

**SYNTHESIS AND CHARACTERIZATIONS OF  
AMORPHOUS CARBON NANOTUBES/  
GOLD PARTICLES HYBRID MATERIALS**

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## ABSTRACT

Carbon nanotubes (CNT) have attracted great attentions due to its unique properties. However, most works being carried out focus on crystalline CNT. In this work, amorphous CNT (a-CNT) were synthesized successfully via a simple chemical technique at 220 °C in a short period of time. Surface morphological studies revealed that as prepared nanotubes present in agglomerated tubular structures with open ends, having diameter of 51.6 nm. The diameter of a-CNT reduced to 40 nm upon functionalization with nitric acid and further reduced to 10.2 nm as treated with auric chloride solution due to introduction of defective sites by these treatments. Both structural and elemental studies confirmed that the nanotubes were carbon and amorphous. From zeta potential measurement, it was found that nitric acid served as the most effective oxidation agent in functionalizing a-CNT with carboxyl groups compared to citric, sulphuric, and hydrochloric acids. Oxidation of nanotubes increased dispersion stability and ensured the successful hybridization between the a-CNT and gold (Au) nanoparticles. Thermal stability of a-CNT decreases with decorations of gold particles on its surface as per findings in Thermogravimetry Analysis (TGA). Electrical conduction are proven to be improved by surface modification where functionalized a-CNT has lower electrical resistivity than as-synthesized a-CNT, and the electrical resistivity decreases significantly with increasing gold content. As-synthesized and modified a-CNT/Epoxy composites exhibits lower electrical resistivity when cured in room temperature compared to 15 °C, where exception was found on functionalized a-CNT. Through transference number measurement, gold particles are found to contribute to the overall electrical conduction via electron conduction.

## ABSTRAK

Nanotube karbon (CNT) telah menarik perhatian yang besar kerana sifat-sifat yang unik. Walau bagaimanapun, kebanyakan kerja penyelidikan dijalankan memberi tumpuan kepada CNT kristal. Dalam karya ini, CNT amorfus (a-CNT) telah disintesis melalui teknik kimia pada suhu 220 °C dalam tempoh masa yang singkat. Kajian morfologi permukaan mendedahkan bahawa nanotube berstruktur tiub dengan hujung terbuka, berdiameter 51.6 nm. Diameter CNT dikurangkan kepada 40 nm apabila difungsionalisi dengan asid nitrik dan dikurangkan lagi kepada 10.2 nm apabila dikacau dengan larutan klorida Auric disebabkan penambahan struktur defek dalam process tersebut. Kedua-dua kajian struktur dan unsur mengesahkan bahawa nanotube karbon dan amorfus. Dari potensi zeta, ia telah mendapati bahawa asid nitrik sebagai agen pengoksidaan yang paling berkesan dalam mengfungsionalisi CNT-dengan kumpulan carboxyl berbanding asid sitrik, sulfurik, dan hidroklorik. Pengoksidaan nanotube meningkatkan kestabilan dalam larutan air dan memastikan hibridisasi berjaya antara a-CNT dan nanopartikel emas (Au). Kestabilan haba CNT berkurangan dengan hiasan zarah emas di permukaannya. Kepekatan yang paling optimum larutan klorida emas dalam rawatan satu-CNT untuk mendapatkan sampel haba stabil adalah 7.5 g/dm<sup>3</sup>. Konduksi elektrik terbukti dipertingkatkan oleh pengubahsuaian permukaan mana functionalized CNT mempunyai rendah kerintangan elektrik daripada yang disintesis CNT-, dan kerintangan elektrik berkurangan dengan ketara dengan peningkatan kandungan emas. As-disintesis dan komposit a-CNT/Epoxy diubahsuai mempamerkan rendah kerintangan elektrik apabila sembuh pada suhu bilik berbanding 15 °C, di mana pengecualian telah dijumpai pada functionalized-CNT. Melalui pengukuran bilangan pemindahan, zarah emas didapati menyebabkan pengaliran elektron.

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## TABLE OF CONTENTS

<b>Title</b>	<b>Page</b>
TITLE PAGE	i
ORIGINAL LITERARY WORK DECLARATION	li
ABSTRACT	iii
ABSTRAK	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi-viii
LIST OF FIGURES	ix-xi
LIST OF TABLES	xii
LIST OF SYMBOLS AND ABBREVIATIONS	xiii
PUBLICATION	xiv
<b>CHAPTER ONE: INTRODUCTION</b>	<b>1</b>
1.1 Background	1-4
1.2 Importance of Study	4-6
1.3 Research Objectives	6
1.4 Scope of Research Work	6-8
<b>CHAPTER TWO: LITERATURE REVIEW</b>	<b>9</b>
2.1 Carbon Nanotubes	9
2.1.1 General Properties of CNT	11-14
2.1.2 Historical Development of CNT	14-17
2.2 Synthesis for Crystalline CNT	17

2.2.1 Arc Discharge	17-19
2.2.2 Laser Ablation	19-21
2.2.3 Chemical Vapor Deposition	21-23
2.2.4 Hydrothermal Synthesis	23-24
2.3 Synthesis methods for Amorphous CNT	24
2.3.1 Chemical Vapor Deposition	25-26
2.3.2 Arc Discharge	26-27
2.3.3 Other Methods	27-30
2.4 Properties of Amorphous CNT	30
2.4.1 Mechanical and Thermal Properties	30-31
2.4.2 Electrical Properties	32-34
2.4.3 Optical Properties	34-40
2.4.4 Suspension Stability	40-42
2.4.5 Hybridization Properties	42-45
2.5 Potential Applications of Amorphous CNT	45-50
<b>CHAPTER THREE: MATERIALS AND METHODS</b>	<b>51</b>
3.1 Raw Materials	51-52
3.2 Preparation of Samples	52-55
3.3 Characterization Method	56
3.3.1 Morphological Studies	56
3.3.2 Microstructural Studies	56
3.3.3 Elemental Analysis	57
3.3.4 Suspension Stability	57

3.3.5 Optical Studies	57-58
3.3.6 Thermal Studies	58
3.3.7 Electrical Studies	58-59
<b>CHAPTER FOUR: RESULTS AND DISCUSSION</b>	<b>60</b>
4.1 Morphological Studies of as-synthesized a-CNT	61-65
4.2 Functionalization of a-CNT	66-67
4.3 Morphological Studies of modified a-CNT	68-76
4.4 Microstructural Studies	77-78
4.5 Elemental Studies	79-81
4.6 FTIR Studies	81-83
4.7 Optical Studies	83-88
4.8 Raman Studies	88-91
4.9 Thermal Studies	91-96
4.10 Electrical Studies	96-102
<b>CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS</b>	<b>103-104</b>
<b>REFERENCES</b>	<b>105-115</b>



## LIST OF FIGURES

<b>Figure 1.1:</b>	The pathway of the research work	8
<b>Figure 2.1:</b>	Types of Carbon Nanotubes: (a) SWCNT; (b) MWCNT; (c) a-CNT (Harns <i>et al.</i> 2009)	10
<b>Figure 2.2:</b>	Schematic diagram of an arc discharge system (Anyo <i>et al.</i> 2006)	18
<b>Figure 2.3:</b>	Schematic diagram of a laser ablation method (Scott <i>et al.</i> 2001)	20
<b>Figure 2.4:</b>	Schematic Diagram of CVD method (Kumar <i>et al.</i> 2010)	22
<b>Figure 2.5:</b>	The kataura plot that shows calculated gap energies with different diameters for different types of materials (Kataura <i>et al.</i> 1999)	36
<b>Figure 2.6:</b>	Energy level diagram of stokes and anti-stokes Raman scattering	38
<b>Figure 2.7:</b>	A typical raman spectrum from a SWCNT sample (Irurzun <i>et al.</i> 2010)	39
<b>Figure 2.8:</b>	(a) Functionalization using –COOH site.(Balasubramanian, 2005). (b) Typical defects in CNT (Hirsch, 2002)	42
<b>Figure 2.9:</b>	Illustration to the Laplace Equation	44
<b>Figure 2.10:</b>	Simulative view of the process for attaching gold nanoparticles to carboxyl functionalized CNT (Jiang <i>et al.</i> 2003)	45
<b>Figure 3.1:</b>	As-synthesized a-CNT in powder form	53
<b>Figure 3.2:</b>	a-CNT/Epoxy composite in coin shape	54
<b>Figure 3.3:</b>	Flow chart of sample preparation	55
<b>Figure 4.1:</b>	FE-SEM images of the as-synthesized a-CNT at different magnification: (a) 5000 X; (b) 10000 X	61
<b>Figure 4.2:</b>	TEM images of the as-synthesized a-CNT at different magnifications: (a) 28000 X; (b) 75000 X	63

<b>Figure 4.3:</b>	HRTEM image of as-synthesized a-CNT	64
<b>Figure 4.4:</b>	Zeta Potential for a-CNT functionalized with (a) HNO <sub>3</sub> , (b) H <sub>2</sub> SO <sub>4</sub> , (c) HCl, (d) Citric Acids and (e) as-synthesis a-CNT	66
<b>Figure 4.5:</b>	FE-SEM images of the as-synthesized a-CNT at different magnification: (a) 5000 X; (b) 10000 X	68
<b>Figure 4.6:</b>	TEM image of nitric acid functionalized a-CNT	70
<b>Figure 4.7:</b>	HRTEM image of nitric acid functionalized a-CNT	71
<b>Figure 4.8:</b>	FE-SEM images of hybridized a-CNT/Au at different magnification: (a) 10000 X; (b) 70000 X	73
<b>Figure 4.9:</b>	HRTEM images of hybridized a-CNT/Au at different magnification: (a) 4,000,000 X; (b) 400,000 X	
<b>Figure 4.10:</b>	XRD patterns for (a) as-synthesized a-CNT; and (b) hybridized a-CNT/Au	75
<b>Figure 4.11:</b>	EDX spectra of a-CNT for (a) as-synthesized; (b) functionalized ; (c) 2.5g/dm <sup>3</sup> ; (d) 5g/dm <sup>3</sup> ; (e) 7.5g/dm <sup>3</sup> ; (f) 10g/dm <sup>3</sup> AuCl <sub>3</sub> solution treated	77
<b>Figure 4.12:</b>	Zeta Potential for a-CNT functionalized with (a) HNO <sub>3</sub> , (b) H <sub>2</sub> SO <sub>4</sub> , (c) HCl, (d) Citric Acids and (e) as-synthesis a-CNT	79
<b>Figure 4.13:</b>	FTIR spectra for a-CNT functionalized with (a) HNO <sub>3</sub> , (b) H <sub>2</sub> SO <sub>4</sub> , (c) Citric Acid, (d) HCl and (e) as-synthesis a-CNT	81
<b>Figure 4.14:</b>	UV-Vis absorbance spectra for (a) as-synthesized; (b) functionalized; (c) 2.5 g/dm <sup>3</sup> (d) 5 g/dm <sup>3</sup> (e) 7.5 g/dm <sup>3</sup> (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution treated; a-CNT.	83
<b>Figure 4.15:</b>	Tauc/Davis-Mott plots for (a) as-synthesized; (b) functionalized;	

	hybridized with (c) 2.5 g/dm <sup>3</sup> (d) 5 g/dm <sup>3</sup> ; (e) 7.5 g/dm <sup>3</sup> ; (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution.	85
<b>Figure 4.16:</b>	Raman Spectra of (a) as-synthesized; (b) functionalized; (c) 2.5 g/dm <sup>3</sup> ; (d) 5 g/dm <sup>3</sup> ; (e) 7.5 g/dm <sup>3</sup> ; (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution treated; a-CNT	89
<b>Figure 4.17:</b>	TGA curves and its derivative of (a) as-synthesized; (b) functionalized; hybridized with (c) 2.5 g/dm <sup>3</sup> ; (d) 5 g/dm <sup>3</sup> ; (e) 7.5 g/dm <sup>3</sup> ; (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution a-CNT	93
<b>Figure 4.18:</b>	Nyquist plots of (a) as-synthesized; (b) functionalized; Hybridized (c) 2.5 g/dm <sup>3</sup> ; (d) 5 g/dm <sup>3</sup> ; (e) 7.5 g/dm <sup>3</sup> ; (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution; a-CNT/Epoxy composites cured in room temperature	97
<b>Figure 4.19:</b>	Nyquist plots of (a) as-synthesized; (b) functionalized; Hybridized (c) 2.5 g/dm <sup>3</sup> ; (d) 5 g/dm <sup>3</sup> ; (e) 7.5 g/dm <sup>3</sup> ; (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution treated; a-CNT/Epoxy composites cured in 15 °C	98
<b>Figure 4.20:</b>	Current variations of (a) as-synthesized; (b) functionalized; (c) 2.5 g/dm <sup>3</sup> ; (d) 5 g/dm <sup>3</sup> ; (e) 7.5 g/dm <sup>3</sup> ; (f) 10 g/dm <sup>3</sup> AuCl <sub>3</sub> solution treated; a-CNT/Epoxy composites with time.	101

## LIST OF TABLES

Table 4.1:	Interplanar spacing ( $d_{hkl}$ ) from HRTEM, XRD and lattice constant (a) with corresponding ( $hkl$ ) values of gold particles	75
Table 4.2:	EDX Elemental analysis for all samples	78
Table 4.3:	Absorption wavelength and $E_g$ values	87
Table 4.4:	The corresponding peaks' frequency (Raman shift) for all samples in Raman Spectra	90
Table 4.5:	Temperatures and percentage weight lost.	95
Table 4.6:	Resistivity and $t_i$ at 15 °C and 27 °C	101

## LIST OF SYMBOLS AND ABBREVIATIONS

CNT	Carbon nanotubes
a-CNT	Amorphous carbon nanotubes
SWCNT	Single-walled carbon nanotubes
DWCNT	Double-walled carbon nanotubes
MWCNT	Multi-walled carbon nanotubes
UV-Vis	Ultraviolet-visible
TEM	Transmission electron microscopy
HRTEM	High resolution transmission electron microscopy
FE-SEM	Field emission scanning electron microscopy
XRD	X-ray diffraction
EDX	Energy-dispersive X-ray
FTIR	Fourier transform infrared
TGA	Thermogravimetric analyzer
$E_g$	Band gap
CVD	Chemical vapour deposition
AAO	Aluminium oxide templates
$Fe(C_5H_5)_2$	Ferrocene
$d_{hkl}$	Interplanar spacing
$h\nu$	Photon energy of the incident light
$n$	Type of optical transition
B	Constant in Tauc/Davis-Mott model
$I_D/I_G$	Intensity ration between G and D bands

## **PUBLICATION**

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