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## Preface

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# Preface

The International Conference on Theoretical and Applied Physics (The ICTAP 2019) is a conference organized by Physical Society of Indonesia (PSI), University of Lampung (Dept. of Physics, Dept. of Physics Education, and Dept. of Geophysics Engineering); Dept. of Physics Education - Raden Intan State Islamic University of Lampung; Dept. of Physics - Technology Institut of Sumatera; Dept. of Physics Education- Univ. of Muhammadiyah Metro; Research Unit for Mineral Technology Lampung- Indonesian Institute of Sciences; Research & Standardization Industry Lampung, and Physics Teacher Forum of Bandar Lampung. It is an annual conference of the Society and moves from one major city to another, started seven years back in Bandung (Capital city of West Java Province), then consecutively moved to Palangkaraya (Capital city of Central Kalimantan Province, 2012), Malang (East Java, 2013), Denpasar (Capital city of Bali Province, 2014), Kendari (Capital city of South-East Sulawesi Province, 2015), Makasar (Capital city of South Sulawesi Province, 2016), Yogyakarta (Capital city of Special Region of Yogyakarta Province, 2017), and Medan (Capital city of South Sumatera Province, 2018).

The ICTAP 2019 was held in Bandar Lampung, Lampung, on 26<sup>th</sup>-28<sup>th</sup> September 2019, with the main theme "Physics and Smart Society." It was aimed for promoting, developing, and disseminating interdisciplinary research from many different fields of physics. Researchers from universities, institutes, and related industries, working on various fields of physics were invited to participate to present papers or just as a participant.

We would like to acknowledge all of those who have supported ICTAP 2019. Each individual and institutional help were very important for the success of this conference. Especially we would like to thank the organizing committee for their valuable advices in the organization and helpful peer review of the papers.

We hope that ICTAP 2019 will be a forum for excellent discussions that will put forward new ideas and promote collaborative researches. We are sure that the proceedings will serve as an important research source of references and the knowledge, which will lead to not only scientific and engineering progress but also other new products and processes.

Dr. rer. nat. Roniyus Marjunus





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No:003/PSI.0172019

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## A preliminary study of phases, elemental mapping, and electrical properties on $\text{Na}_2\text{FeSiO}_4$ derived from rice husk silica

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# A preliminary study of phases, elemental mapping, and electrical properties on $\text{Na}_2\text{FeSiO}_4$ derived from rice husk silica

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**Abstract.** This work reports a preliminary investigation about the phase, element mapping, and electrical properties of  $\text{Na}_2\text{FeSiO}_4$  prepared from rice husk silica,  $(\text{FeNO}_3)_3 \cdot 9\text{H}_2\text{O}$ ,  $\text{NaOH}$ , and  $\text{C}_6\text{H}_8\text{O}_7 \cdot \text{H}_2\text{O}$  using the sol-gel method. A sample sintered at  $800^\circ\text{C}$  with a holding time of 10 hours at peak temperature. The phases identification shows that the main phase of  $\text{Na}_2\text{FeSiO}_4$  had been formed in the sample accompanied by two impurity phases, i.e.,  $\text{Na}_2\text{SiO}_3$  and  $\text{SiO}_2$ . Elemental mapping shows that Na, Fe, Si, and O elements are evenly distributed over the entire surface of the sample. The band gap energy value of the sample is relatively small, around 2.58 eV - 2.87 eV. Its electrical conductivity varies depending on frequency, i.e.,  $6.13 \times 10^{-5}$  S/m at 1 Hz and decreases gradually up to  $4.27 \times 10^{-5}$  S/m at 1000 Hz.

## 1. Introduction

The search for new cathode materials has become a severe concern for researchers to create batteries with high specific capacities and low production costs.  $\text{Li}_2\text{FeSiO}_4$  orthosilicate with polyanion structure attracts the interest of researchers because the structure of the material allows the presence of two lithium ions per formula. Because of that, it can produce high specific capacities; theoretically, it can reach  $330 \text{ mAhg}^{-1}$  [1-2]. The material also has lattice stability compared to other polyanion materials but shows poor electrical conductivity [3]. Besides, the limited availability of lithium causes the cost of making  $\text{Li}_2\text{FeSiO}_4$  to be expensive [4]. Therefore, other materials with similar characteristics but abundant raw materials available in nature need to be developed.  $\text{Na}_2\text{FeSiO}_4$  is a new type of polyanion material that can be used as an alternative to  $\text{Li}_2\text{FeSiO}_4$  because it has a similar ionic radius and potential redox characteristics [5-8].  $\text{Na}_2\text{FeSiO}_4$  has excellent structural stability similar to  $\text{Li}_2\text{FeSiO}_4$ , and high theoretical specific capacity reaches  $278 \text{ mAhg}^{-1}$  [9-11]. Although, in theory,  $\text{Na}_2\text{FeSiO}_4$  has a slightly lower specific capacity than  $\text{Li}_2\text{FeSiO}_4$ ,  $\text{Na}_2\text{FeSiO}_4$  has much higher electrical conductivity and cheaper and also abundant raw materials compared to  $\text{Li}_2\text{FeSiO}_4$ . Electrical conductivity is one crucial factor in determining the performance of a cathode [12]. Therefore,  $\text{Na}_2\text{FeSiO}_4$  is very potential to be developed as a cathode material.

$\text{Na}_2\text{FeSiO}_4$  can be produced using various types of methods, a kind of simple technique that is widely applied is the sol-gel method [13-14]. The source of silica used in this production is generally derived from tetraethyl orthosilicate (TEOS) [14-17]. The use of TEOS as a source of silica may be replaced with silica from rice husk to reduce production costs [18-19]. Rice husk has abundant availability in nature, and from that, rice husk can be extracted with silica reaching 99% purity through simple methods [20]. Besides, silica from rice husk has an amorphous structure and reactive so that it



can be used as a raw material in the manufacture of various materials [21-22]. In our previous studies, rice husk silica was successfully used as a raw material for forsterite [23-24] and cordierite [25-26]. By utilizing rice husk silica in the process of making various materials, especially  $\text{Na}_2\text{FeSiO}_4$ , it can reduce production costs.

In this work, we prepare  $\text{Na}_2\text{FeSiO}_4$  derived from rice husk silica. Preparation was carried out using the sol-gel method and followed by thermal treatment at 800 °C. The work aims to investigate the potential of rice husk silica as a raw material in the manufacture of  $\text{Na}_2\text{FeSiO}_4$  and investigate the possibility of  $\text{Na}_2\text{FeSiO}_4$  as a cathode in batteries system considered from its electrical characteristics. This work clearly describes the structure and electrical properties of the  $\text{Na}_2\text{FeSiO}_4$  sample, which included functional groups, phases, morphology, elemental distribution, bandgap energy, and electrical conductivity.

## 2. Materials and methods

### 2.1. Silica extraction from rice husk

Silica was extracted from rice husk refers to our previous study [27]. As much as 50 grams of rice husk was boiled in 500 ml of 5% KOH solution. The mixture obtained from this process was then left in room temperature for 24 hours and then filtered to obtain a silica sol. Silica sol was added 10%  $\text{HNO}_3$  solution by dropwise to form a gel with a pH of 7. The gel was cleaned using deionized water and then dried at 110 °C to obtain a solid. The solid was ground and then sieve to get silica powder with particle size 200 meshes.

### 2.2. $\text{Na}_2\text{FeSiO}_4$ preparation

$\text{Na}_2\text{FeSiO}_4$  preparation using the sol-gel method refers to previously reported studies [28-31].  $\text{Na}_2\text{FeSiO}_4$  was prepared from  $(\text{FeNO}_3)_3 \cdot 9\text{H}_2\text{O}$ , NaOH, rice husk silica, and  $\text{C}_6\text{H}_8\text{O}_7 \cdot \text{H}_2\text{O}$  with a mole ratio of 1:2:1:1. Silica powder was dissolved in NaOH at 60 °C for 30 minutes, then added  $(\text{FeNO}_3)_3 \cdot 9\text{H}_2\text{O}$  and  $\text{C}_6\text{H}_8\text{O}_7 \cdot \text{H}_2\text{O}$  solution by dropwise until it reached pH 1. The mixture was refluxed at 80 °C for 5 hours and then poured to the beaker glass. It was evaporated at 75 °C under magnetic stirring until a gel was obtained. The gel was dried at 130 °C for 3 hours and then ground to get a fine powder. After that, the fine powder was sintered at 800 °C with a temperature of 3 °C/minute and a holding time of 10 hours at peak temperature.

### 2.3. Functional groups analysis

$\text{Na}_2\text{FeSiO}_4$  sample and KBr powder were ground and then pressed into a pellet. The functional groups in the prepared pellet were analyzed using the Nicolet iS10 FTIR Spectrometer by scanning in the wavelength range of 1250-400  $\text{cm}^{-1}$ . The analysis was conducted by comparing the FTIR spectrum with references published in previous studies.

### 2.4. Phase analysis

The phases were characterized by X'Pert Powder PW 30/40 XRD with  $\text{Cu-K}\alpha$  radiation. Samples were scanned at  $2\theta$  10°-100°. Phase analysis was carried out using the search match method using Qual X software version 2.24 with Crystallography Open Database (COD).

### 2.5. Surface morphology and elemental distribution analysis

The surface morphology and distribution of the elements in the samples were analyzed using SEM/EDS Tescan Vega3.

### 2.6. Band gap energy estimation

Shimadzu UV-2450 UV-Vis spectrophotometer was used to measure the diffuse reflection of  $\text{Na}_2\text{FeSiO}_4$  sample powder in the wavelength range of 200-800 nm. The band gap energy was estimated using the Kubelka-Munk theorem shown by Equation (1)



$$F(R) = K/S = (1 - R)^2/2R \quad (1)$$

where  $F(R)$  is the function of Kubelka-Munk,  $S$  and  $K$  are the scattering and absorption coefficients respectively, and  $R$  is the diffuse reflection. The band gap ( $E_g$ ) and the absorption coefficient is related through the Tauc relation. Tauc relation to the direct band gap is given in Equation (2)

$$(\alpha hv) = A(hv - E_g)^{1/2} \quad (2)$$

where  $\alpha$  is the linear absorption coefficient,  $hv$  is photon energy,  $A$  is the proportional constant, and  $E_g$  is band gap. When incident radiation scatters are perfectly diffuse manner, the absorption coefficient  $K$  becomes equal to  $2\alpha$ . In this case, considering the scattering coefficient  $S$  as constant concerning wavelength, the Kubelka-Munk is proportional to the absorption coefficient  $\alpha$ , applying Equation 1 can be obtained from the relation such as Equation (3)

$$[F(R)hv]^2 = A(hv - E_g) \quad (3)$$

### 2.7. Electrical conductivity measurement

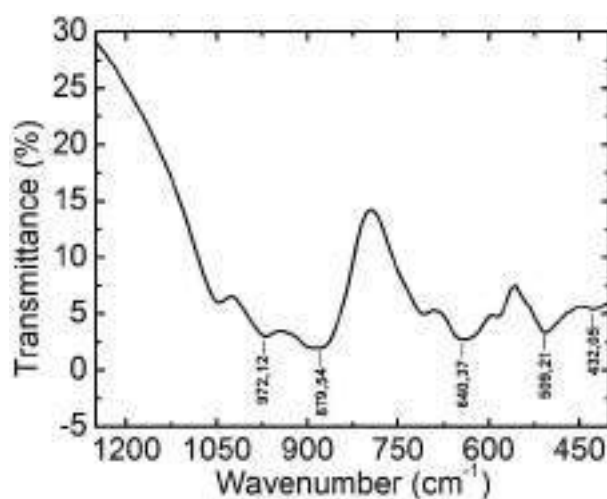
LCR meter was used to measure the conductance of  $\text{Na}_2\text{FeSiO}_4$  pellet with a diameter of  $1 \times 10^{-2}$  m and a thickness of  $3 \times 10^{-3}$  m. The conductance was measured in the frequency range of 1-1000 Hz. The value of the conductance was converted to electrical conductivity using Equation (4)

$$\sigma = G l/A \quad (4)$$

where  $\sigma$  is the electrical conductivity (S/m),  $G$  is the conductance (S),  $l$  and  $A$  are thickness (m) and cross-section of the sample ( $\text{m}^2$ ), respectively.

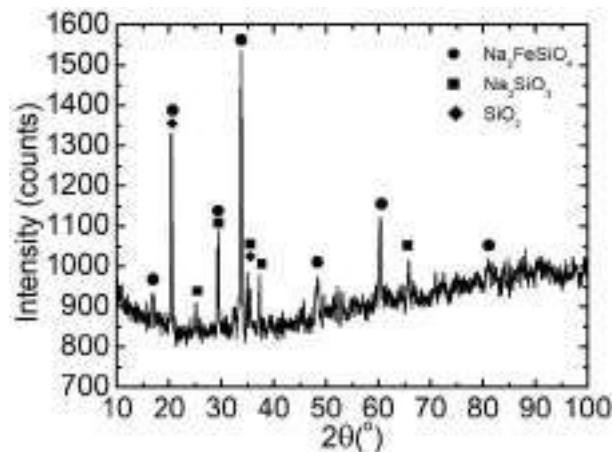
### 3. Result and discussion

The FTIR spectrum of the  $\text{Na}_2\text{FeSiO}_4$  sample shown in Figure 1. It shows the presence of several absorption peaks associated with a typical functional group contained in the  $\text{Na}_2\text{FeSiO}_4$  compound. The absorption peaks at wave numbers  $972.12 \text{ cm}^{-1}$  and  $879.54 \text{ cm}^{-1}$  are related to the vibration stretching of the Si-O group from  $\text{SiO}_4$  tetrahedra [32]. Absorption peaks at wave numbers  $640.37 \text{ cm}^{-1}$  and  $509.21 \text{ cm}^{-1}$  are related to the vibration stretching of the Fe-O group of  $[\text{FeO}_4]$  tetrahedra [33]. Meanwhile, the absorption peak at wave number  $432.05 \text{ cm}^{-1}$  indicates the presence of vibration of the Na-O group of  $[\text{NaO}_4]$  tetrahedra [34]. The appearance of the absorption peaks of the Si-O, Fe-O, and Na-O groups in the FTIR spectrum shows a strong indication that the  $\text{Na}_2\text{FeSiO}_4$  phase has formed in the sample.



**Figure 1.** FTIR spectrum of a sample of Na<sub>2</sub>FeSiO<sub>4</sub> derived from rice husk silica.

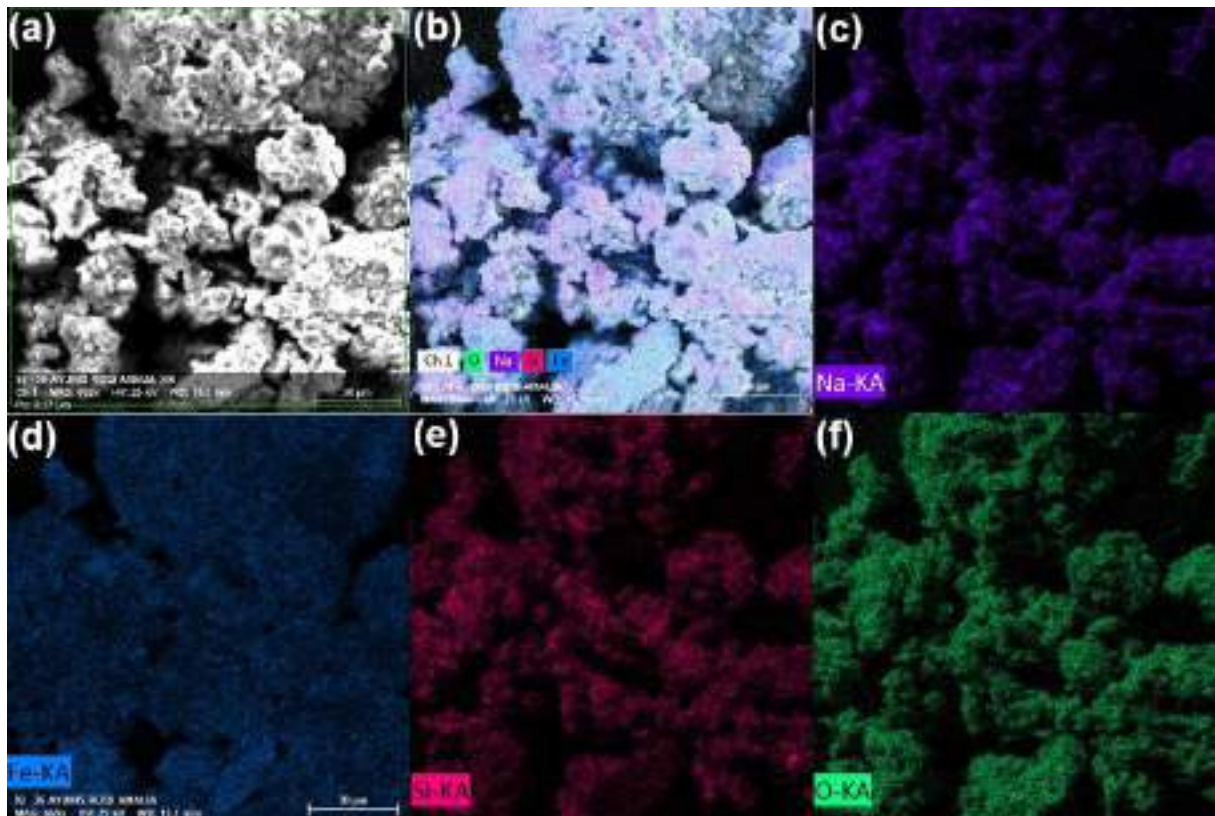
The diffractogram of the Na<sub>2</sub>FeSiO<sub>4</sub> sample shown in Figure 2. The phase analysis conducted by comparing the diffraction lines with the COD database using the search-match method. Referring to previous studies [17], because Na<sub>2</sub>FeSiO<sub>4</sub> is not yet available in the database, the analysis may use crystallographic databases of similar polyanion compounds, for example, Na<sub>2</sub>CaSiO<sub>4</sub>. The compounds have the same crystal structure. The characterization showed that the diffraction line from the Na<sub>2</sub>FeSiO<sub>4</sub> sample was in agreement with the database of Na<sub>2</sub>CaSiO<sub>4</sub> (COD 00-101-0111) which was marked by the presence of diffraction peaks at  $2\theta$  of 16.82°; 20.47°; 29.36°; 33.72°; 48.47°; 60.38°; and 81.09° which correspond to the Miller index (110), (111), (211), (220), (412), (400), (422) and (602) respectively. According to studies conducted by Kee et al., (2016), the formation of the Na<sub>2</sub>FeSiO<sub>4</sub> phase was characterized by the presence of diffraction peaks with the Miller index [17]. The presence of a diffraction peak at  $2\theta$  of 33.72 °, which is the peak with the highest intensity, confirms that the phase is the main phase in the sample. The establishment of this phase is in agreement with the results of FTIR analysis, which shows the presence typically functional groups of the Na<sub>2</sub>FeSiO<sub>4</sub> structure, such as Na-O, Fe-O, and Si-O [35]. Besides the crystalline phase Na<sub>2</sub>FeSiO<sub>4</sub>, the diffractogram also shows diffraction peaks, which indicate the presence of impurity phases such as Na<sub>2</sub>SiO<sub>3</sub> (COD 00-231-08580) and SiO<sub>2</sub> (COD 00-900-0520) as shown in Figure 2. The presence of the Na<sub>2</sub>SiO<sub>3</sub> phase is characterized by the appearance of the diffraction peak at  $2\theta$  of 29.65°, which is the main peak of the phase as well as several other diffraction peaks, as shown in Figure 2. Whereas, the presence of the SiO<sub>2</sub> phase is characterized by the appearance of the peak diffraction peak at  $2\theta$  of 20.50°. The formation of this impurity phase is predicted as a result of thermal energy given to the sample in the thermal treatment that does not sufficiently encourage the entire crystallization process to form the Na<sub>2</sub>FeSiO<sub>4</sub> phase.



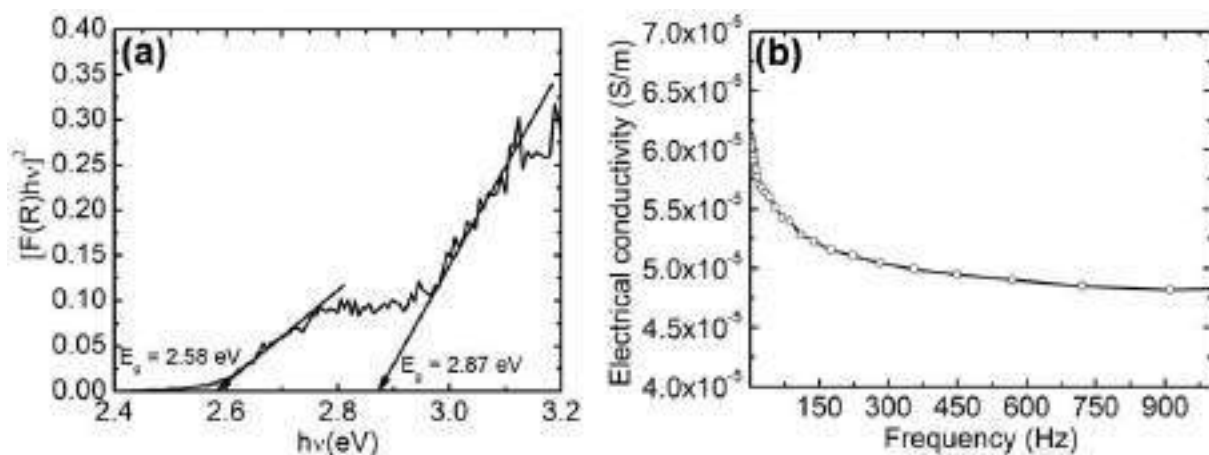
**Figure 2.** Diffractogram of a sample of Na<sub>2</sub>FeSiO<sub>4</sub> derived from rice husk silica.

SEM analysis shows that the Na<sub>2</sub>FeSiO<sub>4</sub> sample consists of micro-scale particles, as shown in Figure 3(a). The constituent elements of Na<sub>2</sub>FeSiO<sub>4</sub>, i.e., sodium (Na), iron (Fe), silicon (Si), and oxygen (O), appear to be evenly distributed on the sample surface as shown in Figure 3(b). The distribution of the elements sodium (Na), silicon (Si) and oxygen (O) on the surface are clearly shown in Figure 3(c)-(f). This mapping element reinforces the results of the phase analysis, which identifies the formation of the Na<sub>2</sub>FeSiO<sub>4</sub> phase, as well as the impurity phase. The results also confirm that silica from the husk is very potential to be used as a raw material in the synthesis of Na<sub>2</sub>FeSiO<sub>4</sub>.

The band gap energy value of the Na<sub>2</sub>FeSiO<sub>4</sub> sample is estimated using the Tauc plot, as shown in Figure 4(a). The Tauc plot has two dominant slopes that intersect the x-axis at 2.58 eV and 2.87 eV. It means that the sample has two different band gaps, i.e., 2.58 eV and 2.87 eV. The presence of two band gap values in the sample is due to the presence of the impurity phase in the sample [36]. This situation is consistent with the results of the phase analysis, which shows the presence of the impurity phases. The band gap energy value estimated from the Tauc plot is low. A high electrical conductivity value follows the low band gap energy value. The electrical conductivity value in frequencies 1-1000 Hz and shown in Figure 4(b). The electrical conductivity of the sample varies with frequency, at a frequency of 1 Hz is  $6.13 \times 10^{-5}$  S/m, and then decreases gradually to  $4.27 \times 10^{-5}$  S/m at a frequency of 1000 Hz. In general, the electrical conductivity of the Na<sub>2</sub>FeSiO<sub>4</sub> sample along the measurement frequency has a much higher value than Na<sub>2</sub>FeSiO<sub>4</sub>, which is only in the order of  $\sim 10^{-12}$  S/m [37]. By considering the characteristics of the electrical properties obtained, it shows that the Na<sub>2</sub>FeSiO<sub>4</sub> samples prepared from rice husk silica have a high potential for use as a cathode.



**Figure 3.** (a) Morphology and elements mapping in a sample of  $\text{Na}_2\text{FeSiO}_4$  derived from rice husk silica, (b) element distribution, (c) Na, (d) Fe, (e) Si, and (f) O distribution.



**Figure 4.** (a) Tauc plot of band gap energy, and (b) Electrical conductivity of a sample of  $\text{Na}_2\text{FeSiO}_4$ .

#### 4. Conclusions

Silica from rice husk is very potential to be used as a raw material in the production of  $\text{Na}_2\text{FeSiO}_4$ , although phase analysis shows the presence of impurities that accompany the primary phase. The formation of the  $\text{Na}_2\text{FeSiO}_4$  phase is supported by the FTIR analysis, which indicates the presence of functional groups that are typical of  $\text{Na}_2\text{FeSiO}_4$ , i.e., Na-O, Fe-O, and Si-O groups from the tetrahedra side. The mapping of the elements also strengthens the formation of this phase. The mapping elements

show that Na, Fe, Si, and O homogeneously distributed on the surface of the sample. Tauc plot indicates that the  $\text{Na}_2\text{FeSiO}_4$  has a band gap value of around 2.58-2.87 eV and electrical conductivity  $6.13 \times 10^{-5}$  S/m at 1 Hz and decreases gradually up to  $4.27 \times 10^{-5}$  S/m at 1000 Hz. This value is far higher than the electrical conductivity of  $\text{Li}_2\text{FeSiO}_4$ . From the electrical conductivity,  $\text{Na}_2\text{FeSiO}_4$  prepared from rice husk silica has excellent potential for use as a cathode material.

## 5. References

- [1] Gong Z and Yang Y. 2011. Recent advances in the research of polyanion-type cathode materials for Li-ion batteries. *Energy Environ. Sci.* **4**: 3223–42
- [2] Bianchini F, Fjellvag H and Vajeeston P. 2017. First-principles study of the structural stability and electrochemical properties of  $\text{Na}_2\text{MSiO}_4$  (M = Mn, Fe, Co and Ni) polymorphs. *Phys. Chem. Chem. Phys.* **19**: 14462-470
- [3] Zhang S, Deng C, Fu B. L, Yang S and Ma L. 2010. Doping effects of magnesium on the electrochemical performance of  $\text{Li}_2\text{FeSiO}_4$  for lithium ion batteries. *J. Electroanal. Chem.* **644**: 150-4
- [4] Jian Z, Yu H and Zhou H. 2013. Designing high-capacity cathode materials for sodium-ion batteries. *Electrochem. Commun.* **34**: 215-18
- [5] Yabuuchi N, Kubota K, Dahbi M and Komaba S. 2014. Research development on sodium-ion batteries. *Chem. Rev.* **114**: 11636–82
- [6] Palomares V, Serras P, Villaluenga I, Hueso K B and Gonzales J C. 2012. Na-ion batteries, recent advances and present challenges to become low cost energy storage system. *Energy Environ. Sci.* **5**: 5884-901
- [7] Hwang J Y, Myung S T and Sun Y K. 2017. Sodium-ion batteries: Present and future. *Chem. Soc. Rev.* **46**(12): 3485-856
- [8] Nayak P K, Yang L, Brehm W and Adelhelm P. 2018. From lithium-ion to sodium-ion batteries: Advantages. *Angew. Chem.* **57**: 102-120
- [9] Feng Z, Tang M and Yan Z. 2018. 3D conductive CNTs anchored with  $\text{Na}_2\text{FeSiO}_4$  nanocrystals as a novel cathode material for electrochemical sodium storage. *Ceram. Int.* **44**(17): 22019-22
- [10] Ye Z, Li S, Wu S, Wu P, Nguyen M C, Guo J, Mi J, Gong Z, Zhu Z Z, Yang Y, Wang Z C and Ho K M. 2016. Robust diamond-like Fe-Si network in the zero-strain  $\text{Na}_x\text{FeSiO}_4$ . *Electrochim. Acta* **212**: 934-40
- [11] Guo S P, Li J C, Xu Q T, Ma Z and Xue H G. 2017. Recent achievements on polyanion-type compounds for sodium-ion. *J. Power Sources* **361**: 285-99
- [12] Li Y, Sun W, Liang J, Sun H, Marco I, Ni L, Tang S and Zhang J. 2016. Understanding the electrochemical properties of  $\text{A}_2\text{MSiO}_4$  (A = Li and Na; M = Fe, Mn, Co and Ni) and the Na doping effect on  $\text{Li}_2\text{MSiO}_4$  from first principle calculation. *J. Mater. Chem.* **4**(44): 17455-63
- [13] Li S, Guo J, Ye Z, Zhao X, Wu S, Mi J X, Yang Y, Wang C and Ho K. 2016. A zero-strain  $\text{Na}_2\text{FeSiO}_4$  as novel cathode material sodium ion batteries. *ACS Appl. Mater. Interfaces* **8**(27): 17233-38
- [14] Guan W, Pan B, Zhou P, Mi J, Zhang D, Xu J and Jiang Y. 2017. A high capacity, good safety and low cost  $\text{Na}_2\text{FeSiO}_4$ -Based cathode for rechargeable sodium-ion battery. *ACS Appl. Mater. Interfaces* **9**(27): 22369–77
- [15] Feng Z, Tang M and Yan Z. 2018. 3D conductive CNTs anchored with  $\text{Na}_2\text{FeSiO}_4$  nanocrystals as a novel cathode material for electrochemical sodium storage. *Ceram. Int.* **44**(17): 22019-22
- [16] Kaliyappan K and Chen Z. 2018. Facile solid-state synthesis of eco-friendly sodium iron silicate with exceptional sodium storage behavior. *Electrochim. Acta* **283**: 1384-89
- [17] Kee Y, Dimov N, Staykov A and Okada S. 2016. Investigation of metastable  $\text{Na}_2\text{FeSiO}_4$  as a cathode material for Na-ion. *Mater. Chem. Phys.* **171**: 45-49

- [18] Prasad R and Pandey M. 2012. Rice husk ash as renewable source for the production of value added silica gel and its application; An overview. *Bull. Chem. React. Eng. Catal.* **7**(1): 1-25
- [19] Todkar B S, Deorukhkar O A and Deshmukh S M. 2016. Extraction of silica from rice husk. *Int. J. Eng. Res. Dev.* **12**(3): 60-74
- [20] Johan E, Ogami K, Matsue N, Itagaki Y and Aono H. 2016. Fabrication of high purity silica from rice husk and its conversion into ZSM-5. *ARPN J. Eng. Appl. Sci.* **11**(6): 4006-10
- [21] Bakar R A, Yahya R and Gan S N. 2016. *Production of high purity amorphous silica from rice husk*. 5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) and 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP). Malaysia: Elsevier **19**: 189-95
- [22] Rivas A L, Vera G, Palacios V, Cornejo M, Rigail A and Solórzano G. 2018. *Phase Transformation of Amorphous Rice Husk Silica*. Frontiers in Materials Processing, Applications, Research and Technology. Singapore: Springer Nature Singapore Pte Ltd: 17-27
- [23] Sembiring S, Riyanto A, Simanjuntak W and Situmeang R. 2017. Effect of MgO-SiO<sub>2</sub> ratio on the forsterite (Mg<sub>2</sub>SiO<sub>4</sub>) precursors characteristics derived from amorphous rice husk silica. *Orient. J. Chem.* **33**(4): 1828-36
- [24] Sembiring S, Riyanto A, Rumiyaniti L, Sembiring Z and Situmeang R. 2019. Effect of sintering temperature on the structural and physical properties of forsterite using amorphous rice husk silica as refractory precursors. *J. Aust. Ceram. Soc.* **3**(8): 1-8
- [25] Sembiring S, Simanjuntak W, Situmeang R, Riyanto A and Sebayang K. 2016. Preparation of refractory cordierite using amorphous rice husk silica for thermal insulation purposes. *Ceram. Int.* **42**: 8431-7
- [26] Sembiring S, Simanjuntak W, Situmeang R, Riyanto A and Junaidi. 2018. Structural and physical properties of refractory cordierite precursors prepared from rice husk silica with different MgO addition. *Ceramics-Silikáty* **62**(2): 163-72
- [27] Sembiring S, Simanjuntak W, Situmeang R, Riyanto A and Karo-Karo P. 2017. Effect of alumina addition on the phase transformation and crystallisation properties of refractory cordierite prepared from amorphous rice husk silica. *J. Asian Ceram. Soc.* **5**(2): 186-92
- [28] Zhang S, Deng C and Yang S. 2009. Preparation of nano-Li<sub>2</sub>FeSiO<sub>4</sub> as cathode material for lithium-ion batteries. *Electrochim. Solid-State Lett.* **63**(2): A136-9
- [29] Meenakshi V, Rajkumar P, Diwakar K, Subadevi R and Sivakumar M. 2016. *Structural investigation of heat-treated Li<sub>2</sub>FeSiO<sub>4</sub> cathode material preparation*. International seminar on Nanoscience and Technology **3**: 10-2
- [30] Crundwell F. 2014. The mechanism of dissolution of minerals in acidic and alkaline solutions: Part II Application of a new theory to silicates, aluminosilicates and quartz. *Hydrometallurgy* **149**: 265-75
- [31] Zhou H, Einarsrud M A and Vullum-Breur F. 2013. High capacity nanostructured Li<sub>2</sub>Fe<sub>x</sub>SiO<sub>4</sub>/C with Fe hyperstoichiometry for Li-ion batteries. *J. Power Source* **235**: 234-42
- [32] Ghaffari A and Behzad M. 2018. Facile synthesis of layered sodium disilicates as efficient and recoverable nanocatalysts for biodiesel production from rapeseed oil. *Adv. Powder Technol.* **29**(5): 1265-71
- [33] Jain R, Luthra V, Aurora M and Gokhale S. 2018. Infrared spectroscopic study of magnetic behavior of dysprosium doped magnetite nanoparticles. *J. Supercond. Nov. Magn.* **32**(2): 20325-33
- [34] Rangasamy V S, Thayumanasundaram S and Locquet J P. 2018. Solvothermal synthesis and electrochemical properties of Na<sub>2</sub>CoSiO<sub>4</sub> and Na<sub>2</sub>CoSiO<sub>4</sub>/carbon nanotube cathode materials for sodium-ion batteries. *Electrochim. Acta* **276**: 102-10
- [35] Zhu L, Zeng Y R, Wen J, Li L and Cheng T M. 2018. Structural and electrochemical properties of Na<sub>2</sub>FeSiO<sub>4</sub> polymorphs for sodium-ion batteries. *Electrochim. Acta* **292**: 190-8

- [36] Nazarkovsky M A, Gun'ko V M, Wójcik G, Czech B, Sobieszek A, Skubiszewska-Zięba J, Janus W and Skwarek E. 2014. Band-gap change and photocatalytic activity of silica/titania composites associated with incorporation of CuO and NiO. *CPTS* **5**(4): 421-37
- [37] Świętosławski M, Molenda M, Natkański P, Kuśtrowski P and Dziembaj R. 2014. Sol-gel synthesis, structural and electrical properties of  $\text{Li}_2\text{CoSiO}_4$  cathode material. *Funct. Mater. Lett.* **6**(7): 1-4

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