Electrical Properties of Microporous Carbon from Biomass Wood; Tamarind, Mahogany, Teak, and Coconut Shell

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Abstract: Microporous carbon has been successfully synthesized from biomass, namely Tamarind Wood (Tamarindus Indica), Mahogany Wood (Swietenia Mahagoni), Teak Wood (Tectona Grandis), and Coconut Shell (Cocos Nucifera). Microporous carbon was synthesized using the carbonization method at 600° for 45 minutes and washed using an ultrasonic cleaner for 6 hours. Next, the micro-porous carbon powder is dried in the sun and grinded mechanically. Microporous carbon powder was characterized by phase, average particles size, gap energy and electrical conductivity using XRD, PSA, UV-vis and LCR meters. The characterization results show that microporous carbon is in the rGO (reduced graphene oxide) phase with a (002) reflection plane in an amorphous carbon graphite structure, the average particle size of Tamarind Wood (8.068 μm), Mahagony Wood (4.409 μm), Teak Wood (3.902 μm) and Coconut shell (3.653 μm). The gap energy measurement results show respectively 1.491 eV, 1.771 eV, 1.821 eV and 2.342 eV with an electrical conductivity value of 142.1×10^{-2} S/m, 1.281×10^{-2} S/m, 0.962×10^{-2} S/m, 0.771×10^{-2} S/m, respectively, Coconut shell, Teak Wood, Mahogany Wood, and Tamarind Wood. This microporous carbon-based wood biomass is semiconductors that have the potential as environmentally friendly energy storage supercapacitor materials.

Keywords: Carbon; Biomass; Electrical properties; Supercapasitor

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http://dx.doi.org/10.12962/j24604682.v20i1.20759
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I. INTRODUCTION

The current and developing issue in national life globally is the issue of climate change and the use of fossil energy. Fossil energy reserves are limited, and efforts are being made intensively to reduce fossil energy consumption and look for alternative energy sources. On the other hand, the development of communication and electronic technology continues to grow rapidly with various innovations and engineering. One effort to support reducing energy consumption is to carry out innovation and engineering in the electronics sector in the form of increasing energy storage efficiency and looking for energy storage materials that are cheap to obtain, easy to manufacture and environmentally friendly [1].

Electrochemical capacitors and batteries are electronic devices that are good energy stores but have limitations. Electrochemical capacitors can charge and discharge in a short time but have a lower energy density (3-5 Wh/kg) compared to Lithium batteries (100 275 Wh/kg) [2]. Supercapacitors are an appropriate alternative for storing electrical energy to replace batteries, considering their promising performance and low manufacturing costs. This is in line with the increasing need for future energy device systems such as hybrid electronic devices, portable electronics, and industrial needs for information technology. The electrode material plays a significant role in the performance of the supercapacitor. Materials based on carbon, conductive polymers and transition metals are commonly used as electrode materials, where currently research has been and is being carried out on electrode materials from agro-industrial waste [3, 4].

Carbon is generally synthesized from fossil sources, which are expensive and have limited availability, so an alternative supply of carbon is needed as a supercapacitor material that is easy to manufacture, cheap and environmentally friendly. Indonesia, as a tropical country, has various plant varieties which are alternative carbon sources. Carbon's ability to store energy as a supercapacitor material depends on the high specific surface area which is related to its electrical conductivity. In this paper, we discuss the manufacture of supercapacitor materials in the form of microporous carbon sourced from unique biomass in Indonesia, namely teak, mahogany, tamarind, and coconut shells. Microporous carbon is synthesized using a simple method, namely carbonization. Physical characterization as an alternative energy storage material is carried out by phase formation, average particle size distribution, gap energy and electrical conductivity. Microporous carbon, a semiconductor made from biological biomass, is expected to be an alternative energy storage supercapacitor material that is cheap, easy to manufacture and environmentally friendly.

TABLE I: Physical and chemical of biomass.

Biomass	Density (kg/m^3)	Selulose	Lignin	Pentosan	Others
Coconut shell	1041	27,31%	33,30%	27,70%	11,69%
Tamarind wood	979	50%	16-33%	-	17-34%
Mahogany wood	656	40-54%	18-33%	6-21%	13%
Teak wood	589	46,5%	29,9%	14,4%	1,8%

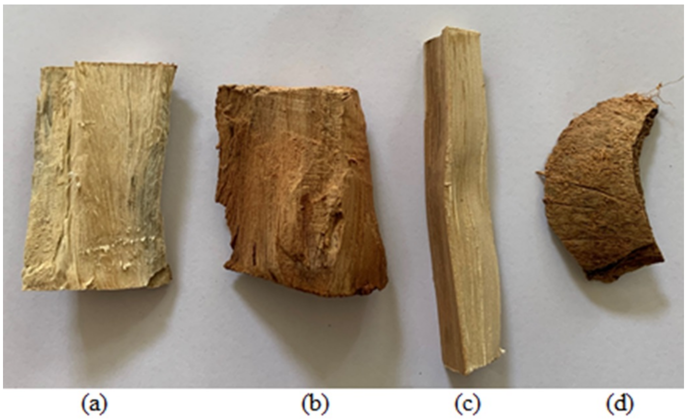


FIG. 1: Biomass raw materials (a). Tamarind wood, (b) Mahagony wood, (c). Teak wood, (d). Coconut shell.

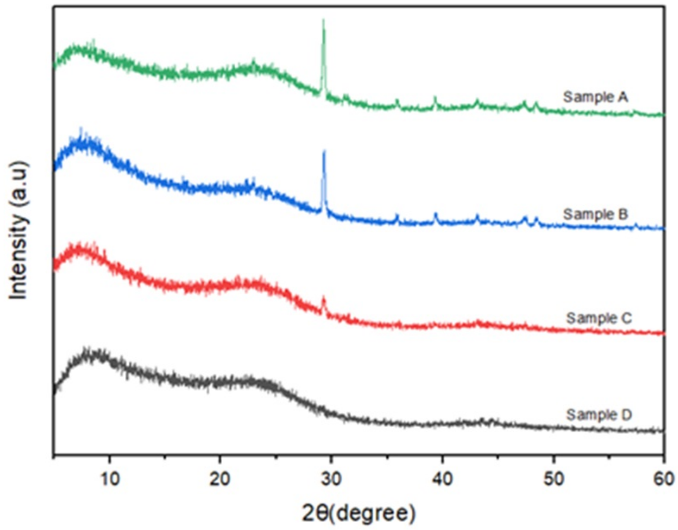


FIG. 2: XRD diffractogram of biomass Tamarind wood (Sample A), Mahagony wood (Sample B), Teak wood (Sample C), and Coconut shell (Sample D).

II. METHODOLOGY

The raw materials for making microporous carbon as an alternative energy storage and are environmentally friendly are tamarind wood (Tamarindus Indica), mahogany wood (Swietenia mahagoni) and teak wood (Tectona grandis) and old coconut shells (Cocos Nucifera). Samples of dry wood trunks and coconut shells were cut into short pieces and burned in the open until charcoal was formed. The charcoal powder was rinsed with water so that the charcoal does not turn into ash and dried in the sun until dry. Dry charcoal powder was ground and filtered using a 200-mesh sieve and heated at 600° for 45 minutes to remove oxygen levels in the charcoal using a Nabertherm furnace. Next, washing was carried out using distilled water in a vacuum cleaner for 5 hours to separate the charcoal from the ash. Deposition was carried out for 2 days to obtain carbon powder clean of impurities. Charcoal powder was heated for 8 hours with a hot plate to reduce the water content so that microporous carbon was obtained. Each microporous carbon powder was phase characterized using X-Rays Difractometry, average particle size distribution using a Paricles Size Analyzer, electrical conductivity using an LCR meter and gap energy using a UV-vis tool.

III. RESULTS AND DISCUSSIONS

The raw materials for the synthesis of biological microporous carbon are old coconut shells (10-12 months old), tamarind logs, mahogany wood, and old teak wood (> 10 years old) with the chemical composition and density shown in Fig. 1 and Table I.

Graphite is a stacked arrangement of carbon forming a hexagonal structure. Material consisting of several layers of carbon is called graphene, where graphene has several characteristics, namely absorbing electromagnetic waves, optical, electrical, mechanical properties, storing energy and magnetic. Several oxygen bonds can be inserted into carbon bonds to form graphene oxide (GO) compounds [5]. Graphene oxide can also be reduced to reduce oxygen atoms and leave bond defects in the form of loose carbon bonds to form reduced graphene oxide (rGO) compounds. Reduced graphene oxide compounds can be formed using electrochemical, chemical, and thermal processes [6].

In this research, the synthesis of microporous carbon was carried out using a thermal process, namely heating at a temperature of 600° for 45 minutes, which is called the carbonization process. The carbon phase formed from carbonization was observed by characterization using x-ray diffraction. The results of carbon phase characterization using x-ray diffraction carried out at an angle range of 0°-60° are shown in Fig. 2. The diffractogram of samples of tamarind, mahogany,

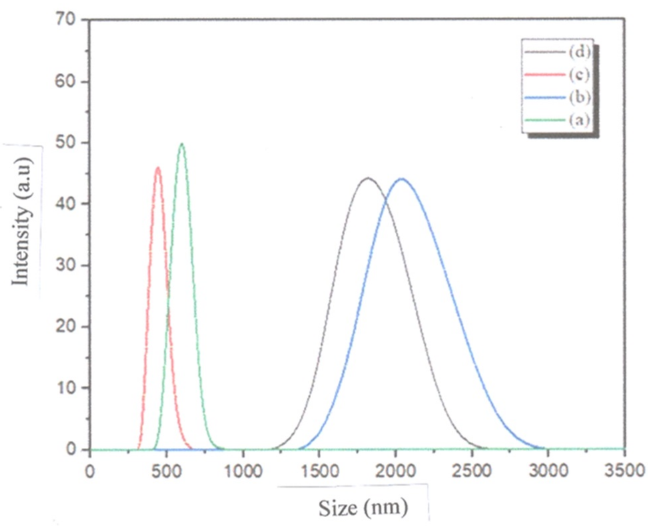


FIG. 3: Average particles size distribussion of microporous carbon (a). Tamarind wood, (b) Mahagony wood, (c). Teak wood, (d). Coconut shell.

teak, and coconut shell charcoal shows an amorphous phase in the range of around 2θ = 20°-30° and shows the formation The rGO phase with the (002) reflection plane has an amorphous carbon graphite structure. The amorphous carbon phase formed is seen in an irregular spectrum and a wide peak shape. The rGO diffraction peak according to the diffraction pattern number PDF 00-041-1487 is a carbon graphite type with a hexagonal space group P63/mmc crystal system. This is confirmed by the FTIR test results which state the presence of the main functional group of rGO, namely C=C bonds with rGO peaks in the angle range 2θ = 20°-30°. The diffraction spectrum of the four samples in Fig. 2 has a wide peak at position 2θ = 20°-30° which indicates an amorphous rGO phase [7]. However, in the diffraction patterns of tamarind, mahogany and teak wood charcoal, there are small sharp peaks in several corners, which are peaks that belong to KCl as an inherent element in natural materials.

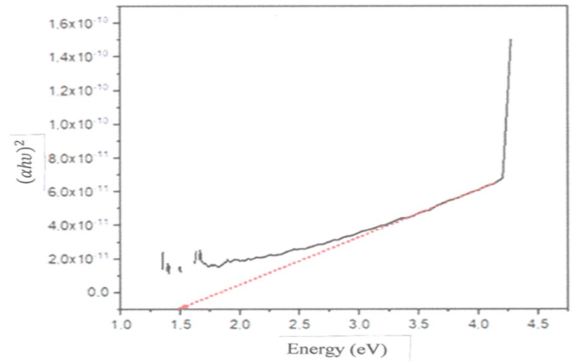
Microporous carbon synthesized using the micrometer scale rGO phase carbonization method. Analysis of the average particles size distribution in this study used the Particles Size Analyzer (PSA). The method used in the PSA tool is Dynamic Light Scattering (DLS), a particles measurement method by shooting light at a sample. When the light hits a particle, the electric field from the light induces oscillating polarization of electrons in the molecule, thus producing a secondary light source and scattering the light. The intensity of the scattered light, polarization, distribution angle and frequency shift are determined by the shape, interaction, and size of the molecules in the scattering material. One of the factors that influences the physical properties of a material is particles size, because the smaller the particles size, the larger the surface area, the smaller the density and the larger the conductivity [8]. If the surface area is large, the particle's ability to conduct heat or electricity is better and the reaction rate is faster. Apart from knowing the particles size, PSA testing can be used to determine the size distribution. The size distribution shows whether the resulting particles size is uniform or not. Based on Fig. 3, it shows that the size distribution of porous carbon particles in the rGO phase from biomass shows that the homogeneous porous carbon particles are uniform or evenly distributed because there is one peak in the test results.

The ability of a material to conduct electric current is called electrical conductivity. The electrical conductivity value is inversely proportional to the resistivity value, the greater the conductivity value of the material, the smaller the resistivity value it has. The electrical conductivity of porous carbon from biomass was measured using an LCR meter at room temperature. An insulator is a type of material that is weak or cannot carry an electric current. Conductors are a type of material that is good at conducting electric current and semiconductors are materials whose electrical conductivity is between a conductor and an insulator. Each material has a different range of conductivity values. Insulator materials have conductivity values between 10^{-8}-10^{-15} S/m, semiconductor materials are in the range 10^{3}-10^{-8} S/m and conductor materials have conductivity values in the range 10^{6}-10^{3} S/m.

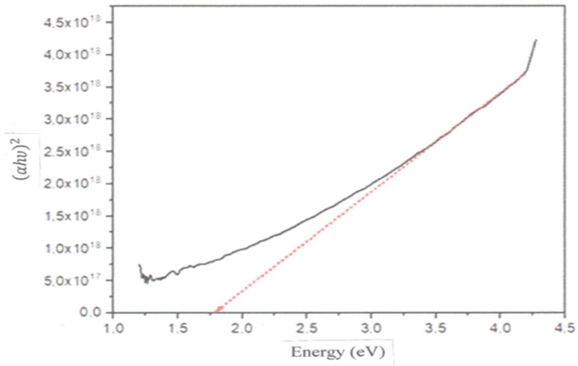
The results of measuring the electrical conductivity of the microporous carbon material are shown in Table II where the coconut shell material has a value of 142.1×10^{-2} S/m. The greater the electrical conductivity value, the greater the ability of a material to conduct current. Based on the electrical conductivity value, the basic materials used in this research are semiconductor materials. This shows that natural graphene from tamarind wood charcoal, mahogany, teak, and coconut shells has dielectricity. Natural graphene from coconut shell charcoal has the highest electrical conductivity value so it will have an impact on energy storage properties and absorption of microwaves. Of the four samples that were tested, the electrical conductivity values obtained were relatively low. This is also a characteristic of semiconductor materials which have a low ability to conduct current. Conductivity is also influenced by the number of free electrons in the conduction band. The freer electrons in the conduction band, the more conductive the material will be.

The level of electrical conductivity of a material is in accordance with the gap energy possessed by each material. The narrower the energy gap, the easier it is for the material to conduct electricity through the conduction of electrons from the valence to the conduction band. The UV-Vis spectrum can be used to determine the energy gap of a material using the Tauc's plot method [4]. Gap energy is the gap that electrons must pass through to move from the valence band to the conduction band. Gap energy is also a parameter in semiconductor materials because the utilization and properties produced by semiconductors depend on the value of the gap energy. Insulator materials have a very large gap between the valence band and the conduction band so that the valence band cannot move to the conduction band. Meanwhile, in conductor materials there is no energy gap and there is overlapping so that electrons can easily move from the valence band to the conduction band, so the conductor material easily transmits electric current.

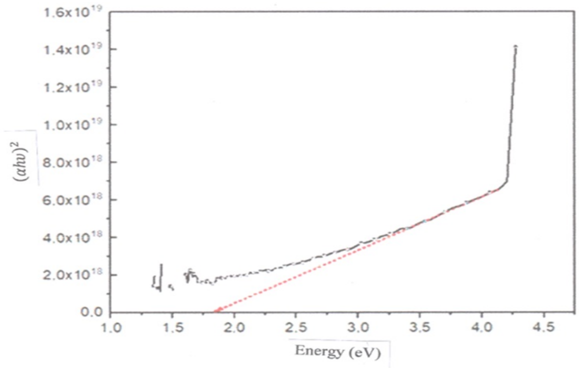
The gap energy value of porous micro carbon is shown



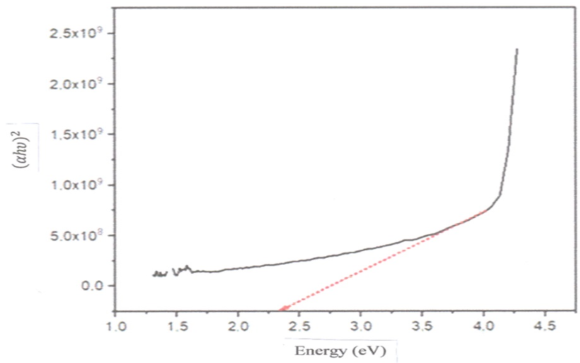
(a) Tamarind wood



(b) Mahagony wood



(c) Teak wood



(d) Coconut shell

FIG. 4: Spectrogram of UV-vis spectroscopy.

TABLE II: Electrical properties and average particles size of microporous carbon.

Biomass Microporous carbon	Average particles size (μm)	Electrical conductivity $\times$ 10^{-2} (S/m)	Gap energy (eV)
Tamarind wood	8.068	0.771	2.342
Mahagony wood	4.409	0.962	1.821
Teak wood	3.902	1.281	1.771
Coconut shell	3.653	142.1	1.491

in Table II, showing that microporous carbon from tamarind biomass has the largest gap energy with the smallest electrical conductivity value compared to microporous carbon made from mahogany, teak, and coconut shells according to the density and particles size. The energy gap value and electrical conductivity of microporous carbon from biomass is a type of semiconductor that has the properties of absorbing microwaves and storing electrical energy so that it has the potential to be an environmentally friendly alternative electronic material.

IV. CONCLUSION

Microporous carbon has been successfully synthesized from the biomass of old tamarind wood, mahogany wood, teak wood, and coconut shells using the carbonization method. Carbonization was carried out at a temperature of 600 ° for 45 minutes and the microporous carbon formed was in the reduced graphene oxide (rGO) phase with a small KCl content in tamarind wood, mahogany wood, and teak wood as a natural material. The main bonds that form rGO are C=C bonds and the impurity atom bonds are C-H, C-O and C=N. The electrical conductivity and gap energy values of microporous carbon from tamarind wood, mahogany wood, teak wood, and coconut shell logs are respectively 0.771 $\times$ 10^{-2} S/m, 0.962 $\times$ 10^{-2} S/m, 1.281 $\times$ 10^{-2} S/m, 142.1 $\times$ 10^{-2} S/m and 2.342 eV, 1.821 eV, 1.771 eV, 1.491 eV are semiconductors that have the potential as environmentally friendly energy storage supercapacitor materials.

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