

NANOFLUIDS-BASED NANOCARBON: SYNTHESIS AND
CHARACTERIZATION

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“I declare that this project entitled “ Nanofluids-based nanocarbon; Synthesis and characterization.”

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NANOFLUIDS-BASED NANOCARBON: SYNTHESIS AND
CHARACTERIZATION

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This Report Is Submitted In Partial Fulfillment of Requirements For the
Bachelor of Mechanical Engineering (Structure & Materials) with Honor

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MAY 2011

DECLARATION

I declare that this thesis entitled “Nanofluid-based Nanocarbon:Synthesis and Characterization “is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :
Name of Candidate : Abangku Farhan Bin Abdul Rashid
Date : 25 MAY 2011

DEDICATION

Special dedication to my mum and family members that always love me,
Mr.Imran Syakir Bin Mohamad, Dr Kalthom bt Husain, my beloved friends, my fellow
colleague,
and all faculty members

For all your love, care, support, and believe in me

ACKNOWLEDGEMENT

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Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project.

ABSTRACT

Nanocarbon has a high rate of thermal conductivity and it has been proven in previous scientific research. Nano-fluid on the stable nanocarbon can be used in varieties of applications such as coolant in automotive sector, heat transfer application and in electronic applications. This study was done to produce the nanofluids based nanocarbon and investigate the stability of nanofluids based nanocarbon. Two types of nanocarbon have been used to produce nanofluids-based nanocarbon which is carbon nanotubes Pyrograf and Nanoamor .Nanocarbon is a hydrophobic material and hydrophobic material means that will not desperse in water. Sodium dodecyl sulfate was used as a dispersing agent to disperse nanocarbon in water. The process to form nanofluids-based nanocarbon, have certain ratios based on calculations that have been made in order to form the stable nanofluids-based nanocarbon. The stable Nanofluid-based nanocarbons have higher thermal conductivity compare to fluid in addition, the existence of nanocarbon in the nanofluid, the thermal conductivity increases. Comparatively Pyrograf shows a higher thermal conductivity than MER of 1.0% in weight percentage, pyrograf has thermal conductivity at temperature at 45 ° C, 0.812 nanoamor 0.645 comparatively.

ABSTRAK

Karbon nano mempunyai kadar konduktivitas termal yang tinggi dan ini telah dibuktikan dalam kajian ilmiah yang telah dijalankan sebelum ini. Bendalir nano berdasarkan karbon nano yang stabil dapat digunakan dalam pelbagai jenis aplikasi contohnya sebagai pendingin dalam kenderaan, agen pemindahan haba dan dalam aplikasi elektronik. Kajian ini dibuat untuk menghasilkan bendalir nano berdasarkan karbon nano dan menyiasat tentang kestabilan bendalir nano berdasarkan karbon nano. Dua jenis karbon nano telah digunakan bagi menghasilkan bendalir nano berdasarkan karbon nano iaitu Karbon nano tiub Nanoamor dan Pyrograf. Karbon nano adalah sejenis bahan yang hidrofobik dan hidrofobik bermaksud bahan yang tidak akan larut dalam air. Sodium dodecyl sulfate digunakan sebagai agent penyebar untuk melarutkan karbon nano dalam air. Untuk menghasilkan bendalir nano berdasarkan karbon nano, nisbah-nisbah tertentu telah dibuat berdasarkan pengiraan bagi menghasilkan bendalir nano berdasarkan karbon nano yang stabil. Bendalir nano berdasarkan karbon nano yang stabil mempunyai konduktivitas termal yang tinggi berbanding bendalir biasa. Selain itu, dengan adanya karbon nano dalam bendalir nano, kadar konduktivitas termal akan bertambah. Pyrograf menunjukkan konduktivitas termal yang tinggi berbanding nanoamor iaitu pada peratus berat 1.0% pyrograf mempunyai konduktivitas termal 0.812 pada suhu 45 °C manakala nanoamor hanya 0.645.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	LIST OF CONTENTS	x
	LIST OF FIGURES	xi
	LIST OF TABLES	xii
	LIST OF SYMBOLS	xiii
CHAPTER I	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Objectives	2
	1.3 Scopes	2
	1.4 Problem Statement	2
	1.5 Expected Result	3
CHAPTER II	LITERATURE RIVIEW	4
	2.1 Carbon	4
CHAPTER	TITLE	PAGE

2.2	Nanocarbon	5
	2.2.1 Single-Walled	6
	2.2.2 Multi-Walled	8
	2.2.3 Properties of Carbon nanotubes	9
	2.2.3.1 CNT's strength	10
	2.2.3.2 CNT's composites	10
	2.2.3.3 Morphology	10
2.3	Fluid	12
2.4	Nanofluid	13
	2.4.1 Morphology of nanofluids	14
	2.4.2 Stability of Nanofluids	20
2.5	Synthesis and Characterization	24
	2.5.1 Scanning Electron Microscopy	25
	2.5.2 Brunauer-Emmet-Teller (BET)	25
CHAPTER III	METHODOLOGY	27
3.1	Experimental Procedure	27
3.2	Flow Chart	28
3.3	Equipment and Chemical Reagents.	29
	3.3.1 Apparatus	29
	3.3.2 Chemical Reagents	29
	3.3.3 Figure of Apparatus and Chemical Reagents	30
3.4	Stability testing Devices	31
3.4	Design for Stability Test	31
	3.4.1 LED Stability Test	31
	3.4.2 Laser Test	34

CHAPTER	TITLE	PAGE
---------	-------	------

CHAPTER IV	RESULT AND DISCUSSION	36
4.1	Experimental Procedure	36
4.2	Synthesis of CNT Nanoamor	37
4.2.1	Stability of Nanoamor	38
4.3	Synthesis of CNT Pyrograf	39
4.3.1	Stability of Pyrograf	40
4.4	Discussion	40
CHAPTER V	CONCLUSION	45
	RECOMMENDATION	46
	REFERENCES	47
	APPENDIX	51

LIST OF FIGURES

NO	TITLE	PAGE
2.1	Single walled Carbon Nanotube	6
2.2	Multi-walled Carbon Nanotube	8
2.3	Scanning electron microscope (SEM) pictures of multi-walled carbon nanotube arrays. (a-c)Top view of a MWCNT array with increasing magnification showing entanglement of the nanotubes at surface. The diameters range from 20 to 30 nm. (d) Side view of the MWCNT array where a patch of outer surface being peeled off, showing	
2.4	SEM micrograph of CNT-2	11
2.5	SANS data in log-log scale	12
2.6	Bubbles from heated wire in pure water and nanofluid of alumina NPs and water	13
2.7	Ordered liquid layer in promoting the formation of interconnected particle morphology	15
2.8	Thermal conductivity enhancement of oil- based fullerene nanofluids	16
2.9.	Thermal conductivity enhancement of water- based MWCNT and fullerene nanofluids..	17
NO	TITLE	PAGE
2.10	Thermal conductivity enhancement of oi l-based fullerene nanofluids.	18
2.11	Validation of the experimental results of the	

	thermal conductivity ofMWCNT nanofluids	.19
2.12 :	Photographs of test particles	
	. (a) MWCNT, (b) CuO, (c) fullerene, (d) SiO ₂ .	22
2.13	Why nanoparticles are better than microparticles.	23
3.1	Flow Chart of Project	28
3.2	3.2: a)Homogenizer b)ultrasonic cleaning unit/heated c)100ml chemical bottle d)multiwalled-carbon nanotube.	30
3.4	Full body	31
3.5	Main body	32
3.6	Front Body	32
3.7	Drawing for LED stability test	33
3.8	Laser Test	34
3.9	Drawing for laser test	35
4.5	Scanning electron microscope (SEM) image of MER (a) and Pyrograf (b) at 2 micron	42
4.6	BET surface area	43
4.7	Total pore volume	44

LIST OF TABLES

NO	TITLE	PAGE
2.1	Measured dynamic viscosities of nanofluids and DI-water	21
2.2	Property of test material for preparing nanofluids	21
4.1	Synthesis of Nanoamor	37
4.4	Synthesis Pyrograf	39

LIST OF SYMBOLS

SYMBOL	DESCRIPTION
%	Percentage
°	Degree
K	Kelvin
p	proton
n	neutron
π	pai @ pai
Φ	volume fractions
η	electron coefficient
δ	electron coefficient

LIST OF ABBREVIATION

ABBREVIATION	DESCRIPTION
PP	poly-propylene
PA	photoacoustic
MWCNT	multi-walled carbon nanotube
CNT	carbon nanotube
SWNT	single walled carbon nanotube
CNFs	carbon nanofibers
CNTFETs	Carbon-nanotube field-effect transistors
IR	infrared
WO ₃	tungsten oxide
CVD	chemical vapor deposition technique
Fe(CO) ₅	iron pentacarbonyl
F ₂	fluorinated
SEM	Scanning electron microscope
PAO	polyalphaolefins
AC	Activated Carbon
BET	Brunauer-Emmet-Teller

CHAPTER I

INTRODUCTION

1.1 Introduction

Nanocarbons can be defined as carbon material built from sp^2 bond building block in a nanoscale, and include various forms of carbons in the range from fullerenes, carbon nanotube to nano-porous material. Among them, one dimensional carbon nanotubes have attracted a wide range of scientists due to their unique morphology and nano-sized scale, furthermore their versatile expected application, in which the challenge is that how to utilize their intrinsic properties of carbon nanotubes, such as mechanical, thermal and electrical properties. It is no doubt that the recent explosive carbon research is due to the discovery of nano-scale carbon materials. After the identification of fullerenes and carbon nanotubes as new allotropes of carbon element in the end of 20th century, chemists, physicists, scientists and engineers started to work intensively due to their extraordinary mechanical and electronic properties. Over the last decade, many applications of nano-carbon have been explored as filler in composite materials, electrodes for fuel cells, individual functional elements of a device and so on. A nanocarbon composite is one of these potential candidates because of its high recrystallisation temperature, which is suitable for power devices operating at high temperatures.

1.2 Objectives

The objectives of research study are ;

1. To synthesis nanofluid-based nanocarbon
2. To analyze the nanofluid stability performances and characterization of the nanocarbon base

1.3 Scope

The study limits is scope to:

1. Formulate nanofluid-based nanocarbon.
2. Investigate the properties of nanocarbon
 - a) surface area
 - b) type of pore
 - c) morphology
3. to analyze the nanofluid performances stability.

1.4 Problem Statements

Current commercial fluid (e.g water and ethylene glycol) have a low thermal conductivity and have some clogging issue. To overcome this problem Nanofluid are formed which is higher thermal conductivity, less clogging due to small particle size. This research is about want to know the synthesis and the characterization of nanofluid-based nanocarbon. Nanofluids are one of the new nanotechnologies that can give a lot of benefits in science and industry. This is because there are a lot of advantages from this nanofluid-based nanocarbon. Carbon nanotube were used in because it have higher thermal conductivity and carbon nanotube are stable in nanofluids. This research is all about the syhnthesis and the characterization of nanofluid based nanocarbon. There will be a lot of information for the nanofluid-based nanocarbon such as the function,

morphology, application of nanofluid based nanocarbon and many more. This will be a lot of experiment because nanofluid is the new technology and did not have the material. We have to produce the nanofluid by doing experiments that can make the nanofluid one of new material that can give a lot of benefits to industry, science and technology.

1.5 Expected Result

In this research, nanofluid based nanocarbon have been produced and the characterization and the synthesis of the nanofluid based nanocarbon have been collected and the research will successful if the objectives of this research have been achieved.

CHAPTER II

LITERATURE RIVIEW

2.1 Carbon

Carbon materials are the most promising adsorbents when adsorption of traces of gases or vapours is considered. (E Díaz 1999a) Recently, new carbon forms like carbon nanofibers (CNFs) or nanofilaments and carbon nanotubes (CNTs) have generated a growing interest in the scientific community. (E Díaz 1999b) The fabrication of carbon aerogels is an important subject both with regard to science and to applications. There are many papers about the fabrication and characterization of carbon aerogels in the literature, but most carbon aerogel materials were synthesized by the method of carbon dioxide supercritical drying. (E Díaz 1999c). Carbon has a lot of advantages compared to other material because it has higher thermal conductivity than other material

2.2 Nanocarbon

Carbon nanotubes (CNTs) are quasi-one-dimensional objects with unique electronic properties.(Q. Fu et al. 2002) Nano carbon tubes are another kind of beautiful, small-scale structure. CNTs are predicted to have higher thermal conductivity than any known material including diamond (Berber.S et al. 2000), have high mechanical strength (Yu, M 2000), are compliant, and can be grown as arrays of relatively high densities (Ren, Z.F et al. 2000). Carbon-based materials such as diamond and in-plane graphite are known to have the highest measured thermal conductivity, so it is not surprising that a new form of carbon, resembling graphite, but with no cross-plane phonon dispersion and without limitations of small crystal size has generated considerable interest, speculation, and research.(Jennifer, L et al. 2004)The stability similarity between shells and nano carbon tubes has been discussed for a long time. (Y. Yin 2006) Carbon nanotube field effect transistors ~CNT-FETs have been shown to be very sensitive to ambient conditions. (MRS Bull. 2004) Carbon nanotubes are good in conductivity and can increase the selectivity in sensor application.

2.2.1 Single-Walled

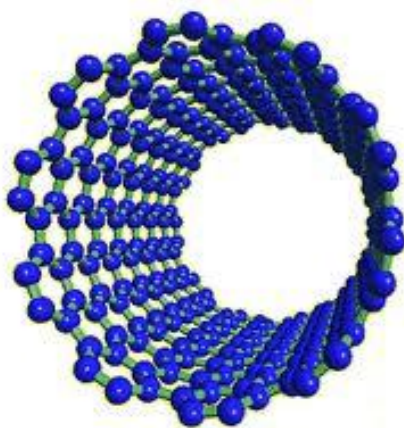


Figure 2.1: Single walled carbon nanotube

Single-walled carbon nanotubes (SWCNTs) have attracted a great deal of attention due to their remarkable properties. (Y. Li et al. 2001). Single-walled carbon nanotubes (SWNTs) have attracted much attention due to their unique structural, mechanical, and electrical properties. (Boul, P. J et al. 1999). They are generally considered as promising building blocks for nanoscale electronics. (Boul, P. J et al. 1999). Single-walled carbon nanotubes (SWCNTs) have been considered as a promising nanostructured material for the realization of future nanoelectronic devices because of their unique electrical properties such as the ballistic transportation of electrons or holes in SWCNTs. (H. Sharma et al. 2008). The growth mechanism of long and aligned single walled carbon nanotubes using a recently reported “fast heating” chemical vapor deposition (CVD) method is discussed. (S. Tan 1998).

Carbon nanotubes are good in mechanical and electrical properties and it is proven by Boul, P. J and Massachussets in their journal. They have used single-walled carbon nanotubes for nanoelectronic devices. Carbon nanotubes also have high carrier mobility, ballistic transport and high compatibility with high dielectrics. Various types of metal contacts have been investigated for single-walled carbon nanotubes, especially for semiconducting single-walled carbon nanotube field-effect transistors (SWNT FETs)

aimed at utilizing the advanced materials properties including high carrier mobility, ballistic transport, and high compatibility with high dielectrics. (Massachusetts 2001).

Carbon nanotube are good in mechanical and electrical properties and it is proven by Boul, P. J and Massachussets it their journal. They have use single-walled carbon nanotubes for nanoelectronic devices. Carbon nanotubes also have high carrier mobility, ballistic transport and high compability with high dielectrics. A single tube has a diameter of 0.8–1.2 nm and a length of several microns. (Herholz K 2008). Single-walled carbon nanotube (SWCNT) interconnects have firstly been used to replace copper wire on today's silicon chip, which is demonstrated in (G. F. Close et al.,2008). Carbon nanotube (CNT) interconnects have drawn more and more attention for future integrated circuit technology in the IC community, due to their high current capability, excellent thermal and mechanical properties (A.Naeemi 2007) Thermal effect should be taken into consideration in the design of CNT interconnects.The thermal conductance of a SWCNT has strong effect on its longitudinal temperature distribution.(E.Pop,et al. 2006).

The average diameter of the SWNTs produced in these experiments is 1.0 nm with a standard deviation for the diameter distribution of 17%.(SM. Sze 1981). Single walled carbon nanotubes (SWNTs) have been shown to be highly sensitive gas sensors. (G. Gu et al.2002).

2.2.2 Multi-Walled

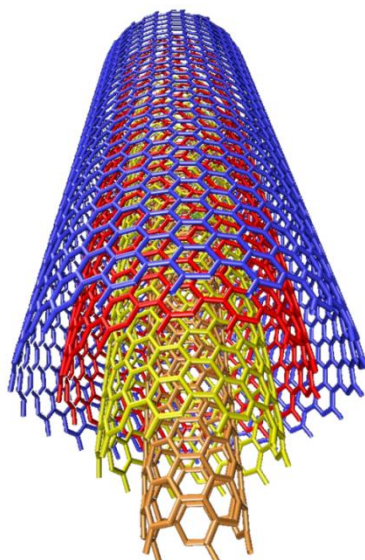


Figure 2.2 : Multi-walled Carbon Nanotube

Multi-wall Carbon Nanotube (MWCNT) arrays of different density and length have been grown on Silicon and Copper surfaces using chemical vapor deposition. (Jennifer L et al. 2008). SWCNT's have lower thermal conductivity than MWCNT's and that is because MWCNTs have a current carrying capacity equal to that of the SWCNTs, but with simpler fabrication due to easier control of the growth process. (Imam mahedai 2010a). CNTs are predicted to have higher thermal conductivity than any known material including diamond (Berber, S et al. 2000), have high mechanical strength (Yu, M 2000), are compliant, and can be grown as arrays of relatively high densities (Ren, Z.F et al. 2000). MWCNTs have a current carrying capacity equal to that of the SWCNTs, but with simpler fabrication due to easier control of the growth process. (Imam mahedai 2010b). SWCNT's and MWCNT's formed by several concentric shells that have diameter ranging from several nanometers to tens of nanometers while the former one has only one shell with diameter ranging from 0.4 to 4 nm. (Imam mahedai 2010c).

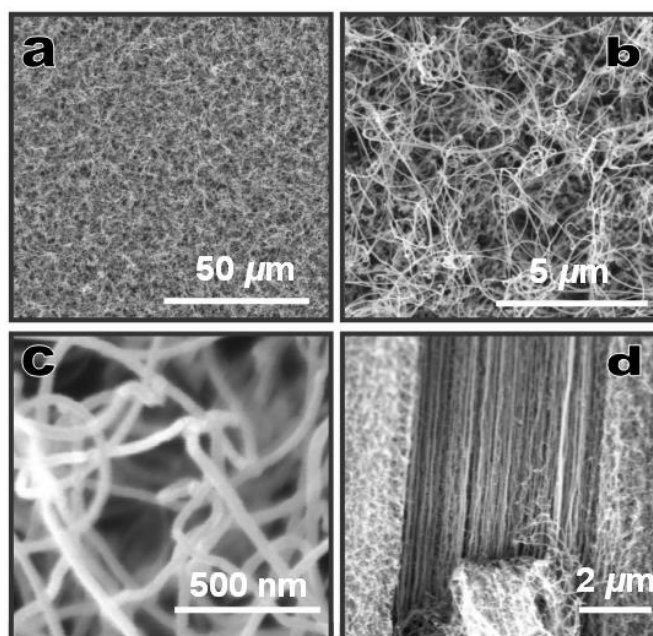


Figure 2.3: Scanning electron microscope (SEM) pictures of multi-walled carbon nanotube arrays. (a-c) Top view of a MWCNT array with increasing magnification showing entanglement of the nanotubes at surface. The diameters range from 20 to 30 nm. (d) Side view of the MWCNT array where a patch of outer surface being peeled off, showing vertical alignment of the tubes.

2.2.3 Properties of Carbon Nanotubes

Carbon nanotubes, long, thin cylinders of carbon, were discovered in 1991 by S. Iijima. *S. Iijima* (1991) These are large macromolecules that are unique for their size, shape, and remarkable physical properties. They can be thought of as a sheet of graphite (a hexagonal lattice of carbon) rolled into a cylinder. These intriguing structures have sparked much excitement in the recent years and a large amount of research has been dedicated to their understanding. Currently, the physical properties are still being discovered and disputed. What makes it so difficult is that nanotubes have a very broad range of electronic, thermal, and structural properties that change depending on the different kinds of nanotube (defined by its diameter, length, and chirality, or twist). To

make things more interesting, besides having a single cylindrical wall (SWNTs), nanotubes can have multiple walls (MWNTs)--cylinders inside the other cylinders. (Thomas A. Adams II 2006).

2.2.3.1 CNT's strength

The strength of a material is not as well defined as the Young's modulus, because it depends not only on the type of material, but also on its history, the atmosphere, the pressure, and the temperature, and the measuring system (fluctuations in load can modify the strength). (J.-P. Salvetat et al. 1999a) CNTs have great potential for applications requiring high-modulus high-strength materials. (J.-P. Salvetat et al. 1999b) Theory and experiments show that the Young's modulus of CNTs is at least as high as graphite and can be even higher for small SWNTs. (J.-P. Salvetat et al. 1999c) The theoretically predicted properties of CNTs – high strength, extraordinary flexibility and resilience – are now being observed by experimentalists.

2.2.3.2 CNT's composites

The high modulus and the low weight of carbon fibres make them ideal reinforcing agents in a variety of composite materials used in the aircraft and sports industries. It is worth recalling that the parameter that should be maximized for structural applications involving flexural loading is E/ρ^2 , ρ being the density (K.K. Chawla 1987).

2.2.3.3 Morphology

Single walled nanotube (SWCNT) consists of cylinder with only single wall while multi-walled nanotubes (MWCNT) comprise an array of concentrically nested rings like the rings in the trunk of a tree. (D SEN1 et al. 2008) Synthesis of CNTs can be

achieved by various methods that involve the catalytic decomposition of a carbon containing gas or solid. (K Dasgupta et al. 2008)

It is shown that although the source of carbon remains unchanged in all cases, the variation in synthesis parameters has a significant effect on CNT morphology and their number density. (J Bahadur¹ et al. 2008) It is also revealed that SANS is an effective tool to characterize the radial distribution, specific surface area of CNT. (S Mazumder et al. 2008) Further, it also gives a measure of the scaling behaviour of structures in a statistical sense for various synthesis conditions of CNT. As the hydrogen storage property of CNTs is closely associated with its radial distribution, the present study can throw light to construct a correspondence between the hydrogen storage capacity and the cylinder morphology. (D Sathiyamorthi et al. 2008)

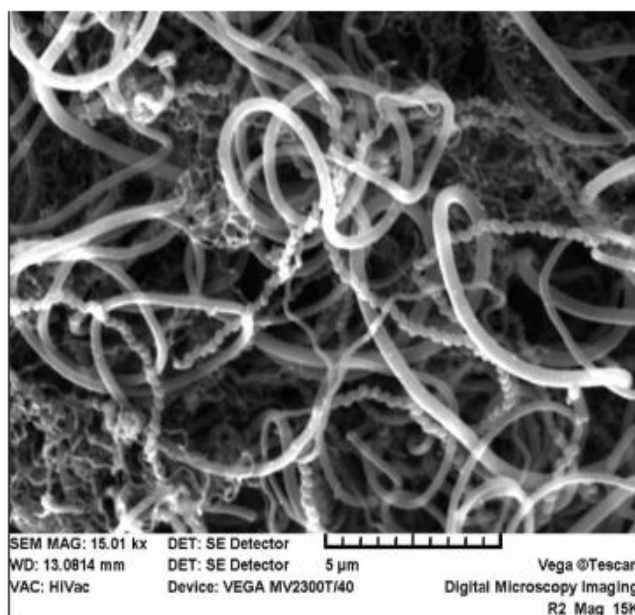


Figure 2.4 SEM micrograph of CNT-2.

(D Sen et al. *Morphology of carbon nanotubes prepared via chemical vapour deposition technique using acetylene: A small angle neutron scattering investigation* 2008)

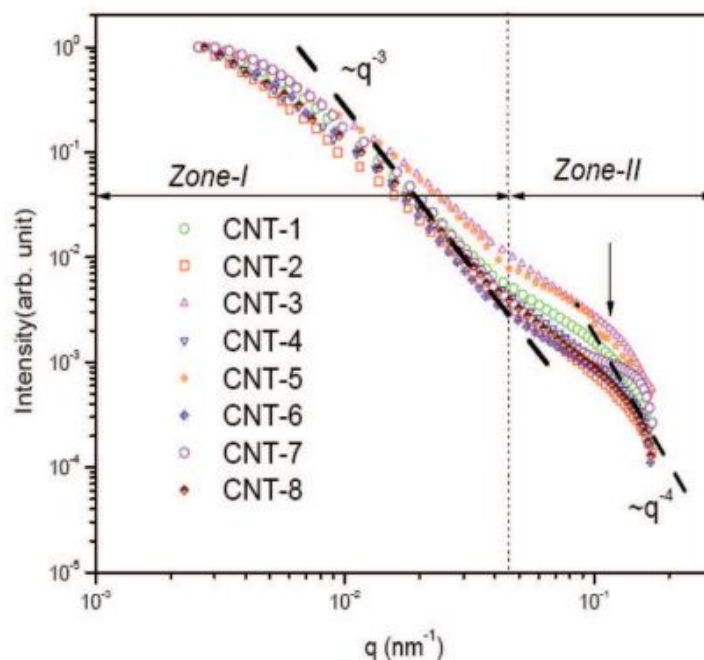


Figure 2.5 SANS data in log-log scale.

(D Sen et al. *Morphology of carbon nanotubes prepared via chemical vapour deposition technique using acetylene: A small angle neutron scattering investigation* 2008)

2.3 Fluid

In physics, a fluid is a substance that continually deforms (flows) under an applied shear stress, no matter how small. Fluids are a subset of the phases of matter and include liquids, gases, plasmas and, to some extent, plastic solids. In common usage, "fluid" is often used as a synonym for "liquid", with no implication that gas could also be present. For example, "brake fluid" is hydraulic oil and will not perform its required function if there is gas in it. This colloquial usage of the term is also common in medicine and in nutrition.

Fluid viscosity is a very important factor for fluid dispensing, and it has important effect on the volume and velocity of the fluid that jetting from the nozzle outlet. This paper analyses the force that the fluid gives to needle both with low and high viscosity situation and establishes formulas. (Li Shihui 2006). Suppose fluid temperature is constant in the fluid jetting process, and the temperature influence on fluid can be neglected. (Chen Kuiyu 2007). Fluid mean flow velocity and equivalent velocity based on fluid kinetic energy can be got by Matlab program. (Chen Kuiyu 2007).

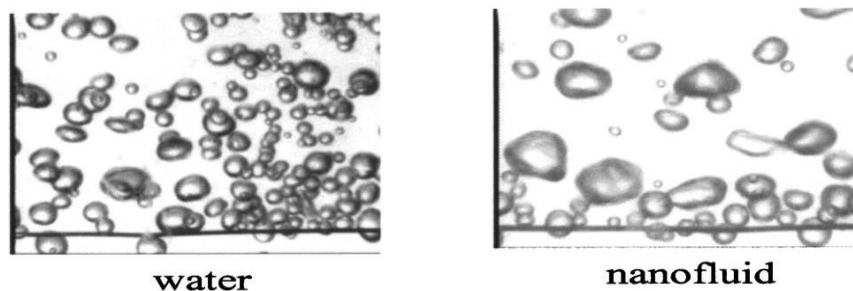


Figure 2.6 Bubbles from heated wire in pure water and nanofluid of alumina NPs and water

(<http://www.prlog.org/10495522-nanoparticles-emit-em-radiation-to-enhance-thermal-conductivity-and-boiling-heat-transfer.htm>)

2.4 Nanofluid

Nanofluids are gaining in popularity among academic researchers and receiving more attention from industry as they continue to demonstrate heat transfer improvements in liquid cooling processes. (Wong, J et al. 2008). Nanofluids are dilute liquid suspensions of nanoparticles with at least one critical dimension smaller than $\sim 100\text{nm}$. Much attention has been paid in the past decade to this new type of composite material because of its enhanced properties and behavior associated with heat transfer (Masuda et al. 1993), mass transfer (Krishnamurthy et al. 2006), wetting and spreading (Wasan and Nikolov 2003) and antimicrobial activities (Zhang L et al. 2007), and the number of

publications related to nanofluids increases in an exponential manner. Nanofluids, a mixture of nanoparticles and fluid, have enormous potential to improve the efficiency of heat transfer fluids. (Hong, Tae-Keun 2000). Nanofluids are prepared with ethylene glycol and nanocrystalline powder synthesized by a chemical vapor condensation process.

The enhanced thermal behaviour of nanofluids could provide a basis for an enormous innovation for heat transfer intensification, which is of major importance to a number of industrial sectors including transportation, power generation, micro-manufacturing, thermal therapy for cancer treatment, chemical and metallurgical sectors, as well as heating, cooling, ventilation and air-conditioning. Nanofluids are also important for the production of nanostructured materials (Kinloch et al. 2002), for the engineering of complex fluids (Tohver et al. 2001), as well as for cleaning oil from surfaces due to their excellent wetting and spreading behaviour (Wasan & Nikolov 2003). 'Nanofluids' is the accepted nomenclature for slurries containing a mixture of a base fluid and suspensions of nano-scale particulates, or nanoparticles. (Wong, J et al. 2008) When nanofluids are used in a liquid cooling process, the purely convective mode of heat transfer with the base fluid alone now becomes a heat transfer problem with convection and conduction effects. (Wong, J et al. 2008). Nanofluids exhibit an enhancement of thermal conductivity after sonication. (Hong, Tae-Keun 2000)

2.4.1 Morphology of nanofluids

The nanoparticle morphology in nanofluids can vary from a well-dispersed configuration in base fluids to a continuous phase of interconnected configuration. Such a morphology variation will change nanofluid's effective thermal conductivity significantly (Fan J et al. 2010) a phenomenon credited to the particle clustering/aggregating in the literature (Wang LQ et al. 2010) This appears obvious

because the nanofluid's effective conductivity stems mainly from the contribution of continuous phase that constitutes the continuous path for thermal flow (F Wang LQ et al. 2010). Although particle clustering/aggregating offers a way of changing particle morphology, it is not necessarily an effective means. The research should thus focus not only on the clustering/aggregating, but also on the general ways of varying morphology.

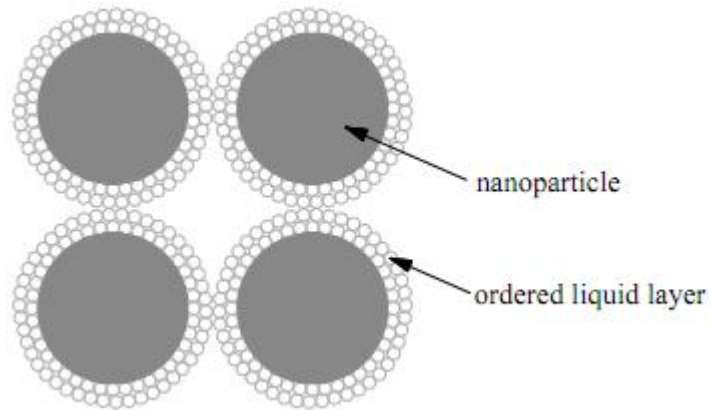


Figure 2.7 Ordered liquid layer in promoting the formation of interconnected particle morphology

(L. Wang et al. *Toward nanofluids of ultra-high thermal conductivity*, 2011)

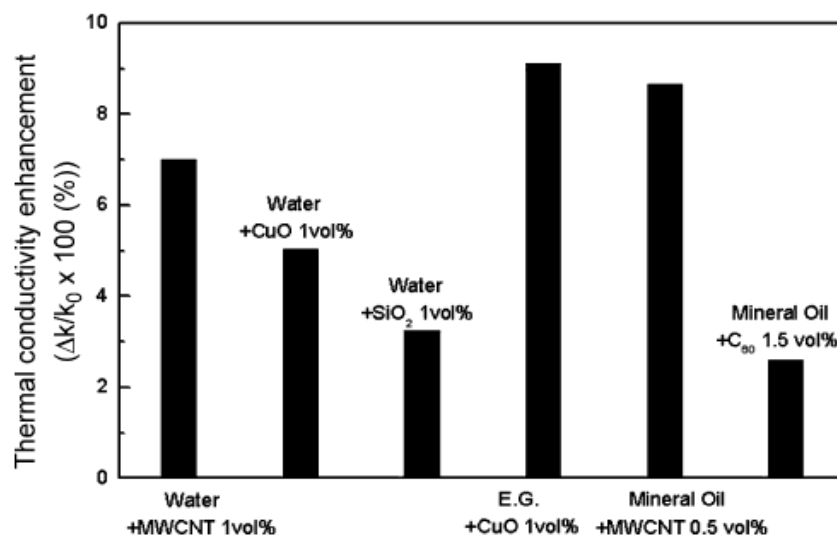


Figure 2.8. Test results of thermal conductivity of nanofluids.

(Y. Hwang *et al.* / *Thermochimica Acta* 455 (2007) 70–74)

Figure 2.6 shows the thermal conductivity enhancement of nanofluids. MWCNT nanofluid has the highest thermal conductivity enhancement among water-based nanofluid whereas SiO₂ nanofluid has the lowest one. (Y. Hwang *et al.* 2007a) From this result, it is shown that the thermal conductivity enhancement of nanofluid depends on that of the suspended particles. Many previous researches show the similar results. (Y. Hwang *et al.* 2007b) Also, it is shown that MWCNT-in-oil nanofluid has higher thermal conductivity enhancement than that of MWCNT-in-water, and that CuO-in-ethylene glycol nanofluid has higher thermal conductivity enhancement than that of CuO-in-water. (Y. Hwang *et al.* 2007c) These results imply that higher thermal conductivity enhancement can be obtained for basefluid of lower thermal conductivity. (Y. Hwang *et al.* 2007d)

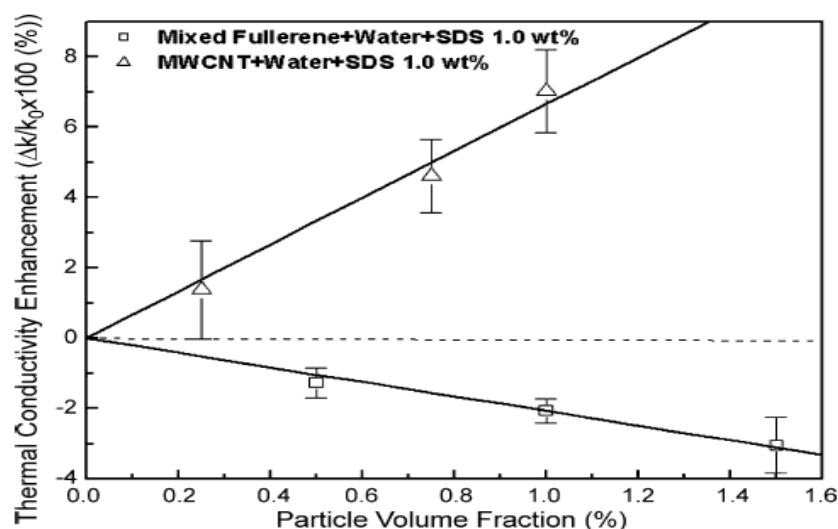


Figure 2.9. Thermal conductivity enhancement of water-based MWCNT and fullerene nanofluids.

(Y. Hwang *et al.* / *Thermochimica Acta* 455 (2007) 70–74)

Figure 2.7 shows the thermal conductivity enhancements of waterbased MWCNT and fullerene nanofluids as a function of the particle volume fraction. (Y. Hwang et al. 2007a) The value k is the thermal conductivity of basefluid or nanofluid according to the subscripts. (Y. Hwang et al. 2007b) The results show that the thermal conductivities of waterbased MWCNT nanofluids increase with increasing particle volume fraction, while the thermal conductivities of waterbased fullerene nanofluids are decreased with increasing particle volume fraction. (Y. Hwang et al. 2007c) It is believed that the thermal conductivity of fullerene is 0.4W/mK which is lower than that of water. (Y. Hwang et al. 2007d) For MWCNT nanofluid, the thermal conductivity is increased by 7.0% at volume fraction of 1.0%. On the other hand, the thermal conductivity is decreased by 3.0% at a volume fraction of 1.5%. (Y. Hwang et al. 2007d)

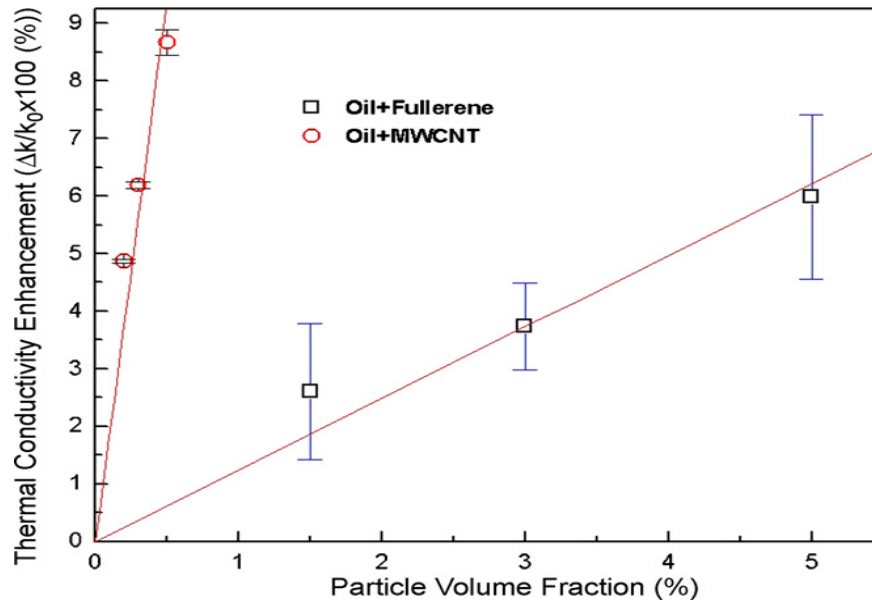


Figure 2.10 Thermal conductivity enhancement of oil-based fullerene nanofluids.

(Y. Hwang et al. / *Thermochimica Acta* 455 (2007) 70–7)

Figure 2.8 shows the thermal conductivity enhancements of oilbased MWCNT and fullerene nanofluids as function of the particle volume fraction. (Y. Hwang et al. 2007a) In case of MWCNT nanofluid, the thermal conductivity is increased up to 8.7% at 0.5 vol%. (Y. Hwang et al. 2007b) And the thermal conductivity of fullerene nanofluid is

increased by 6.0% at 5 vol%. (Y. Hwang et al. 2007c) It is shown that the thermal conductivity of MWCNT nanofluid is much higher than that of fullerene nanofluid because the thermal conductivity of MWCNT is much higher than that of fullerene. (Y. Hwang et al. 2007d) It is also believed that the thermal conductivity of nanoparticles strongly affects on the thermal conductivity enhancement of nanofluids. (Y. Hwang et al. 2007e)

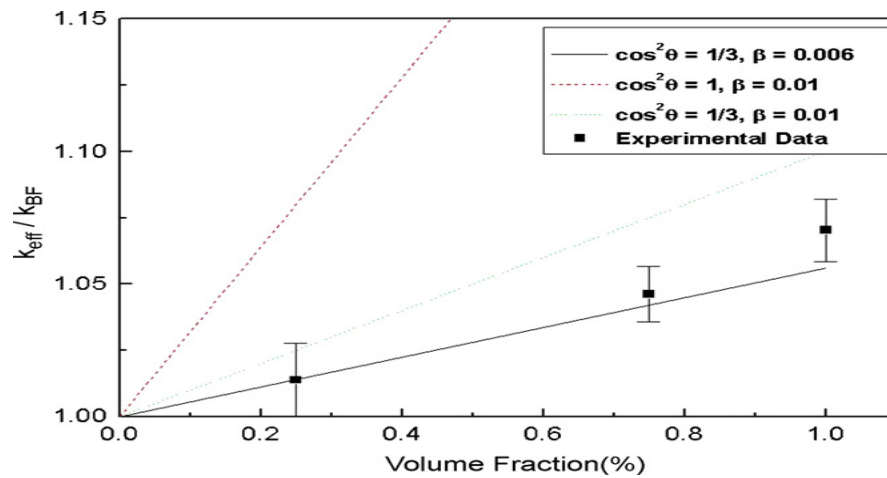


Figure 2.11. Validation of the experimental results of the thermal conductivity of MWCNT nanofluids.

(Y. Hwang et al. / *Thermochimica Acta* 455 (2007) 70–7)

Figure 2.9 shows validation of experimental results of the thermal conductivity of MWCNT nanofluids. (Y. Hwang et al. 2007a)

2.4.2 Stability of nanofluids

Nanofluid is a kind of new engineering material consisting of nanometer-sized particles dispersed in base fluid. In this study, various nanoparticles, such as multi-walled carbon nanotube (MWCNT), fullerene, copper oxide, and silicon dioxide have been used to produce nanofluids for enhancing thermal conductivity and lubricity. As base fluids, DI water, ethylene glycol, and oil have been used. .(Y. Hwang et al. 2006).

Nanofluid technology becomes a new challenge for the heat transfer fluid because of their higher thermal conductivity (J.A. Eastman et al. 2001) and stability than those of the conventional heat transfer fluid or the suspensions of micro-sized particles. In recent researches, carbon nanotube (CNT) is the excellent media to enhance the thermal conductivity of a base fluid when added at a small fraction (M.J. Biercuk et al. 2002). Thermal conductivities of the CNT nanofluids are increased up to 19.6 and 150% at a volume fraction of 0.01, respectively. The thermal conductivities of base fluids, such as DI water, ethylene glycol and oil, are 0.613, 0.252 and 0.107 W/mK, respectively. (Y. Hwang et. al 2006a). The stability of nanofluid has been estimated with UV–vis spectrophotometer. .(Y. Hwang et. al 2006b). Stability of nanofluid has been influenced by the characteristics between base fluid and suspended nanoparticles.(J.K. Lee et al. 2006).

The stability of nanofluid based nanocarbon are important because thermal conductivity enhancement depends on the volume fraction of the suspended particles, thermal conductivities of the particles and basefluids. Stability of nanofluid is strongly affected by the characteristics of the suspended particle and basefluids such as the particle morphology, the chemical structure of the particles and basefluid.(C.H. Lee et al. 2006)

Table 2.1 : Measured dynamic viscosities of nanofluids and DI-water

<div>Viscosity at 20°C</div> <div>Working fluid</div>	Viscosity measured in present study [mPa*sec]	Viscosity from Cengel[13] at 20°C [mPa*sec]	Thermal conductivity measured in the present study [W/mK]	Thermal conductivity from Cengel[13] at 10°C [W/mK]
DI Water	1.016	1.002	0.586	0.580
Nanofluid (Au nanoparticles)	1.036	--	0.597	--
Nanofluid (Carbon nanoparticles)	1.125	--	--	--

Table 2.2 Property of test material for preparing nanofluids

Property of test material for preparing nanofluids

	MWCNT	Fullerene	CuO	SiO ₂	H ₂ O	Ethylene glycol	Oil
Density (g/cm ³)	2.6	1.6	6.32	2.22	1	1.11	0.915
Thermal conductivity (W/mK)	~3000	0.4	76.5	1.38	0.613	0.252	0.107
Average size							
<i>L</i>	10-50 μ m	~10 nm	33 nm	12 nm	-	-	-
<i>D</i>	10-30 nm						

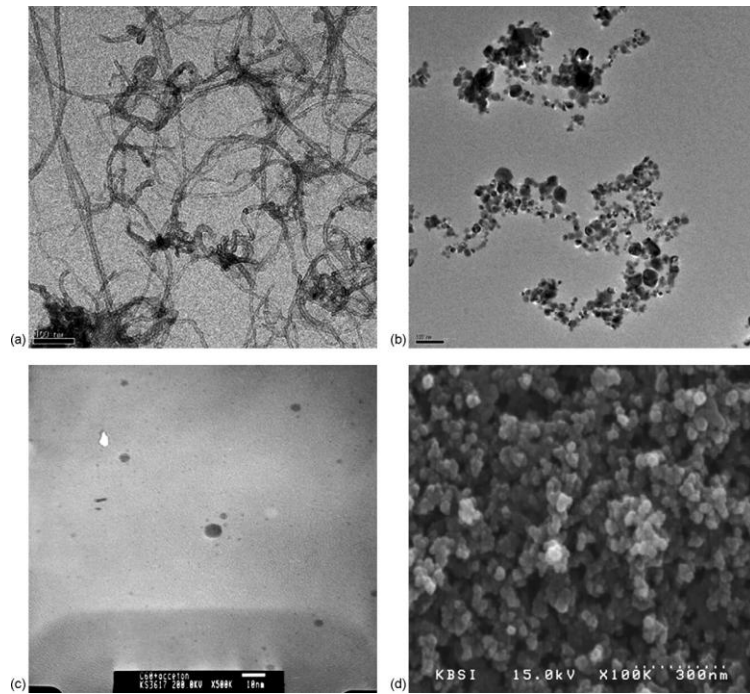


Figure 2.12 . Photographs of test particles. (a) MWCNT, (b) CuO, (c) fullerene, (d) SiO₂.

(Stability and thermal conductivity characteristics of nanofluids. Department of Mechanical Engineering, Pusan National University.)

Why Nanoparticles Are Better Than Microparticles

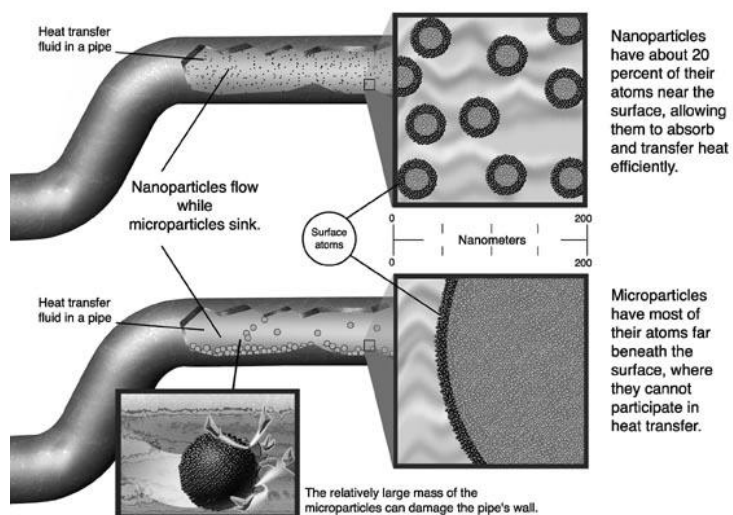


Figure 2.13 Why nanoparticles are better than microparticles.

(http://www.anl.gov/Media_Center/News/2004/nanofluidsbig.html)

2.5 Synthesis and Characterization

2.5.1 Scanning Electron Microscopy

Scanning electron microscopy (SEM) and x-ray microanalysis can produce magnified images and in situ chemical information from virtually any type of specimen. The two instruments generally operate in a high vacuum and a very dry environment in order to produce the high energy beam of electrons needed for imaging and analysis. With a few notable exceptions, most specimens destined for study in the SEM are poor conductors and composed of beam sensitive light elements containing variable amounts of water.

In the SEM, the imaging system depends on the specimen being sufficiently electrically conductive to ensure that the bulk of the incoming electrons go to ground. The formation of the image depends on collecting the different signals that are scattered as a consequence of the high energy beam interacting with the sample.

Backscattered electrons and secondary electrons are generated within the primary beam-sample interactive volume and are the two principal signals used to form images. The backscattered electron coefficient (η) increases with increasing atomic number of the specimen, whereas the secondary electron coefficient (δ) is relatively insensitive to atomic number. This fundamental difference in the two signals can have an important effect on the way samples may need to be prepared. The analytical system depends on collecting the x-ray photons that are generated within the sample as a consequence of interaction with the same high energy beam of primary electrons used to produce images.

There are two approaches to dealing with the frequent impasse that may exist between the properties of the sample and the optimal operating conditions of the SEM. We can either modify the instruments so they employ less invasive procedures or we can modify the specimen to make it more robust to the withering beam of high energy electrons. With a few exceptions, both approaches are a compromise.

Sample preparation is an absolute prerequisite for microscopy and analysis.

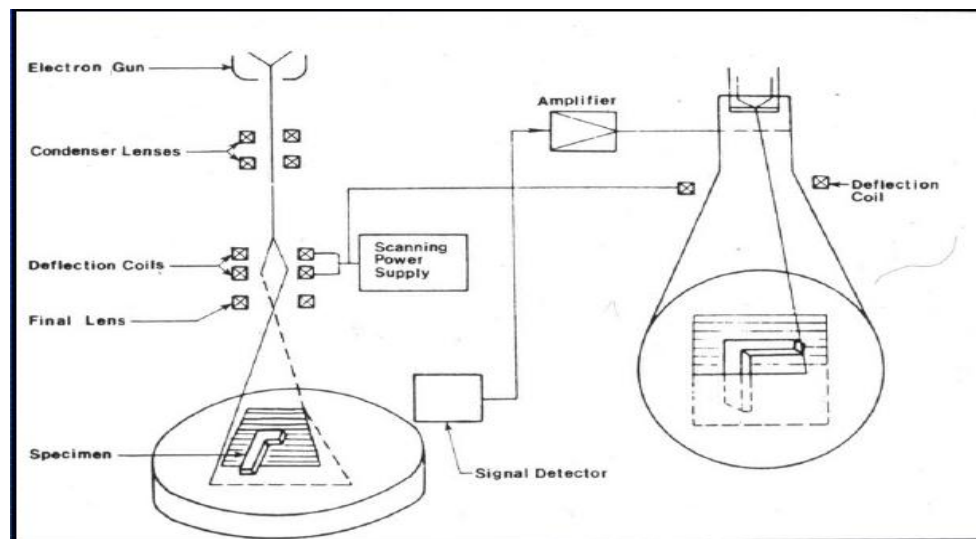


Figure 2.14 : The basic premise of an SEM is that signal produced from a scanned area of the specimen is displayed as an image with the exact same scan pattern on a CRT. (Source : <http://www.scribd.com/doc/15977565/Sem>)

2.5.2 Brunauer-Emmet-Teller (BET)

BET theory is a rule for the physical adsorption of gas molecules on a solid surface and serves as the basis for an important analysis technique for the measurement of the specific surface area of a material. In 1938, Stephen Brunauer, Paul Hugh Emmett, and Edward Teller published an article about the BET theory in a journal for the first time; “BET” consists of the first initials of their family names.

No other type of adsorption method can offer the same scope for the characterization of porous solids as gas adsorption. Adsorption from solution measurements are easy to carry out, but are often difficult to interpret. Although immersion calorimetry is experimentally demanding, the technique can yield useful information provided that the corresponding adsorption isotherm data are also available.

Nitrogen (at 77 K) is the most widely used adsorptive for the characterization of porous materials. Although the Brunauer–Emmett–Teller (BET) theory is based on an over-simplified model of multilayer adsorption, the BET method continues to be used as a standard procedure for the determination of surface area. Generally, the derived values of BET-area can be regarded as effective areas unless the material is ultramicroporous (i.e. containing pores of molecular dimensions). It is advisable to check the validity of the BET-area by using an empirical method of isotherm analysis. In favourable cases, this approach can be used to evaluate the internal and external areas. The computation of mesopore size distribution should be undertaken only if the nitrogen isotherm is of Type IV. Because of network–percolation effects, analysis of the desorption branch of the hysteresis loop may give a misleading picture of the pore size distribution; also, a considerable range of delayed condensation is to be expected if the pores are slit-shaped. Recent work on MCM-41, a model mesoporous adsorbent has improved our understanding of the mechanisms of mesopore filling. Adsorptive molecules of different size are required to provide a realistic evaluation of the micropore size distribution.

CHAPTER III

METHODOLOGY

3.1 Experimental Procedure

The 100 ml of distilled water have been weight by using analytical balance and put into the 100 ml bottle. Then, carbon nanotube (nanoamor/pyrograf) and sodium dodecyle sulfate have been weight with the ratio that has been get with from the formulation. Put the carbon nanotube and sodium that have been weight into the distilled water. The distilled water with SDS and carbon nanotube was homogized by using homogenizer for one minute at 10000 rpm. After that, the solutions have been ultrasonic by using ultrasonic cleaning unit for 60 minutes and temperature 25°C at highest frequency. The pH is set to 9 and the solution have been homogenize for another 5 minutes at 10000 rpm.

3.2 Flow Chart

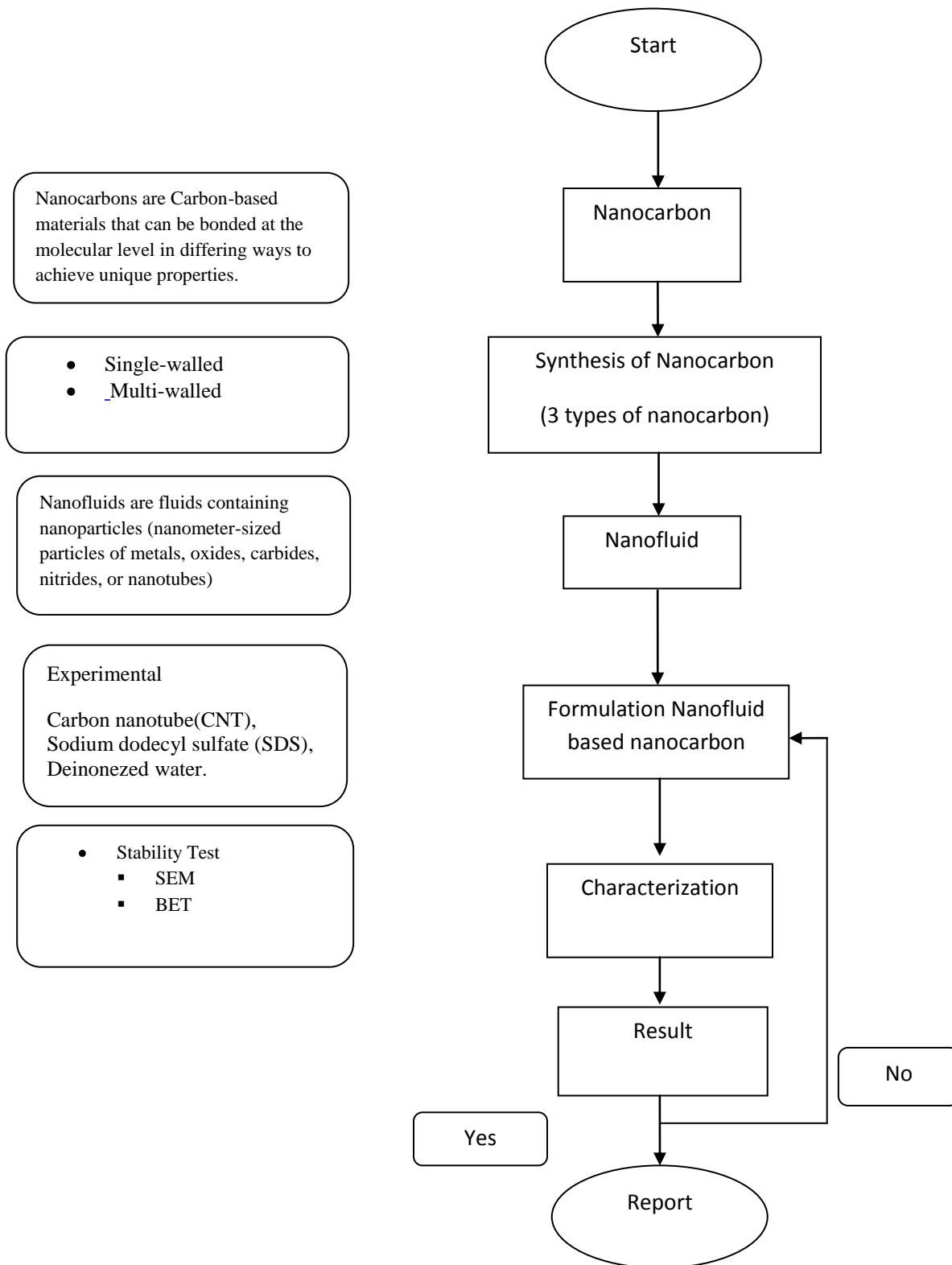


Figure 3.1: Flow Chart of Project

3.3 Equipment and Chemical Reagents.

3.3.1 Apparatus

The apparatus that was used to form nanofluids based nanocarbon are homogenizer. It is used for the homogenization of various types of material, such as tissue, plant, food, soil and many others. Laboratory bottle are also used to run the experiment it is used to place the nanofluids based nanocarbon. Besides that, ultrasonic cleaning unit are also used in this experiment. Furthermore, to weight the specimen analytical balance are used and other apparatus that used are 100ml chemical bottle.

3.3.2 Chemical Reagents

The chemical reagents that have been used to form nanofluids based nanocarbon are Multi-walled carbon nanotube. There are two types of multi-walled that have been used which is Nanoamor and Pyrograf. Besides that sodium dodecyl sulfate were used as dispersing agent and the base fluid is distilled water.

3.3.3 Figure of Apparatus and Chemical Reagents



a)



b)



c)



d)

Figure 3.2: a)Homogenizer b)ultrasonic cleaning unit/heated c)100ml chemical bottle d)multiwalled-carbon nanotube.

3.4 Stability Testing Devices

There are several types of observation that have been use to check the stability of nanofluid based nanocarbon. The type to check the stability are ;

- a. Visible Lights
- b. LED Test
- c. Laser Stability Test.

3.4.1 Stability Test Device

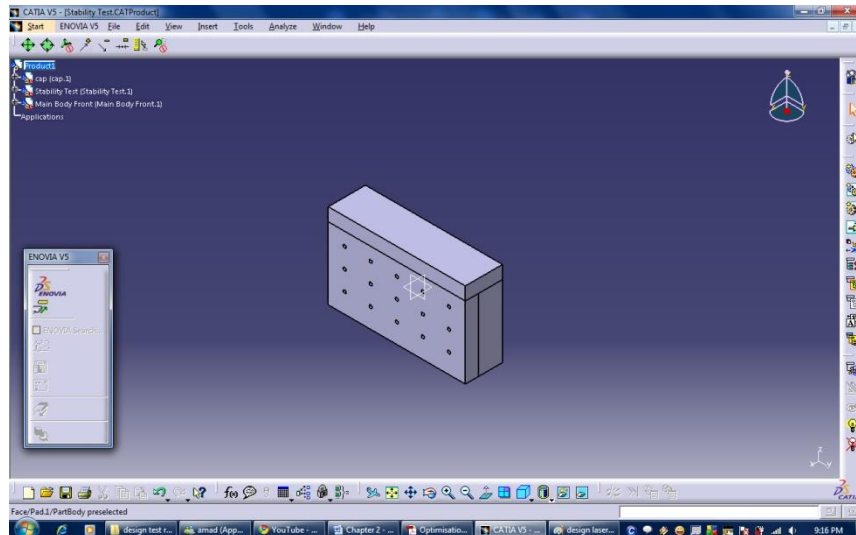


Figure 3.3: Full body

This is full body of stability test. It is use to check the stability of Nanofluids based nanocarbon. It operates with LED and LDR. LED is place at the hole and then if the LDR receive light, so the specimen is not good in the stability. It is because of the light still can go through the solution. Light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. It can also be referred to as a photoconductor. LED is a semiconductor light source. LEDs

are used as indicator lamps in many devices and are increasingly used for other lighting.

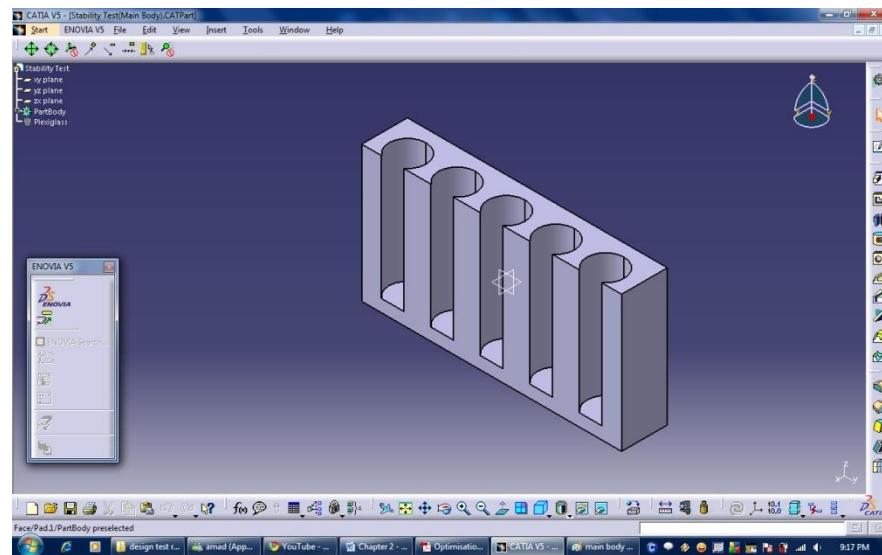


Figure 3.4 : Main body

This is the place where the specimen will be placed and can checked the stability of the specimen.

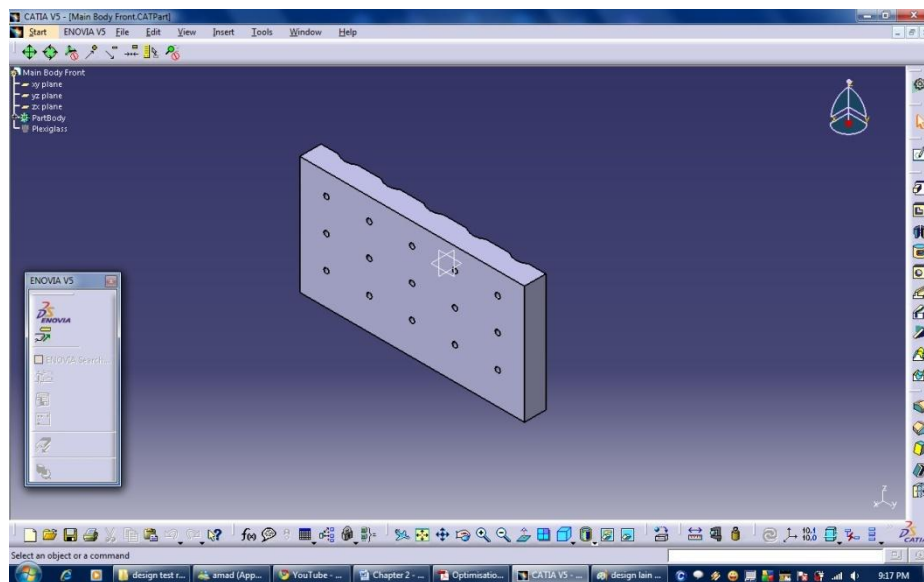


Figure 3.5: Front Bod

The hole is use to place the LED which is to check the stability of the specimen.

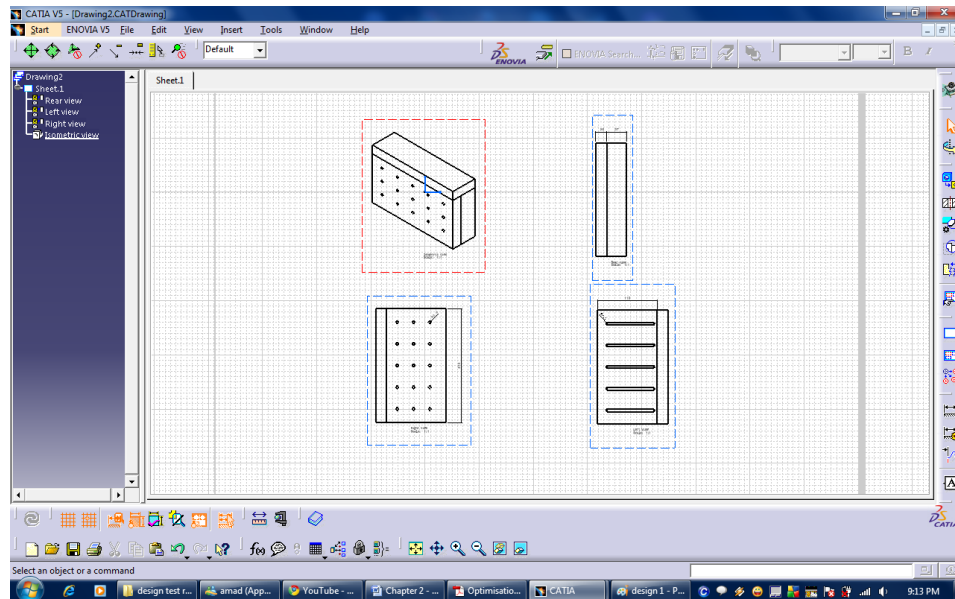


Figure 3.6: Drawing for LED stability test

The full drawing of the LED stability test which is show the front view of the object,side view and top view of the LED stability test.

3.4.2 Laser Test

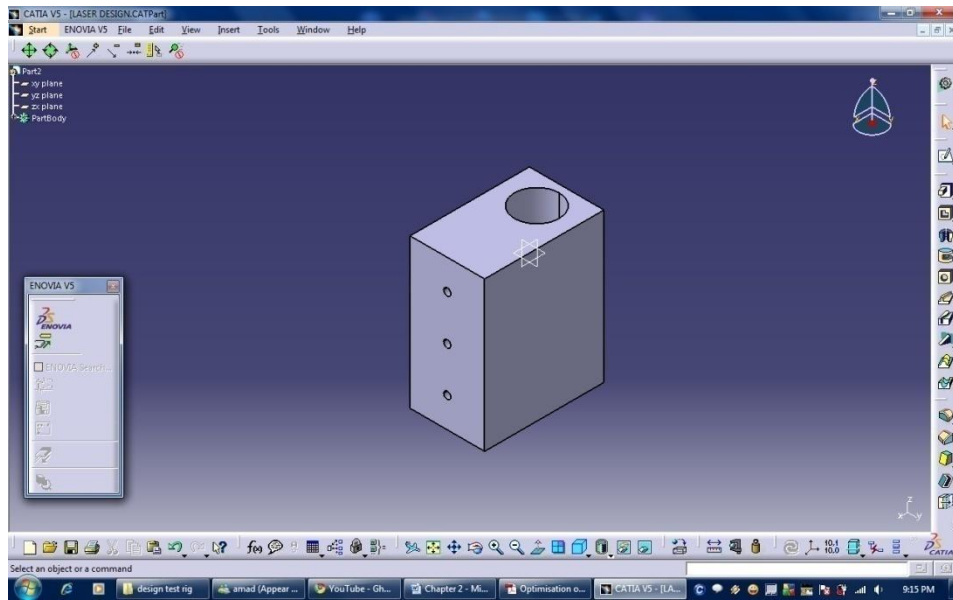


Figure 3.7: Laser Test

The laser test is used to check the stability of the specimen. It is laser and LDR. The operation of the laser test is the laser will place at the hole and if the LDR can receive light from the laser, it means that the specimen is not stable.

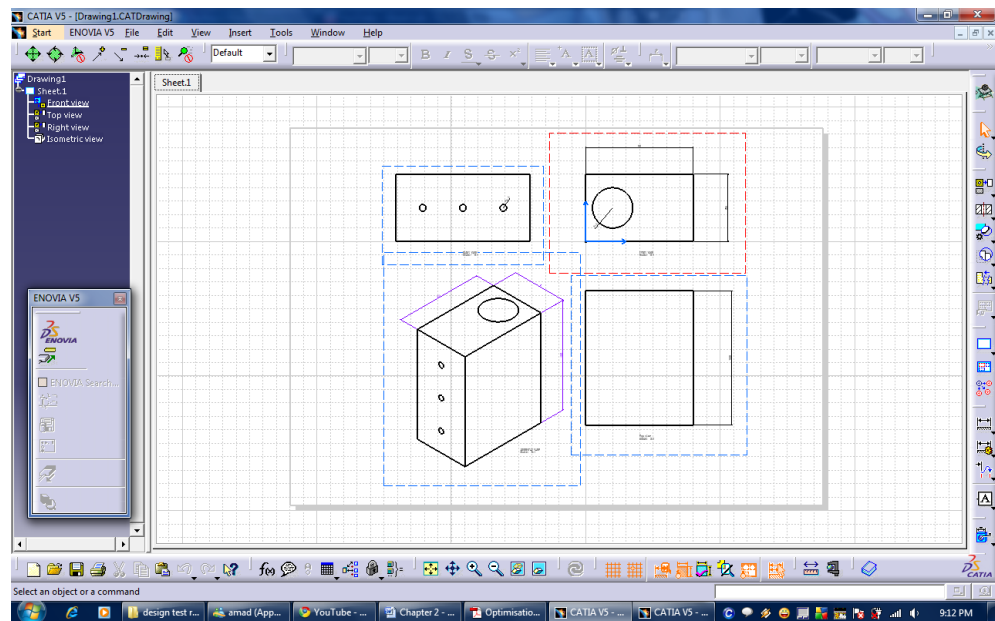


Figure 3.8: Drawing for laser test

This is the full drawing of the laser test. It shows the front, side and the top view of the laser test.

CHAPTER IV

RESULT AND DISCUSSION

4.1 Experimental Procedure

The 100 ml of deionized water have been weight by using analytical balance and put into the 100 ml bottle. Then, carbon nanotube (nanoamor/pyrograf) and sodium dodecyle sulfate have been weight with the ratio that has been get with from the formulation. Put the carbon nanotube and sodium that have been weight into the deioneized water. The deionized water with SDS and carbon nanotube was homogized by using homogenizer for one minute at 10000 rpm. After that, the solution have been ultrasonic by using ultrasonic cleaning unit for 60 minutes and temperature 25°C at highest frequency. The pH is set to 9 and the solution have been homogenize for another 5 minutes at 10000 rpm.

4.2 Synthesis of CNT Nanoamor

Nanofluid formulation CNT Nanoamor

Density of CNT
(g/cm³) : 1.7
Density of SDS
(g/cm³) : 1.01
Volume water (mL) : 100

No	Code	CNT (wt%)	Water(mL)	SDS(wt%)	V CNT	V SDS
1	N107	0.20	99.0831	0.08	0.1176	0.0792
2	N108	0.40	99.6063	0.16	0.2353	0.1584
3	N109	0.50	99.5079	0.20	0.2941	0.1980
4	N110	0.60	99.4094	0.24	0.3529	0.2376
5	N111	0.80	99.2126	0.32	0.4706	0.3136
6	N112	1.00	99.0157	0.40	0.5882	0.3960

Table 4.1 Synthesis Nanoamor

Table above shows the synthesis of Nanoamor. There is the ratio between the deionized water, carbon nanotube and Sodium dodecyl sulfate (SDS). In this table, the density of CNT that have be used is 1.7 g/cm³ and the density of SDS is 1.01 g/cm³.

4.2.1 Stability of Nanoamor

Based on the six samples that have been formed, all of the specimens are stable. We have been observing with visual test for 100 hours and after that the most stable specimen can be detected. For the 1st hours the specimen is mostly still good and got no sediments under the bottle. There are different on the ratio of CNT with SDS and it cause of the stability of the specimen. The more good ratio of CNT with SDS, the more stable of the specimen. SDS is use as dispersing agent, as we all know that SNT are hydrophobic which is cannot disperse in water, so the SDS solve the problem and make the CNT can well disperse in water.

The stability test was running by using stability testing device which is LED devices and Laser test. Sample was places in the device and there will show whether the sample is stable or not same goes to Laser test. Both testing are using the same method to check the stability of the sample.

4.3 Synthesis of CNT Pyrograf

Nanofluid formulation CNT Pyrograf

Density of CNT
(g/cm³) : 2
Density of SDS
(g/cm³) : 1.01
Volume water (mL) : 100

No	Code	CNT (wt%)	Water(mL)	SDS(wt%)	V CNT	V SDS
1	N207	0.20	99.8208	0.08	0.10	0.0792
2	N208	0.40	99.6416	0.16	0.20	0.1584
3	N209	0.50	99.5520	0.20	0.25	0.1980
4	N210	0.60	99.4624	0.24	0.30	0.2376
5	N211	0.80	99.2832	0.32	0.40	0.3168
6	N212	1.00	99.1040	0.40	0.50	0.3960

Table 4.2 Synthesis Pyrograf

Table 4.3 shows the synthesis table for Pyrograf. There is the ratio between the deionized water, carbon nanotube and Sodium dodecyl sulfate (SDS). In this table, the density of CNT that have be used is 2.00 g/cm³ and the density of SDS is 1.01 g/cm³.

4.3.1 Stability of Pyrograf

Based on the six samples that have been formed, all of the specimens are stable. We have been observing with visual test for 100 hours and after that the most stable specimen can be detected. For the 1st hours the specimen is mostly still good and got no sediments under the bottle. There are different on the ratio of CNT with SDS and it cause of the stability of the specimen. The more good ratio of CNT with SDS, the more stable of the specimen. SDS is use as dispersing agent, as we all know that SNT are hydrophobic which is cannot disperse in water, so the SDS solve the problem and make the CNT can well disperse in water.

The stability test was running by using stability testing device which is LED devices and Laser test. Sample was places in the device and there will show whether the sample is stable or not same goes to Laser test. Both testing are using the same method to check the stability of the sample.

4.4 Discussion

From the thermal conductivity test that have been done, the result show that pyrograf have higher thermal conductivity than MER. The graph from Pyrograf CNT show improvement of thermal conductivity increased of weight percentage of CNT. Besides that at high temperature, it is hows higher thermal conductivity than lower temperature due to, Brownian Motion. MER shows different value, due to Sedimentation, and less stability than Pyrograf.

We conclude that between Pyrograf CNT gave better enhancement of thermal conductivity compared to MER CNT. But there are explanation why Pyrograf gave such amazing results.

4.4.1 Types of CNT

Types of CNT may affect the thermal conductivity of each CNT. From data that we have collected from each of manufacturer, Pyrograf and MER are two different types of CNT

Table 4.3 Types of CNT

CNT	Type
MER	Multi-walled nanotube (MWNT)
Pyrograf	Carbon nanofiber (CNF)

MER consist of multi-walled nanotubes but Pyrograf consist of carbon nanofiber. Here we can see that Pyrograf have surplus value compared to MER. The advantage of Pyrograf is the length of the tubes.

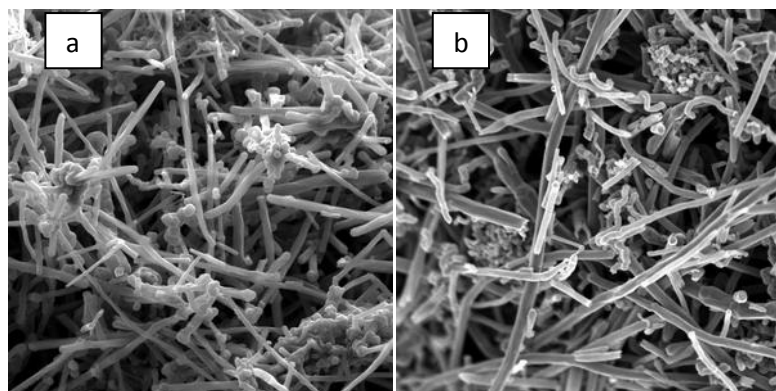


Figure 4.1 Scanning electron microscope (SEM) image of MER (a) and Pyrograf (b) at 2 micron

From figure above, we can see difference between MER and Pyrograf. MER consist of short length of tubes but Pyrograf have longer and continuous length of tubes. Length of tubes may affect the thermal conductivity of each nanofluids in terms of absorption area of nanotubes. The longer the tubes, the higher surface area of CNT, hence the higher thermal conductivity will be obtained.

4.3.2 Surface Area

Surface area can affect the thermal conductivity of CNT. Smaller particle have a bigger surface area than larger particle for the same mass. This explanation based on “Bread and Butter” theory. Each time we cut a new slice of bread we got a new extra surface. The thinner we cut a new slice, we got a higher extra surface. We used BET surface area testing method to calculate the surface area of CNT that we used to produce nanofluids. BET surface area testing is the most popular method to check surface area of certain compound and can give the most accurate surface area for the compound.

Table 4.4 Data from BET surface area testing

CNT	BET Surface Area, m²/g	Total pore volume, cc/g
MER	1.015×10^2	8.816×10^{-2}
Pyrograf	1.718×10^3	1.078

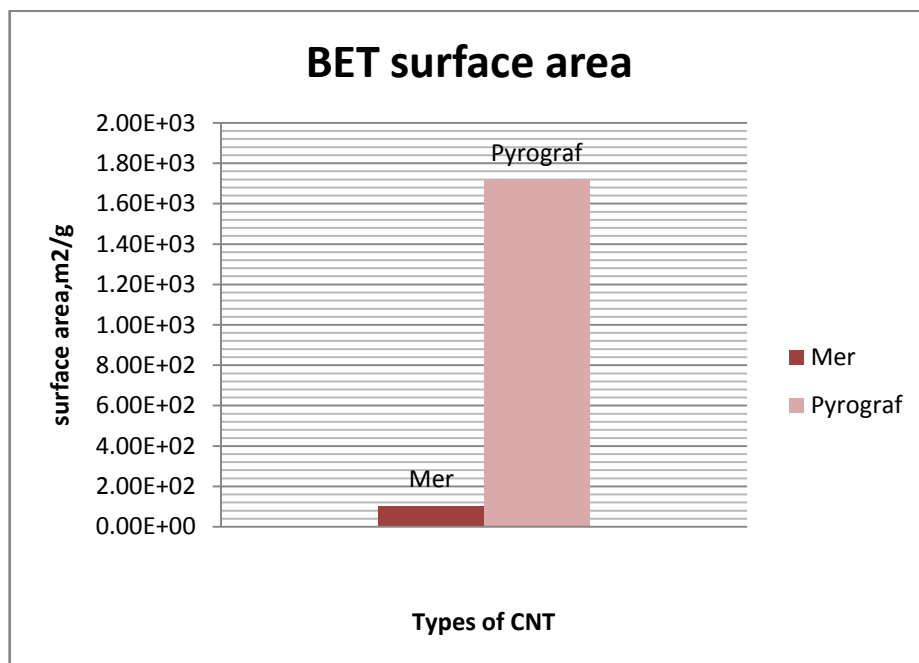


Figure 4.2 BET surface area

From data that we collected from BET testing, Pyrograf has the largest surface area compared to MER. The high surface area is due to high distribution of micropores in this sample. Note that high surface area is good for thermal conductivity.

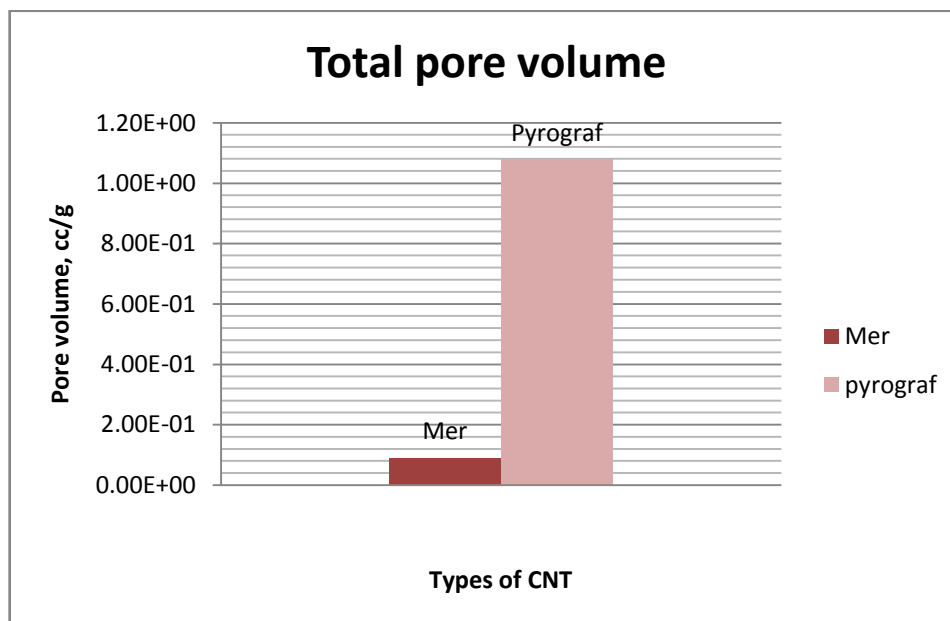


Figure 4.3 Total pore volume

Porosity plays important role because from porosity of a substance, we can determine the absorption capacity of the substance. We can determine the porosity by calculating the total pore volume, which is combination of micro, meso and macro pores. In this case, once again Pyrograf gave enormous result by obtaining the highest pore volume leaving MER a huge difference of pore volume.

CHAPTER V

5.1 CONCLUSION

This research is centres on nanofluid-based nanocarbon. The synthesis and the characterization of nanofluid-based nanocarbon will be discovered in this research. Nanocarbons can be defined as carbon material built from sp^2 bond building block in a nanoscale , and include various forms of carbons in the range from fillarence, carbon nanotube to nano-porous material. In this research nanofluids-based nanocarbons have been discovered such as the apparatus and the chemical reagents to make nanofluids based nanocarbon and the standard procedure how to produce nanofluid-based nanocarbon. The result show that all of samples are stable therefore, the synthesis of nanofluids based nanocarbons are corrects. The data show that Pyrograf are more stable than nanoamor because pyrograf is patented, very fine, and highly graphitic. We conclude that between Pyrograf CNT gave better enhancement of thermal conductivity compared to MER CNT. The results clearly show that each of CNT that we tested gave slight enhancement of thermal conductivity of the based fluid. This indicates that CNT was proven and have capacity to enhance the thermal conductivity of distilled water even though there are differences between CNT that we tested. In our case, Pyrograf have a better thermal conductivity at 45C, 1.0 wt% with 0.812 W/mK and it enhanced the based fluid as high as 31.15%. With high number of surface area and total pore volume, this shows that Pyrograf CNT have a brighter usage to be commercialized and

be used as nanoparticles to be suspended inside conventional heat transfer fluids. But there are explanation why Pyrograf gave such amazing results. Fluid with high thermal conductivity has great potentials for lot of application such as industrial cooling application, automotivce coolant, heat transfer application and electronic application.

5.2 RECOMMENDATION

Stable nanofluid based nanocarbon can be check accurately if use the laser test and stability test. In this research the laser test and stability test cannot be used because it not finished fabricate by the time that nanofluid based nanocarbon have to be tested. The more accurate stability of nanofluid based nanocarbon can be achieved if the specimen can be tested with lasert test and stability test. So the recommendation is nanofluid based nanocarbon should be tested with the laser test and stability test to get more accurate reading.

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APPENDIX 1

GANTT CHART PSM 1

Week \ Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Select the title and Confirmation.									M I D T E R M B R E A K								
Phase 1																	
Introduction																	
Literature review																	
Selected material																	
Methodology																	
Report PSM 1 writing																	
Submit report																	

GANTT CHART PSM 2

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