https://doi.org/10.52676/1729-7885-2026-1-29-35
УДК 44.29.29

RICE HUSK-DERIVED ACTIVATED CARBON AS A POTENTIAL ANODE MATERIAL FOR LITHIUM-ION BATTERIES

N. Saitova[1], K. Askaruly[1], Y. Yeszhan[1], R. Amrousse[2], Y. Yevlampiyeva[3], S. Azat[1*]

[1] NP JSC "K.I. Satbayev KazNRTU", Almaty, Kazakhstan
[2] Chouaib Doukkali University, El Jadida, Morocco
[3] NP JSC "Shakarim University", Semey, Kazakhstan

* *E-mail for contacts: seytkhan.azat@gmail.com*

This work investigates the synthesis and application of activated carbon derived from rice husk (RH) as a sustainable anode material for lithium-ion batteries (LIBs). The RH precursor underwent a sequence of pretreatment steps including washing, drying, pyrolysis at 500 °C in argon atmosphere, chemical activation with KOH at 850 °C , and subsequent desilication. The resulting material exhibited a well-developed micro/mesoporous structure with a high specific surface area (>900 m²/g) and structural stability. Morphological analysis confirmed a uniform porous carbon matrix, while XRD revealed the formation of amorphous carbon. Electrochemical performance tests showed that the RH-derived carbon retained a reversible capacity of ~280–300 mAh/g over 50 charge–discharge cycles, indicating excellent cyclic stability and lithium-ion intercalation capability. Cyclic voltammetry and galvanostatic tests demonstrated predominant pseudocapacitive behavior, associated with surface functionalities and structural defects induced by KOH activation. Compared to conventional graphite (372 mAh/g), this bio-derived carbon offers competitive capacity with lower cost and better sustainability. The study highlights the potential of RH-based activated carbon as a scalable and eco-friendly alternative for next-generation energy storage devices, particularly in LIBs and supercapacitors. Future work will focus on optimizing activation parameters and exploring heteroatom doping to further enhance conductivity and rate performance.

Keywords: *activated carbon, rice husk, anode, lithium-ion batteries, capacity.*

INTRODUCTION

The rapid development of portable electronics, electric vehicles, and stationary energy storage systems requires the creation of reliable, energy-intensive, and environmentally friendly batteries. Among all existing technologies, lithium-ion batteries (LIB) have taken a leading position due to their high specific energy, long service life and wide operating temperature range. However, despite their widespread use and success, further improvement of LIBs is unthinkable without a thorough revision and optimization of the composition of anode materials.

Modern trends in electrochemical energy are increasingly demanding the replacement of traditional graphite, which has a limited theoretical capacity (372 mAh/g), with new materials with greater efficiency and stability. In this regard, special attention is paid to sustainable and affordable resources, in particular, carbon materials obtained from biomass. Activated carbon synthesized from agricultural waste such as rice husk demonstrates high potential due to its porous structure, high specific surface area and low cost [1]. These materials not only allow the processing of biomass, reducing the environmental burden, but also provide decent electrochemical performance when used in LIB anodes, as shown in recent years.

In recent years, biomass as a renewable, environmentally friendly and widely available source of carbon has been actively considered by the scientific community as a promising raw material for the production of anode materials used in lithium-ion batteries. The advantages of biomass are its ubiquity, low cost, high environmental sustainability, and the ability to recycle agricultural and industrial waste.

There are many examples in the literature of successful use of various types of biomass, from rice husks and wood waste to coconut shells and starch, as feedstocks for the synthesis of activated carbon anodes. The most commonly used types of biomass are:

Rice husk: contains up to 20% amorphous SiO_2, which requires a desilification stage. After KOH activation and heat treatment at 600-800 °C, a specific surface area of > ~900 m^2/g and a stable capacity of ~300-400 mAh/g are achieved. The electrode retains >280 mAh/g after 50 cycles [2–4];

Coconut shell: characterized by high density, low ash content, forms a microporous structure. When activated at 800 °C, a surface area of >1000 m^2/g and a capacity of ~420 mAh/g with high cyclic stability are achieved [5].

Sugar cane (bagasse): when H_3PO_4 is treated and carbonized at 600 °C , a meso- and microporous material with a capacity of ~350 mAh/g and a surface area of ~850 m^2/g is obtained. It is characterized by low cost and ease of scaling [6].

Wood and sawdust (acacia, eucalyptus): after H_3PO_4 activation, a structure with 80% micropores is formed, BET-an area of ~1240 m^2/g. It demonstrates a stable capacity of ~370 mAh/g during cycling [7].

Starch and corn waste: after nitrogen dosage (NH_4NO_3, urea), they form functionalized carbon with high conductivity and capacity >400 mAh/g, BET area

>1100 m^2/g. They provide good charge/discharge rate and stability [8].

Peanut husks, walnut shells, banana peels and other organic waste: during heat treatment and activation of KOH or H_3PO_4, activated carbon is formed with a porosity and a capacity of 350–400 mAh/g, BET-an area of ~800–1000 m^2/g. They have a low ash content and a high content of volatile components [7].

The choice of biomass is determined by its chemical composition, the content of volatile substances, the level of ash content and the content of functional groups that are formed during activation. Such wastes, as a rule, undergo preliminary carbonation followed by chemical activation, most often using KOH or H_3PO_4, which contributes to the formation of a developed microporous or mesoporous structure. Additional alloying with materials containing nitrogen, phosphorus, or metals makes it possible to improve electronic conductivity and increase the number of active sites for reversible intercalation of lithium ions. This is especially important for increasing the specific capacity and improving the speed of charging and discharging processes. In particular, nitrogen functional groups contribute to the formation of pseudo-capacitor reactions, increasing the overall electrical capacity. The presence of natural silica in the feedstock, such as in rice husks, requires a desilification stage, which provides additional stabilization of the material structure and prevents its destruction during prolonged cycling. Thus, an integrated approach, including the selection of the appropriate type of biomass, the activation method, the temperature treatment regime and alloying additives, allows us to obtain activated carbon with specified morphological and electrochemical properties optimal for specific applications in LIB.

Below is a table summarizing data on various types of biomass, their activation methods, and the electrochemical characteristics obtained.

Table 1. Properties of activated carbon from various types of biomass

Type of biomass	Activation method	Temperature (°C)	BET surface area (m^2/g)	Specific capacity (mA·h/g)
Rice husk	KOH + desilication	600–850	~900	~300–400
Coconut shell	Chemical (KOH)	800	>1000	~420
Sugar cane	H_3PO_4	700	~850	~350
Acacia (wood)	H_3PO_4	600	~1240	~370
Starch / corn	Nitrogen doping	800	>1100	>400
Peanut husks and etc.	Combined methods	600–850	~800–1000	~350–400

This comparative characteristic makes it possible to identify the most efficient and stable carbon materials from available raw materials for use in lithium-ion battery anodes.

Activated carbon produced from biomass is becoming increasingly important as an anode material for lithium-ion batteries due to its low cost, stability of raw materials and high specific surface area. Methods for producing activated carbon from various types of biomass include two key steps: carbonation and subsequent chemical activation.

Carbonation is the heat treatment of biomass in an atmosphere of an inert gas (usually nitrogen or argon) at temperatures in the range of 400–800 °C. During this process, thermal decomposition of organic components, removal of volatile substances, dehydration and the beginning of carbonation occur. Carbonation promotes the formation of a primary carbon matrix with a porous structure, in which micropores will then develop. The key parameters of carbonation are temperature, heating rate, holding time and type of inert gas. Optimal carbonation conditions make it possible to achieve a uniform structure, minimal residual volatile compounds, and a good carbon base for subsequent activation. For example, at a temperature of 600–700 °C, the maximum carbon yield is observed while maintaining the precursor structure.

After carbonization, chemical activation is carried out, aimed at increasing the specific surface area and pore volume. Chemical activation is a key step in the production of highly efficient activated carbon with a developed porous structure and high specific surface area. Unlike physical activation, in which activation occurs under the influence of gas (CO_2, H_2O) at high temperatures, chemical activation involves the preliminary interaction of a carbon precursor with a chemical reagent, most often alkalis or acids, followed by the thermal decomposition of these compounds. Potassium hydroxide (KOH), phosphoric acid (H_3PO_4), and in some cases sulfuric acid (H_2SO_4) are most often used as activating agents. These substances are embedded in the carbon structure and, under high-temperature treatment (600-900 °C), cause expansion, dissolution and burning of less stable areas. The result is the formation of a developed porous structure, mainly micropores (less than 2 nm), as well as parts of mesopores (2–50 nm).

Thus, when KOH is activated, reactions with carbon are observed, resulting in the formation of metallic potassium, hydrogen, and potassium carbonates, which contribute to the expansion of the carbon lattice and the formation of micropores.

The activation of H_3PO_4 promotes the formation of a stable amorphous carbon structure, improves the thermal stability of the material, and introduces phosphoric functional groups that improve the electrical conductivity and wettability of the surface. It is important to note that the choice of reagent and activation conditions directly affects the morphology, chemical composition and electrochemical characteristics of the final product.

For example, activated carbon obtained from coconut shells by KOH activation at 800 °C showed a specific capacity of more than 420 mAh/g on cycle 50 [5]. Acacia wood treated with phosphoric acid and activated at 600 °C demonstrated a BET area of 1240 m^2/g and stable performance in lithium ion batteries [7]. In another study [4], activated carbon was synthesized from rice husks using KOH and desilification, which made it possible to achieve a specific surface area of more than 900 m^2/g and a specific capacity of about 400 mAh/g. In addition, carbon from sugar cane waste (bagasse) obtained using H_3PO_4 demonstrated a capacity of about 350 mAh/g and good stability under high current loads [6].

The use of nitrogen-containing precursors, such as corn starch or gelatin, makes it possible to further improve the electrical conductivity of the carbon material by forming functional groups (for example, pyridine and pyrrole) that improve the rate of charge transfer. In the study [8], nitrogen-doped carbons from starch were synthesized, which have high stability and a specific capacity of more than 400 mAh/g.

Therefore, the choice of the pretreatment method, activation reagent, and temperature regime has a decisive effect on the structure, porosity, and electrophysical properties of the carbon material. The use of biomass as a raw material allows not only to reduce the environmental burden, but also to create efficient anode materials for lithium-ion batteries with good performance characteristics and the possibility of scalable production.

In addition, activated carbon from RH is actively used in supercapacitors, where its high electrical conductivity and developed porosity ensure effective surface charge accumulation by the mechanism of a double electric layer (electrostatic adsorption). Thanks to this, outstanding specific power parameters, high energy efficiency and a service life of over 100 000 cycles are achieved. These properties make this material an ideal electrode for devices operating in conditions of high frequency charge-discharge cycles [4].

Thus, the search for efficient anodes from renewable raw materials is becoming a strategically important area in the development of new generation battery technologies.

PRODUCTION OF ACTIVATED CARBON FROM RICE HUSKS BY CHEMICAL ACTIVATION

One of the key steps in obtaining a highly efficient anode material based on rice biomass is the preliminary preparation of raw materials, ensuring the purity, stability and reproducibility of the process. In this work, rice husk (RH), which has a high content of carbon and amorphous silica, was used as the initial carbon-containing precursor.

At the first stage, the rice husk was thoroughly rinsed with distilled water with repeated repetition of the procedure to remove dust, sand, soil residues and soluble organic substances (Figure 1.1). This process is critically important to prevent contamination in the subsequent stages and to ensure the uniformity of the resulting carbon material. After washing, the samples were dried in a forced convection dryer at a temperature of 100–120 °C for 6 hours (Figure 1.2). The high drying temperature helped to remove bound moisture and volatile components, while preserving the structure of the feedstock. This ensured the necessary thermal and chemical stability of the rice husk before subsequent carbonation (Figure 1.3).

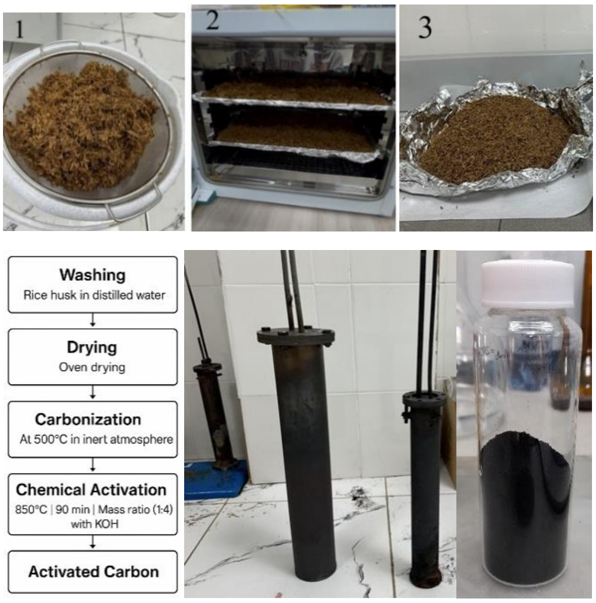

Figure 1. Washed rice husks (1); Drying at a temperature of 100–120 °C (2); Industrially suitable rice husks (3)

Carbonation was carried out in a tubular furnace under uniform heating to a temperature of 500 °C at a rate of 8.5 °C/min, in a controlled atmosphere of argon supplied at a rate of 400 ml/min to prevent oxidation and ensure stable pyrolysis conditions. After reaching the set temperature, the samples were kept in the oven for one hour, which contributed to the removal of volatile organic compounds and partial degradation of organic components.

As a result, thermal degradation of lignin, hemicellulose and cellulose, which make up the structure of rice husks, occurred with the formation of amorphous carbon and residual inorganic components, including silicon dioxide. These products form an initial carbon skeleton with limited porosity, which can subsequently be refined at the stage of chemical activation. The resulting carbon skeleton plays an important role in ensuring mechanical stability and serves as the basis for further structural improvement of the material.

Further, before activation, the samples obtained after carbonation (Figure 2.1) were crushed and thoroughly mixed with the activator (KOH) in a mass ratio of 1:4 (RH:KOH) (Figure 2.2) and kept at a temperature of 90 °C for 12 hours. This mode ensured a uniform diffusion of alkali into the structure of the carbon precursor, creating conditions for deep activation during subsequent thermal combustion. During activation, weakly bound organic residues were destroyed and chemically active areas were formed on the surface (Figure 3).

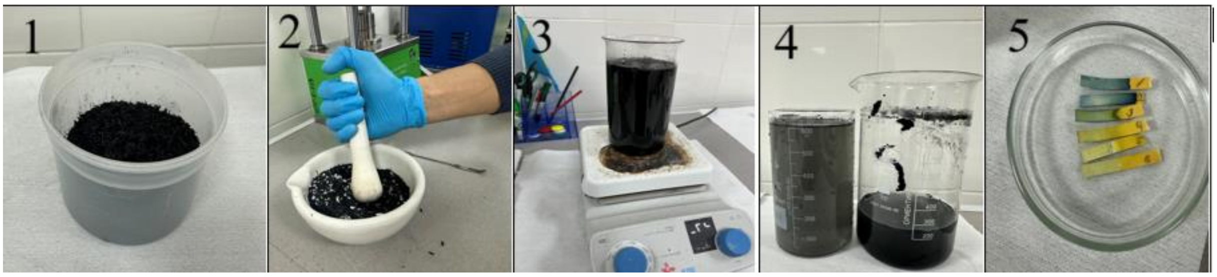

*Figure 2. Carbonized RH (1); Mixing with KOH activator (2);
The desilification process using boiling and neutralizing pH (~7) (3–5)*

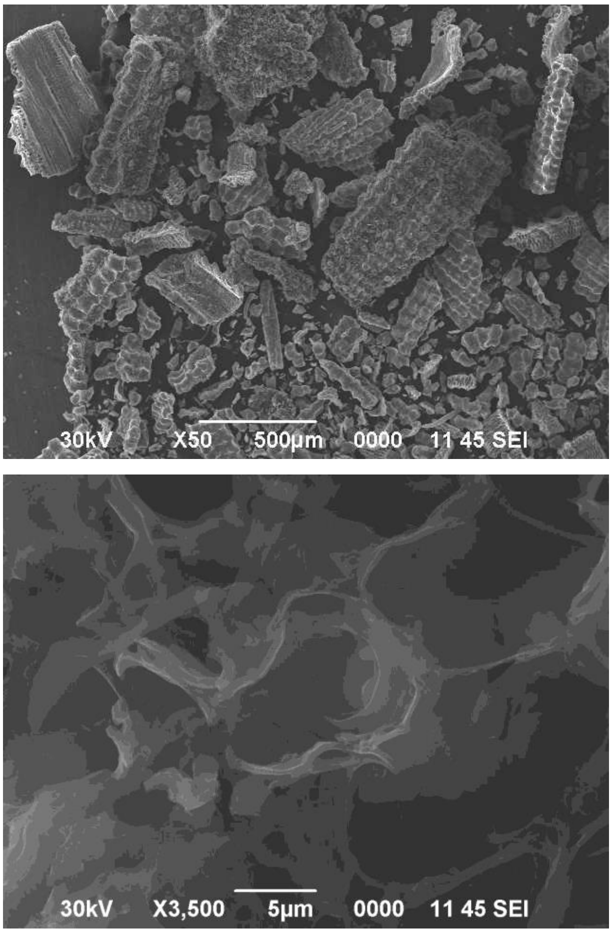

Figure 3. SEM image of the resulting activated carbon

The KOH-impregnated samples were then placed in a tubular furnace and heated to a temperature of 850 °C for 3.5 hours in an inert atmosphere. During thermal activation, potassium hydroxide reacted with carbon, forming pores and enlarging the specific surface of the material. High temperature promotes the dehydration of KOH, its transition to the active state, as well as the formation of micro- and mesoporous structures. It is extremely important to ensure an even temperature distribution and a constant flow of inert gas in order to prevent local overheating and undesirable side reactions. The result of this step is a highly developed porous carbon material structure suitable for efficient intercalation of lithium ions.

From a physical point of view, activation is accompanied by dehydration, degassing and partial leaching of inorganic components, which improves ionic conductivity and reduces resistance during operation as part of a lithium-ion battery. Chemical activation not only increases the surface area, but also creates a favorable morphology dominated by micropores, which are necessary for effective intercalation of Li^+ ions.

This was followed by a desilification step aimed at removing SiO_2 residues. During boiling, KOH residues remain in the solution, and at high temperatures it can react intensively with silicates, which is accompanied by the release of large amounts of heat and gas. This leads to rapid foaming of the solution and, if not adequately controlled, can cause emissions or even an explosion of vapors, especially in a closed system. That is why it is extremely important to observe the temperature regime and control ventilation. After boiling, the samples were repeatedly washed using the precipitation-decantation method until a neutral pH (~7) was reached (Figures 2.3–2.5).

The final stage included drying the samples at 130 °C for 7–8 hours, after which the resulting activated carbon was ready for morphology analysis and testing as an anode for LIB (Figure 3). This sequence of steps made it possible to obtain a material with high microporosity, specific surface area and electrochemical stability, as demonstrated in [4, 5].

RESULTS AND DISCUSSION

The morphological and structural characteristics of activated carbon obtained by chemical activation of KOH play a key role in its effectiveness as an anode material for lithium-ion batteries. During the activation of KOH, a developed porous structure is formed, which is confirmed by the results of scanning electron microscopy. The SEM images show extensive microporous and mesoporous channels evenly distributed over the surface of the particles, which indicates an intense interaction of KOH with the carbon matrix during thermal activation. Additionally, the uniformity of the pore distribution is observed, which contributes to improved ionic conductivity, as well as increased stability during multiple charge and discharge cycles, as demonstrated in [4].

The results of X-ray diffraction analysis (XRD) demonstrate the presence of amorphous carbon with a wide diffuse peak in the range of $2\theta = 23–24°$, characteristic of randomly oriented graphene-like structures (Figure 4). The absence of clear crystal reflexes confirms the destruction of the ordered structure of the initial biomaterial and the formation of an amorphous phase [3].

The electrochemical behavior of activated carbon synthesized from rice husks by chemical activation using KOH was investigated by cyclic voltammetry, galvanostatic charge-discharge, and electrochemical impedance spectroscopic analysis.

Cyclic voltammetry curves obtained at various scanning speeds (0.1–1.0 mV/s) show an almost rectangular shape, which indicates the presence of a highly developed porous structure and the predominance of surface pseudocapacitor processes (Figure 5). The area enclosed inside the cyclic voltammetry loop increases in proportion to the scanning speed, which indicates good conductivity and ion mobility [4].

Galvanostatic charge-discharge tests have confirmed that at a current of 100 mA/g, the material retains a capacity of more than 280 mAh/g for 50 cycles, demonstrating not only initial efficiency, but also stability during long-term cycling (Figure 6). The carbon matrix saturated with mesopores ensures charge distribution over the volume, reducing the current density in the active areas and thereby increasing the service life of the anode. The data obtained indicate that rice husk coal can be used in batteries designed for high-load modes and long operating cycles [4].

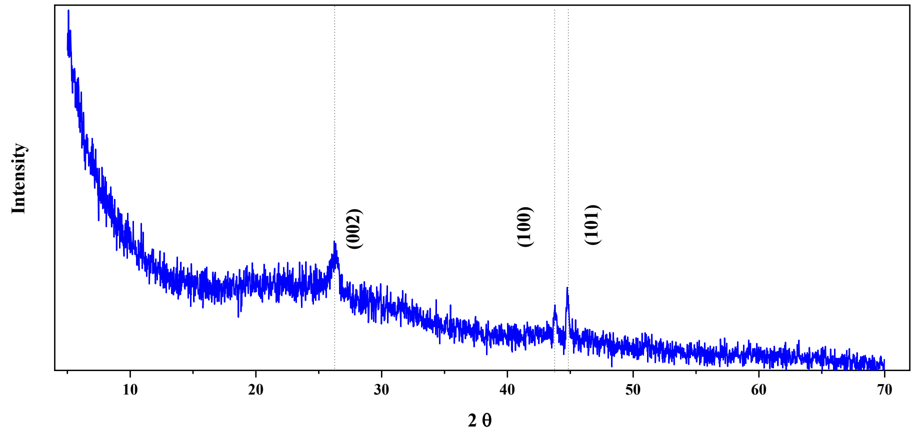

Figure 4. XRD pattern of activated carbon

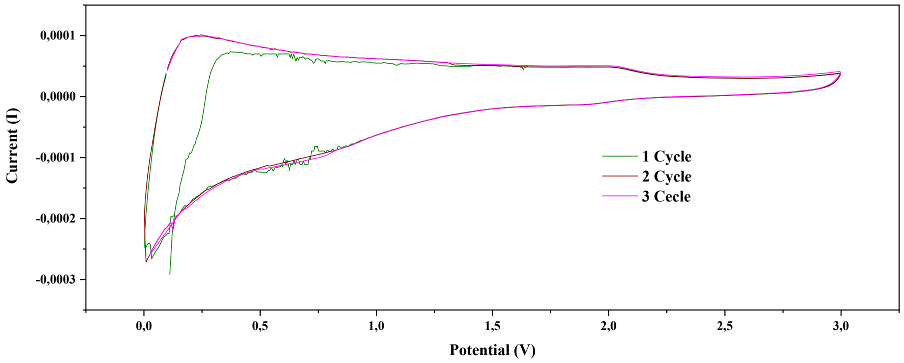

Figure 5. Cyclic voltammetry of activated carbon

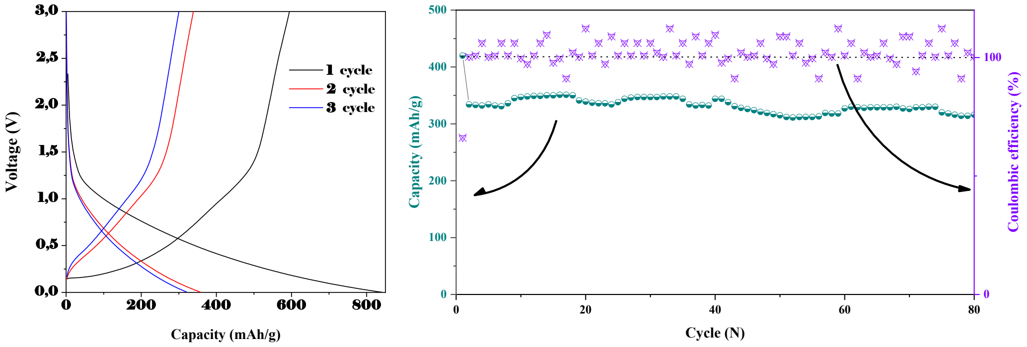

Figure 6. Galvanostatic charge-discharge curve and cycling stability with coulombic efficiency of activated carbon

Comparative analysis with graphite (372 mAh/g), SiO (~1500 mAh/g, but with low stability), and MXene (~400–450 mAh/g) shows that activated carbon based on rice husks occupies an intermediate position, providing a balance between capacity, stability and cost. This makes it a competitive material for LIB applications with a long service life and high reversible capacity [4, 9]. Coulomb efficiency showed around 100 percent throughout the entire cycle.

A comparative analysis of carbon materials synthesized from various types of biomass indicates their high potential for use in modern energy storage devices, including lithium-ion batteries (LIB), supercapacitors, and hybrid systems. Special attention is paid to activated carbon obtained from rice husks due to its unique structural and electrochemical characteristics.

Thus, activated carbon based on RH demonstrates excellent compatibility with lithium-ion technology, acting as an effective anode material. Its highly developed microporous structure and specific surface area exceeding 900–1000 m^2/g contribute to the uniform distribution and intercalation of lithium ions. This reduces the likelihood of lithium dendrites forming and increases the material's resistance to mechanical damage during cycling, which is especially critical for applications requiring long service life and reliability, in particular in electric vehicles, portable electronics, and stationary energy systems [3, 4].

Current research is moving beyond monofunctional storage devices and is focusing on the development of hybrid solutions, such as lithium-ion supercapacitors (LIS), in which activated carbon is used in conjunction with lithium-intercalation materials, including metal oxides or carbon composites. This symbiosis makes it possible to combine the advantages of two technologies: high specific energy LIB and high specific power of supercapacitors, which is especially important for energy-intensive and dynamic applications [9].

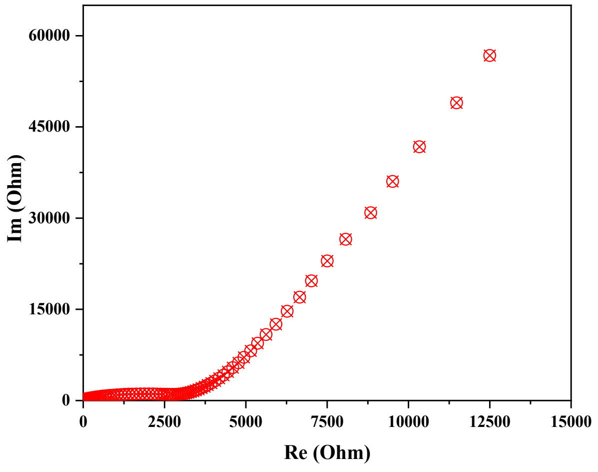

Figure 7. Nyquist diagram curve of activated carbon

The impedance spectrum of a lithium-ion half-cell with an activated carbon anode is presented as a Nyquist diagram. In the high-frequency region (Figure 7), the curve intersects the real-part impedance axis at values of approximately 2–3 kOhm. In the mid-frequency region, there is no pronounced semicircle. In the low-frequency region, the spectrum is characterized by an extended slope, reaching Re(Z) values of approximately 12–13 kOhm and Im(Z) values of approximately 55–60 kOhm.

Activated carbon obtained from rice husks demonstrates high potential as a functional material in various types of energy storage devices. Its characteristics can be further improved by doping processes (for example, with nitrogen or phosphorus), as well as the creation of composites based on MXene, metal oxides or heteroatomic structures, which opens up broad prospects for further optimization of new generation anode and electrode materials.

CONCLUSION

The results demonstrate that activated carbon obtained from rice husks by KOH chemical activation and desilication can serve as a promising anode material for lithium-ion batteries. Its high specific capacity, cycling stability, and well-developed microporous structure make it a competitive alternative to traditional anodes. In the future, research will focus on optimizing the parameters of pyrolysis as an economically advantageous method for producing activated carbon, as well as on selecting the temperature and pressure that ensure the development of a microporous structure. This will improve the electrode characteristics and adapt the material for use in conditions of high currents and extreme temperatures.

Acknowledgement

This research is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (№ BR24992873).

REFERENCES

1. Faheem Ahmed, Ghazzai Almutairi, Prince M.Z. Hasan, Sarish Rehman, Shalendra Kumar, Nagih M. Shaalan, Abdullah Aljaafari , Adil Alshoaibi , Bandar Al Otaibi, Kaffayatullah Khan. Fabrication of a Biomass-Derived Activated Carbon-Based Anode for High-Performance Li-ion Batteries // Micromachines. – 2023. – Vol. 14 (1). – Art. 192. – https://doi.org/10.3390/mi14010192
2. Xiang Peng1, Jijiang Fu, Chengcheng Zhang, Jingyuan Tao, Lan Sun, and Paul K. Chu. Rice Husk-Derived Activated Carbon for Li-Ion Battery Anode // Nanoscience and Nanotechnology Letters. – 2014. – Vol. 6 (1). – P. 68–71. – https://doi.org/10.1166/nnl.2014.1714
3. Yusuke Abe, Masahiro Tomioka, Mahmudul Kabir,Seiji Kumagai. Role of SiOx in rice-husk-derived anodes for Li-ion batteries // Scientific Reports. – 2022. – Vol. 12. – Art. 975. – https://doi.org/10.1038/s41598-022-04979-5
4. Yerdauletov M.S., Nazarov K., Mukhametuly B., Yeleuov M.A., Daulbayev C., Abdulkarimova R., Yskakov A., Napolskiy F., Krivchenko V. Characterization of Activated Carbon from Rice Husk for Enhanced Energy Storage Devices // Molecules. – 2023. – Vol. 28. – Art. 5818. https://doi.org/10.3390/molecules28155818
5. Kuan-Ching Lee, Mitchell Shyan Wei Lim, Zhong-Yun Hong, Siewhui Chong, Timm Joyce Tiong, Guan-Ting Pan, Chao-Ming Huang. Activated Carbon Monolith Deri-

ved from Coconut Husk Fiber as Electrode Material for Supercapacitor Energy Storage // *Energies.* –2021. – Vol. *14*(15). – Art. 4546. https://doi.org/10.3390/en14154546

6. Dwiyaniti, M., Krisnawati, N. L., Pramono, A. E., Subhan, A., Setiabudy, R., and Hudaya, C. Electrochemical characteristics of sugarcane bagasse-activated carbon as cathode material of lithium-ion capacitors // Journal of Applied Research and Technology. – 2023. – Vol. 21(4). – P. 571–580. https://doi.org/10.22201/icat.24486736e.2023.21.4.1976
7. Yang H, Ye S, Zhou J and Liang T. Biomass-Derived Porous Carbon Materials for Supercapacitor // Front. Chem. – 2019. – Vol. 7. – Art. 274. – https://doi.org/10.3389/fchem.2019.00274
8. Aoqi Huang, Yibo Tu, Qichao Yu. Preparation and electrochemical properties of nitrogen-doped starch hard carbon anode materials for lithium-ion battery // International Journal of Electrochemical Science. – 2024. – Vol. 19 (10). – Art. 100774. – https://doi.org/10.1016/j.ijoes.2024.10077
9. Obinna Egwu Eleri, Fengliu Lou, Zhixin Yu. Lithium-Ion Capacitors: A Review of Strategies toward Enhancing the Performance of the Activated Carbon Cathode // Batteries. – 2023. – Vol. 9(11). – Art. 533. – https://doi.org/10.3390/batteries9110533

КҮРІШ ҚАУЫЗЫНАН АЛЫНҒАН БЕЛСЕНДІРІЛГЕН КӨМІР – ЛИТИЙ-ИОНДЫ БАТАРЕЯЛАР ҮШІН ПЕРСПЕКТИВТІ АНОД

Н. Саитова[1], Қ. Асқарұлы[1], Е. Есжан[1], Р. Амрус[2], Е. Евлампиева[3], С. Азат[1]*

[1] «Қ.И. Сәтбаев атындағы ҚазҰТЗУ» КеАҚ, Алматы, Қазақстан
[2] Чоуайб Дуккали университеті, Эль-Джадида, Марокко
[3] «Шәкәрім университеті» КеАҚ, Семей, Қазақстан

* *Байланыс үшін E-mail: seytkhan.azat@gmail.com*

Бұл мақалада күріш қауызынан (ҚҚ) физика-химиялықсинтездеу арқылы белсендірілген көмір алу тәсілі және оны литий-ионды батареялар үшін анодтық материал ретінде пайдалану қарастырылған. Әртүрлі термиялық өңдеу режимдерінде алынған үлгілердің морфологиялық, құрылымдық және электрохимиялық қасиеттері салыстырмалы түрде зерттелді. Арнайы беттік модификация мен десиликация арқылы материалдың меншікті сыйымдылығы мен циклдік тұрақтылығын арттыру механизмдері талданды. 600 °C температурада өңделіп, кейіннен KOH ерітіндісімен белсендірілген көмір шамамен 300 мА·сағ/г меншікті сыйымдылықты 50 цикл бойы сақтап, жоғары тұрақтылық көрсетті. Бұл нәтиже оны дәстүрлі графиттің тиімді баламасы ретінде қарастыруға мүмкіндік береді.

Түйін сөздер: *белсендірілген көмір, күріш қауызы, анод, литий-ионды батарея, десиликация, сыйымдылық.*

АКТИВИРОВАННЫЙ УГОЛЬ ИЗ РИСОВОЙ ШЕЛУХИ КАК ПЕРСПЕКТИВНЫЙ АНОДНЫЙ МАТЕРИАЛ ДЛЯ ЛИТИЙ-ИОННЫХ БАТАРЕЙ

Н. Саитова[1], Қ. Асқарұлы[1], Е. Есжан[1], Р. Амрус[2], Е. Евлампиева[3], С. Азат[1]*

[1] НАО «КазНИТУ им. К.И. Сатпаева», Алматы, Казахстан
[2] Университет Шуайба Дуккали, Эль-Джадида, Марокко
[3] НАО «Шәкәрім университет», Семей, Казахстан

* *E-mail для контактов: seytkhan.azat@gmail.com*

В работе представлены результаты получения активированного угля из рисовой шелухи (РШ) с применением физико-химической активации, а также его характеристика как анодного материала для литий-ионных батарей. Проведено сравнение морфологических, структурных и электрохимических свойств материалов, полученных при различных режимах термической обработки. Исследованы механизмы улучшения удельной ёмкости и циклической стабильности за счёт поверхностной модификации и десиликации. Активированный уголь, полученный при 600 °C с последующей обработкой KOH, продемонстрировал высокую стабильность в 50 циклах при удельной ёмкости ~300 мА·ч/г, что делает его перспективной альтернативой традиционному графиту.

Ключевые слова: *активированный уголь, рисовая шелуха, анод, литий-ионные батареи, десиликация, ёмкость.*