

بسم الله الرحمن الرحيم





شبكة المعلومات الجامعية التوثيق الالكتروني والميكرو فيلم



جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار





بعض الوثائق الأصلية تالفة





بالرسالة صفحات
لم ترد بالأصل





**Ain Shams University
Faculty of Science
Chemistry Department**



Preparation and characterization of modified carbon -based electrodes for energy storage devices

A Thesis

**Submitted to Chemistry Department Faculty of Science
Ain Shams University in Partial Fulfillment for Requirements
Of the Master Degree of Science (M.Sc) in Chemistry**

By

Hany Khammar Imbaby Abdel- Fattah

B Sc in Chemistry Faculty of Science Ain Shams University 2013

Under Supervision of

Prof. Dr. Hamdy Hassanien Hassan

Professor of Physical Chemistry

Chemistry Department, Faculty of Science, Ain Shams University

Dr. Hesham Samir Abdel-Samad

Lecturer of Physical Chemistry

Chemistry Department, Faculty of Science, Ain Shams University

Dr. Abdalla Abdelwahab Abdelsalam

Lecturer Material Science and Nanotechnology Department, Faculty of

Postgraduate Studies for Advanced Science, Beni Suf University

2019



Ain Shams University
Faculty of Science
Chemistry Department



Approval Sheet

Preparation and characterization of modified carbon -based electrodes for energy storage devices

By

Hany Khammar Imbaby Abdel- Fattah

B Sc in Chemistry Faculty of Science Ain Shams University 2013

This thesis for master degree has been approved by

Prof. Dr. Hamdy Hassanien Hassan

Professor of Physical Chemistry, Chemistry Department, Faculty of Science,
Ain Shams University

Dr. Hesham Samir Abdel-Samad

Lecturer of Physical Chemistry Chemistry, Department, Faculty of Science,
Ain Shams University

Dr. Abdalla Abdelwahab Abdelsalam

Lecturer Material Science and Nanotechnology Department, Faculty of
Postgraduate Studies for Advanced Science, Beni Suef University

Head of Chemistry Department

Prof. Dr. Ayman Ayoub Abdel-Shafi

2019



Ain Shams University
Faculty of Science
Chemistry Department



Student Name: Hany Khammar Imbaby Abdel- Fattah

Scientific Degree: M.Sc.

Faculty Name: Faculty of Science Ain Shams University

Graduation Year: 2013

Granting Year:

Head of Chemistry Department
Prof. Dr. Ayman Ayoub Abdel-Shafi

2019



﴿ قالوا سبحانك لا علم لنا إلا ما علمتنا

إنك أنت العليم الحكيم ﴾

صدق الله العظيم [البقرة ٣٢]

To my Family

And

My son ZAIN

ACKNOWLEDGEMENT

- *At First, I'd like to knee praying to ALLAH for helping me to do this work.*

- *I would like to express my deepest gratitude, sincere thanks and appreciation to my professor and supervisor **Prof. Dr. Hamdy H. Hassan** for his kind patience with me during the entire work great help and guide to me.*

- *Also, I would like to express my deepest gratitude, sincere thanks and appreciation to **Dr. Hesham Samir Abdel-Samad** for his great help and support to me.*

- *Finally I would like to thanks and appreciation to **Dr.Abdalla Abdelwahab Abdelsalam** for his great help, guide and support. To me*

Table of Contents

Table of Content.....	I-V
Table of Figures	VI-IX
Tables of Tables	X- XI
List of Abbreviations.....	XII-XIV
Abstract	XV
Chapter One.....	1
1 Introduction.....	1
1.1 Classification of energy storage technologies.....	2
1.2 Historical background	2
1.3 The Performance of different types of energy storage devices (Ragone plot)	4
1.4 Conventional capacitors	6
1.5 Electrolytic capacitors	8
1.6 Supercapacitors	8
1.7 Mechanisms of charge storage in supercapacitors	10
1.7.1 Electric double layer mechanism.....	10
1.7.2 Pseudo-capacitance mechanism	13
1.8 Classification of Supercapacitors	13

1.8.1	Electrochemical Double-Layer Capacitors.....	15
1.8.1.1	Carbon gels	16
1.8.2	Pseudo-capacitors	18
1.8.2.1	Conducting polymer (poly aniline).....	18
1.8.3	Hybrid Capacitors.....	22
1.8.3.1	Composite electrodes.....	22
Chapter Two		24
2	Experimental: Materials and Measurement Methods.....	24
2.1	Chemicals and electrode materials fabrication	24
2.1.1	Materials	24
2.1.2	Synthesis of carbon xerogels (CX).....	24
2.1.3	Synthesis of polyaniline (PANI).....	25
2.1.4	Synthesis of cobalt doped carbon xerogels (Co-CX)	26
2.1.5	Synthesis of PANI/CX composites.....	26
2.1.6	Synthesis of PANI/Co-CX composite	27
2.1.7	Electrode preparation.....	28
2.2	Physical Characterization of electrode materials	29
2.2.1	Surface characterization and pore size analysis	29
2.2.2	X-ray diffraction (XRD).....	29

2.2.3	Fourier transform infrared spectroscopy (FTIR).....	30
2.2.4	Field emission scanning electron microscope (FE-SEM)	30
2.2.5	Transmission Electron Microscope, (TEM).....	31
2.3	Electrochemical characterization of electrode materials	31
2.3.1	Cyclic voltammetry (CV)	31
2.3.2	Galvanostatic charge-discharge (GCD).....	32
2.3.3	Electrochemical Impedance Spectroscopy (EIS)	33
2.4	Calculation of specific capacitance	34
Chapter Three.....		37
3	Enhanced stability of simply prepared polyaniline-based electrodes towards supercapacitors application using carbon xerogels as a support material.....	37
3.1	Aim	37
3.2	Results and discussion.....	38
3.2.1	Physicochemical properties	38
3.2.1.1	Surface characterization and pore size analysis	38
3.2.1.2	X-ray diffraction (XRD)	43
3.2.1.3	FTIR spectroscopy	46

3.2.1.4	Field emission scanning electron microscope FE-SEM	48
3.2.2	Supercapacitors application	50
3.2.2.1	Cyclic voltammetry (CV)	50
3.2.2.2	Galvanostatic charge-discharge GCD	56
3.2.2.3	The Ragone plots and the stability test.....	60
3.2.2.4	Electrochemical impedance spectroscopy (EIS)	63
Chapter Four.....		74
4	Polyaniline@Cobalt doped Carbon Xerogels composite as Efficient Electrode for Supercapacitors	74
4.1	Aim	74
4.2	Results and discussion.....	75
4.2.1	Physicochemical properties	75
4.2.1.1	Surface characterization and pore size analysis	75
4.2.1.2	X-ray diffraction (XRD)	77
4.2.1.3	FTIR spectroscopy	79
4.2.1.4	FE-SEM and TEM	81
4.2.2	Supercapacitors application	84
4.2.2.1	Cyclic voltammetry/ CV	84
4.2.2.2	Galvanostatic Charge-Discharge (GCD)	89