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Advanced Progress in the Sustainable Use of Biomass Resources in Lithium-Ion Batteries

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Abstract: With the depletion of traditional fossil energy sources, it is imperative to use new energy sources to replace traditional energy sources. Battery, as a kind of energy storage device, has an important role in the energy field. Biomass resources, due to green, environmentally friendly, low cost and good performance, using them to produce a new generation of battery components is one of the most important research hotspots in the energy field. This paper discusses and analyses the current status of the mainstream lithium-ion batteries (LIBs) containing components, such as anode, diaphragm, and electrolyte, and reviews the latest progress in electrochemical properties, mechanical properties, and thermal stability of biomass resources from their sources and their application throughout the whole process of LIBs in recent years. Finally, the prospects and challenges of using biomass resources to replace the traditional components of lithium-ion batteries are envisioned.

Keywords: Biomass, lithium-ion batteries, diaphragms, electrodes, electrolytes

1. Introduction

With the rapid growth of the global population, mankind's demand for energy is increasing day by day. Energy is an important foundation for economic development and social progress, as well as an important strategic high ground for national security. According to statistics, 80 per cent of the world's energy sources are provided by traditional fossil fuels, which are causing the growing challenges of climate change and biodiversity loss, thus stimulating the exploration of sustainable non-fossil energy conversion technologies.

Sustainability can be achieved through the use of renewable raw materials, renewable energy and green resources. Therefore, the sustainable development of lithium-ion batteries (LIBs) has become an important issue. The materials used in sustainable batteries should be environmentally friendly throughout their life cycle of use and disposal. Considering this situation, research has been carried out to improve and manufacture high-capacity batteries using green, recyclable and sustainable materials. Carbon being one of the most abundant elements on earth, the total biomass waste of the entire biosphere as a whole is estimated to be about 550Gt C (1Gt C=1015g of carbon), with 80% of the sources being plants and 15% being microorganisms [1]. However, a large amount of biomaterial is wasted every year, which includes forestry biomass, animal wastes, and agricultural wastes. The use of these biomass as a preparation of carbon and advanced carbon materials is becoming a new trend, including photocatalysis, photovoltaic power generation, and energy storage devices. In particular, the use of biomass resources to develop a new generation of electrochemical energy storage provides new ideas for sustainable development.

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Diaphragms play an important role in metal ion batteries (MIBs) by conducting ions and separating the cathode and anode to prevent short-circuiting of the battery [2]. The diaphragms in mainstream LIBs currently on the market are made using polyolefins, which are widely used due to their excellent electrochemical strength and stability. However, polyolefin membranes are mainly non-polar and have poor solubility when compatible with polar organic solvents, leading to a significant reduction in the electrolyte absorption capacity of LIBs. In addition, due to the low glass transition temperature and melting point of olefins, thermal contraction of the diaphragm can lead to internal short-circuiting, fire, or even explosions, which is a serious safety hazard. Biomass materials have high chemical stability, electrical properties, and mechanical strength, allowing for the manufacture of ultra-thin, robust, and highly ion-conductive diaphragms. The whole production process is green, biodegradable and rich in sources, making it an ideal replacement material for olefin diaphragms.

In terms of negative electrodes for batteries, negative electrodes made of metal and graphite are prone to uneven deposition, resulting in the growth of dendrites that puncture the diaphragm and cause short circuits in the battery, which results in batteries with low theoretical specific capacity and low cycle efficiency and safety and stability of the battery. Biochar is beginning to gain the attention of researchers due to its high specific surface area, as well as its small expansion rate, and the fact that it is less prone to dendrites and rich in heteroatoms.[3]

In the case of electrolytes, the production process consumes a lot of energy and requires the use of many toxic substances, which not only results in a waste of resources, but recycling is also an important factor in polluting the environment. Biopolymer hydrogels are used as a semi-solid electrolyte as a carrier for ionic conduction, with high electrical conductivity, thermal stability, mechanical robustness, and biodegradability.[4] In addition, the ability to create synergistic effects with electrodes provides an effective strategy to improve the performance of electrolytes.[4]

In this paper, the mainstream applications of LIBs electrodes, electrolytes, and diaphragms in recent years are reviewed, as well as the results of biomass resources used for the above components, and the performances of biomass battery components in terms of electrochemical performance, stability, and mechanical properties are compared to provide a basis for decision-making for further optimisation of the new generation of green battery components.

2. Biomass carbon negative electrodes

In LIBs, Li^+ continuously undergoes embedding/de-embedding reactions between the cathode and anode electrodes for charging and discharging purposes.[5] Negative electrode materials need to maintain good structural stability during battery charge/discharge cycling to avoid performance degradation due to volume change, shedding or collapse. At the same time, the selection and design of anode materials also need to consider their safety to prevent potential risks such as short circuit and thermal runaway. The advantages of using traditional metal oxides as lithium-ion battery anode are high theoretical capacity, small voltage hysteresis, high theoretical capacity, etc. However, during the same discharge process, there will be a significant volume change of charging and discharging (>300%), which leads to electrochemical collapse and a sharp decline in battery performance.[6] Graphite is currently the dominant negative electrode material on the market because of its good electrical conductivity, low expansion rate, good stability, and lack of dendrite generation. However, graphite faces great challenges of limited theoretical specific capacity (372mAh g^{-1}) and poor rate capability. Currently, commercially available lithium-ion batteries with metal and graphite as the anode can hardly meet the growing and urgent demand for the wide application of electric or hybrid vehicles.[6] The biomacromolecule network, which provides a large number of binding sites for lithium ions, has a stable backbone structure after carbonization. Compared with traditional graphite electrodes, biomass carbon has higher theoretical capacity and is less prone to dendrites and has very

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excellent stability, making it an ideal precursor. Currently there are three strategies for making anode using biomass materials, including doping, activation, and alloying.

2.1. Doping

Doping is a simple composite method. It is mainly achieved by carbonizing the biomass material and then adding heteroatoms to the framework. Currently, common elements such as P, N, O and B are commonly used for doping.

Water hyacinth is a natural plant capable of spontaneous silicon production, and its silicon is mainly stored in its cell walls. Liu [7] et al. reported a Si doped anode material, EC-SiOC, obtained directly by one-step carbonization using water hyacinth as precursor. Although the Si percentage of the fabricated EC-SiOC is only 18.8%, it has a high reversible capacity of 749.9 mAh g^{-1} and an initial coulombic efficiency of 98.2%. Compared with the traditional thermally reduced silicon to make anode, it saves 80% of resource consumption and has high reversible capacity and initial coulombic efficiency. Conventional metal oxides have high ionic capacity, conversion potential, voltage hysteresis and so on, however, the expansion and contraction rate is too large during the battery charging and discharging process, which leads to unstable batteries and a significant reduction in performance. Qiao [6] et al., using lychee peel as a precursor, produced a three-dimensional N-doped anode with a basic skeleton of biogenic carbon and the surface of the skeleton was covered with MnOx nanoparticles through the addition of reagents such as potassium permanganate and melamine. particles on the three-dimensional N-doped lychee exocarp lamellar carbon. (shown in Fig. 1(a)) greatly improved the electrochemical capacity and also overcame the disadvantage of poor stability of conventional metal electrodes. Electrochemical tests show that the reversible capacity is as high as 515.5 mAh g^{-1} after 1000 cycles at 2A g^{-1}. Even at the ultra-high current density of 20A g^{-1}, the high reversible capacity of 309.2 mAh g^{-1} can still be provided after 1000 cycles, which shows the excellent lithium storage capacity, and it is also the best fast-charging lithium-ion battery negative electrode reported so far. Temperature is an important limitation in real-world EV driving. At low temperatures, the lithium ion transport rate slows down considerably and the battery efficiency is significantly reduced. In this case, the solid electrolyte interphase (SEI) layer is the main factor influencing the charge transfer at the electrode-electrolyte interface and is a decisive step in the lithium ion transport kinetics. Nurbolat [8] et al. employed date core as a carbonization precursor, and the synthesised nitrogen-doped hard carbon with porous structure was further modified with LiF to generate a LiF-rich artificial SEI. It was found that the 3 wt % LiF-modified hard carbon (NHC/3LiF) cathode could provide 525 mAh $g^{-1}$and 280 mAh g^{-1} after 50 cycles at RT and 100 cycles at LT, respectively. In addition, NHC/3LiF can provide 72 mAh g^{-1} capacity at a high current of 2 C after 500 cycles at -20 ℃. Chen [3] et al. carbonized water hyacinth to prepare a honeycomb and heteroatom-rich biochar negative electrode (Shown in Fig. 1(b)). The biochar had a rate capacity of 229.7 ± 0.9 mAh g^{-1} at 3000 mA g^{-1} and a higher initial reversible specific capacity of 697 ± 4.3 mAh g^{-1} at 50 mA g^{-1}. The residual capacity after 200 cycles was 720 ± 30.2 $mAhg^{-1}$.

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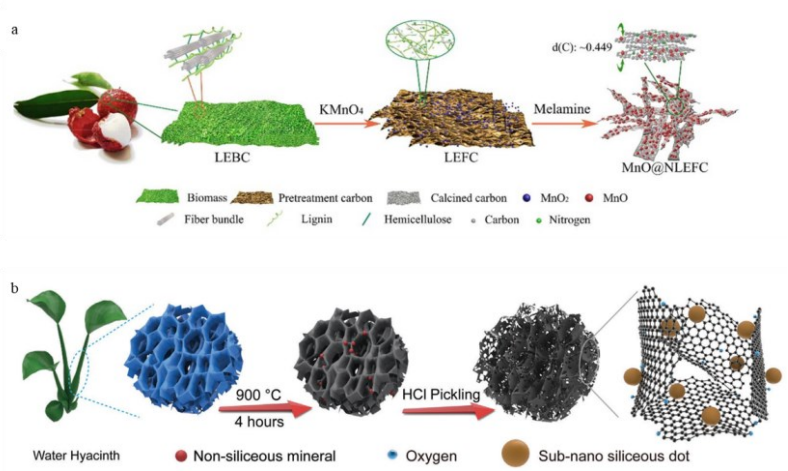

Figure 1: (a) 3D N-doped lychee exocarp lamellar carbon enriched with MnOx nanoparticles using lychee peel as a precursor; (b) honeycomb biochar LIBs anode using water hyacinth as a precursor

2.2. Activation

Biomass carbon materials in practice, often also need to be activation treatment, to further improve its performance, to make up for the lack of a single treatment. The main ways include physical activation, chemical activation and template activation. Physical activation improves its properties through high temperature and high pressure hydrothermal reactions, while chemical activation increases ionic binding sites by introducing more particles through chemical reagents. The template method is a way to synthesise porous materials using different materials as templates, mainly using organic templating agents, surfactants and organic carbon derived from the assembly to build porous structures through interactions at the molecular level.

Traditionally, the use of biomass materials to produce carbon loads generally starts with pretreatment of the precursor to remove impurities, followed by further activation to produce the desired electrode material. The activation methods are mainly hydrothermal activation, pyrolysis activation and addition of activator, the former is treated by pyrolysis with water steam at high temperature, and the latter is to promote the activation by adding chemicals. The former method requires a large amount of energy consumption, the process is cumbersome, and the reaction process is not easy to control. Through template activation, the introduction of activators can increase the porosity and introduce heteroatoms more easily to further enhance the performance of the battery. Thus,Balahmar [9] et al, used KOH as an activator for the one-step activation of eucalyptus wood chips, flowering plant Milkweed Violet and seaweed, skipping the hydrothermal treatment and pyrolysis steps. In general, the size and distribution of pore size on the anode affects the lithium storage performance. Micropores can provide adsorption sites for ions, mesopores will cut off the transport of ions, and macropores act as storage reservoirs for ions. The knot shows that the biomass material treated by KOH in one step has a large number of micropores and macropores, indicating that it has a very high theoretical specific capacity. Furthermore,Zhang [10] et al, synthesised a hierarchical porous carbon (LHPC) of lignin by using lignin as a template and KOH as an activator, and thanks to the rich pore size network, the anode fabricated from this material has good cycling performance and theoretical specific capacity. However, the above activation process still requires the use of a large number of additional chemical reagents, and thus, the self-activation mechanism was developed. This mechanism can extend the carbon lattice and synthesise highly porous structures using intermediates that are present in the biomass itself. Self-activation methods are cost-effective and environmentally friendly compared to conventional activation methods.[11]

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2.3. Alloying

Addition of metal elements to the carbon framework is also an effective method. By means of organometallic frameworks (MOFs), coordination compounds are synthesised and electrodes prepared with equally good performance.

Conventional metals, with their large number of ionic binding sites, are able to bring a large theoretical specific capacity to the battery, however, they are prone to swelling, resulting in a battery with low stability. Various solutions have been proposed. Metal-organic framework (MOF) is a structure that forms ligands by combining inorganic metals with organic ions. This structure not only has a high theoretical specific capacity, but also gives the battery good stability due to the metal framework.[5] However, the structure is complicated, and it is difficult to achieve the desired structure by adjusting the binding of metal ions and ligands, and the synthesis process needs to consume a large amount of metal minerals, which is not friendly to the environment in the long run. One solution is to use metal alloying with biomass carbon to prepare green and efficient battery anodes. MoS_2 is a typical two-dimensional material that has attracted great interest in the field of energy storage in recent years, with strong covalent forces in its S-Mo interactions and weak van der Waals bonds between the S-Mo-S layers. According to the electron transfer reaction ($MoS_2 + 4Li^+ + 4e^- \rightarrow Mo + 2Li_2S$), MoS_2 can provide a high theoretical capacity of 670 mAh g^{-1}.Wang [12] et al, synthesised the biomass carbon material HHPOC (Fig. 2(a)) using fungus as a precursor, alloying MoS_2 multilayer nanosheets in combination with a biomass carbon framework gave an improved specific capacity of 707.4 mAh g^{-1} , whereas the negative electrode consisting of only MoS2 only had a real specific capacity of 580.2 mAh g^{-1} , and the biocarbon made by fungus as a precursor only had a 215.5 mAh g^{-1} of real specific capacity, it can be seen that the electrical performance of the negative electrode was significantly improved after alloying. In addition, thanks to the stable biomass framework structure (Fig. 2(b)), the capacity hardly decayed even after 500 cycles at 1600 mA g-1.Chen [13] et al. successfully prepared novel MnO, H2SO4 pretreated oil tea pollen carbon (SCPC) by synergising $Mn(NO_3)_2$/ SCPC with precursor wet impregnation treatment and thermal annealing through carbonization and hydrolysis of oil tea pollen. The material was modelled on oil tea pollen (shown in Fig. 2c), with the presence of a large number of multilayered microporous spherical structures, with a low discharge voltage, a high initial discharge capacity of 1490 mAh g^{-1} at 0.1 A g^{-1} , a retention of 60% after 100 cycles, and an additional discharge capacity of 612 mAhg-1at a very high current of 2A g^{-1}.Rangaraj [14] et al. prepared ZnS doped chicken feather carbon (ZnSCFC) composites using waste chicken feathers (CFs) as raw material over a simple two-step process. After 150 cycles at 100 mA g^{-1}, its reversible capacity is still 788 mAh g^{-1} with good multiplicative performance.

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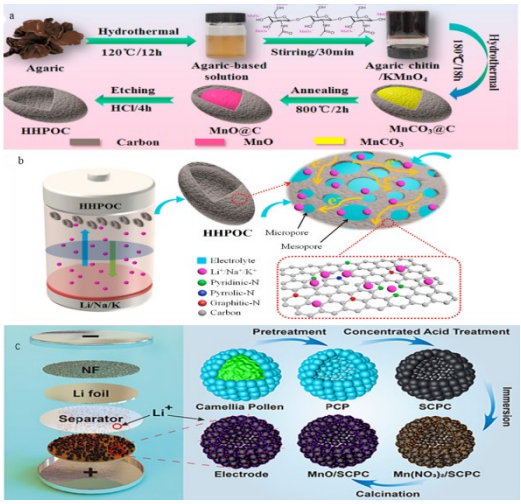

Figure 2: (a) Schematic diagram of HHPOC synthesis process. (b) Schematic diagram of alkali ion storage of HHPOC anode material. (c) Schematic diagram of the synthesis of hollow MnO/SCPC microspheres

3. Biomass diaphragm

Diaphragm is one of the important components in batteries, its function is mainly to separate the positive and negative electrodes, to prevent the battery from short-circuiting, and to allow specific ions to pass through. A good diaphragm needs to have good porosity, ion absorption, stability, conductivity, interfacial resistance, electrochemical stability, discharge capacity and so on. Currently, most of the battery separators on the market are polyolefins, however, their low compatibility with the electrolyte, high shrinkage, and tendency to produce dendrites are their biggest drawbacks. Common solutions are to improve the compatibility of the diaphragm with the electrolyte by coating ceramic nanoparticles on the polyolefin or to replace the traditional diaphragm with heat-resistant materials such as polyimide (PI), polyacrylonitrile (PAN) and aramid. However, the porosity of these materials is generally low, which greatly reduces the efficiency of the battery.[15] In addition, this type of diaphragm is very difficult to degrade, which is not conducive to the recycling of batteries. Biomass diaphragms, composed of natural biomolecules or their derivatives, have uniform and good porosity to provide a stable channel for ion transport, good electrolyte compatibility, not easy to expand, can inhibit the formation of dendrites, has good flexibility, is the ideal alternative to the traditional polyolefin diaphragm. Cellulose, chitosan, lignin, chitosan are all common biomass diaphragm resources, usually by compounding with other solvents to prepare high-performance membrane materials.

3.1. Cellulose diaphragm

Cellulose is currently the world's most abundant biomass resource from a wide range of sources. Its inherent porous structure and good electrolyte compatibility, and extremely high mechanical strength make it the best choice for biomass resource utilization. Cellulose contains two main categories, cellulose derivatives, and nanocellulose. Cellulose derivatives are usually those soluble compounds obtained by chemical modification of cellulose through esterification or etherification processes. Nanocellulose consists of nanoscale cellulose particles with different high aspect ratios extracted after chemical, mechanical or microbial fermentation processes.[16] They can be further classified into cellulose nanocrystals (CNCs), cellulose nanofibers (CNFs) and bacterial cellulose (BC), and the applications of the above types of cellulose in diaphragms are described below.

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Aromatic polyamide (PPTA) nanofibers (ANFs) have excellent mechanical properties and thermal stability, and are often added to the matrix as functional reinforcement. Yang [17] A BC/ANF composite membrane was prepared by et al. The highest porosity reached 83.9%, which was higher than the 73.7% of the control BC membrane. Notably, the porosity decreased significantly when the percentage content of ANF reached 7%, which was due to the agglomeration of ANF. In addition, the body resistances of 2% ANFs/BC and 4% ANFs/BC were 1.2 and 3.3 Ω, respectively, which were significantly lower than that of the control BC (6.7 Ω), and the electrical conductivities were 12.54 and 4.23 mS cm^{-1}, respectively, which were significantly larger than that of the BC's ionic conductivity, 2.25 mS cm^{-1}. After 100 cycles, the batteries using the 2% ANFs/BC diaphragm After 100 cycles, the discharge capacity retention rate of the battery with 2% ANFs/BC diaphragm was 93%, which was significantly higher than that of BC diaphragm at 86.5%.Cheng [18] et al. prepared a high-performance diaphragm OBCS by grafting chitosan (CS) onto BC, which has a porosity of 65.8 %, an electrolyte uptake of 358 %, and maintains 90% capacity after 100 cycles, with a specific discharge capacity of 148 mAh g^{-1} , which is superior to that of the commercial polypropylene diaphragm of 138 mAh g^{-1}. The interfacial resistances of BC, OBCS-100, OBCS200, and OBCS-400 were characterized to be about 640 Ω, 200 Ω, 310 Ω, and 320 Ω, respectively. The interfacial resistances of BC, OBCS-100, OBCS200, and OBCS-400 were characterized to be about 640 Ω, 200 Ω, 310 Ω, and 320 Ω, respectively, which were much lower than that of the polypropylene diaphragm of 880 Ω. This is due to the excellent electrolyte wettability and porous nature of OBCS, which greatly reduced the interfacial resistance between the diaphragm and the electrode sheet. Liu [19] al. composited polyimide (PI) with DBDPE and cellulose nanofibers (CNF) to prepare a diaphragm with good heat resistance, abundant porosity, and excellent mechanical properties by phase conversion method. Its pore size distribution was 20 nm and the porosity was around 78%. The tensile strength reached 25.4 MPa, the modulus of elasticity reached 550.1 MPa, and there was no significant change in thermal stability when working at a high temperature of 200 degrees Celsius. Polyimide (PI) film is very safe with excellent chemical resistance, insulation and self-extinguishing, however, its poor compatibility with the electrolyte limits its use in separators. Deng [20] al. developed an environmentally friendly hydrogen-bonded cross-linked cellulose/PI-COOH composite diaphragm using electrostatic spinning. Thanks to its rich hydrogen bonding, the mechanical properties of the membrane were significantly improved. Its tensile strength is as high as 34.2 MPa, which is five times higher than that of the PI diaphragm (6.8 MPa). At a current intensity of 166.2 mAhg-1, it possesses 90% of the highest initial discharge capacity, while the PI-based $LiFePO_4$ half-cell only has 86%.CNC is a cellulose with a rod-like structure and a smooth, clean surface. A tree called kapok located in the region of Malaysia has a cellular composition that contains a large amount of CNC and has a porosity of up to 80%. Mohamed et al. [21] A self-assembled membrane was prepared by extracting CNC from Kapok species by aqueous suspension cast evaporation technique. After scanning electron microscopy and transmission electron microscopy, it was found to be porous and homogeneous with a porosity of 52.82 ± 7.79%, and the adsorption efficiencies of 10 mg/L and 5 mg/L aqueous methylene blue solutions reached 79% and 85%, respectively.

3.2. Other types of diaphragms

In addition to cellulose, there are a large number of green resources in living organisms. For example, chitosan, lignin, and biological proteins can be processed to prepare high-performance battery diaphragms.

Chitosan, the second largest polysaccharide in the world, is derived from the deacetylation of chitin. Chitosan is derived from the deacetylation of chitin. It is found in a wide range of sources, mainly in the shells of living organisms, such as crab shells and shrimp shells. Chitosan has a good affinity for polar organic solvents due to the abundance of polar functional groups -NH2 and -OH. Therefore, it

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is an ideal raw material for biofilm (Shown in Fig. 3.) Song [15] et al, Use chitin, borrowed the paper-making process, and produced a kind of chitosan nanofiber paper diaphragms (CSNFs) by modulating the aspect ratio of chitosan fibers and thus controlling the porosity through homogenization treatment. (Shown in Fig. 3.) The experimental results showed that the CNFs with a pore size of 400 nm had good wettability and mechanical strength. The electrolyte uptake reached 281% in LiFePO4/LiPo batteries, and the capacity people remained more than 95% after 100 cycles at a discharge rate of 0.1 C. The electrical conductivity of the CNFs reached 1.15mS cm^{-1}, which was significantly higher than that of the ionic conductivity of the polyolefin separator of 0.41mS cm^{-1}.

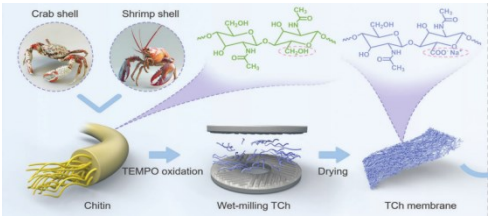

Figure 3: Preparation of septa from chitosan extracted from shrimp shells

Soya proteins (SPI), are biomolecules that make up the structure of legumes. It has a high percentage of composition in legumes, however, due to its high rigidity, it exhibits low mechanical strength and water resistance. In order to compensate for its deficiencies, Uranga [22]et al, extracted cellulose from seaweed and compounded it with SPI to produce a diaphragm using freeze-drying method. The two were observed under electron microscope and found to be newly compatible with good and uniform porosity. Mercury intrusion porosimetry (MIP) showed that the porosity of the membrane was in the range of 80-90%. It is worth noting that when the cellulose content reaches 50%, the electrolyte absorption capacity reaches 1000%, far exceeding the 150% absorption rate of commercially available polyethylene diaphragms. At C/10, C/5, C/2, 1C, and 2C, the discharge capacity reached 144, 141, 133, 112, and 61 mAh g^{-1}, respectively, and the Coulombic efficiency was close to 100%, demonstrating the good process reversibility of the diaphragm. After 100 cycles, the capacity remained almost constant.

Lignin, the second most abundant biomass resource besides cellulose, is rich in functional groups and has a high carbon content, which is often used to make ideal materials for batteries by composite methods. Zhang [23] et al. prepared lignin/PAN fiber diaphragms using electrostatic spinning technique. It was found that the discharge capacity was 148.9 mAh g^{-1} at a lignin: PAN weight ratio of 3:7. The capacity retention was as high as 95% after 50 cycles at 0.2C. The porosity reached 70%.

4. Electrolytes

The electrolyte enhances the transport of ions by providing ion transport between two electrodes in a battery. To a large extent, the electrolyte can determine the electrochemical stabilization potential, cycling stability, ionic conductivity and other properties of the device. They can be divided into three main categories according to their state. Liquid electrolyte lithium-ion batteries (LE), gel polymer electrolyte lithium-ion batteries (GPE), and all-solid polymer electrolyte lithium-ion batteries (SPE). Due to its high conductivity, LE is the dominant battery type on the market today. However, easy liquid leakage, which in turn causes safety hazards, is the main problem faced by LE. Therefore, GPE and SPE have become the research direction of new batteries, and the current research mainly focuses on GPE (shown in Fig. 4). We will elaborate on the use of biomass resources in GPE.

Wang [24] et al, acetylated nanocellulose to produce a corresponding gel electrolyte and then added ester groups as lithium salts. It was found that at the optimum degree of substitution (DS) of 2.37, the resulting acetylated CNF (GACNF-3) GPE electrolyte had an uptake capacity of 301%, an

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ionic conductivity of 2.73×10^{-3}Scm-1, and a Li^+ ionic mobility number of 0.65. The tensile strength of Li/GACNF-3GPE/Li reached 37%. The tensile strength of 3GPE/Li was 37.66 MPa.

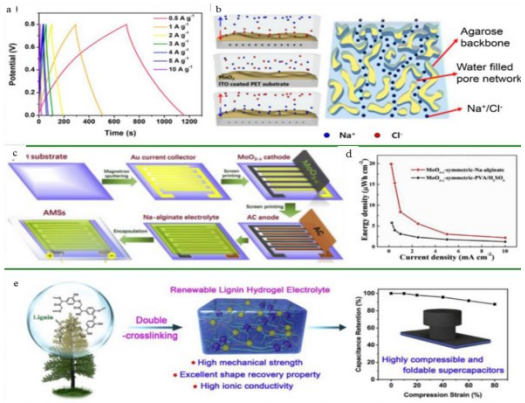

Figure 4: (a) Electrostatic charging/discharging (GCD) diagram of a flexible supercapacitor employing an agarose gel electrolyte; (b) Schematic diagram of ion transport in an agarose gel; (c) Fabrication process of asymmetric micro-supercapacitors using sodium alginate bio-hydrogel electrolyte; (d) Energy density depending on different current densities. (e) Fabrication process of renewable double cross-linked lignin hydrogel electrolyte and assembled highly foldable and compressible SC

5. Summary and outlook

Biomass resources, as abundant resources on earth, have a very great potential for application. LIB components made from biomass resources such as cellulose, lignin, chitosan, bioprotein, agar, etc., are green and sustainable, and also have a very high theoretical specific capacity, mechanical strength, electrolyte compatibility, as well as lower interfacial resistances and higher low-temperature ionic transport rates, which are superior to those made from traditional fossil resources.

However, the wide variety of living organisms and the high variation in biomass resource content between species pose challenges for stable access to feedstocks. The complex structure of biomacromolecules and the lack of research on the synergistic effects of certain components and the whole require a lot of research to accelerate the application of green resources in the field of new energy.

References

[1] C. Senthil, C. W. Lee, Renew. Sustain. Energy Rev. 2021, 137, 110464.
[2] J. Wei, Q. Ma, Y. Teng, T. Yang, K. H. Wong, Y. Cui, B. Zheng, D. Li, D. Luo, A. Yu, Adv. Energy Mater. 2024, 14, 2400208.
[3] X. Chen, F. Li, S. Su, H. Chen, J. Zhang, D. Cai, Environ. Chem. Lett. 2021, 19, 3505.
[4] T. Xu, K. Liu, N. Sheng, M. Zhang, W. Liu, H. Liu, L. Dai, X. Zhang, C. Si, H. Du, K. Zhang, Energy Storage Mater. 2022, 48, 244.
[5] M. Shen, H. Ma, Coord. Chem. Rev. 2022, 470, 214715.
[6] X. Zuo, K. Chang, J. Zhao, Z. Xie, H. Tang, B. Li, Z. Chang, J. Mater. Chem. A 2016, 4, 51.
[7] Liu Z., Wang X., Hu J., Meng J., Niu C., Liu F., Cui L., Yu R., Mai L., Adv. Energy Mater. 2023, 13, 2301715.
[8] N. Issatayev, K. Tassybay, N.-L. Wu, A. Nurpeissova, Z. Bakenov, G. Kalimuldina, Carbon 2024, 229, 119479.
[9] N. Balahmar, A. S. Al-Jumialy, R. Mokaya, J. Mater. Chem. A 2017, 5, 12330.
[10] W. Zhang, J. Yin, Z. Lin, H. Lin, H. Lu, Y. Wang, W. Huang, Electrochimica Acta 2015, 176, 1136.
[11] H. Jing, J. Energy Chem. 2018,03,011.
[12] H. Wang, D. Ren, Z. Zhu, P. Saha, H. Jiang, C. Li, Chem. Eng. J. 2016, 288, 179.
[13] X. Chen, Chem. Eng. J. 2023,145117.

DOI: 10.54254/2755-2721/2025.23747

[14] V. Muthukumaraswamy Rangaraj, A. Achazhiyath Edathil, P. Kadirvelayutham, F. Banat, Mater. Chem. Phys. 2020, 248, 122953.
[15] Y. Song, G. Zhao, S. Zhang, C. Xie, R. Yang, X. Li, Carbohydr. Polym. 2024, 329, 121530.
[16] E. Lizundia, D. Kundu, Adv. Funct. Mater. 2021, 31, 2005646.
[17] Y. Yang, C. Huang, G. Gao, C. Hu, L. Luo, J. Xu, Carbohydr. Polym. 2020, 247, 116702.
[18] C. Cheng, Carbohydr. Polym. 2022,120489.
[19] Y. Li, J. Chen, P. Cai, Z. Wen, J. Mater. Chem. A 2018, 6, 4948.
[20] J. Deng, Chem. Eng. J. 2021,133934.
[21] M. A. Mohamed, W. N. W. Salleh, J. Jaafar, A. F. Ismail, M. Abd Mutalib, A. B. Mohamad, M. F. M. Zain, N. A. Awang, Z. A. Mohd Hir, Carbohydr. Polym. 2017, 157, 1892.
[22] Serra J. P., Uranga J., Gonçalves R., Costa C. M., De La Caba K., Guerrero P., Lanceros-Mendez S., Electrochimica Acta 2023, 462, 142746.
[23] J. Zhang, H. Xiang, Z. Cao, S. Wang, M. Zhu, Green Energy Environ. 2024, S2468025724001274.
[24] W. Wang, Z. Li, H. Huang, W. Li, J. Wang, Chem. Eng. J. 2022, 445, 136568.