



**CHARACTERIZATION AND ANALYSIS ON THE QUALITY OF THE  
ANODE MATERIAL OF USED LOW VOLTAGE LITHIUM ION  
BATTERY**

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by

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## **APPROVAL**

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisory committee is as follow:

.....  
(ASSOC. PROF. DR. MOHD ASYADI AZAM BIN MOHD ABID)

## ABSTRAK

Bateri litium-ion adalah salah satu daripada jenis bateri yang digunakan secara meluas. Bateri ini adalah sel sekunder atau bateri yang boleh dicas semula berkali-kali. Oleh itu, banyak penyelidik telah menganalisis kualiti bateri litium-ion. Bateri ini terdiri daripada tiga komponen utama iaitu anod (elektrod negatif), katod (elektrod positif) dan elektrolit. Tambahan pula, terdapat banyak penyelidikan tentang pencirian bahan anod baru, tetapi terdapat sedikit penyelidikan mengenai pencirian pada morfologi, struktur dan keadaan bahan anod yang telah digunakan. Selepas itu, tiada penyelidikan yang lepas mengenai pembongkaran bateri litium-ion dan bahan anod. Tujuan kajian ini adalah untuk membongkar bateri litium-ion komersial dan bahan anod yang telah digunakan dan menyelidik pencirian anod seterusnya belajar dan membandingkan ia dengan pencirian bahan anod yang baru. Bateri litium-ion komersial yang telah digunakan telah dibongkar dengan menggunakan teknik dan peralatan yang khusus (pemotong paip), seterusnya anod akan diekstrak. Selepas itu, analisis morfologi dengan *scanning electron microscopy (SEM)* telah dijalankan untuk mengkaji bentuk bahan anod yang telah digunakan. Seterusnya, analisis komposisi dan struktur dengan *X-ray diffraction (XRD)* dan *Raman spectroscopy* telah dijalankan untuk menganalisis permukaan dan struktur kristal bahan anod yang telah digunakan. Selepas pembongkaran, analisis morfologi dan komposisi dijalankan, kondisi dan pencirian bahan anod yang baru dan yang telah digunakan telah dibandingkan dan akan dikaji perbezaan antara mereka. Penyelidikan ini sangat penting untuk dijalankan bagi menyediakan pencirian dan perbezaan antara bahan anod yang baru dan yang telah digunakan untuk meningkatkan lagi prestasi bateri litium-ion dalam bidang elektrik dan automotif pada masa hadapan.

## **ABSTRACT**

Lithium-ion battery is one of the most widely used type of battery. It is a secondary cell or rechargeable battery that can be charged and discharged many times. Therefore, there are many researchers have analyzed the quality of lithium-ion battery. This battery consists of three main components; anode (negative electrode), cathode (positive electrode) and electrolyte. Furthermore, the problems are there are many researches about the characterization of the new anode material, but there is little research about the characterization on morphology, condition and structure of the used anode material. Then, there are also no previous research about the disassembly of the lithium-ion battery and anode material. The purpose of this study is to disassemble the used commercial lithium-ion battery and anode material, then study and compare the characterizations of used and new anode materials. The used commercial lithium-ion battery has been disassembled by using specific technique and equipment (pipe cutter), then the used anode material will be extracted. After that, the morphological analysis with scanning electron microscopy (SEM) has been carried out to study the form and shape of the both anode materials. Next, the composition and structure analysis with X-ray diffraction and Raman spectroscopy have been conducted to analyze the surface and crystalline structure of the both anode materials. After that, the condition, the morphological and compositional structure of both anode material have been compared based on their characterizations and relate them with quality. This research is significantly important to be carried out as to provide the characterizations and contrast of both new and used anode material that will improve the performance of the lithium-ion battery in electrical and automotive fields in the future.

## **DEDICATION**

Only

my beloved father, Faizal bin Ismail

my appreciated mother, Ramlah binti Alwi

my adored sisters, Balqis and Bahirah

for giving me moral support, money, cooperation, encouragement and also understandings

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# TABLE OF CONTENT

Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Contents	v
List of Tables	ix
List of Figures	x
List of Abbreviations	xii
List of Symbols	xiii

## CHAPTER 1: INTRODUCTION

1.1	Background of Study	1
1.2	Problem Statement	3
1.3	Objectives	4
1.4	Scopes	5

## CHAPTER 2: LITERATURE REVIEW

2.1	Lithium-Ion Battery	6
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2.1.1	History of lithium-ion battery	7
2.1.2	Conventional batteries	7
2.1.2.1	Lead acid battery	8
2.1.2.2	Alkaline battery	8
2.1.2.3	Nickel cadmium battery	9
2.2	Composition of Lithium-Ion Battery	9
2.2.1	Anode	10
2.2.2	Cathode	10
2.2.3	Electrolyte	11
2.3	Characterization of Anode	11
2.3.1	Morphological analysis by using scanning electron microscopy (SEM)	11
2.3.2	Composition and structure analysis	13
2.3.2.1	X-ray diffraction (XRD)	13
2.3.2.2	Raman spectroscopy	16
2.4	Electrochemical Properties of Lithium-Ion Battery	18
2.5	Research Gap and Summary	19

## **CHAPTER 3: METHODOLOGY**

3.1	Overview of Methodology	21
3.2	Raw Material Preparation and Characterization	23
3.3	Disassembly of Used Lithium-Ion Battery	23
3.4	Morphological Analysis with Scanning Electron Microscopy (SEM)	25
3.4.1	Sample mounting	26

3.4.2	Sample grounding	27
3.4.3	Conductive graphite isopropanol base	27
3.4.4	Detectors and techniques	28
3.5	X-Ray Diffraction (XRD)	28
3.5.1	Sample orientation and texture	28
3.5.2	Crystallite size and strain	29
3.5.3	Sample preparation height	29
3.6	Raman Spectroscopy	30
3.7	Comparison of Anode (Negative Electrode)	31
3.8	Summary of Methodology	32
3.9	Expected Outcomes	33

## **CHAPTER 4: RESULTS AND DISCUSSIONS**

4.1	Overview	35
4.2	Disassembly of Used Lithium-Ion Battery	36
4.3	Morphological Analysis with Scanning Electron Microscopy (SEM)	37
4.4	Composition and Structure Analysis	40
4.4.1	X-ray diffraction (XRD)	40
4.4.2	Raman spectroscopy	42
4.5	Summary	44

## **CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS**

5.1	Conclusions	46
5.2	Recommendations	48
5.3	Sustainability Element	49

<b>REFERENCES</b>	<b>50</b>
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## LIST OF TABLES

2.1	Lithium-ion battery and lead acid battery	8
2.2	Comparison of nickel cadmium and lithium-ion battery	9

# LIST OF FIGURES

1.1	Construction of lithium-ion battery	2
1.2	(a) Discharging flow and (b) charging flow of lithium-ion battery	2
2.1	Composition of lithium-ion battery	10
2.2	SEM image of Si/Ag nanocomposites	13
2.3	The XRD patterns of the GOF, GFMs, and GeO <sub>2</sub> -NPs@GFM-2	16
2.4	Raman spectra of Moso bamboo-derived carbon	17
2.5	Raman spectra of GO and ZnS/GAs (GZ85) composites	17
2.6	Raman spectra of the raw nano-Si	18
3.1	Flowchart of methodology	22
3.2	Used lithium-ion battery	24
3.3	Pipe cutter	24
3.4	Personal protective equipment (gloves, goggle and mask)	25
3.5	Simple pin disc mount with a sample attached using conducting tape	26
3.6	Large round mounting platform and an aluminum pin disc	26
3.7	Raman spectroscopy illustration	30
3.8	Raman spectroscopy of carbon materials	31

3.9	Rayleigh and Raman scattering (Stokes and anti-Stokes)	31
3.10	Anode (negative electrode) material	33
3.11	SEM image of graphite	34
3.12	XRD pattern and Raman spectra of graphite	34
4.1	Disassembled used lithium-ion battery	36
4.2	Used and new anode material	36
4.3	1 kX magnification SEM images of a) new and b) used anode material	38
4.4	3 kX magnification SEM images of a) new and b) used anode material	39
4.5	XRD pattern of new anode material	41
4.6	XRD pattern of used anode material	41
4.7	Raman spectra of new anode material	43
4.8	Raman spectra of used anode material	43

## LIST OF ABBREVIATIONS

LIB	-	Lithium Ion Battery
PP	-	Polypropylene
PE	-	Polyethylene
HEV	-	Hybrid Electric Vehicles
EC-DMC	-	Ethylene Carbonate–Dimethyl Carbonate
FESEM	-	Field Emission Scanning Electron Microscopy
SAED	-	Selected Area Electron Diffraction
SEM	-	Scanning Electron Microscopy
XRD	-	X-Ray Diffraction
PXRD	-	Powder X-Ray Diffraction
PET	-	Poly(Ethylene Terephthalate)
HTT	-	Heat Treatment Temperature



## LIST OF SYMBOLS

Li-Ion	-	Lithium-Ion
LiPF <sub>6</sub>	-	Lithium Hexafluorophosphate
NiCd	-	Nickel Cadmium
LiMO <sub>2</sub>	-	Lithium Metal Oxide
NiO	-	Nickel Oxide
Ni-Mn	-	Nickel-Manganese
NiMn <sub>2</sub> O <sub>4</sub>	-	Nickel Manganite
KTO	-	Potassium Octatitanate
N <sub>2</sub>	-	Nitrogen
kV	-	Kilovolt
°	-	Degree
Cu K $\alpha$	-	Copper K(alpha)
Å	-	Angstrom
$\lambda$	-	Wavelength
min <sup>-1</sup>	-	Per minute
mA	-	Milliampere
kX	-	Kilo magnification
o	-	Degree

nm	-	Nanometer
$\theta$	-	Theta
a.u.	-	Arbitrary unit
$I_D/I_G$	-	Intensity ratio
$\text{cm}^{-1}$	-	Per centimeter

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

This study is about to investigate the characterization and analysis on the quality of the anode material of used low voltage lithium-ion battery. Nowadays, lithium-ion battery (li-ion is the most widely used type of battery. Tesla, Inc. is one of the company that used lithium-ion battery on their electric cars as it shows that lithium-ion battery is significant on these days. Lithium-ion battery is a rechargeable battery and it used lithium-based materials on the cathode electrode.

The components of this battery are made of four; anode, cathode, separator and electrolyte. One of the most commonly used cathode material is Lithium Cobalt Oxide (Lithium Cobaltate) or Lithium Manganese Oxide (Lithium Manganate) while anode is graphite, the electrolyte is Lithium hexafluorophosphate ( $\text{LiPF}_6$ ) and the separator is Polypropylene (PP) or Polyethylene (PE). The separator is a porous membrane that is very thin that separates the cathode (positive electrode) and anode (negative electrode). Lithium-ion batteries consists two current collectors. Cathode (positive electrode) use aluminium while anode (negative electrode) use copper as their current collector.

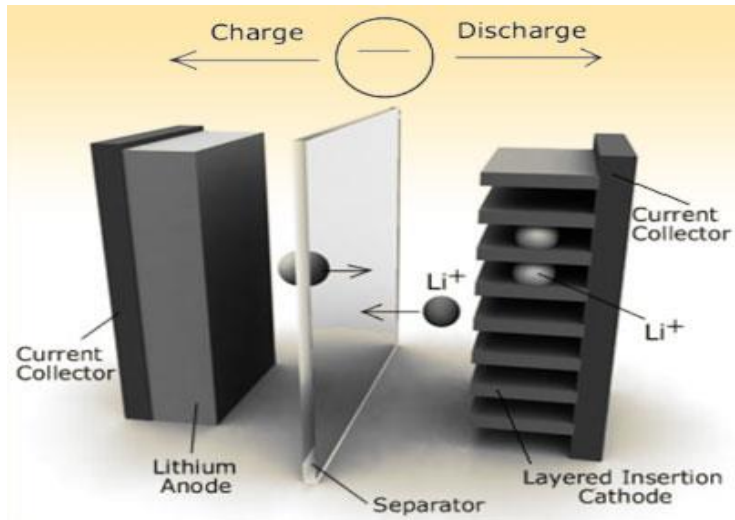


Figure 1.1: Construction of lithium-ion battery.

There are working principle of lithium-ion battery. When lithium-ion battery is discharging, lithium ions move via electrolyte from the anode (negative electrode) to the cathode (positive electrode). While when lithium-ion battery is charging, the lithium ions move from the cathode (positive electrode) through the electrolyte to the anode (negative electrode).

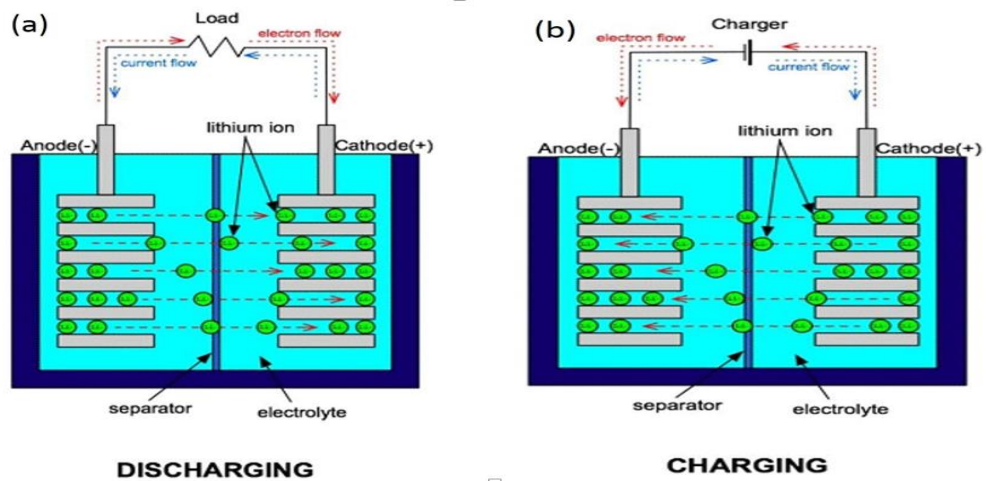


Figure 1.2: (a) Discharging flow and (b) charging flow of lithium-ion battery.

There are some reasons why lithium is used on the battery. One of the reasons is lithium is one of the first alkali that listed on the periodic table. As we know, the properties of alkali are low melting and boiling points. After that, they are very soft and light solid metal, have low density and high specific heat. Lithium-ion battery very have high energy density and lot of energy can be stored.

Nowadays, the most commonly used anode material is graphite. This is because the graphite powder on the anode electrode meets the voltage requirements of cathode electrode that are extremely light, porous and durable. One of the best characteristics of suitable and best anode electrode are have excellent conductivity, lightweight and low cost. Other materials that suitable for the anode electrode is silicon and carbon.

## **1.2 Problem Statement**

In this modern era that have advanced technology, quality is the most important factor and aspect of the electrodes; both anode and cathode. In order to enhance the quality of the anode electrode, many challenges must be faced and developed in the researches before investigate the characterization of the material and compare the characterizations of the anode electrode. Some of the challenges on this study are constraint of time and the budget provided. This study overcomes those problems and achieve the desired results for the better future.

One of the problems that need to be solve in this study is the conditions of the used anode (negative electrode) of lithium-ion battery. This is because there are many previous research that study about the conditions of new anode (negative electrode) but there are less about the conditions of the used anode (negative electrode) of lithium-ion battery. Lithium-ion battery is one of the most widely used type of battery, so there are concerns about the conditions of the used anode to ensure that the quality of lithium-ion battery is still good.

After that, the other problem is there are unknown characterizations of the used anode (negative electrode) of lithium-ion battery. The unknown characterizations include morphology

and structure of the used anode (negative electrode) of lithium-ion battery. The previous studies only showed and experimented on the new anode (negative electrode), so there are some curiosity about the morphology and structure of the used anode (negative electrode) of lithium-ion battery. These unknown characterizations are important because it will be different from the used anode (negative electrode) of lithium-ion battery.

The next problem that need to be solved is the comparison of the characterizations between the used and new anode (negative electrode) of lithium-ion battery. The comparison includes structure, condition and morphology of both anode (negative electrode) of lithium-ion battery. There are not many comparison between both anode (negative electrode) on previous research, so this study will differentiate the morphology, condition and structure of the used and new anode (negative electrode) of lithium-ion battery.

### **1.3 Objectives**

- i. To disassemble the used commercial lithium-ion battery and extract the anode (negative electrode) from the lithium-ion battery.
- ii. To analyze the morphological structure and composition of the used anode (negative electrode) of disassembled commercial lithium-ion battery.
- iii. To study the comparison of characterizations between the used and new anode (negative electrode) of disassembled commercial lithium-ion battery.

## 1.4 Scopes

The scope of this study are:

- i. In order to support the first objective, the power bank will be disassemble by using the specific equipment to pull out the lithium ion battery. Then, lithium ion battery will be disassembled to extract the anode (negative electrode). This is because to observe the condition of the used anode (negative electrode) of lithium-ion battery.
- ii. In order to achieve the second objective, the analysis will be carried out to analyze the characterizations of the used anode (negative electrode) of disassembled commercial lithium-ion battery. These analysis includes morphological, condition and structure of the used anode (negative electrode).
- iii. In order to support the third objective, the morphology, condition and structure of the used and new anode (negative electrode) of disassembled commercial lithium-ion battery will be compared. This study consists of six samples, the used and new anode (negative electrode) for each analysis. These characterizations will be compared and discussed in parallel to study the difference of both anode (negative electrode).

## **CHAPTER 2**

### **LITERATURE REVIEW**

This chapter is mainly describe the theory and research which have been defined and done by various researcher years ago. Related information of previous studies are extracted as references and discussion based on their research about the morphological, structure and composition analysis on the anode material of lithium ion battery.

#### **2.1 Lithium-Ion Battery**

Rechargeable batteries such as lithium-ion batteries are one of the best options to meet the increasing demand for electric energy storage such as mobile applications and developing electric vehicles (Ozanam & Rosso, 2016). There are working principle of lithium-ion battery. When lithium-ion battery is discharging, lithium ions move via electrolyte from the anode (negative electrode) to the cathode (positive electrode). While when lithium-ion battery is charging, the lithium ions move from the cathode (positive electrode) through the electrolyte to the anode (negative electrode).

There are some reasons why lithium is used on the battery. One of the reasons is lithium is one of the first alkali that listed on the periodic table. As we know, the properties of alkali are