TECHNIUM

Romanian Journal of Applied Sciences and Technology

ISSN: 2668-778X

vol. 16 / 2023

The 7th International Conference on Science Technology

organized by
Faculty of Social Science and
Law Universitas Negeri Manado and
Consortium of International Conference
on Science and Technology

The Innovation Breakthrough in Digital and Disruptive Era

PLUS COMMUNICATION

International Communication & PR

TECHNIUM

Technium: Romanian Journal of Applied Sciences and Technology
Vol. 16, 334-340, October, 2023
ISSN: 2668-778X
www.techniumscience.com

Activated Carbon Coconut Shell as Base of Anode Battery: A Review

Erwan Adi Saputro[1,2*], *Sukirmiyad*[2,] ,*Susilowati*[1,2], *Silvana Dwi Nurherdiana*[1,2], *Diana* Silvia Rahma Wardhani[1], and *Kirana* Aurelia Salshabila[1] , *Nurten* Sahan[3]

[1] Chemical Engineering Department, University of Pembangunan Nasional "Veteran" Jawa Timur, , 60294 Surabaya, Indonesia
[2] Environmental science Department, University of Pembangunan Nasional "Veteran" Jawa Timur, , 60294 Surabaya, Indonesia
[3] Chemistry Department, Cukurova University, Adana,Turkey

Abstract. Presently, there is a rapid and significant advancement in battery technology. Consequently, there is a concurrent rise in the demand for energy to fulfil every day, industrial, and transportation requirements. A promising avenue for diminishing reliance on non-renewable energy sources is the innovative conversion of waste materials into alternative energy reservoirs. In this context, the conversion of discarded coconut shells into activated carbon emerges as a valuable strategy for fabricating battery anodes. Several constituents, including activated carbon, LiOH, TiO_2, and adhesives, can be employed in the production of battery anodes. The amalgamation of activated carbon with LiOH yields an electrical conductivity of 2.064 x 10^{-3} Sm^{-1}, along with a specific capacitance of 4.46154 F/g for activated carbon derived from coconut shells. Alternatively, other carbon composites exhibit superior electrical conductivity, registering a value of 15.31 x 10^{-2} Sm^{-1}, accompanied by a specific capacitance of 140.2 F/g. This comprehensive literature review aims to serve as a pivotal resource for selecting optimal raw materials in the synthesis of battery anodes. The result of this review substantiates that activated carbon sourced from coconut shells is one of favourable materials for crafting battery anodes.

* Corresponding author: erwanadi.tk@upnjatim.ac.id

Technium: Romanian Journal of
Applied Sciences and Technology
Vol. 16, 334-340, October, 2023
ISSN: 2668-778X
www.techniumscience.com

1 Introduction

The need for energy around the world is now increasing due to population growth and current economic developments. Increasing trend toward new and clean energy resources becomes inevitable that renders energy storage and its technologies popular topic in order to provide uninterrupted energy use.

Almost all electronic goods require batteries as a source of energy, and the newest one today is that batteries are used as an energy supply for transportation. The battery is an electric cell in which a reversible electrochemical process occurs. The reversible electrochemical process is a process of changing chemical energy into electrical energy (discharging process), and the process of electrical energy into chemical energy (charging process). [1]. Secondary batteries are rechargeable and use urgently needed in the era of globalization considering in particular renewable energy systems, transportation and electric equipment. Secondary batteries consist of lithium-ion batteries, lithium polymer batteries, lead acid batteries, and electric nickel metal hydride batteries [2].

Generally, lithium ion battery type is used in electric transportation. The lithium battery consists of an electrode cell, an electrolyte cell, and a separator cell. Lithium battery electrode cell consists of an anode and a cathode. One of the active carbon-based lithium battery anode materials has been widely developed by using activated carbon which are made of many materials. Additionally, the manufacturing process of activated carbon can also be influenced by several factors [3]. Therefore, this article purpose to provide information, ideas, and activities to evaluate previous research to provide suggestions for further research on battery anodes which are derived from activated carbon.

2 .Result and discussion

2.1 Coconut shell as anode material

Usually, coconut shell is used as a raw material for making charcoal and activated carbon. This is because coconut shells can produce a calorific value of around 6,500 -7,600 kcal/g [4]. Coconut shell, is usually used as a craft material, fuel and briquettes. Besides, coconuts shell is natural waste materials are recycled to use energy storage application as an anode material for secondary battery.

2.2 The manufacturing of activated carbon

Activated carbon is obtained from a heating process at high temperatures. Activated carbon has a surface area ranging from 300 – 2000 m^3/gr. Surface area and pores of activated carbon can be modified. Activation is a process of converting carbon that has a low absorption power into carbon that has a higher absorption power. There are two method to activate carbon, namely physically and chemically. Physical activation is carried out by heating the carbon to high temperatures, where the carbon will have an increasing pore size and surface area. Chemical activation is carried out by adding chemicals such as $FeCl_3$, NaOH, H_2SO_4, etc. [5].

Coconut shells that have been collected are crushed into granules and washed thoroughly. Furthermore, the clean coconut shell is dried in the sun to dry for approximately 1-2 days. Then the carbonization process conducted in a furnace at 400°C for 1 hours. The resulting carbon is then ground using a grinder [6]. Then sizing to 200 mesh. The next stage is the physical chemical activation process. Carbon is soaked in acetone solution for 24 hours and then dried in open air. The carbon is re-fired in a muffle furnace at 700°C for 2 hours. Then the activated carbon is soaked in 1M KOH solution for 2 hours. Activated carbon is stained using filter paper, then washed using distilled water until pH=7. Then the carbon is dried in an oven at an active temperature of 110°C [7].

2.3 Advantages of activated carbon

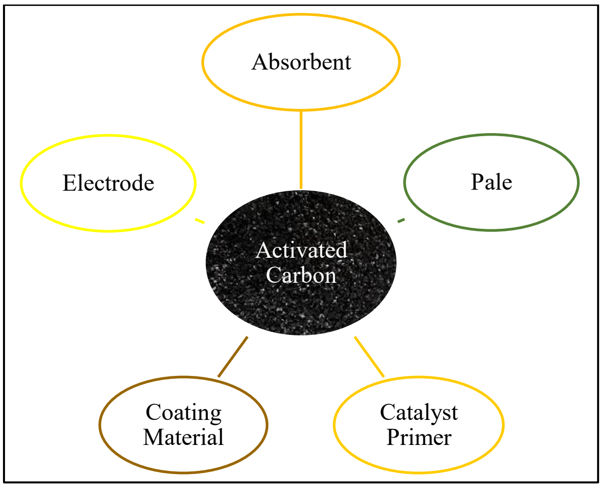


Fig. 1. Advantages of activated carbon.

2.3.1 Absorbent

Absorbent is a solid substance that can absorb certain components of a fluid phase in the adsorption process. In general, adsorbents are made of materials that have very small pores. Activated carbon is one of the most widely used types of adsorbents, because activated carbon has high porosity and a large surface area making it effective for water and waste treatment [8].

2.3.2 Pale

Bleaching made from activated carbon is used to remove interfering substances that can cause unwanted colours and odours, as well as freeing solvents from interfering substances.

2.3.3 Catalyst carrier

In the realm of catalysts, two primary categories exist, namely homogeneous catalysts and heterogeneous catalysts. Homogeneous catalysts are those that share the same phase as the reactants participating in the chemical reaction. In contrast, heterogeneous catalysts exist in distinct phases from the reactants. For the latter, a carrier is essential to enhance the catalyst's efficacy. Notably, activated carbon has demonstrated its proficiency as a catalyst carrier in both gaseous and liquid phases [9].

2.3.4 Coating material

Activated carbon can be used as a coating material, which can be used to control agricultural agrochemical contamination and increase plant growth. Activated carbon binds to urea residues and increases the microbial population that degrades pollutant and insecticide residues [10].

2.3.5 Electrode

An electrode is a conductor through which electric current enters or exits a medium, typically an electrical circuit or an electrolytic cell. In other words, it is a material or component that facilitates the transfer of electrical charges between an electrical circuit and a non-metallic conductor or an ionic solution.

In the context of batteries and electrolysis, electrodes play a crucial role in facilitating redox reactions by serving as sites for electron transfer. In these systems, one electrode is referred to as the anode, where oxidation (loss of electrons) occurs, while the other electrode is called the cathode, where reduction (gain of electrons) takes place [9].

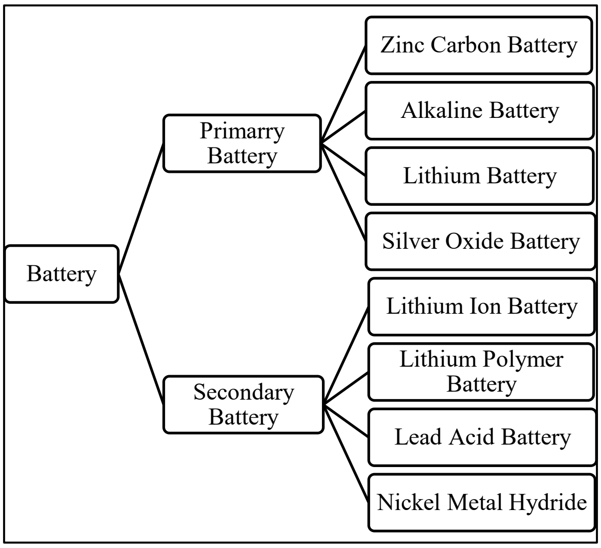
2.4 Battery

A battery is an apparatus capable of transforming stored chemical energy into electrical energy, suitable for powering electronic devices. This device comprises a positively charged terminal (cathode) and a negatively charged terminal (anode), with an intervening electrolyte serving as an energy-conducting medium [11]. There are two types of batteries namely, primary batteries and secondary batteries. A secondary battery is a battery that can be recharged (Rechargeable Battery), for example, a mobile phone battery. Primary battery is a battery that is disposable or disposable. Primary batteries have high economic value. The primary battery is composed of three important components, namely a carbon rod as the anode (positive pole of the battery), zinc (Zn) as the cathode (negative pole of the battery) and paste as the electrolyte (conductor) [12].

2.5 Battery type

2.5.1 Primary battery

Primary battery is a type of battery that can only be used once and then discarded. The electrode material of the secondary battery cannot reverse direction when removed. Primary batteries consist of zinc-carbon batteries, alkaline batteries, lithium batteries, and silver oxide batteries [13].



Zinc carbon battery is a type of battery that has light and medium power. The zinc carbon battery has a zinc anode (Zn), a manganese dioxide (MnO_2) cathode and an acid electrolyte [13].

Alkaline batteries are classified as dry batteries or commonly called primary batteries, which can be used once and after they are used up they are thrown away. Alkaline batteries have electrodes made of zinc metal (zinc) and manganese dioxide. Alkaline battery sizes on the market are C, AA, AAA, N, D, and square (9V). The electrolyte material commonly used is potassium hydroxide (NaOH) which is alkaline [14].

Silver oxide batteries produce high energy with a relatively small and lightweight form. These batteries are in the form of coins or buttons and are used in watches, calculators, etc [15].

Lithium batteries have the best performance among the existing primary battery types. Lithium batteries are usually used in watches. Coin-shaped lithium battery [16].

2.5.2 Secondary battery

Secondary battery is a type of battery that can be recharged and used several times. The chemical process in the secondary battery is a reversible process. There are several types of secondary batteries. Lithium-ion batteries use intercalated lithium compounds as the electrode material, intercalated lithium is different from metallic lithium which is usually used in non-rechargeable lithium batteries. Lithium-ion batteries are usually used for electronic equipment, because they have the best energy density, no memory effect, and experience a slow loss of

TECHNIUM

Technium: Romanian Journal of
Applied Sciences and Technology
Vol. 16, 334-340, October, 2023
ISSN: 2668-778X
www.techniumscience.com

content when used. Lithium ions move from the negative electrode to the positive electrode when discharged and back when the battery is being recharged. Apart from that, lithium-ion batteries are also used in the military industry, electric vehicles, etc [17].

Polymer lithium batteries bear striking resemblance to lithium-ion batteries, differing in the electrolyte composition. Unlike traditional lithium-ion batteries, polymer lithium batteries forego liquid electrolytes and instead employ a dry polymer electrolyte, configured in the form of a thin plastic film layer. These film layers are interposed between the anode and cathode, facilitating the exchange of ions. However, a notable drawback of these batteries lies in the relatively sluggish ion exchange through the dry polymer electrolyte, resulting in reduced charging and discharging rates [17].

Lead acid battery is a type of battery that uses lead acid as its chemical substance. There are two types of lyad acid batteries including starting batteries and deep cycle batteries.

Nickel metal hydride battery is a type of battery that is made with components that are more affordable and environmentally friendly. These batteries use hydrogen ions to store energy. Nickel metal hydride batteries consist of a mixture of nickel and titanium. These batteries usually contain components of other metals such as manganese, aluminium, cobalt, zirconium, and vanadium. These metals generally function as a catcher for the released hydrogen ions to ensure they do not reach the gas phase [17].

2.6 Difference supercapacitors and lithium-ion batteries

Supercapacitors have very high capacitance values, capacitance values on supercapacitors can reach up to thousands of farads. The capacitor consists of a pair of porous electrodes, an electrolyte solution and a separator. The supercapacitor's energy storage mechanism is the same as that of conventional capacitors, namely by charge separation. When charging the supercapacitor, a positive charge will accumulate on one plate, and a negative charge will accumulate on the other plate. This causes an electric field to arise between the two plates as energy storage [18].

Table 1. Comparison of supercapacitor specifications with lithium-ion batteries.

Characteristics	**Supercapacitor**	**Li-ion battery**
Working temperature	-40°C - 65°C	Charging: 0 - 45°C Discharge: -20 - 60°C
Discharge duration	Milliseconds – 60 minutes	Minutes
Age in cycles	100,000+	1000 – 10000+
Specific energy (Wh/kg)	2.5 – 1.5	75 – 200
Specific power (W/kg)	500 – 5000	150–315
Cost per unit of energy (&/kWh)	10000	100 – 2500
Cost per unit of power ($/kW)	130-515	1200 – 4000

Supercapacitor is an efficient energy storage system which can store energy through electric double layer and faradic reactions. In terms of user resistance, supercapacitors increase safety because there are no corrosive materials and fewer toxic materials [19].

Batteries can store energy chemically which involves chemical reactions. In batteries, changes occur in the battery molecules during the charging and discharging process. This can cause material degradation in the battery, so that its working life becomes shorter than supercapacitors. The energy storage mechanism in supercapacitors does not involve chemical reactions but physically by means of charge separation. This causes supercapacitors to be charged and discharged faster than batteries. The power possessed by the supercapacitor is also greater [18].

Table 2. Comparison of materials for masing activated carbon for supercapasitor anode battery.

Active carbon material	Research result	Source
Candlenut shell – H_3PO_4	The variable used is the mass ratio of carbon – TiO_2. The highest electrical conductivity was found in the mass variation of carbon-TiO_2 (10%:90%), namely 1.11 x 10^{-7} S/cm. Carbon with a mass variation of 20% carbon and 80% TiO2 has the highest capacitance value of 128 µF.	[20]
Coconut shell - KOH	The variable used is the ratio of LiOH to activated carbon. The material with the highest electrical conductivity is Li/AC 2/1 with an electrical conductivity of 2.064 x 10-3 Sm^{-1}. The spectrum at wave number 3694 cm^{-1} shows stretching of the –OH functional group. Li/AC 2/1 material has a pore volume of 5.35 x 10^{-4} ccg^{-1} and a pore radius of 16.83 Å. Activated carbon has the highest pore volume of 8 x 10^{-4} ccg^{-1} with a pore radius of 16.85 Å. Li/AC 2/1 the anodic peak is at 2.3 V and the cathodic peak is at 3 V.	[21]
Candlenut shell – H_3PO_4	The variable used in this study is the concentration of LiOH. The optimum conductivity and capacitance values were found at 1.5 g LiOH concentrations, namely 2.34 x 10^{-6} S/cm and 327.93 µF	[3]

Rice husk - KOH	The variables used include adhesive concentration and electrolyte concentration. The conductivity of rice husk activated carbon electrodes obtained a value of 15.31 × 10^{-2} S. m^{-1} for rice husk activated carbon samples without CMC. The highest specific capacitance value is 8.56 F/g in 2M KOH electrolyte treatment and a scan rate of 25 mV/s	[22]
Candlenut shell – H_3PO_4	The variable used is sintering temperature. Optimal conductivity was obtained at 1.0805x10^{-4} S/cm and the largest capacitance value of the anode material was obtained at 198.6 µF at sintering temperature 450°C	[23]
Graphite - KOH	The variable used in this study is the comparison of graphite with activator. The relatively high current density of 0.2 A g^{-1} in the sample KOH to graphite ratio (1:2), which shows a reversible specific capacity of 100.3 mAh g^{-1} after 100 cycles, which is higher than the other activated carbon samples.	[24]
Coconut shell	The variable used is the type of activator. The activators used include HCl, NaOH and K_2CO_3. The largest specific capacitance value was obtained in the AC3 sample, namely an activated carbon sample activated with K_2CO_3 solution with a value of Csp=4.46154 F/g.	[6]
Rotten carrots – $ZnCl_2$	The variable used is the activation temperature. The best pore volume of the sample is at the activation temperature of 700 where the pore volume is 0.9294 $cm^3.g^{-1}$ and the specific capacitance is 131-137 Fg^{-1}. The specific energy obtained from the 700 activation temperature sample is 28.4-29.1 $Wh.kg^{-1}$. The specific power obtained from the 700 activation temperature sample is 89.1-142.5 $kW.kg^{-1}$.	[13]
Cocoa - KOH	The variable used in his research is the activator concentration. The highest carbon element content was in the sample activator concentration of 0.4 M which was 91.49%. The sample specific capacitance activated using 0.4 M is 140.2 F/g.	[25]
PET - NaOH	The variable used is the activation time. The LTO/C 3% - 90 minutes sample has the highest average particle size of 0.524. LTO/C 3% mixed for 90 minutes achieved the highest conductivity value of 3.05 x 10^{-2} S/m. The highest specific capacitance is achieved with LTO/C 3% 90 minutes which is 149.8 mAh/g.	[26]
Charcoal	Charcoal is activated at 900°C - 1400°C, added with 9% PVDF adhesive. Then given the electrolyte KCl 1M. A specific capacitance of 65-70 F/g is obtained. The ESR value obtained is quite low, namely 0.5Ω with good cyclic stability.	[27]
Rice husk - NaOH	The variables used in the experiment were rice husk activated carbon and rice husk carbon. The best results obtained were rice husk activated carbon with a capacitance of 1908 mAhg-1. After 100 cycles, the capacity remains at 448 mAhg−1 at 0.2 C.	[28]
Melon peel - KOH	The variable used is carbon activation temperature. The best research results obtained were samples with an activation temperature of 900. The specific capacitance obtained was 404 Fg-1. The actual obtained energy density is 29.30 Wh kg-1 at a power density of 279.78 W k g-1.	[8]
Palm bunches – KCl salt	The variable used is the concentration of activator. The best research results were in samples with an activator concentration of 25% which obtained kcapacitance of 5.88 mF/g with a pore size of 5.43µm.	[29]
Bamboo - KOH	The variables used include the concentration of the activator solution, the type of electrolyte, and the volume of the electrolyte. The best research results were in samples with an activator solution concentration of 12% with the type of electrolyte NaOH and a volume of electrolyte of 15 ml which obtained daya of 103.0336 mWatt.	[11]

3 Discussion

According to Syifaurrahma (2021) from several previous research results for battery anodes derived from activated carbon made from coconut shell, an electrical conductivity of 2,064 x 10-3 S/m was obtained [21]. In Suryadi (2022), a battery anode derived from activated carbon made from coconut shells obtained a specific capacitance of 4.46154 F/g. The results of previous research on battery anodes from activated carbon made from coconut shells are still inferior to other materials [6]. According to Huda's research (2022), battery anodes derived from activated carbon made from rice husk can produce a conductivity of 15.31 x 10-2 S/m and a specific capacitance value of 8.56 F/g [22]. According to Nuradi (2022), battery anodes derived from cocoa-based activated carbon can produce a specific capacitance of 140.2 F/g [25]. The results of the electrical conductivity and capacitance obtained are not only influenced by the raw materials used, the treatment of the raw materials can also affect the results obtained. The treatment of raw materials that can affect the results obtained include activator concentration, temperature at activation, adhesive concentration, anode mixture, etc.

4 Conclusion

Anode batteries can be produced using activated carbon from various raw materials, activators, adhesives, and various processes. The sintering temperature for the manufacture of anode batteries usually varies between 400-500 °C. In the manufacture of anode batteries, activated carbon from coconut shells has an advantage, where activated carbon from coconut shells can produce higher conductivity and capacitance compared to activated carbon from other raw materials. Anode batteries can be made by mixing activated carbon with other chemicals such as LiOH. Activated carbon mixed with LiOH also produces higher conductivity and capacitance than other mixtures. According to Syifaurrahma (2021), a mixture of activated carbon made from raw materials and LiOH can produce a greater conductivity compared to a mixture of LiOH and other ingredients [21]. In addition, according to Suryadi (2022) activated carbon derived from coconut shells also obtained a higher capacitance value than other materials such as activated carbon from palm bunches and candlenut shells [6]. The conductivity and capacitance values obtained from the battery anode derived from a mixture of LiOH and activated carbon made from coconut shells are also still inferior to activated carbon made from rice husks and cocoa.

References

[1] D. Vlany, D. Puspita, C. Pujiastuti, and S. Priyono, "Kajian Magnesium Silikat Untuk Anoda Baterai Lithium Bahan Baku Ampas Tebu," *J. Tek. Kim.*, vol. 16, no. 2, 2022.

[2] N. M. A. Wijaya, I. N. S. Kumara, and Y. Divayana, "Perkembangan Baterai Dan Charger Untuk Mendukung Pemasyarakatan Sepeda Listrik Di Indonesia," *J. SPEKTRUM*, vol. 8, no. 1, p. 15, 2021.

[3] H. Susana and Astuti, "Pengaruh Konsentrasi LiOH terhadap Sifat Listrik Anoda Baterai Litium Berbasis Karbon Aktif Tempurung Kemiri," *J. Fis. unand*, vol. 5, no. 2, 2016.

[4] M. Y. Suhandoko, *Pengaruh Variasi Komposisi Biobriket Dari Tempurung Kelapa Dan Kayu Randu Terhadap Lama Didih Air*. 2018.

[5] M. Reza, L. Ernawati, M. D. Pusfitasari, N. Sylvia, A. H. Noor, and L. G. Ali, "Karakterisasi Karbon Aktif Dari Kulit Pisang Kepok Sebagai Superkapasitor," *J. Tek. Kim.*, vol. 16, no. 2, pp. 53–60, 2022.

[6] H. R. Suryadi *et al.*, "Pengaruh jenis aktivator terhadap nilai kapasitansi elektroda karbon dari tempurung kelapa - The influence of activator types on the capacitance value of carbon electrodes from coconut shell," *J. Aceh Phys.Soc*, vol. 11, no. 2, pp. 52–58, 2022.

[7] L. Cundari, P. Yanti, and K. A. Syaputri, "Pengolahan Limbah Cair Kain Jumputan Menggunakan Karbon Aktif dari Sampah Plastik," *J. Tek. Kim.*, vol. 22, 2016.

[8] S. Hatina and E. Winoto, "Pemanfaatan Karbon Aktif Dari Serbuk Kayu Merbau Dan Tongkol Jagung Sebagai Adsorben Untuk Pengolahan Limbah Cair Aas," *J. Redoks*, vol. 5, no. 1, p. 32, 2020.

[9] S. O. B. Ginting, D. Daniel, and N. HIndryawati, "Impregnasi Natrium Hidroksida pada Karbon Aktif Cangkang Jengkol sebagai Katalis dalam Pembuatan Biodiesel," 2017.

[10] M. S. Rohman and A. Fauzi, "Pengaruh Pelapisan Arang Aktif pada Pupuk UREA Terhadap Efisiensi Penggunaan Pupuk UREA dan Produktivitas Tanaman Pakan," *J. Ilm. Mhs. Undip*, vol. 1, no. 1, pp. 12–16, 2013.

[11] P. Pahlevi and M. Agmeiro, "Prototipe Baterai Berbasis Karbon Aktif Dari Bambu Betung (Tinjauan Pengaruh Karbon Aktif Dan Elektrolit Dalam Meningkatkan Daya Baterai)," *J. Kinet.*, vol. 11, no. 1, pp. 1–23, 2020.

[12] M. Nasution, "Karakteristik Baterai Sebagai Penyimpan Energi Listrik Secara Spesifik," *JET (Journal Electr. Technol.*, vol. 6, no. 1, pp. 35–40, 2021.

[13] S. Ahmed, A. Ahmed, and M. Rafat, "Supercapacitor performance of activated carbon derived from rotten carrot in aqueous, organic and ionic liquid based electrolytes," *J. Saudi Chem. Soc.*, vol. 22, no. 8, pp. 993–1002, 2018.

[14] W. nyoman I. Setiawan, S. Supriono, I. B. Fery Citarsa, I. M. Budi Suksmadana, and W. Warindi, "Teknik Pengisian Ulang Baterai Alkaline Nonrechargable Bekas Untuk Memperpanjang Umur Pemakaian," *J. Sains Teknol. Lingkung.*, pp. 147–154, 2021.

[15] A. Akbar, *Tas Elektronik Berbasis Solar Cell Dan Pemanfaatan Piezoelectric*. 2016.

[16] muhammad ulumul Khasan, F. Baskoro, A. Widodo, and N. Kholis, "Analisa Performa Baterai Lithium-air, Lithium-sulfur, All-Solid-State Battery, Lithium-ion Pada Kendaran Listrik Muhammad," *J. Tek. Elektro*, vol. 10 No 03, pp. 597–607, 2021.

[17] M. thowil Afif and I. Ayu Putri Pratiwi, "Analisis Perbandingan Baterai Lithium-Ion, Lithium-Polymer, Lead Acid dan Nickel-Metal Hydride pada Penggunaan Mobil Listrik - Review," *J. Rekayasa Mesin*, vol. 6, no. 2, pp. 95–99, 2015.

[18] V. Lystianingrum, "Superkapasitor Sebagai Alternatif Penyimpan Energi Untuk Bus Listrik Di Indonesia : Potensi Dan Tantangan," *Researchgate*, no. November 2019.

[19] N. Kurniawati and T. Surawan, "Superkapasitor Dari Karbon Aktif Limbah Daun Teh Sebagai Bahan Elektroda," *J. Teknol.*, vol. 8, no. 1, pp. 76–83, 2020.

[20] A. Aflahannisa and A. Astuti, "Sintesis Nanokomposit Karbon-TiO2 Sebagai Anoda Baterai Lithium," *J. Fis. Unand*, vol. 5, no. 4, pp. 357–363, 2016.

[21] A. Syifaurrahma, Arnelli, and Y. Astuti, "Lioh/coconut shell activated carbon ratio effect on the conductivity of lithium ion battery anode active material," *Molekul*, vol. 16, no. 3, pp. 233–241, 2021.

[22] A. nurul Huda, I. Lestari, and S. Hidayat, "Pemanfaatan Karbon Aktif dari Sekam Padi Sebagai Elektroda Superkapasitor," *J. Ilmu dan Inov. Fis.*, vol. 6, no. 2, pp. 102–113, 2022.

[23] V. S. I. Negara, "Pengaruh Temperatur Sintering Karbon Aktif Berbasis Tempurung Kemiri Terhadap Sifat Listrik Anoda Baterai Litium," *Fis. Unand*, vol. 4, no. 2, pp. 178–184, 2015.

[24] Z. Tai, Q. Zhang, Y. Liu, H. Liu, and S. Dou, "Activated carbon from the graphite with increased rate capability for the potassium ion battery," *Carbon N. Y.*, vol. 123, pp. 54–61, 2017, doi: 10.1016/j.carbon.2017.07.041.

[25] R. F. Nuradi, M. Muldarisnur, and Y. Yetri, "Synthesis of Supercapacitor from Cocoa Fruit Peel Activated Carbon for Energy Storage," *J. Ilmu Fis. | Univ. Andalas*, vol. 14, no. 2, pp. 86–94, 2022.

[26] B. Priyono, B. Rifky, F. Zahara, and A. Subhan, "Enhancing Performance of Li4Ti5O12 with Addition of Activated Carbon from Recycled PET Waste as Anode Battery Additives," *Evergreen*, vol. 9, no. 2, pp. 563–570, 2022.

[27] P. Shabeeba, M. S. Thayyil, M. P. Pillai, P. P. Soufeena, and C. V. Niveditha, "Fabrication and Characterization of Activated Carbon Electrode for the Application of Supercapacitors," *Russ. J. Electrochem.*, vol. 54, no. 3, pp. 302–308, 2018.

[28] K. Yu, J. Li, H. Qi, and C. Liang, "High-capacity activated carbon anode material for lithium-ion batteries prepared from rice husk by a facile method," *Diam. Relat. Mater.*, vol. 86, no. 2017, pp. 139–145, 2018.

[29] H. M. Waluyo, I. D. Faryuni, and A. Muid, "Analisis Pengaruh Ukuran Pori Terhadap Sifat Listrik Karbon Aktif Dari Limbah Tandan Sawit Pada Prototipe Baterai," *J. Fis. FLUX*, vol. 14, no. 1, p. 27, 2017.