

CONTENTS

	Page No.
Title Page	i
Certificate of Approval	ii
Certificate from supervisor	iii
Acknowledgements	iv
Declaration	v
List of Symbols and Abbreviations	vi
Abstract	vii
Contents	viii
Chapter 1 Introduction	1
1.1 A brief history of carbon nanotubes	2
1.2 Structure	4
1.3 Properties	7
1.4 Synthesis methods	11
1.4.1 Arc discharge	11
1.4.2 Laser ablation	14
1.4.3 Chemical vapor deposition	16
1.4.3.1 Catalyst	18
1.4.3.2 Growth mechanisms	23
1.4.3.3 Growth morphologies	26
1.5 Motivation, objectives and organization of thesis	27
Chapter 2 Experimental details	31

2.1	Catalyst preparation	31
2.1.1	Deposition of the elemental metal catalysts using thermal evaporation	32
2.1.1.1	Thermal evaporation	32
2.1.1.2	Preparation process	34
2.1.2	Deposition of metal complex catalysts using spin coater	35
2.1.2.1	Spin coating	35
2.1.2.2	Lithography	36
2.1.2.3	Preparation process	37
2.2	Growth of carbon nanotubes by chemical vapor deposition	39
2.2.1.	The chemical vapor deposition system	41
2.3	Characterization methods	44
2.3.1.	X-ray diffraction	44
2.3.2	Atomic force microscopy	46
2.3.3	Scanning electron microscopy	49
2.3.4	Transmission electron microscopy	50
2.3.5	Energy dispersive X-ray Spectroscopy	53
2.3.6	Raman spectroscopy	53
Chapter 3	Growth and characterization of carbon nanotubes by chemical vapor deposition using elemental metal catalysts	57
3.1	Synthesis of carbon nanotubes using thermally evaporated elemental Fe as metal catalyst	57
3.1.1	Growth temperature dependence on the Fe catalyzed growth of carbon nanotubes	57
3.1.1.1	Experimental details	57

	3.1.1.2 Results and discussion	58
	3.1.1.3 Summary	67
	3.1.2 Pre-heating effect on the Fe catalyzed growth of carbon nanotubes	68
	3.1.2.1 Experimental details	68
	3.1.2.2 Results and discussion	68
	3.1.2.3 Summary	77
3.2	Synthesis of carbon nanotubes using thermally evaporated elemental Ni metal catalyst	78
	3.2.1 Experimental details	78
	3.2.2 Results and discussion	78
	3.2.3 Summary	86
Chapter 4	Growth and characterization of carbon nanotubes by chemical vapor deposition using a metal complex as catalyst	87
4.1	Synthesis of carbon nanotubes using spin coated Fe-Mod-PR	87
	4.1.1 Effect of growth temperature on the carbon nanotubes grown using Fe-Mod-PR	87
	4.1.1.1 Experimental details	87
	4.1.1.2 Results and discussion	88
	4.1.1.3 Summary	94
	4.1.2 Lithographically defined site selective growth of carbon nanotubes using Fe-Mod-PR	95
	4.1.2.1 Experimental details	95
	4.1.2.2 Results and discussion	95
	4.1.2.3 Summary	104

4.2	Synthesis of carbon nanotubes using spin coated Ni-Mod-PR	105
4. 2.1	Lithographically defined site selective growth of carbon nanotubes using Ni-Mod-PR	105
4.2.1.1	Experimental details	105
4.2.1.2	Results and discussion	105
4.2.1.3	Summary	114
Chapter 5	Summary, conclusions and scope for future work	115
5.1	Summary	115
5.2	Conclusions	118
5.3	Scope for future work	118
5.4	Author's contribution	119
	References	120
	List of research publications	135
	Author's Vitae	137