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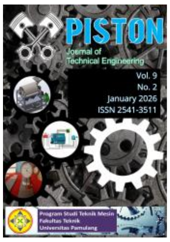

Synthesis of Graphene-Like Carbon from Coconut Shell and Electrical Conductivity Properties

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Abstract: Demand for batteries continues to increase in line with the growth of electric vehicles, while the availability of lithium in nature is limited. One alternative is the use of renewable natural materials, such as coconut shells, to produce functional carbon materials. This study aims to synthesize graphene-like carbon (GLC) from coconut shells using pyrolysis and sonication methods. The process was carried out through drying at 150–200 °C and pyrolysis at 700 °C. XRD characterization showed main peaks at 2θ ≈ 23.11° and 43.75° (150 °C/700 °C), and 23.15° and 43.38° (200 °C/700 °C), with an interlayer spacing of 0.35 nm and a shift in the C (002) peak from pure graphite, indicating the formation of nanosized graphene layers. FTIR analysis confirmed the presence of O–H, aromatic C=C, C=O, and C–O groups, indicating a hexagonal carbon framework with oxygen functionality on the surface. The Raman spectrum showed ID/IG ratios of 0.84 and 0.83, indicating structural disorder while still consistent with graphene-like characteristics. Conductivity tests showed relatively stable electrical conductivity with gradual electron energy loss at small current increases, allowing better control of electron mobility.

Keywords: Graphene-like carbon (GLC), Coconut shell, Pyrolysis, Sonication, Functional carbon materials.

Abstrak: *Permintaan baterai terus meningkat seiring dengan pertumbuhan kendaraan listrik, sementara ketersediaan litium di alam semakin terbatas. Salah satu alternatif yang dapat dikembangkan adalah pemanfaatan bahan alam terbarukan, seperti tempurung kelapa, untuk menghasilkan material karbon fungsional. Penelitian ini bertujuan untuk mensintesis graphene-like carbon (GLC) dari tempurung kelapa melalui metode pirolisis dan sonikasi. Proses sintesis dilakukan melalui tahap pengeringan pada suhu 150–200 °C dan pirolisis pada suhu 700 °C. Karakterisasi XRD menunjukkan puncak utama pada 2θ ≈ 23,11° dan 43,75° (150 °C/700 °C), serta 23,15° dan 43,38° (200 °C/700 °C), dengan jarak antar-lapis sebesar 0,35 nm serta pergeseran puncak C (002) dari grafit murni, yang mengindikasikan terbentuknya lapisan grafena berukuran nano. Analisis FTIR mengonfirmasi keberadaan gugus O–H, C=C aromatik, C=O, dan C–O, yang menunjukkan kerangka karbon heksagonal dengan keberadaan gugus oksigen pada permukaan. Spektrum Raman menunjukkan rasio ID/IG sebesar 0,84 dan 0,83, yang mengindikasikan adanya ketidakteraturan struktur namun masih konsisten dengan karakteristik graphene-like. Uji konduktivitas menunjukkan nilai konduktivitas listrik yang relatif stabil dengan kehilangan energi elektron yang bertahap pada peningkatan arus yang kecil, sehingga memungkinkan kontrol mobilitas elektron yang lebih baik.*

Kata kunci: *Graphene-like carbon (GLC), Tempurung kelapa, Pirolisis, Sonikasi, Material karbon fungsional.*

INTRODUCTION

The demand for high-energy-density storage systems continues to increase along with the growth of electrical appliances and electric vehicles. Lithium-ion batteries (LIBs) have been used as the dominant energy source for electronic equipment. However, large-scale commercial production of LIBs faces severe challenges, including limited natural resources, high production costs, and post-consumer waste. The need for high-performance and low-cost batteries is driven by the growth of the electromobility market to meet key requirements such as adequate driving range and fast-charging capabilities. The development of efficient and cost-effective energy storage systems is essential for creating a renewable energy-based power supply. Graphite has dominated the market share of anode materials to date. Carbon-based materials are widely adopted and play an important role in mankind's culture [1].

Graphene is considered one of the most remarkable achievements in the field of science and technology. Single-layer hexagonal crystals of graphite, which represent the simplest form of carbon materials with a C–C bond distance of 0.142 nm, have received great attention in the fields of sensors, biomedicine, composite materials, and microelectronics [2], [3]. A wide variety of applications such as conductive transparent films, ultra-sensitive chemical sensors, thin-film transistors, quantum dot devices, and anti-corrosion coatings have been tested and established. Industrial-scale production of graphene for these applications relies heavily on the scalability and simplicity of synthesis methods. This factor was a major bottleneck in the past but has been significantly improved in recent years [4].

Along with its unique quantum confinement phenomena, graphene exists in several forms such as graphene nanoribbons, nanosheets, nanoplates, and three-dimensional graphene. The electronic and quantum properties of graphene remain subjects of fundamental research. Each carbon atom in graphene is sp^2-hybridized and forms three covalent bonds with neighboring carbon atoms. The sp^2 hybridization results from the combination of s, p_x, and p_γ orbitals, leaving one free electron per carbon atom. This free electron occupies the pz orbital, which lies perpendicular to the graphene plane and forms a π bond. The pz orbitals play an important role in determining the chemical and physical behavior of graphene [5]. Owing to its ability to accommodate a wide variety of intercalants and alloying species, graphite can be considered a versatile electrode material for use in sodium-ion batteries and potassium-ion batteries. However, graphite in various forms such as natural graphite, synthetic graphite, soft carbon, and hard carbon still suffers from significant crystal structure expansion during charge–discharge cycles under high-power conditions.

METHODS

Preparation of Graphene-Like Carbon

This study employed a pyrolysis method to produce graphene-like carbon (GLC) sheets from coconut shells. The process was initiated with a preliminary combustion step at temperatures of 150 °C and 200 °C for 2 hours. This was followed by pyrolysis at 300 °C for 1 hour and further pyrolysis at 700 °C for 1 hour. Sonication was subsequently performed for 1 hour to assist in the exfoliation of carbon layers. Prior to the pyrolysis process, coconut shell powder was soaked in distilled water for 72 hours. The soaked material was then dried for 1 hour and subsequently dried on a hot plate at a temperature of 100 °C for 1 hour.

RESULT AND DISCUSSION

Characterization of Graphene like carbon

It is well known that the diffraction peak of pure graphite appears at 2θ around 26° due to its interlayer spacing of 0.335 nm [6]. The X-ray diffraction (XRD) patterns of coconut shell–derived carbon were analyzed for samples dried at temperatures of 150 °C and 200 °C, followed by pyrolysis at 700 °C, as illustrated in Figure 1. The results confirm the formation of graphene-like structures from coconut shells under the applied conditions.

For samples dried at 150 °C and subsequently pyrolyzed, diffraction peaks were observed at 2θ around 23.11° and 43.75°. Meanwhile, samples dried at 200 °C and pyrolyzed under the same conditions exhibited diffraction peaks at 2θ around 23.15° and 43.38°. These results are consistent with previous studies reporting similar diffraction characteristics for graphene-like carbon materials [1], [7], [8].

Based on Figure 1(a), variations in the drying temperature do not significantly affect the diffraction characteristics of the samples. This is indicated by the relatively similar peak positions observed in each sample, suggesting the successful formation of graphene-like carbon. In addition, a slight shift of the diffraction peaks toward lower angles compared to pure graphite was observed, which is commonly associated with increased interlayer spacing and structural disorder in graphene-like carbon materials [9]. The weak intensity of the diffraction peaks further indicates the presence of nanosized graphene layers with limited stacking order within the carbon structure [10].

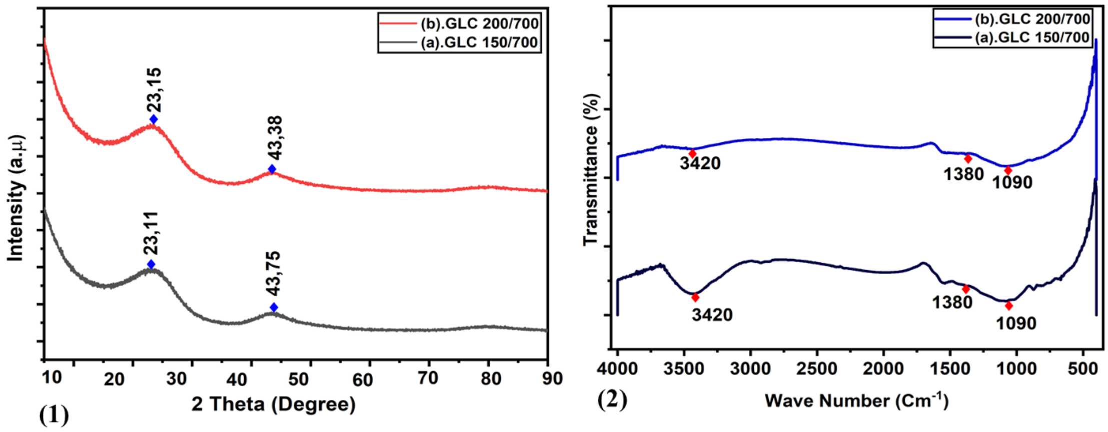

Figure 1. (a) XRD patterns and (b) FTIR spectra of graphene-like carbon derived from coconut shells

Figure 1(b) presents the FTIR spectra of graphene-like carbon obtained from coconut shells at a drying temperature of 150 °C followed by pyrolysis at 700 °C. A strong and broad absorption band observed at approximately 3420 cm⁻¹ corresponds to O–H stretching vibrations, indicating the presence of hydroxyl groups on the surface of the material. This confirms the existence of oxygen-containing functional groups in the graphene-like carbon structure. An absorption band at around 1380 cm⁻¹ is associated with C–H bending vibrations, which typically indicate the presence of methyl groups (–CH_3), particularly symmetric bending modes. In addition, the band observed at approximately 1090 cm⁻¹ corresponds to C–O stretching vibrations, suggesting that single carbon–oxygen bonds remain within the carbon framework [11], [12].

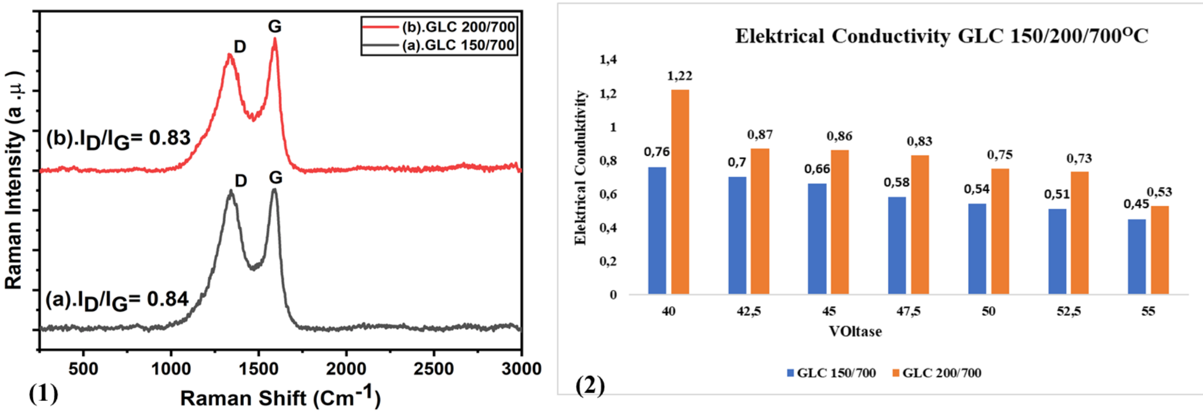

Figure 2. (a) Raman spectra and (b) electrical conductivity of graphene-like carbon derived from coconut shells

Figure 2(a) shows the Raman spectra of graphene-like carbon samples. The Raman spectrum of the sample dried at 150 °C and pyrolyzed at 700 °C exhibits two dominant peaks at 1342.67 cm⁻¹ corresponding to the D band and 1592.87 cm⁻¹ corresponding to the G band, with an ID/IG ratio of 0.84, indicating the presence of structural disorder. Meanwhile, the sample dried at 200 °C and pyrolyzed at 700 °C shows dominant peaks at 1340.65 cm⁻¹ for the D band and 1592.91 cm⁻¹ for the G band, with an ID/IG ratio of 0.83. These results indicate similar structural characteristics for both samples and are consistent with previous studies on graphene-like carbon derived from biomass materials [13], [14].

Figure 2(b) presents the electrical conductivity behavior of graphene-like carbon samples under varying applied voltages. Electrical conductivity measurements were performed using approximately 0.40 g of sample placed inside a fuse holder and covered with a fuse cap. Alligator clips were connected to the positive and negative terminals of a digital multimeter and a DC power supply. The applied voltages were varied at 40 V, 42.5 V, 45 V, 47.5 V, 50 V, 52.5 V, and 55 V, while the current was maintained at 9 A.

At an applied voltage of 40 V, the sample dried at 150 °C and pyrolyzed at 700 °C exhibited a current of 0.76 μA, which decreased to 0.45 μA at 55 V. In contrast, the sample dried at 200 °C and pyrolyzed at 700 °C produced a higher current of 1.22 μA at 40 V and 0.53 μA at 55 V. These results indicate that the combination of drying at 200 °C and pyrolysis at 700 °C produces graphene-like carbon with improved electrical conductivity and lower initial resistance compared to the sample dried at 150 °C. The observed conductivity behavior suggests good electrical stability of graphene-like carbon, characterized by gradual electron energy loss at relatively small current changes. This behavior enables more effective control of electron mobility and supports stable electrical conduction, which is advantageous for extending the service life of graphene-based battery materials [15], [16].

CONCLUSIONS

Graphene-like carbon (GLC) was successfully synthesized from coconut shells through drying at temperatures of 150 °C to 200 °C followed by pyrolysis at 700 °C. XRD, FTIR, and Raman characterizations confirmed the formation of a graphene-like nanostructure with oxygen-containing functional groups. Electrical conductivity measurements demonstrated relatively stable electrical properties under varying applied voltages. Overall, the results indicate that graphene-like carbon derived from coconut shells has strong potential as a sustainable carbon-based functional material for energy-related applications.

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