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The Innovation Breakthrough in Digital and Disruptive Era
Activated Carbon Coconut Shell as Base of Anode Battery: A Review

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Abstract. Presently, there is a rapid and significant advancement in battery technology. Consequently, there is a concurrent rise in the demand for energy to fulfill 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, TiO2, and adhesives, can be employed in the production of battery anodes. The amalgamation of activated carbon with LiOH yields an electrical conductivity of $2.064 \times 10^{-3}$ 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 $15.31 \times 10^{-2}$ 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.
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 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 m²/gram. 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 FeCl₃, NaOH, H₂SO₄, 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 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

Absorbent

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 (MnO₂) 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
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 lead 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>
<thead>
<tr>
<th>Characteristics</th>
<th>Supercapacitor</th>
<th>Li-ion battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working temperature</td>
<td>-40°C - 65°C</td>
<td>Charging: 0 - 45°C</td>
</tr>
<tr>
<td>Discharge duration</td>
<td>Milliseconds – 60 minutes</td>
<td>Discharge: -20 - 60°C</td>
</tr>
<tr>
<td>Age in cycles</td>
<td>100,000+</td>
<td>1000 – 10000+</td>
</tr>
<tr>
<td>Specific energy (Wh/kg)</td>
<td>2.5 – 1.5</td>
<td>75 – 200</td>
</tr>
<tr>
<td>Specific power (W/kg)</td>
<td>500 – 5000</td>
<td>150 – 315</td>
</tr>
<tr>
<td>Cost per unit of energy ($/kWh)</td>
<td>10000</td>
<td>100 – 2500</td>
</tr>
<tr>
<td>Cost per unit of power ($/kW)</td>
<td>130-515</td>
<td>1200 – 4000</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Active carbon material</th>
<th>Research result</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut shell - KOH</td>
<td>The variable used is the ratio of LiOH to activated carbon. The material with the highest electrical conductivity is LiAC 2/1 with an electrical conductivity of 2.064 x 10-3 S/cm. The spectrum at wave number 3694 cm-1 shows stretching of the –OH functional group. LiAC 2/1 material has a pore volume of 5.35 x 10-7 cm3 and a pore radius of 16.83 Å. Activated carbon has the highest pore volume of 8 x 10-7 cm3 with a pore radius of 16.85 Å. LiAC 2/1 the anodic peak is at 2.3 V and the cathodic peak is at 3 V.</td>
<td>[21]</td>
</tr>
<tr>
<td>Candlenut shell – H3PO4</td>
<td>The variable used is the ratio of carbon – TiO2. The highest electrical conductivity was found in the mass variation of carbon-TiO2 (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.</td>
<td>[20]</td>
</tr>
<tr>
<td>Candlenut shell – H3PO4</td>
<td>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.</td>
<td>[3]</td>
</tr>
</tbody>
</table>
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 Syifurrarahma (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


