to add as much hydroxyl groups as possible to the long chains of MWCNTs in order to develop MWCNTs with polar characteristics that could be industrially utilized in various fields.

These are the following properties of the MWCNTs that we have and that will be tested in our experiment.

Diameter: less than 10nm.
Length 1-2 um
Purity 95%
Net weight: 5g
Purchased from: Helix Material Solution Ltd.

Figure 12- 150mg of pristine MWCNT

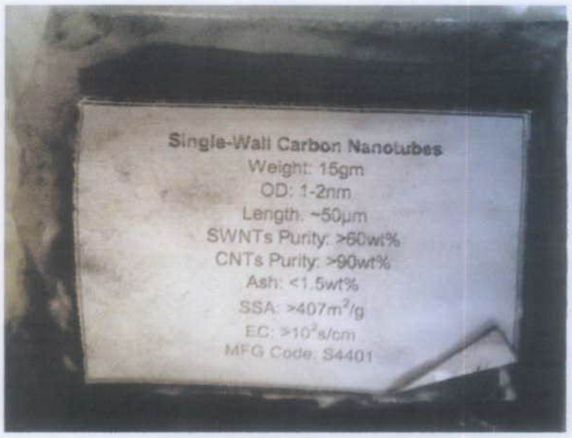
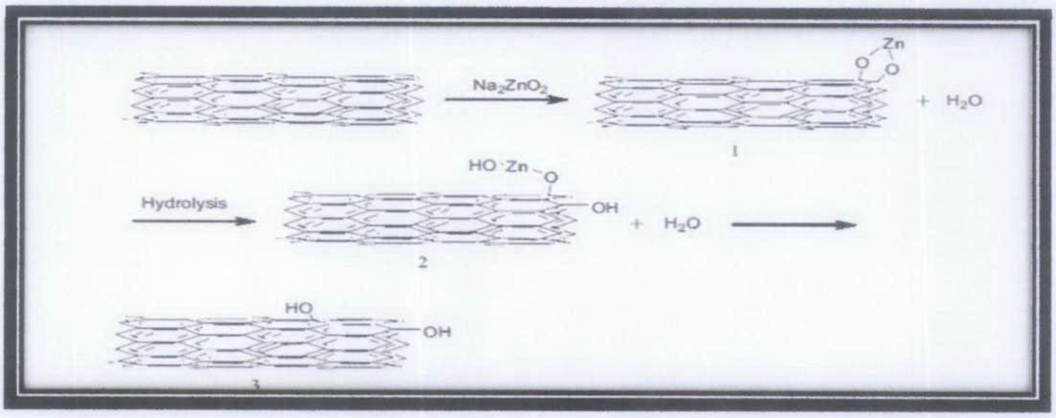


Figure 13- prisitine MWCNT

4.1. A Schematic Diagram of the Procedure of Adding a Hydroxyl Group to the Multi Walled Carbon Nanotubes



4.2. Collecting 150mg of Multiwall Carbon Nanotubes.

Using an electronic Balance 150mg of Carbon nanotubes are collected in order to be treated and mixed with around 70mL of Liquids.

Figure 14- Sample of Carbon Nanotubes collected

4.2.1. Dispersing the MWCNTs into 50mL of TetrahydroFuran (THF)

The Figure on the right, represent the 150mg of MultiWalled Carbon Nanotubes before being mixed with around 50mL of tetrahydrofuran (THF) before being prepared for sonication.

Figure 15 - Chemicals Before Mixing

4.2.2. Sonication for the (THF + MWCNTs) Sample for 3 hours at room Temperature.

The sample of the (THF + MWCNT's) was sonicated for 3 hours at 60KHz. Below is an image captured from the Ultrasonic bath Used at UTP, Block 4.

Figure 16 - UltraSonicator Bath Setup

Figure 17- Sample Test Tube in Water being Sonicated

4.2.3. : Preparation of Sodium Zincate Solution.

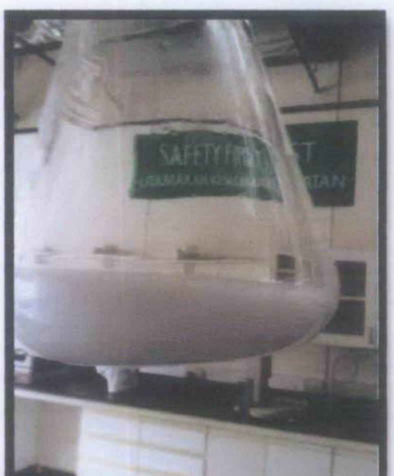


Figure 18- Prepared Sodium Zincate with excess Zinc Oxide Powder.

Solutions of sodium zincate may be prepared by dissolving zinc, zinc hydroxide, or zinc oxide in an aqueous solution of sodium hydroxide. [9] Simplified equations for these complex processes are:

ZnO + H2O + 2 NaOH → Na2Zn $(OH)_4$

Zn + 2 H2O + 2 NaOH → Na2 $Zn(OH)_4 + H_2$

To start with, the following chemicals were mixed:

- 0.12 g of Sodium Hydroxide Tablets was weighted.
- 20mL of Deionized Water
- Excess Zinc Oxide powder.

The solution was left to react for 30 minutes, 100um Filter papers were used to remove Unreacted Zinc Oxide.

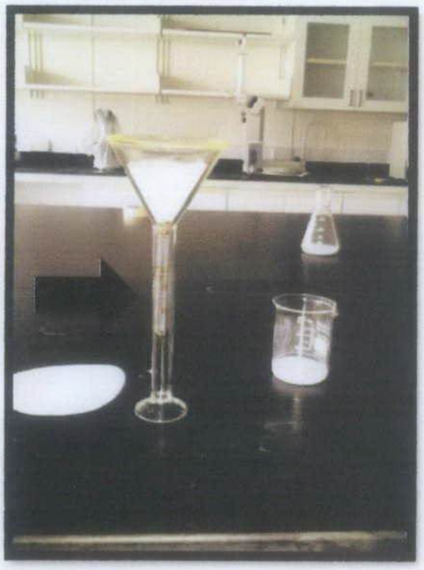


Figure 19- Filtering Unreacted Zinc Oxide

Figure 20- Filtered Sodium Zincate

4.2.4. Mixing Sodium Zincate with the sonicated (THF+ MWCNT's) Suspension and doing sonication for 12 hours.

After preparation and filtration of Sodium Zincate, it is added to the THF and MWCNTs in order to achieve the Hydroxyl Reaction and the whole mixture is being sonicated for 12 hours

Figure 22- Mixture being Sonicated

Figure 21- Mixture after Sonication for 12 hours

4.2.5. Characterization of Carbon Nanotubes under TEM

In order to confirm that our proposed Method didn't cause any damage to the MWCNTs, Transmission Electron Microscope Scanning is Essential. Samples from the pristine Multi- Walled Carbon Nanotubes are collected and testified after being dissolved in propanol solution. Characterization of MWCNTs before and after the treatment basically gave us a more meaningful look of the dispersion and confirmed the proposed method is reliable for Dispersing MWCNTs effectively without damaging the Intrinsic characteristics of CNT.

Figure 23- Pristine CNT Sample before Treatment

The Diagram on the right were taken from TEM results scanned at University Technology PETRONAS, Centralized Lab at **50nm** magnification which shows elongated MWCNTs bundles in agglomeration. The results will be further discussed in the Results and Discussion Section.

The Diagram on the right was also captured at University Technology PETRONAS Centralized Lab. The sample was after the proposed treatment which shows reduction in agglomeration due to the existence of the OH polar group.

Figure 24-Treated MWCNTs sample after Treatment

4.2.6. Analyzing samples under the Fourier Transform Infrared Spectroscopy (FT-IR)

The FT-IR stands for Fourier Transform Infrared Spectroscopy; the preferred method uses Infra-red Radiations and passes it through a sample. Some of these rays are absorbed b the sample and some of it are being transmitted. Thus, the resulting spectrum represents the molecular absorption and transmission, creating a molecular fingerprint of the sample.

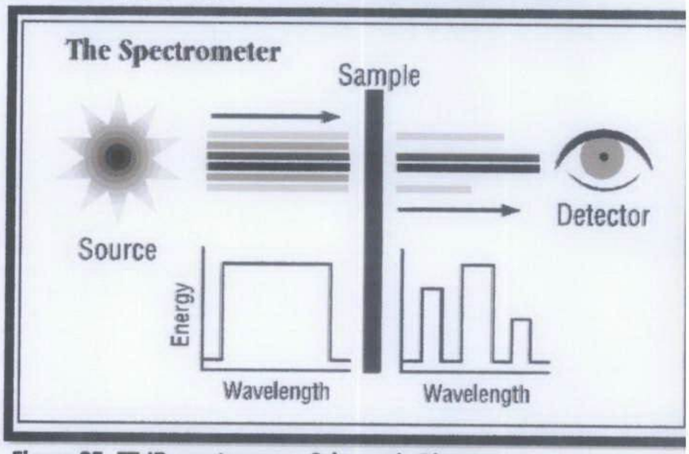


Figure 25- FT-IR spectroscopy Schematic Diagram

It is similar to finger prints; there are no two unique molecular structures that produce the same infrared spectrum. Therefore, this method helps us to identify the type of molecular bonds in each sample.

The FT-IR could help us to find the following information:

- Identify the unknown materials.
- Determine the quality or consistency of a sample.
- Help us determine the amount of components in a mixture.

Infra-Red Spectrum

The infra-red spectrum can result in a positive identification (qualitative analysis) of every material. The size of the peaks in the spectrum is a direct indication of the materials and bonds that exist in the sample. In other words, the spectrum could help us to prove bonds or attachment of the Hydroxyl groups by comparing our results to the spectrum database.

4.2.7. Advantages of using FT-IR spectroscopy over other techniques

FT-IR spectroscopy is a well-known preferred method over disperse or filter methods for several reasons including the following:

- It is a non-destructive technique.
- It requires no external calibration and is precise and reliable enough.
- It collects several scans per second.
- It has a great optical throughput
- It is easy to prepare and not time consuming.
- It is user friendly compared to older methods of analyzing

4.2.8. Sample Analysis Process

The FT-IR was developed to overcome the limitations faced with dispersive instruments that were used to analyze the samples for molecular detection. Most interferometers emit a **beam splitter** which takes the emitted infrared beam from the IR emitter and divides the signal it into two optical beams. One of those beams is being reflected off of a flat mirror which is fixed in place. The other beam is reflected off of a flat mirror which is on a mechanism which allows this mirror to move a very short distance (few millimeters) away from the beam splitter. The two beams are reflect off of their respective mirrors and are recombined when they meet back at the beam splitter. After that, the result is being process using the two beams interfering with each other. The signal is called an interferogram which has a unique property at every data point. The result shows signals at every infrared frequency which comes from the source.

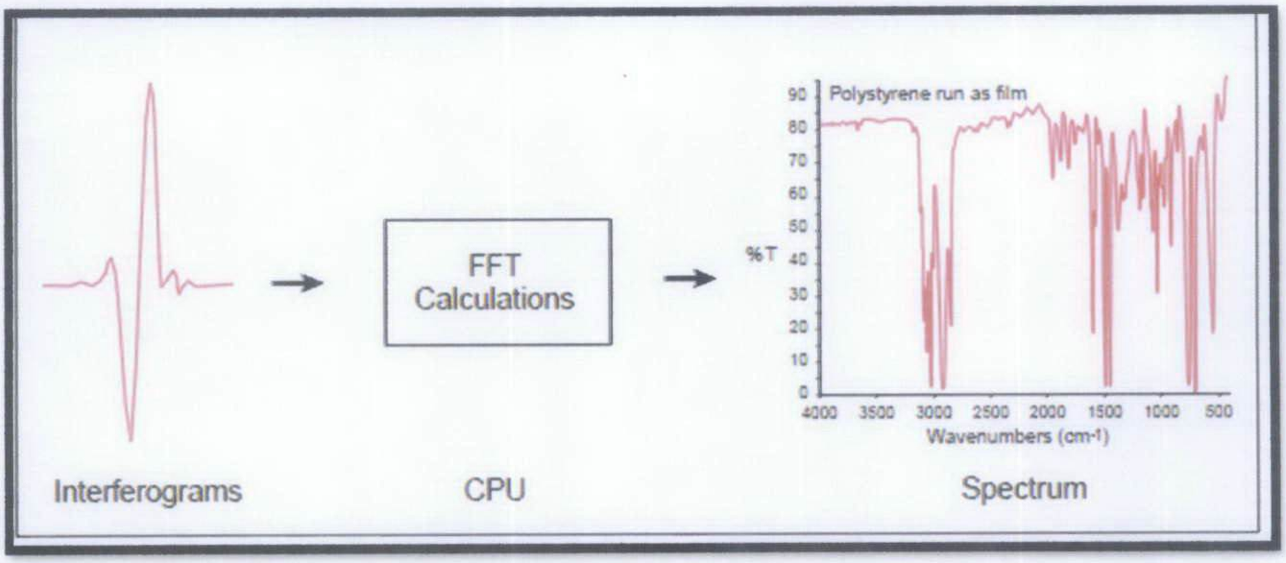


Figure 26-FT-IP spectroscopy Process

5.0. Results

5.1. TEM (Transmission Electron Microscope) Images before Treatment

100nm

50nm

20nm

10nm

10nm

10nm

20nm

50nm

20nm

10nm

10nm

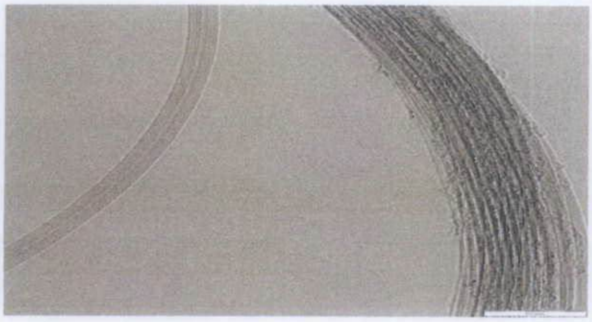
10nm

5.2. TEM (Transmission Electron Microscope) Images after Treatment

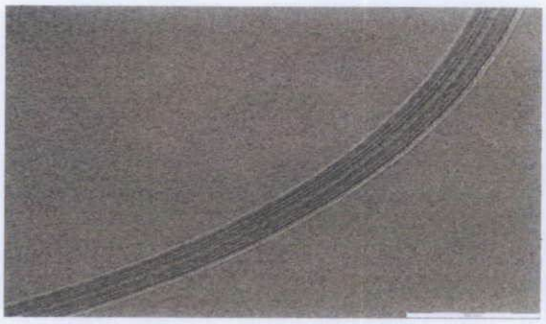
100nm

20nm

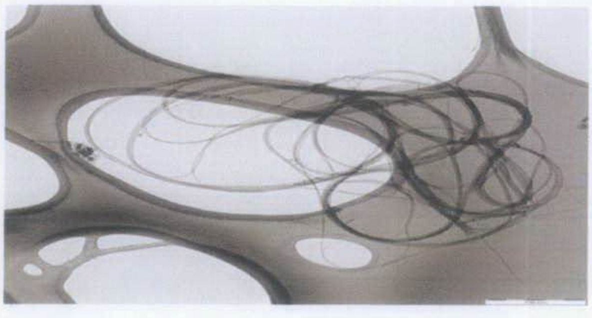
10nm



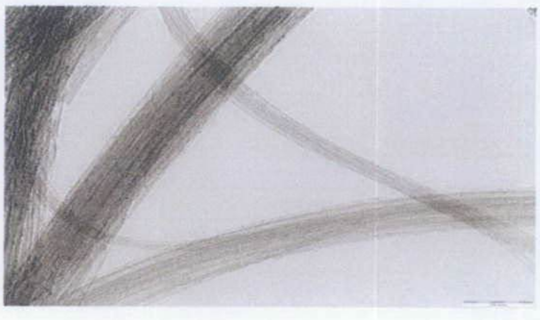
10nm



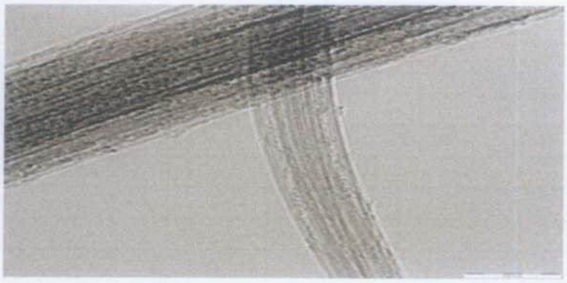
200nm



20nm



10nm



10nm

5.3. FT-IR Spectroscopy Results

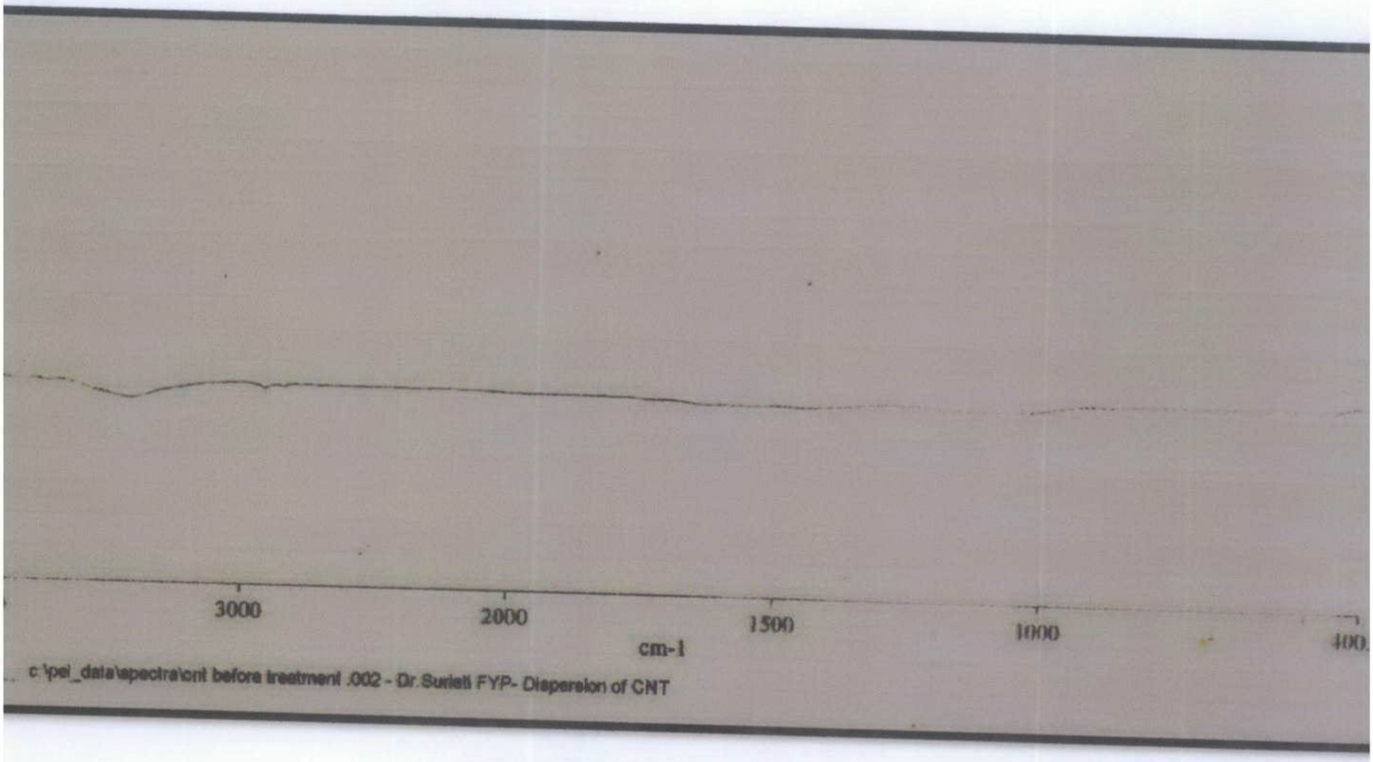


Figure 28-FT-IR of pristine MWCNTs

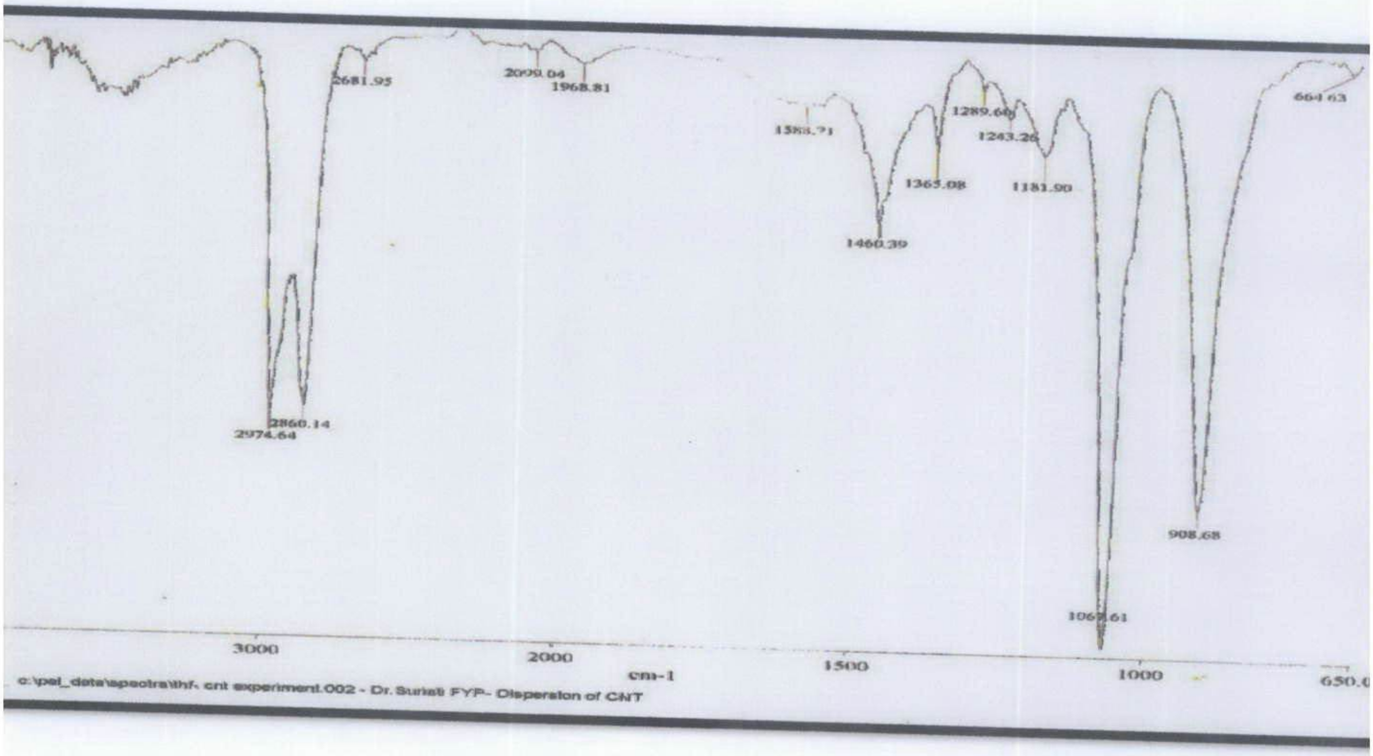


Figure 27-FT-IR of THF suspension

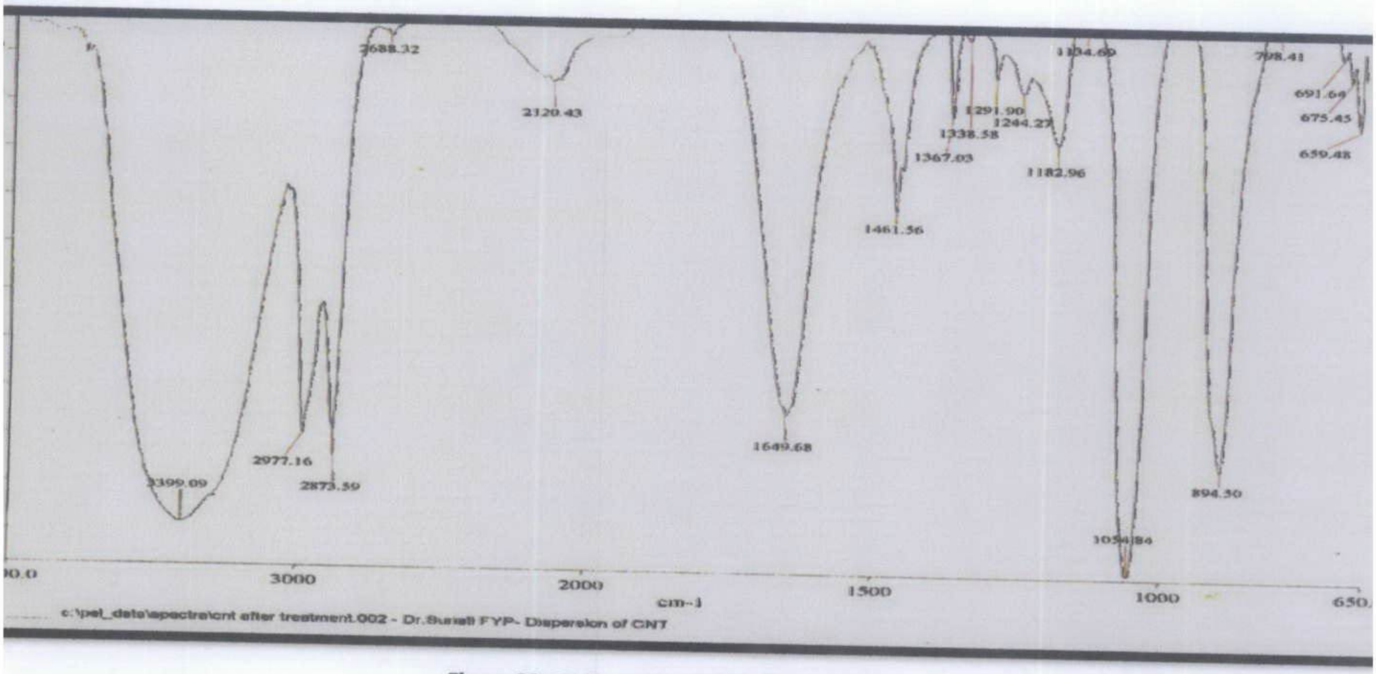
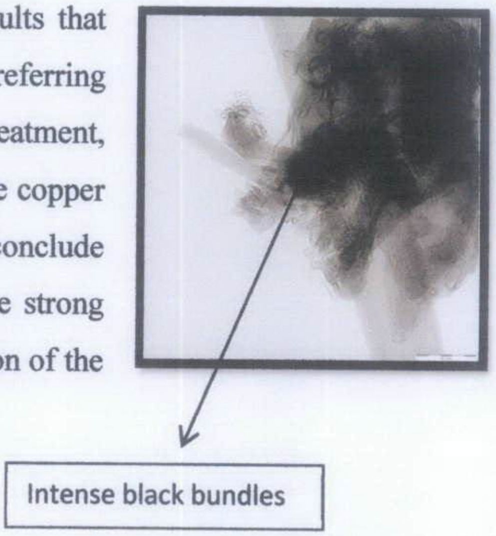


Figure 29- FT-IR results of CNT after Treatment

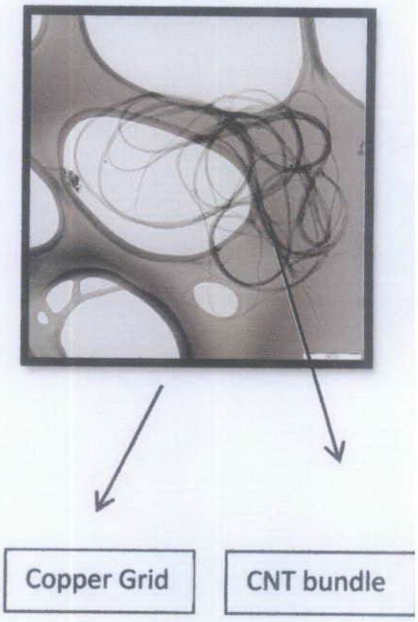
6.0. Discussion

6.1. TEM Images

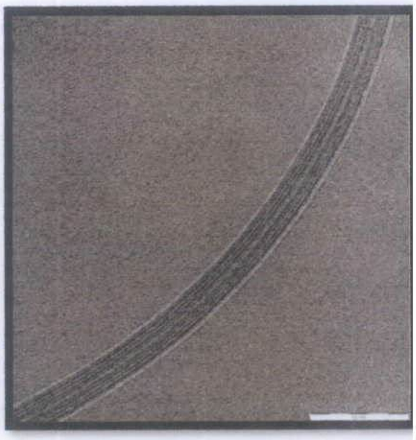
From the results above, we could indicate from the TEM results that agglomeration significantly decreased after the treatment. By referring to the Images on the right which shows TEM images before treatment, we can notice intense black MNCNTs in agglomeration over the copper plate used for detection purposes in the TEM. We could also conclude the bundles of MWCNTs in agglomeration which is due to the strong van der wall forces as well as π- π bonds that cause agglomeration of the MWCNTs.



Comparing the images before and after treatment, we can notice a significant reduction in agglomeration. We could also notice the sample of MWCNTs over the copper plate and absence of large agglomerations (intense black bundles) on the copper grid.



6.2. Preservation of the intrinsic structure of MWCNT



By referring to the right image captured of the MWCNT after treatment, we can show that our experimental procedure preserved the Multi-walled bundle as we cannot identify any cracks or broken bundles throughout all the results collected from TEM. This also shows that ultra-sonication is a safe and effective dispersion technique.

6.3. FT-IR Spectroscopy of MWCNTs

As we could refer to the graph of pristine MWCNTs being scanned under the FT-IR, we could analyze that no variation in the graphical data indicating that all the IR radiation passed the Sample due to absence of molecular bonds

6.4. FT-IR Spectroscopy of MWCNTs after treatment [10]

After the analysis of the FT-IR graph, the following results could be concluded:

- Existence of the stretching vibration band of O–H at 3430 cm−1.
- The bending stretching vibration band of C–O–H at 1367 cm−1.
- The stretching vibration band of C–O at 1054.84 cm−1
- The FT-IR spectrum of MWNT-OHs also clearly shows two characteristic bands at 1461.56 cm−1 and 1649.68 cm−1, assigned to the stretching vibration of C-C and the stretching vibration of OH group respectively.

These characteristic bands indicate that the hydroxyl groups are introduced on the surface of

MWNTs and the graphitic structure of carbon nanotubes are preserved.

7.0. Conclusion

In conclusion, the experimental project successfully reduced the dispersion of Multi-walled carbon nanotubes significantly as well as improve solubility and dispersion in polar and ionic liquids which helps us to utilize the outstanding characteristics of CNTs. Also, FT-IR results have proved the addition of the OH bonds to the carbon atoms in the MWCNTs bundles which is notices from analyzing the spectrum results and comparing the stretching vibraion bands of pristine CNT samples, THF samples as well as finalized Carbon nanotubes samples after treatment.

8.0. Recommendations and Future Work

- Repeating the experiment with much lower concentration of MWCNTs (e.g 1.5mg) and preparing an excess solution of sodium zincate. Repeating the process with such reactants could help us investigate addition of excess OH ions to the CNT bundle and comparing it with the initial sample.

- Hydration of the treated MWCNTs with polar properties and using it in applications includes Nano-material selection, mechanical reinforcement of polar MWCNT with polystyrene and other Nano-composites.

- Addition of alternative polar molecules other than the hydroxyl group and comparing the dispersion properties of such groups. Also, their performance though TEM and FT-IR spectroscopy.
-
- Developing Industrial Nano-composites using the polar characteristics of functionalized MWCNTs

9.0.GHANT CHART

9.1. FYP I FINAL YEAR PROJECT I

Week Number/Title	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research on CNT properties	■													
Ionic fluids and Sonication properties		■	■											
CNT dispersion methods Most promising updated methods				■										
Finalising proposal and experimental plan					■	■	■							
Confirming safety environment with Lab technican and equipment to use								■						
First Experimental trial and results analysis									■	■	■			
Working on characterization of CNTs using SEM & TEM												■	■	■

9.2. FYP II FINAL YEAR PROJECT II GHANT CHART

Week Number/Title	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Modification of CNT thesis	■													
Ionic fluids properties		■												
Sodium Zincatre preparation			■	■										
Ultrasonication of THF & CNT					■	■	■							
First and second experimental Trials								■	■	■				
TEM & FT-IR spectroscopy										■	■			
Analysis and conclusion												■	■	■

10.0. References

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APPENDIX I

				Conclusion
Rupesh Khare	2005	Carbon nanotubes based composites	Detailed explanation of CNTs properties as well as basic methods of synthesis of CNTs and its effect on its properties.	CNTs exhibit untraditional thermal, electrical and mechanical properties due to its unique structure. Results showed that CNTs have extremely low electrical resistance, high stiffness and axial strength as well as the highest thermal conductivity recorded
G.T.Caneba,C.Dutta,V.Agrawal, M.Rao (CanebaGT 2010)	2010	Novel Ultrasonic dispersion of carbon nanotubes	Increase dispersion efficiency of carbon nanotubes using double sonic source	Efficient dispersion of CNTs into DMF compared to single sonic source. A likely theoretical reason for the dramatic increase of dispersion stated that resonance effects in form of intermittency chaos have been proposed.
Jean-Noel Guye (Carbon_nano_tubes FINAL)	Dec 2009	Carbon nanotubes Properties	Detailed explanation of CNTs characteristics, and risk assessment.	CNTs are one of the most prominent nanomaterial but careful care and hazard precautions need to be taken into account. CNTs should be avoided to be inhaled as they were found to have the same health impacts as asbestos.
H.Sato, M.Sano (Dispersion of carbon nanotubes using antifoam)	2008	Characteristics of ultrasonic dispersion of carbon nanotubes aided by antifoam	To improve ultrasonic dispersion as a result of adding an antifoam	Dispersion ability of ultra-sonication is significantly improved by antifoam, increasing the dispersed amount. It was also found that antifoam is particularly useful with short ultra-sonication times and improves ultra-sonication by breaking thick bundles into thinner.
Aida Nasiri (Effects of dispersion of thermal conductivity and stability of nanofluid)	2010	Effect of dispersion method on thermal conductivity and stability of Nano fluid.	To investigates the effects of dispersion which might affect the properties of CNT	Thermal conductivities of CNT are greatly dependent on its preparation methods. Also functionalized suspensions showed the best synthesized CNT properties. Thermal conductivities decrease with time which also depends on CNT preparation techniques .

7	A straight Forward and reliable method for the characterization of carbon nanotube	Nov 2010	A straight Forward and reliable method for the characterization of carbon nanotube	To characterize the damage and disaggregation to CNTs after dispersion	The proposed method will be an easy way to test CNTs under the SEM microscope which would also help us to access the our dispersion techniques.
8	http://www.nano-lab.com/nanotubesuspensions.html	2010	A detailed Explanation of CNT solubility with hydroxyl groups	To identify a suitable solvent that makes the CNT molecules accessible before Hydroxyl Treatment	NanoLab prepares suspensions of carbon nanotubes in solvents and shared its experimental results on the effectiveness of sonication and Ionic Liquids
9	Synthese und Kristallstruktur von $Na_2Zn(OH)_4$	25 Jan 1999	An Detailed explanation of preparation of Sodium Zincate	How to prepare sodium Zincate from common Laboratory Chemicals	This Journal is a main reference for the preparation of Sodium Zincate from Sodium Hydroxide and ZnO.
10	A facile preparation of multiwalled carbon nanotubes modified with hydroxyl groups and their high dispersibilityiin ethanol	May 2011	A facile preparation of multiwalled carbon nanotubes modified with hydroxyl	Performance of MWCNTs with Hydroxyl Group	This journal explains the procedure for Developing a simple experiment to prepare sodium zincate and explains the reactions that occur between sodium zincate and the walls of the multi carbon nanotubes.
11	Rike Yudianti	May 2011	Analysis of a functional Group on multi-walled Carbon nanotube Surface	Analyze the importance of adding functional groups to MWCNTs	Functionalization of CNTs play an important role in creating CNT hybride material. In the study integrated analysis of functional group sites in the pristine and MWCNTs showed great results in the FT-IR and TEM
12	Thermo Nicolet Corporation	2001	Introduction to Fourier Transform Infrared Spectrometry	Comparing FT-IR with other methods of molecular detection and analysis	This journal is an excellent reference for explaining the introductory procedures of using an FT-IP as well as explaining briefly how the FT-IR works

[illegible]	J.Ma,F,Yu	2010	Preparation of CNT	Analyzing the properties of CNTs and how to preserve its intrinsic structure during experimental work	In order to achieve stability for CNTs, the proposed method shouldn't chemically interact with thee CNT bundle
[illegible]	X-L.Zhang	2010	Properties of Hydroxyl group	The journal describes the nonlinear properties of hydroxyl groups modified with MWCNTs.	MCNTs with modified OH groups improve solubility and dispersability characteristics of CNTs.
[illegible]	M.T.Byrne	2008	Chemical Functionalisation of carbon nanotubes for the mechanical reinforcement of polystyrene composites	This journal describes the uses of polar functionalized groups attached to CNTs into mechanical reinforcement	Mechanical reinforcement using polar-MWCNTs enhance the mechanical properties of polystyrene composites.