Study of the effect of supercapasitors types on crystal structure and microstructure of supercapasitor electrode materials

by Edward B.o. Sihite , Budiarto Stepanus

Submission date: 12-Mar-2020 01:03PM (UTC+0700)

Submission ID: 1274160721

File name: tal_Structure_and_Microstructure_of_Supercapasitor_Electrode_Mat (3.1M)

Word count: 3215

Character count: 17463

3rd NICTE 2019

NOMMENSEN INTERNATIONAL CONFERENCE ON TECHNOLOGY AND ENGINEERING

Universitas HKBP Nommensen

PRO DEO ET PATRIA

INNOVATION AND APPLICATION OF INTERDISCIPLINARY RESEARCH IN SCIENCE, TECHNOLOGY, AND ENGINEERING

ABSTRACT

25-26 JULY 2019
MEDAN, INDONESIA

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

國立中正大學
National Chung Cheng University

IOP Publishing

PBN
Pangeran Beton Nusantara
Ready Mix Concrete & Batching Plant

DELI
Besi Ulir Kualitas SNI
SNI 07-2052-2002

Organized by:
Faculty of Engineering
Universitas HKBP Nommensen

3rd NICTE

Conference Organization

INITIATOR INSTITUTION
Faculty of Engineering
University of HKBP Nommensen

ORGANIZING INSTITUTION
University of HKBP Nommensen
Czech University of Life Sciences Prague
National Chung Cheng University

Honorary Chair :
Ir. Nurdin Tampubolon, MM
Dr.Haposan Siallagan, SH, MH

International Advisory Board :
Prof. Cheng Yuan Chang, CYCU – Taiwan
Assoc.Prof.Jiri Masek, CULS, Rep.Ceko
Prof. Yupiter H P Manurung – Malaysia
Dr.Himsar Ambarita, USU-Indonesia

Chairman :
Dr.Mula Sigiro, M.Si, PhD

Co-Chairman :
Dr.Ir. Timbang Pangaribuan, MT

Secretary :
Dr. Richard A.M Napitupulu, ST., MT

Parallel and Scientific Session:
Drs. Samse Pandiangan, MSc, PhD

Editorial Board :
Assoc. Prof. Petr Valasek, PhD., CULS – Czech
Ing. Abraham Kabutey, PhD., CULS – Czech
Doc. Ing. Michal Petru, Ph.D, TUL – Czech
Assoc. Prof. Dr. Gurkan AK. Gundil, OMU – Turkey
Prof. Shiao-Shing Chen PhD, NTUT – Taiwan
Prof. Poki Chen, PhD., NTUST – Taiwan
Dr. Darmawan Napitupulu, LIPI – Indonesia
Dr. Mula Sigiro, PhD., UHN – Indonesia
Dr.Mohd. Shahriman bin Adenan, UiTM – Malaysia
Dr. Turnad Lenggo Ginta, UTP – Malaysia
Dr.Samse Pandiangan, UHN – Indonesia
Dr. Tumiur Gultom, UNIMED – Indonesia
Dr. Riko Arlando Saragih, UKM – Indonesia

Treasurer :
Yetty R. Saragih, ST.MT.

Committee Member :
Parulian Siagian, ST.MT.
Libianko Sianturi, ST. MT.
Ir.Partahi Lumbangaol, M.Eng,Sc
Charles SP. Manurung, ST.MT.
Dr.Ir.Sindak Hutauruk, MSEE
Engelica Manurung, S.Pd

Keynote Speakers:

Prof.Tseng, Chung-Jen, PhD- Department of Mechanical Engineering, National Central University,Taiwan

Dr.Ing Azis Boing Sitanggang-Departemen Teknologi Pangan, Institut Pertanian Bogor, Indonesia

Prof. In Kyo Kim- Marketing and Design Thinking Centre, Gangneung Wonju National University, Korea

Dr.Mira Kartiwi- Department of Information System,International Islamic University Malaysia

Reviewer :

Dr. Tumiur Gultom, UNIMED – Indonesia
Dr. Janter Simanjuntak, UNIMED – Indonesia
Dr. Rondang Tambun, USU – Indonesia
Prof. Dr. Dyah Herwindiati, UNTAR – Indonesia
Assoc. Prof. Dr. Hugeng, UMN – Indonesia
Dr. Mukhtar Panjaitan, UHN – Indonesia
Dr. Samse Pandiangan, UHN – Indonesia
Dr. Sindak Hutauruk, UHN – Indonesia
Dr. Richard AM. Napitupulu, UHN – Indonesia
Himsar Ambarita, Dr.Eng., USU – Indonesia
Prof. Hsieh, Hung-Nien PhD, Taiwan
Dr. Janner Simarmata, UNIMED – Indonesia
Dr. Sabam Malau, NHU – Indonesia
Dr. Noverita Situmorang, USU - Indonesia
Dr. Tulus B. Sitorus, USU - Indonesia
Dr. Emil Kaburuan, BINUS – Indonesia
Dr. Azridjal Aziz, UNRI – Indonesia
Dr. dr. Jenny Ria, NHU – Indonesia
Prof. Yupiter Manurung, UTM – Malaysia
Prof. Cheng Yuan Chan, CYCU – Taiwan
Prof. Shyh-Leh Chen, CCU – Taiwan
Dr. Gunawan Wang, BINUS – Indonesia
Dr. Sagir Alva, BINUS – Indonesia
Dr. Suganda Girsang, BINUS – Indonesia
Assoc. Prof. Petr Valasek, CULS – Czech
Dr. Dedi Trisnawarman, UNTAR – Indonesia
Ing. Abraham Kabutey, PhD., CULS – Czech
Dr. Hotman Manurung, UHN – Indonesia
Jimmar Tan, MEng, ISTP – Indonesia
dr. Novita S. MSc, NHU – Indonesia
Robbi Rahim MT, ITM – Indonesia
Partahi Lumbangaol MEng, UHN – Indonesia
Timbang Pangaribuan MT, UHN – Indonesia
Charles Manurung, MT, UHN – Indonesia
Yetti Riris Saragi MT, UHN – Indonesia
Pandapotan Siagian MSc, ITDel – Indonesia

Administration and Supporting Staff :

Roslin Pasaribu
Parulian Sirait, S.Kom
Sungguh Rahmat Bohalima
Poltak Siahaan
Dody Siahaan
Hermina Hutapea
Mianna Siregar
Delfrida Purba
Wandro Siregar
Joel Bonatuah Sipayung

IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Study of the effect of supercapasitors types on crystal structure and microstructure of supercapasitor electrode materials

To cite this article: Edward B.O. Sihite *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **725** 012042

IOP Conf. Series: Materials Science and Engineering **725** (2020) 012042 doi:10.1088/1757-899X/725/1/012042

Study of the effect of supercapasitors types on crystal structure and microstructure of supercapasitor electrode materials

Edward B.O. Sihite[1], Stepanus[1], and Budiarto[2]

[1]Departement of Electrical Engineering, Faculty of Engineering, Universitas Kristen Indonesia
[2]Departement of Mechanical Engineering, Faculty of Engineering, Universitas Kristen Indonesia, Jl. MayjenSutoyo no.2, Cawang, Jakarta

[1]edwardsihite@uki.ac.id, stepanus@uki.ac.id, [2]budidamz@uki.ac.id

Abstract. Research on the effect of supercapacitor types on crystal structure and microstructure on the electrode material of supercapacitors has been carried out. Supercapacitor is a new technology developed from conventional capacitors for storing the energy needed. Supercapacitors have energy densities far greater than conventional capacitors and have a much larger power density than batteries. This research was carried out to determine the crystal structure, crystal lattice diameter size, microstructure and elemental composition of the different types of electrode materials of supercapacitors namely 4.700 µF, 6.800 µF, and 15.000 µF. Tests carried out included the determination of the crystal structure and size of the crystal lattice using X-ray diffractometers and observations of surface morphology and elemental composition by Scanning Electron Microscopy and X-ray Disversive Energy. The XRD test results from the three supercapacitor electrode materials have the form of a Cubic central body or Cubic Body Center structure, with a crystal lattice diameter between 25 - 428 nm. The results of observations with SEM-EDXS show that the microstructure of phase particles is scattered in the boundary area of the main phase (matrix). And the chemical composition is C: 6-7% by weight, O: 34-36% by weight, Al: 53-58% by weight, and P: 0.23-0.60% by weight.

1. Introduction

In today's modern life, electricity is a major necessity that cannot be avoided. Various technologies exist today, most of which require electrical energy storage devices. For example cellular phones and laptops need batteries as energy storage devices. However, the problem is that the battery has a small enough power density besides that it also takes a long time to charge (store) the electrical energy into the device. Therefore, technology is needed that has greater energy density and power density and shorter charging times to meet future technological needs. So far there has been great interest among researchers to develop and refine more efficient energy storage devices. One of these devices is a supercapacitor.

Supercapacitors have been used extensively in the fields of electronics and transportation, such as digital telecommunications systems, computer and pulse laser systems, hybrid electrical vehicles, and so on. Supercapacitors have several advantages compared to conventional batteries and capacitors, including a longer life time, principles and simpler models, shorter charging times, safety and high power density of 10-100 times greater.

Supercapacitor or Electrochemical Double Layer Capacitor (EDLC) has high power density, high energy density and has a long life cycle. This tool has several components

IOP Conf. Series: Materials Science and Engineering **725** (2020) 012042 doi:10.1088/1757-899X/725/1/012042

including electrodes, electrolytes and separators. The electrode consists of semiconductor materials such as carbon. Electrolytes can be either liquid or non-liquid depending on the manufacture of the supercapacitor. While this separator is made from a membrane that serves to pass ions that exchange from positive and negative electrodes.[2,3]

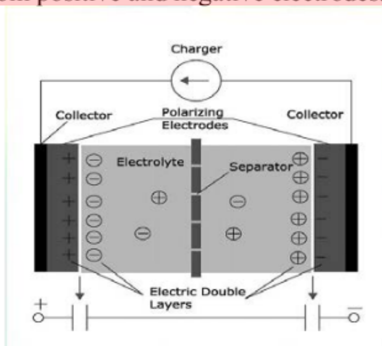

Figure 1. Type of configuration of supercapacitors

The working principle of a supercapacitor as shown in Figure 1 is that when charging, the ions from the two electrodes exchange through the separator. The negative ion from the positive electrode will move towards the negative electrode through the separator membrane and vice versa. When the ion exchange is stored in the supercapacitor, when discharge, the ions from the two electrodes that exchange the charge process return to their original position. The negative ion returns to the positive electrode so vice versa. The load in this process is removed from the supercapacitor and can be used for various purposes.[2]

2. Methodology

Materials and tools

The commercial material used in this study is the supercapacitor electrode material. The material is cut into a laboratory scale into 21 parts with a size of 10 mm x 10 mm x 0.05 mm. Equipments are used in this research is X-ray diffractometer with Cu K-α monochromatic radiation source (1.54056 Å), Miniflex 600,Rigaku brand, and SEM-EDXS brand ZEISS.

Ways of working.

a. X-ray diffractometer Source of Cu K-α monochromatic radiation (1.54056 Å).

Figure 2. *X-Ray Diffractometer (XRD) Miniflex 600*

The purpose of testing using XRD Miniflex 600 is to determine the size of the crystal lattice diameter, the degree of crystallinity, space group. Based on the position of the peaks

IOP Conf. Series: Materials Science and Engineering **725** (2020) 012042 doi:10.1088/1757-899X/725/1/012042

generated from XRD experimental data with a large angle of 2θ and comparing it with the database obtained from COD (Crystallography Open Database) Inorg REV 198327 2017.07.03 can get the phase that matches the tested sample. To find out the size of the crystal lattice diameter and the shape of the crystal can be known by using the D.Scherrer equation [1]:

$$t = k\lambda / (\beta \cos\theta) \quad \ldots 1$$

Information :
t = Size of crystallite diameter
k = Scherrer Provisions (0.89)
λ = Wavelength of X-ray diffraction (1.54046Å)
β = Overall width of maximum diffraction peak (FWHM)
θ = Bragg angle read by XRD engine

The XRD test data obtained were used to estimate crystallite size through analysis of the widening values of each crystal sample. Of the highest peaks generated from the tested samples shown from the image and obtained FWHM values.

b. Scanning Electron Microscopy Energy Dispersive X-Ray Spectroscopy (SEM-EDXS)

The microstructure, surface morphology and particle size of solid samples were analyzed using SEM-EDXS. EDXS can make elemental mapping by giving different colors to each element on the surface of the material being observed. It can also be used to analyze quantitatively and qualitatively.

The principle is the wave nature of electrons which is diffraction at a very small angle. Electrons are scattered by charged samples (due to their electrical properties). The formed image shows the structure of the sample being tested.

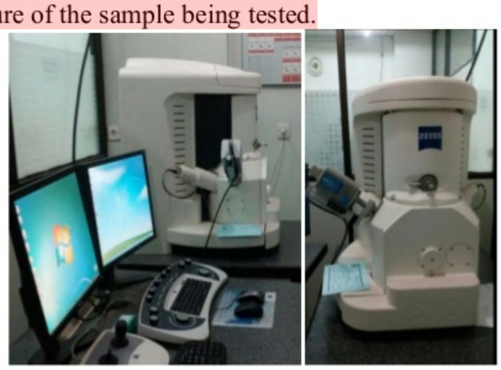

Figure 3. *Scanning Electron Microscopy* (SEM) ZEIS

3. ResultAnd Discussion

a. Crystal structure analysis

In this study, the samples tested were supercapacitor electrode material to identify the crystal shape, space group, X-ray diffraction intensity, and crystal lattice diameter size. The relationship between the crystal grain size and the effect of the magnitude of the capitance is 4.700 µF, 6.800 µF, and 15.000 µF to be analyzed. The grain size of the crystal is influenced by the width of the XRD spectrum, which is the FWHM value and the angle 2θ. If the value of FWHM and angle 2θ are small then the size of the grain of a large crystal is also the opposite.

The XRD test results of the three supercapacitor material samples in the form of X-ray diffractogram can be seen in figures 4, 5 and 6 and tables 1, 2, and 3, below.

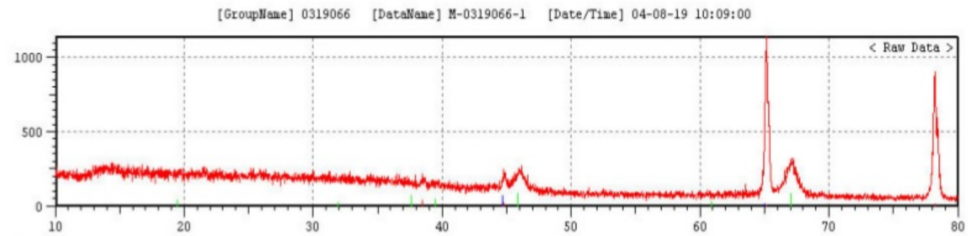

Figure 4. X-ray diffractogrampattern from a sample of 4.700 μF supercapacitors

Table 1. Data on XRD test results for supercapacitors 4.700 μF

Posisi 2θ (⁰)	Intensity (cts)	FWHM (⁰)	Space group	Crystal form	Chemical Elements	Size of dia. crystal (nm)
65.18	542.44	0.3811	Fm-3m	Cubic	Fe	428,312
78.24	688.29	0.5778	Im-3m	Cubic	Al	311,500

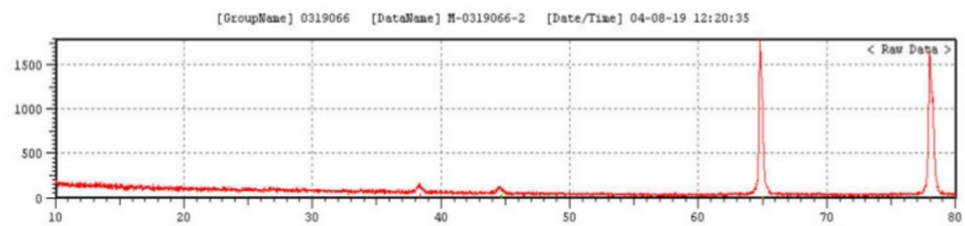

Figure 5. X-ray diffractogram pattern from a sample of 6.800 μF supercapacitors

Table 2. Data on XRD test results for supercapacitors 6.800 μF

Posisi 2θ (⁰)	Intensity (cts)	FWHM (⁰)	Space group	Crystal form	Chemical Elements	Size of dia. crystal (nm)
64.81	1080	0.1088	Fm-3m	Cubic	Al	149,302
77.96	956	0.956	Im-3m	Cubic	Fe	185,216

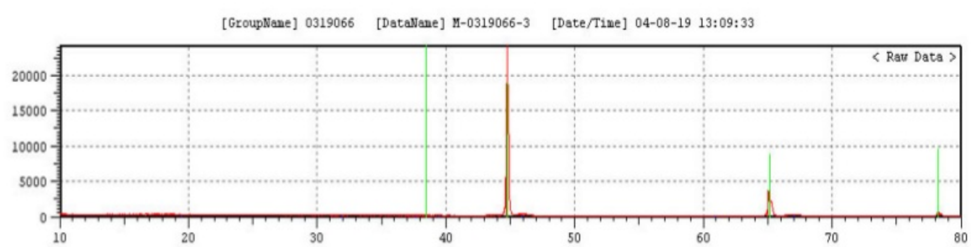

Figure 6. X-ray diffractogram pattern from a sample of 15.000 μF supercapacitors

IOP Conf. Series: Materials Science and Engineering **725** (2020) 012042 doi:10.1088/1757-899X/725/1/012042

Table 3. Data on XRD test results for supercapacitors 15.000 µF

Posisi 2θ (^{0})	Intensity (cts)	FWHM (^{0})	Space group	Crystal form	Chemical Elements	Size of dia. crystal (nm)
44.78	22060	0.5778	Im-3m	Cubic	Fe	25,649
65.16	14600	0.1468	Fm-3m	Cubic	Al	110,809

In figure 4, the diffractogram of a sample of 4.700 µF supercapasitors is seen at 2θ = 65,18^0 with an intensity of 542 cps, space group Im-3m, cubic crystal shape, chemical element iron (Fe) and crystal diameter size 428,312 nm and aluminum chemical elements (Al) and the size of the crystal diameter is 311,500 nm. Compared to figure 6, a sample of 15.000 µF supercapacitors was seen in 2θ = 44,78^0 with an intensity of 22060 cps, Im-3m space group, cubic crystal form, iron (Fe) chemical element and 25,649 nm crystal diameter size and 14600 cps intensity, aluminum chemical elements (Al) and the size of the crystal diameter of 110.809 nm.

From the X-ray diffraction pattern shows the most dominant peaks from images 4, 5 and 6, are at 2θ = 44,78^0 (figure 6) with an intensity of 22060 cps and a crystal diameter size of 25,649 nm. The higher the intensity of X-ray diffraction shows the stronger the bond and the smaller the grain boundary between the sample particles. In addition, the stronger the bond and the smaller the grain boundaries have implications for the hardness of the material and the ability of the material to conduct electricity and heat. From the above analysis showed that there is a relationship between the value capacitance of the three supercapacitor electrode material samples to the crystal lattice diameter size. Where was explained above.

b. Microstructure analysis and composition

The SEM-EDX spectrum was taken on the surface of the electrode material samples of supercapacitors 4.700 µF, 6.800 µF, and 15.000 µF shown in Figures 7, 8, and 9 and the chemical composition and quantification of the spectrum were presented in percent weight. The analysis results obtained information that the chemical composition of the three samples had C, O, Al and P.

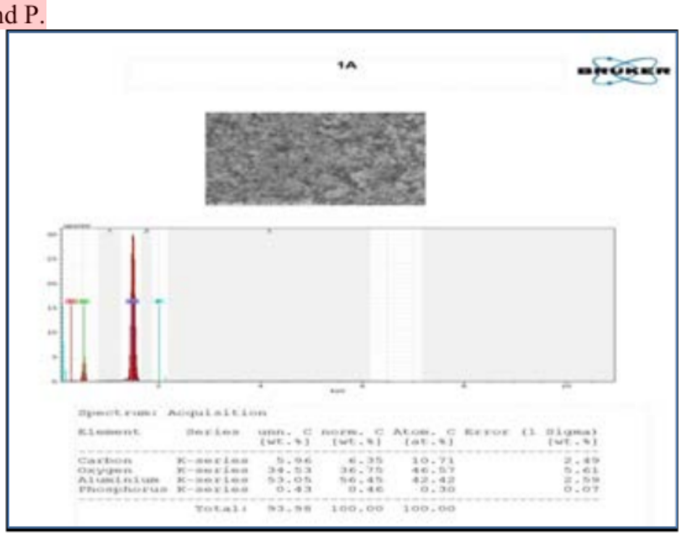

Figure 7. Microgram of the electrode material of the supercapacitor 4.700 µF, magnification of 5000x

IOP Conf. Series: Materials Science and Engineering **725** (2020) 012042 doi:10.1088/1757-899X/725/1/012042

From figures 7, 8 and 9, the results of observations with SEM-EDXS show that the microstructure of phase particles is scattered in the boundary area of the main phase (matrix). And the chemical composition is C: 6-7% by weight, O: 34-36% by weight, Al: 53-58% by weight, and P: 0.23-0.60% by weight.

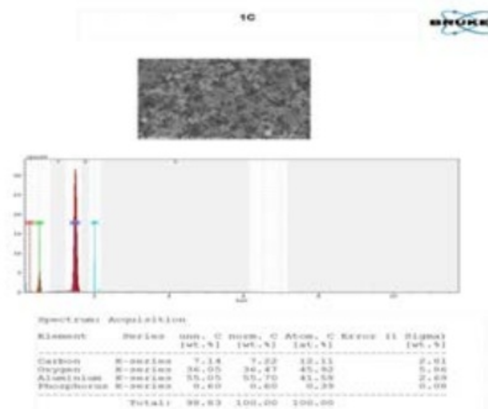

Figure 8. Microgram of the electrode material of the supercapacitor 6.800 µF, magnification of 5000x

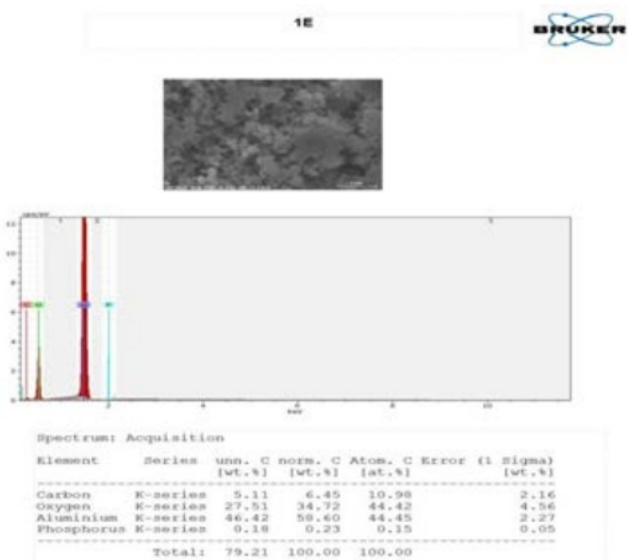

Figure 9. Microgram of the electrode material of the supercapacitor 15.000 µF, magnification of 5000x

Figure 7 shows the surface marphology in the form of pores of carbon, aluminum and phosphorus powder with a magnification of 5000 times. The results of observations with SEM-EDXS showed that the microstructure of phase particles spread over the boundary area of the main phase (matrix). And its chemical composition is C: 6% by weight, O: 34% by weight, Al: 53% by weight, and P: 0.23% by weight. The results of testing the crystal structure and microstructure and chemical element composition showed the presence of the most dominant element of aluminum (Al) from the three supercapacitor electrode material samples. And there is a relationship between the magnitude of the capacitance value of the Crystal lattice diameter size, the greater the capacitance value, the smaller the crystal lattice diameter size in the three superkasitor electrode material samples. The results of this SEM test were strengthened by Stepanus researchers who said that it included the pseudocapacitor because it had particles that were white and crystalline. As well as the superiority of energy storage supercapacitors are located in two layers coated with activated carbon in the absence of chemical reactions. This is what causes supercapacitors to be able to store more energy.[5]

4. Conclusion

The results of the characterization and analysis of the crystal structure and microstructure test and chemical element composition in the commercial supercapacitor materials and the development of the PSMM-FT-UKI using SEM and XRD can be concluded that: - The three supercapacitor materials have a structure namely cubic crystal center or Cubic Body Center, with the diameter of the crystal lattice between 25 - 428 nm. - Microstructure of supercapacitor material has phase particles scattered in the boundary area of the main phase (matrix). And the chemical composition is C: 6-7% by weight, O: 34-36% by weight, Al: 53-58% by weight, and P: 0.23-0.60% by weight. There is a relationship between the magnitude of the capacitance value of the crystal lattice diameter size, the greater the value of the capitance, the smaller the crystal lattice diameter size in the three samples of the superkasitor electrode material.

Acknowledgement

Gratitude is addressed to the Chancellor of UKI through the Dean of the Faculty of Engineering who has funded this independent research with number 77 / UKI.F6.D / PPM1.1 / 2019. Also Ir. Bambang Widodo,MT as the Head of Departement of Electrical Engineering and Mrs. Afifah, ST who helped SEM-EDXS.

Reference

[1] Edward B. O. Sihite, Budiarto. 2019.*Analisis Pengaruh Penuaan dan Media Pendingin Terhadap Kekerasan dan Struktur mikro Paduan CuHfCo* Jurnal Kajian Ilmiah Vol 19, (2019).

[2] Jayalakshmi M, Balasubramanian K. 2008. *Simple Capacitors to Supercapacitors-An Overview*. Int. J. Electrochem. Sci., 3: 1196 – 1217: 1202.

[3] Destyorini, *et al* .2010. *Pengaruh Suhu Karbonisasi Terhadap Struktur dan Konduktivitas Listrik Arang Serabut Kelapa.* Jurnal Fisika 122-132. No.123.

[4] Hadiyawarman, Agus Rijal, Bebeh Wahid Nuryadin, Mikrajuddin Abdullah & Khairurrijal. 2008. *Fabrikasi Material Nanokomposit Superkuat, Ringan dan Transparan Menggunakan Metode Simple Mixing*. Jurnal Nanosains & Nanoteknologi, Vol. 1, 14-15.

[5] Stepanus. 2018. *Master Thesis Karakterisasi Super kapasitor Melalui Scanning Electron Microscope Dan Fourier Transform Infrared Spectroscopy.* Program Magister Teknik Elektro, Program Pascasarjana UKI, 2018.

PBN

PT. PANGERAN BETON *Nusantara*

Ready Mix Concrete & Batching Plant

Contact: 081223388543 / 08116088543

3rd NICTE | NOMMENSEN INTERNATIONAL CONFERENCE ON TECHNOLOGY AND ENGINEERING

CERTIFICATE
OF APPRECIATION

is awarded to

EDWARD B.O SIHITE

In recognition of valuable contribution as

PRESENTER

entitled :

Study of the Effect of Supercapasitors Types on Crystal Structure and Microstructure of Supercapasitor Electrode Materials

in the 3rd Nommensen International Conference on Technology and Engineering

25-26 July 2019, Medan, Indonesia

Dr. Haposan Siallagan, SH., MH
Rector

Dr. Mula Sigiro, M.Si., Ph.D
Chairman

Study of the effect of supercapasitors types on crystal structure and microstructure of supercapasitor electrode materials

ORIGINALITY REPORT

80%	9%	80%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Edward B.O. Sihite, Stepanus, Budiarto. "Study of the effect of supercapasitors types on crystal structure and microstructure of supercapasitor electrode materials", IOP Conference Series: Materials Science and Engineering, 2020 Publication	66%
2	"Conference Organization", IOP Conference Series: Materials Science and Engineering, 2020 Publication	9%
3	Submitted to Aston University Student Paper	3%
4	"1st Nommensen International Conference on Technology and Engineering", IOP Conference Series: Materials Science and Engineering, 2017 Publication	1%
5	sinta3.ristekdikti.go.id Internet Source	1%

6	iopscience.iop.org Internet Source	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		