Synthesis of Hard Carbon from Waste Teak Wood Powder as Anode Material for Lithium-ion Batteries

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Abstract: Electrochemical energy storage technologies such as rechargeable batteries show considerable progress due to their high efficiency, flexible power, long life cycle, and low maintenance. Graphite is a common anode material used in lithium-ion batteries. However, there are several shortcomings in graphite anode material, one of which is poor structural stability. Therefore, hard carbon is the most promising candidate for lithium-ion battery anodes due to its high storage capacity, low working potential, and cycle stability. This research utilizes teak sawdust waste as a hard carbon battery anode. They were approached by the carbonization method at temperatures of 350°C and 450°C. In general, X-Ray Diffraction (XRD) results show an amorphous structure of carbon atoms. The morphological structure known through the Scanning Electron Microscopy with Energy Dispersive X-ray (SEM-EDX) test shows a fiber shape. The mass percent of carbon at a temperature of 450°C was higher than at a temperature of 350°C, which was 67.93%. Then the battery performance test was carried out with the highest discharge capacity value obtained at a temperature of 450°C at 191.56 mAh/g. Based on the results of this study, teak sawdust waste material has the potential as an anode for rechargeable batteries and can prevent environmental pollution.

Keywords: lithium-ion battery, hard carbon, anode, carbonization

1. Introduction

Batteries are a source of electrical energy that is needed in all circles of society where most electronic equipment uses batteries as a source of electrical energy. Based on their use, batteries are divided into two types, namely primary batteries and secondary batteries. Primary batteries are batteries that can only be used for one time. While the secondary battery is a battery that can be used repeatedly (rechargeable). With this secondary battery, of course, it can save more costs because the energy can be renewed if it runs out. There are many types of rechargeable batteries, including lead-acid, alkaline, nickel-cadmium, nickel-hydrogen, nickel-metal hydride, nickel-zinc, lithium cobalt oxide, lithium-ion polymer, lithium sulfur, vanadium redox batteries. , lithium nickel manganese cobalt and sodium sulfur (Liang, 2014).

Increasing the use of renewable energy such as solar power requires more efficient and affordable energy storage. Electrochemical energy storage technology based on rechargeable batteries shows considerable progress due to high efficiency, flexible power, long cycle life and low maintenance. Lithium ion batteries with the advantages of good chargeability, easy maintenance and long cycle life have been widely used as a power source for portable electronic devices and electric vehicles (Li et al., 2016). At this time, consumers need energy efficient storage media at an affordable cost, better energy density and security aspects, as well as a longer life cycle (Hagos et al., 2019).

Long-cycle, low-cost batteries are a key driver for electric vehicles, and energy storage on the smart grid. To date, lithium ion batteries have become one of the most widely used energy storage systems (Qian et al., 2016). The use of lithium ion batteries which are the most popular rechargeable batteries from other rechargeable batteries because they have a good energy density so that they can produce a long enough energy life and have a recharge speed. In addition, lithium ion batteries can operate over a high temperature range. This is one of the important advantages so that lithium ion batteries have thermal stability which can increase battery safety in use (Sugiantoro & Gunawan, 2016). Lithium ion batteries with the advantages of high energy density, good rate capability, and long cycle life have been widely used as a power source for portable electronic devices and electric vehicles (Li et al., 2016).

Among all lithium ion battery components, electrode material is the main factor limiting battery performance. The negative electrode material (anode), is an important part of lithium ion batteries and has an important influence on the electrochemical performance of the battery. In lithium ion batteries, carbon anode materials have the advantages of low electrode potential, high cycle efficiency, long cycle life, and good safety performance which make them the anode material of choice for lithium ion batteries. At present, graphite is a common carbon anode material which has a good layered structure, is suitable for lithium ion intercalation and deintercalation so that it has high conductivity and high reversible specific capacity and has become a widely used commercial negative electrode material. However, there are several shortcomings in graphite anode materials, namely poor structural stability which results in a decrease in specific capacity and a reduction in energy storage life and electrolyte decomposition which will result in a large irreversible capacity during the first discharge process. These drawbacks largely limit the application of graphite anode materials in high performance lithium ion batteries (Rao et al., 2020). Hard carbon is the most promising candidate material for lithium ion battery anodes due to its high storage capacity, low working potential and cycle stability (Wang et al., 2021).

Hard carbon derived from biomass waste is very common because of its abundant availability in nature and has an easy conversion process to carbon structure. At present, in order to prepare low cost hard carbon anodes, various biomass sources such as banana peel, nanofiber cellulose, sucrose, rice husk, peat, orange peel and so on have been used as precursors for carbon materials, showing suitable electrochemical performance when used as anodes. for batteries (Yasin et al., 2019). Hard carbon is one of the most attractive materials due to its lower redox potential, structural stability, and relatively low cost (Moctar et al., 2018). In general, hard carbon materials are amorphous carbon containing a mixture of interconnected pores and turbostratic nanodomains, and are usually obtained by heating carbon-rich precursors/resources at relatively higher temperatures (Yasin et al., 2019). The term hard carbon is used to describe carbonaceous materials that do not turn into graphite even at temperatures above 3000°C. Synonymously it can be written as the definition of "carbon that cannot be graphitized" (Dahn et al., 1995).

The abundance of natural resources in Indonesia is a solution to meet domestic hard carbon needs without having to import from other countries where Indonesia has extensive plantations and agriculture so that it produces abundant biomass waste such as rice husks, corn cobs, coconut shells, and wood waste. Teak wood is one type of wood that is widely used to produce furniture and furniture. The processing of teak wood includes several household products such as tables, chairs, cabinets and other furniture. The process of making this furniture produces solid waste such as wood sawdust and has not been used optimally, so it is still wasted (Erawati & Helmy, 2019). This study aims to determine the potential of teak sawdust waste as raw material for rechargeable battery anodes so that it can determine the performance of the resulting battery and can prevent environmental pollution.

2. Experimental

2.1. Preparation of Hard Carbon

Sample preparation was carried out by washing 50 g of teak powder using distilled water. The sample was dried in an oven at a temperature of 110°C for 4 hours to evaporate the water content and reduce the humidity of the sample and pulverized using a 100 mesh sieve. Then the sample was activated by immersion in H_3PO_4 10% for 24 hours. Samples were neutralized using distilled water and dried in an oven at 110°C for 4 hours to remove moisture. Then samples were carbonized at 350°C and 450°C for 80 minutes and ground until smooth.

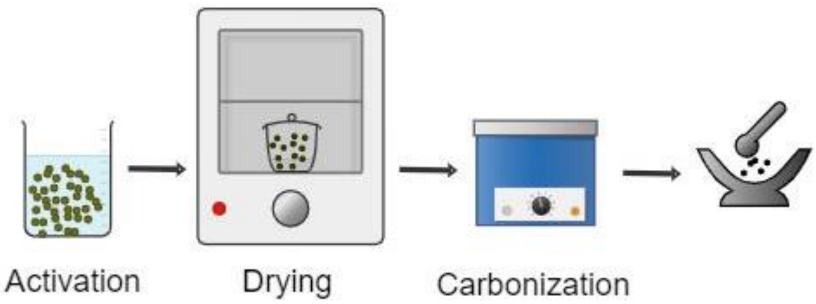

Figure 1. Hard carbon synthesis from teak wood powder

2.2. Material Characterization

Material characterization was carried out using X-Ray Diffraction (XRD) and Scanning Electron Microscopy with Energy Dispersive X-ray (SEM-EDX) to XRD (EQ-

MD-10 precision mini XRD) was used to identify crystal structure employing CuKα radiation with λ = 1.5406 at 2θ. SEM-EDX (Jeol JSM-6510LA, Tokyo, Japan) was used to determine particle morphology and composition of the elements contained in the sample.

2.3. Battery assembly and electrochemical analysis

The sample that has been obtained is continued in the anode coating process where the slurry is made by mixing the active material (hard carbon) with AB and PVDF in N-Methyl-2 pyrrolidone (NMP) solvent then the slurry is coated on a copper sheet using a coater. The anode sheet was dried in an oven at 120°C for 30 minutes and repeated for the other side. Finally, the battery is assembled into a cylindrical cell battery and electrochemical analysis was used the NEWARE Battery Analyzer to determine the capacity of the battery made.

3. Results and Discussion

3.1. Synthesis of Hard Carbon from Teak Wood Powder Waste

The activation process is carried out to dissolve impurities so that the pores on the carbon surface can be opened (Erawati & Afifah, 2018). The hard carbon synthesis method used is the carbonization method. Carbonization method is one method that can be used to manufacture hard carbon from biomass. This method is divided into two stages of heating, namely low temperature heating and high temperature heating. Heating at low temperatures is useful for reducing water content and destroying crystalline structures, while heating at high temperatures is carried out to convert carbon sources into carbon particles (Shuo et al., 2010). In this study, teak sawdust was carbonized at a temperature of 350°C and 450°C for 80 minutes.

3.2. Hard Carbon Material Characterization

Sample testing using XRD to determine the crystal structure and SEM to determine particle morphology was carried out with temperature variations of 350°C and 450°C.

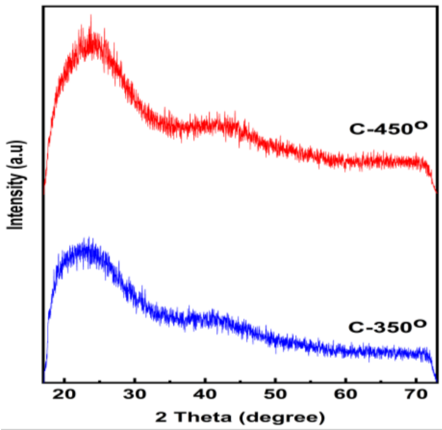

Figure 2. XRD results at 350°C and 450°C

The graph of XRD characterization results, hard carbon with temperature variations of 350°C and 450°C can be seen in Figure 1. It can be seen that the resulting graph is in the form of an amorphous structure which is characterized by the irregularity of the resulting peaks. High and low peaks resulting from XRD characterization can be influenced by the given temperature where the highest peak is at 450°C ($2\theta = 23{,}77^o$).

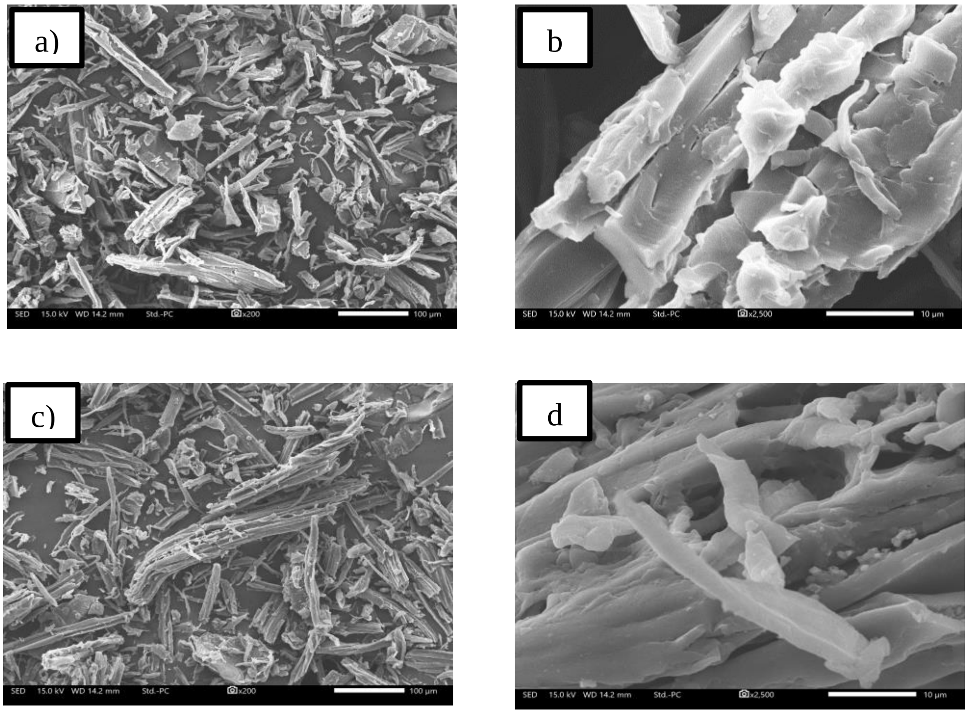

Figure 3. SEM results a) at a temperature of 350°C magnification x200 b) at a temperature of 350°C magnification x2500 c) at a temperature of 450°C magnification x200 b) at a temperature of 450°C magnification x2500

Based on the results of the SEM characterization above, it can be seen that at x200 magnification the shape is not homogeneous. While at x2500 magnification the morphology is fiber. In table 1, a temperature of 350°C has a mass percent carbon of 64.55% while at a temperature of 450°C it has a mass percent of 67.93%. A temperature of 450°C has a higher mass percent of carbon than a temperature of 350°C. The higher the given temperature, the greater the mass percent of carbon produced. This is in accordance with the literature where the temperature of 450°C has a higher carbon content than the temperature of 350°C.

Table 1. Chemical composition of hard carbon prepared at different temperature heating

Temperature	**Mass%**		
	C	O	Total
350^oC	64.55	33.45	100
450^oC	67.93	32.07	100

3.3. Battery Electrochemical Characterization

The battery is tested using a battery analyzer, namely the charge-discharge test. This charge-discharge characterization is used to determine the capacity of the battery during charging-discharge.

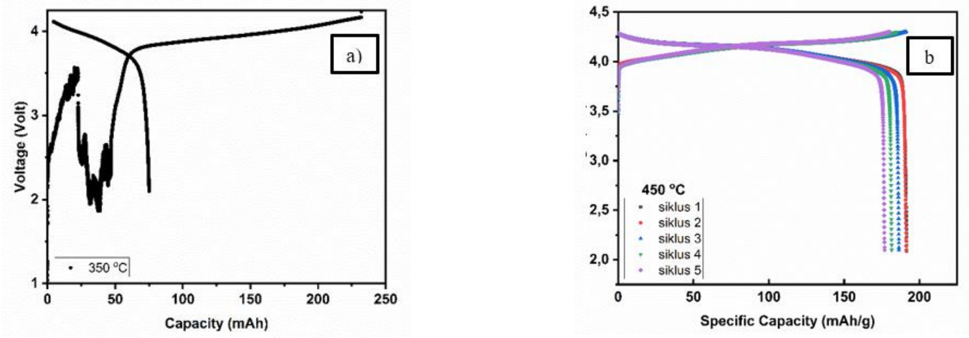

Figure 4. Battery charge-discharge test using hard carbon-based anode prepared at different temperature heating, a) at 350oC b) at 450oC

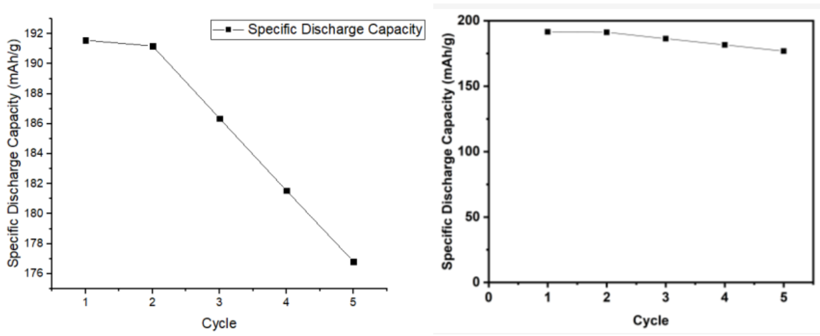

Figure 5. Specific Discharge Capacity of Battery using hard carbon-based anode prepared at at 450ºC

From Figure 4 shows the performance value of the specific capacity of the battery with variations in temperature. The graph with the resulting voltage increase showing the charge on the battery. While the graph with the resulting voltage drop shows the discharge of the battery. Based on Table 2, at 350°C, one cycle is obtained with a specific discharge capacity of 147.02 mAh/g. Meanwhile, at a temperature of 450°C, five cycles were obtained where in cycle 1 it had a specific discharge capacity value of 191.56 mAh/g to cycle 5 of 176.81 mAh/g. Based on the specific discharge capacity value, a battery with a temperature of 450°C has a larger capacity than a temperature of 350°C in the charging and discharging process. While Figure 5 shows that the ratio of the battery retention capacity is 92.3%, where the greater the ratio, the better the battery performance, meaning that the battery is still in a stable condition in the first cycle. This can be caused by a battery with a temperature of 450°C which has a higher carbon element compared to a temperature of 350°C.

Table 2. Discharge Specific Capacity Value Results

Temperature	Cycle	Rated discharge specific capacity (mAh/g)
C-350	1	147.02
C-450	1	191.56
	2	191.18
	3	186.36
	4	181.53
	5	176.81

4. Conclusion

Electrodes in high-performance batteries are a fundamentally important thing to be developed. Waste teak sawdust can be made as anode hard carbon rechargeable batteries. The carbonization method was chosen for the synthesis of hard carbon from teak sawdust with a temperature variation of 350°C and 450°C. The sample characterization test using XRD showed an amorphous or irregular structure with the highest peak at 450°C (2θ = 23.77o). The morphology of the resulting particles is fiber, which at a temperature of 450°C has a higher mass percent, which is 67.93%. Furthermore, the battery performance test was carried out, with the results that at a temperature of 450°C it had a discharge capacity value of 191.56 mAh/g.

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