Preparation of Rice Husk-Based C/SiO₂ Composites and Their Performance as Anode Materials in Lithium Ion Batteries

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In this study, we used a carbonization method to prepare biomass-based C/SiO₂ composites from rice husks for use in lithium ion batteries. Carbonization was carried out at different temperatures in an N₂ atmosphere and a heating rate of 5 °C min⁻¹, and the biomass-based C/SiO₂ composites were obtained. The results showed that the lithium ion batteries maintained good cycling performance under a current density of 100 mA g⁻¹. At the same time, they had a good performance rate at different current densities. According to thermogravimetric analysis, x-ray powder diffraction patterns, Fourier transform infrared spectroscopy, Raman spectroscopy and other data for the biomass-based C/SiO₂ composites, 700°C was the optimal carbonization temperature. At this temperature, some of the carbon was carbonized, and the sp² hybridized carbon in the surface functional group was weakened. Simultaneously, the connection of sp² hybridized carbon in C=C greatly improved the properties of the materials. According to the Brunauer–Emmett–Teller results, the biomass-based C/SiO₂ composites obtained by carbonization of rice husks had micropores, which provided active sites for insertion and extraction of Li⁺. This method is in line with the concept of environmental protection, as carbonization is a simple process, and rice husks are by-products of processing.

Key words: Biomass-C/SiO₂ composites, lithium ion batteries, rice husks, carbonization temperature

INTRODUCTION

Rice husk (RH) is an agricultural by-product of abundant yield, with annual output of about 120 million tons globally.^{1,2} However, current RH treatments are limited to traditional routes such as fertilizer additives, paving materials, biofuel or landfill, which do not fully avoid the negative impact to the environment, so the methods for utilizing RHs need to be improved to solve environmental problems.³ Since RHs are composed mainly

of silicate, hemicellulose, cellulose and lignin,^{4,5} they can be used as carbon/silica-based composites (C/SiO₂) for energy storage after extraction of volatile matter.^{1,6}

Silicon-based materials have high specific capacity and low discharge platform, and have been investigated as potential anode materials for lithium ion batteries (LIBs) in recent years. Carbon-based materials are always coated on the surface of silicon-based materials, which not only enhances the conductivity, but also controls the expansion of volume.^{7,8} A variety of C/SiO₂ composites have been studied extensively by scientists.⁹ Guo et al.⁹ used tetraethyl orthosilicate (TEOS) as the silicon source and sugar as the carbon source to

prepare C/SiO₂ composites as the anode materials for LIBs. Yang et al.¹⁰ used the sol-gel method to prepare C/SiO₂ composites by TEOS and sucrose. The prepared C/SiO₂ composites have good electrochemical performance, but the application as an anode material for LIBs is limited by the defects in workmanship and materials, such as the complicated preparation processes and the cost and toxicity of raw materials. RH-biomass is naturally composed of organic carbon and silica, and a large amount of Si is absorbed from the soil in the form of silicic acid (Si(OH)₄ or Si(OH)₃O⁻) during the growth of rice, and finally stored as nano-sized silica, which accumulates around the microdomains of cellulose.^{11,12} When RH is pyrolyzed under inert gas, a three-dimensional structure of C/SiO₂ composites is obtained without any complicated coating techniques.¹³ Given the simplicity of the preparation methods and the abundance and non-toxic nature of the raw materials, many researchers have been studying rice husk-based C/SiO₂ (RH-based C/SiO₂) composites.¹³ Ju et al.¹⁴ prepared RH-based C/SiO₂ composites by a two-step carbonization method and used them in LIBs.

According to previous reports, the carbonization temperature has an important influence on the amorphous morphology and surface functional groups of RH-based C/SiO₂ composites during preparation.^{15,16} These characteristics are strongly related to the specific capacity, coulombic efficiency and stability of the negative electrode in LIBs. Surface functional groups reduce initial coulombic efficiency because of the consumption of Li⁺. Yu et al.¹⁷ prepared carbon-based materials by the carbonization of cellulose in RHs. Analysis showed that the temperature affected the value of C/O in the materials, which means that the functional groups in the material were influenced by temperature. At 500°C, there were far fewer functional groups in the material than in the non-carbonized cellulose. The porosity of the materials increased the number of active sites and their electrical conductivity. Cui et al.³ obtained porous RH-based C/SiO₂ composites with a certain amount of activator (ZnCl₂) and carbonization temperature ranging from 500°C to 650°C. With an increase in temperature, the internal structure of C/SiO₂ was affected rather than the content of the composites. As the temperature increased, C, O and Si were relatively homogeneously distributed. It was beneficial for increasing the electronic conductivity of SiO₂ and efficiently preventing the aggregation of SiO₂ particles during Li⁺ insertion and extraction.⁵ The stacking of carbon layers was found to enhance the cyclic stability of LIBs. According to Li et al.,¹⁸ when the carbonization temperature was 500°C, the basic carbonization of RHs was completed, and a further increase in temperature affected the formation of the layered structure of carbon.

In our work, RHs were pyrolyzed at temperatures ranging from 400°C to 800°C. Changing the

temperature affected the degree of amorphism, surface functional groups and the sp² hybridized carbon in C=C of the RH-based C/SiO₂ composites. Finally, we explored the effect of C/SiO₂ composites as the anode electrode material on the performance of LIBs, such as the initial coulombic efficiency, specific capacity and stability of the electrode. Our data analysis examined the optimal carbonization temperature, meaning that the material obtained at this temperature gave LIBs with the highest initial coulombic efficiency and specific capacity, with the best cycling stability and rate performance.

PREPARATION AND TESTING

Preparation of Materials

Clean and dried RHs were heated in a quartz tube reactor under flowing nitrogen at 250°C for 30 min (heating rate: 10°C/min), followed by a 2-h calcination at 700°C (heating rate: 5°C/min). The carbonized sample was refluxed with 1 M HCl for 2 h to remove impurities such as alkali metal oxides, cooled to room temperature, washed free of acid with distilled water, and dried in an oven at 100°C overnight. Finally, high-efficiency ball milling was used to obtain rice husk ash (RHA).

The final carbonization temperatures were set at 400°C, 500°C, 600°C, 700°C and 800°C for samples labeled RHA-400, RHA-500, RHA-600, RHA-700 and RHA-800, respectively.

Sample Characterization

X-ray powder diffraction (XRD) patterns were assessed with a 6100 x-ray diffractometer (Shimadzu) using a copper target with a scanning range of 10°–80°, scanning speed of 6 min⁻¹, voltage of 40.0 kV and current of 30.0 mA. The specific surface area of the sample was measured using the Brunauer–Emmett–Teller (BET) method for the N₂ adsorption/desorption curve. A Fourier transform infrared (FTIR) spectrometer (Shimadzu FTIR-8400S) was used to measure the functional groups of the sample. The test range was 500–4000 cm⁻¹. KBr was ground and pressed. A DTA-60H thermal analyzer (Shimadzu) was used for thermogravimetric analysis (TGA) of RHs. The atmosphere was air, the range of temperatures was 50–800°C and the heating rate was 10°C min⁻¹. Raman spectra were measured by an inVia Raman spectrometer (Renishaw) with a range of 500–2500 cm⁻¹.

Electrochemical Measurements

According to the ratio of the active material/acetylene black/binder polyvinylidene fluoride (PVDF) (8:1:1 m/m/m), the mass was accurately weighed. An appropriate amount of *N*-methylpyrrolidone (NMP) was added dropwise, and the solution was stirred for more than 5 h. The current collector was copper foil. The mixture

was uniformly coated on the copper foil and dried under vacuum at 100°C for 12 h. The dried copper foil coated with the mixture was sliced. The wafer was cut into a diameter of 1.2 cm, which was used as an anode electrode material for LIBs. The battery test was carried out by fabricating a CR2025 coin cell using 1 M LiPF₆ in ethylene carbonate (EC)/diethyl carbonate (DEC)/dimethyl carbonate (DMC) (1:1:1 v/v/v). A pure lithium metal foil was used as the counter electrode, and the battery system was assembled in an argon-filled glove box. A CT-4008 battery testing system (Neware) was used to measure the electrochemical performance.

RESULTS AND DISCUSSION

Figure 1 shows the changes in weight during the pyrolysis of RHs. It can be seen that the TGA is divided into three stages. The weight loss centered around 100–250°C is due to the loss of moisture and other volatiles on the surface of RHs. The active pyrolysis zone for RHs is attributed to the evolution of volatiles emitted upon decomposition of primary hemicellulose and cellulose, which varies from 250°C to 350°C. A third weight loss occurs due to the loss of volatile vapors and aromatic condensation processes that are part of the intricate pyrolytic reactions between about 350°C and 550°C. The precursor breaks down completely around 550°C, and any change that appears beyond this temperature is due to the carbon layer organization.² According to the TGA, the organic matter in the RHs is basically decomposed at 575°C. When the temperature is between 575°C and 700°C, the TGA is slightly increased, which proves that the high temperature affects the structure of the carbon layer. Later, the curve has basically stabilized.

The contents of the C/SiO₂ samples are given in Fig. 1 and Table I. During the carbonization of RHs, the formation of other by-products, such as CO, CO₂ and levoglucosan, may cause a certain loss of carbon.³ The amount of carbon loss increases with

increasing carbonization temperature, and the change is obvious, which means that the main factors affecting the properties of the material are the structure of the carbon layer and the carbon content, which varies with the temperature.

Figure 2a shows the preparation process for the C/SiO₂ composites. The C/SiO₂ composites obtained after the carbonization of RHs are easy to break in the black fluffy strip state. This is because the biomass C/SiO₂ composites still retain the general shape of RHs after carbonization, in which silica acts as a skeleton and distributes in a network,^{19,20} and carbon is filled in the network. According to Fig. 2b and c, ball milling results in the reduction in the particle size of RHA. The reduction in particle size facilitates adhesion of the material to the copper foil during the coating process.

The XRD of pyrolyzed RHs at different carbonization temperatures are shown in Fig. 3. It can be seen from the figure that the carbonization of RHs forms two broad peaks, at (002) and (100).²¹ The diffraction patterns showing a broad peak for the reflection around 22° suggest amorphous C (002) and amorphous SiO₂ (JCPDS No. 47-0715). During the stacking process, a slight coherence is formed between the carbon, which makes the material more stable and also increases the electrical conductivity.⁷ A weak broad peak corresponding to the (100) reflections can be seen around 44°, indicating the presence of honeycomb structures formed by sp² hybridized carbons.¹⁵ The honeycomb structure itself has the advantage of large space and strong stability. Moreover, no sharp peaks are observed in the XRD patterns, which indicates their amorphous state. These are important reasons why the material is relatively stable and has large specific capacity. As can be seen from Fig. 3, the peak (002) exists at a carbonization temperature between 400°C and 800°C, which means that amorphous carbon in the RHs can be partially carbonized at a low temperature. As the carbonization temperature is increased, the degree of graphitization becomes strong, the stacking of carbon becomes tight and the relationship between them becomes close. The peak (100) appears between 600°C and 800°C, becoming gradually apparent at 700°C. When the temperature is increased, this peak becomes intense, which indicates that the increasing temperature causes the material to develop toward a stable structure and increases the specific capacity.

Figure 4 shows the changes in the functional groups during the pyrolysis of RHs examined by FTIR analysis. It can be seen from the figure that the surface functional groups varied to some extent at different carbonization temperatures. Li et al.¹⁸ reported that carbonized carbon obtained at low temperature as the electrode material exhibited low initial coulombic efficiency. Because a large number of oxygen-containing functional groups exist on the surface of carbonized carbon, they cause an irreversible reaction.²² The C=O in the acetyl and ester

Fig. 1. TGA of RHs. Inset, TGA of carbonized RHs.

Table I. Comparison of content of carbon and SiO ₂ in samples		
Sample	Content of carbon (%)	Content of SiO ₂ (%)
RHA-400	77	23
RHA-500	73	27
RHA-600	67	33
RHA-700	62	38
RHA-800	55	45

Fig. 2. (a) Preparation process for C/SiO₂ composites, (b) SEM of RHA before ball milling and (c) SEM of RHA after ball milling.

groups is represented by the band at 1712 cm⁻¹. The two groups are mainly derived from the decomposition of hemicellulose and lignin (the products are ferulic acid and *p*-coumaric acid).²³ When the temperature rises, the C=O is greatly weakened because the high temperature destroys the bond to form CO₂ and CO escaping from the RHs. The 1606 cm⁻¹ peak represents the vibration modes of C=C derived from the aromatic ring formed by carbonization of lignin.²¹ The peak intensity strengthens with increasing temperature, reaching maximum intensity at 700°C. With a continued rise in temperature, the intensity decreases, indicating that C=C is the most stable at 700°C, which is conducive to the stability of the material. There is a

shoulder peak at 1209 cm⁻¹ in the spectra representing the vibration of C–O. The peak is derived from the ether bond in the secondary alcohol and the aliphatic group, which is weakened with the increase in temperature. Simultaneously, the C is the sp² hybridized form.²⁴ As shown in the XRD, when the temperature increases, the sp² hybridized carbon in the functional group forms a honeycomb structure with reduced content. This peak at 1108 cm⁻¹ is caused mainly by the asymmetric and symmetric stretching of Si–O–C and Si–O–Si bonds.²⁵ The intensity strengthens with increasing temperature. The Si and C are derived from silica, lignin and cellulose, respectively. As mentioned above, silica is mainly deposited around lignin and

Fig. 3. XRD of RHA at different carbonization temperatures.

Fig. 4. FTIR of C/SiO₂ composites at different carbonization temperatures.

cellulose. The temperature increase tightens the connection between Si–O and Si–C. The region around 804 cm^{−1} is characteristic of Si–O–Si stretching modes. The band at 500 cm^{−1} is associated with the Si–O bending mode.²³ When the temperature increases, the two peaks at both places become strong. As shown in the FTIR, when the temperature increases, the functional groups (C–O and C=O) decrease, which is not beneficial to the initial coulombic efficiency of LIBs. As the temperature rises, the sp² hybridized carbon of the oxygen-containing functional group and the C=C gradually forms a honeycomb structure, which improves the stability of the material.

The Raman spectra of the carbons are shown in Fig. 5. From the picture, there are two factors which affect the material properties. One is the degree of amorphous material, and the other is the structure of the sp² hybridized carbon bond. The peak of the D-band near 1340 cm^{−1} is related to edges, other

Fig. 5. Raman spectra of RH-C/SiO₂ composites at different carbonization temperatures.

defects and disordered carbon in the graphite structure, while the G-band appearing at 1590 cm^{−1} is attributed to the vibration of sp²-bonded carbon atoms in a 2D hexagonal lattice.^{18,26} The I_D/I_G intensity ratio represents the degree of graphitization of the material.²⁵ The I_D/I_G of RHA-400, RHA-500, RHA-600, RHA-700 and RHA-800 are 0.5120, 0.5306, 0.7466, 0.8421 and 0.5910, respectively. It can be seen that the ratios increase and then decrease with the rise in temperature. The value of I_D/I_G is larger at 700°C, which means a higher degree of disorder and more edges and other defects, which favors an enhanced reversible capacity of the anode, while the intensity of the sp² hybridized carbon is lower. We conclude that it is possible that some of the sp² hybridized carbon gradually forms a honeycomb structure with increasing temperature. This result is consistent with the XRD and FTIR results. The enhancement in the amorphous degree plays a large role in increasing the specific capacity of the material, because more active sites of Li⁺ are provided.¹⁸

Figure 6a, b and c demonstrates the cycling performance of the RH-derived C/SiO₂ composites under different carbonization temperatures evaluated at a current density of 100 mA g^{−1} for 40 cycles. It can be seen from the three graphs that the first specific capacity of LIBs gradually increases with the increase in temperature. The first specific capacity and the initial coulombic efficiency decrease at 800°C because of an increased degree of graphitization and the collapse of the mesopores at higher carbonization temperatures. The highest value of the first specific capacity and the initial coulombic efficiency occur at 700°C. At low temperatures (below 700°C), there is insufficient thermal energy for graphene sheets to rotate into a parallel alignment, which results in a large number of non-parallel and unorganized single layers of carbon in the low-temperature carbons. In addition, there are abundant mesopores in the low-temperature

Fig. 6. Cyclic performance: (a) capacity retention behavior as a function of cycle number, and (b) coulombic efficiency against cycle number. (c) Charge/discharge curves at a current rate of 100 mA g⁻¹. Inset shows charge/discharge curve of RHA-400.

carbons. As a result, the number of sites for lithium insertion increases. With increasing temperature (such as 700°C), the thermal energies reach values high enough to break the links between adjacent sheets and favor alignment in parallel orientations. Meanwhile, the mesopores collapse and fuse into

macropores, which leads to a decrease in the number of sites for lithium insertion. Next, we analyze the stability of the material. After 40 cycles, the coulombic efficiencies of the four samples (RHA-400, RHA-500, RHA-600 and RHA-800) are basically stable at around 95%. Because the temperature is low, the stacking of the carbon layer is not tight enough. At the same time, some sp² hybridized carbon has not been connected to the stable honeycomb structure. At 700°C, the coulombic efficiency is stable at about 99% after 40 cycles, which indicates that the structure of the C/SiO₂ composites is stable at this temperature, while the coulombic efficiency after cycling is restored to 95% at 800°C. The material is more stable during cycling than that obtained at low temperatures (400°C, 500°C and 600°C). This is because the high temperature causes the stacking and linking between carbon and carbon more compact. But the stable structure of the material is damaged to some extent. This agrees with the results of the above test. The activated composites improved the performance of LIBs on the first cycle according to research by Cui et al.,³ but the specific capacity was reduced by half after 40 cycles. Although the C/SiO_x composites prepared by Ju et al.¹⁴ had high first specific capacity, the initial coulombic efficiency was low. The results of the summary are shown in Table II.

As shown in Table II, the initial coulombic efficiency increases with increasing temperature. At 700°C, the initial coulombic efficiency reaches 61%. Compared with the other anodes, the RHA-700 anode shows the best cyclability, with coulombic efficiency of 99% after the 40th cycle, and reversible capacity maintained at 453 mA h g⁻¹. The decomposition of RHs has been completed, which means that amorphous carbon has been formed at 700°C. Meanwhile, the stacking of sp² hybridized carbon and the formation of a honeycomb structure have basically been completed. The results are consistent with the TGA of RHs, FTIR and Raman spectroscopy. The material at this temperature is the most stable and has the most active sites. If the temperature is further increased, the structure of the material will be destroyed and the pore structure formed will collapse or melt into large pores.²⁶ Because the number of active sites is reduced, the specific capacity is decreased. After 40 cycles, the samples of different temperatures can maintain a certain specific capacity, and the coulombic efficiency is basically maintained above 95%. This is because silica in the composites plays an important role in the macroscopic stability of the material and a series of changes in the carbonization process. It has been reported that some C was continually stacked in layered form and silica was embedded in the layers during the carbonization of RHs.¹¹ In this way, the three-dimensional structure of the material can be maintained during the charging and discharging process. The first increase in coulombic efficiency with temperature may be due to the fact

Table II. Comparison of electrochemical performance of obtained samples and others

Sample	First specific capacity (mA h g ⁻¹)	Initial coulombic efficiency (%)	40th cycle of specific capacity (mA h g ⁻¹)
RHA-400	29	38	13
RHA-500	546	39	205
RHA-600	566	45	260
RHA-700	673	61	453
RHA-800	654	51	396
S3 ³	2400	45	900
SiO ₂ /C ¹⁴	1000	45	600

that there are fewer organic functional groups on the surface of RHs and less Li⁺ is consumed. According to XRD, Raman spectroscopy, FTIR and electrochemical performance, we know that the optimal temperature is 700°C. The C/SiO₂ composites at this temperature have the highest specific capacity and the highest initial coulombic efficiency. Next, we specifically analyze the distribution of the pore structure, electrochemical cycling stability and rate performance of the material at 700°C.

Figure 7a shows the nitrogen adsorption isotherms for RHA-700. The type-IV isotherm indicates the existence of mesopores, and the type-H4 hysteresis loops suggest the presence of slit-shaped pores and the formation of slits due to the accumulation of flake particles in the materials.³ This is caused by the condensation of gas inside the mesopores.¹⁹ The specific surface area of the material is 270.63 m² g⁻¹ at relative pressure of 0.01–0.99. The total pore volume is 0.2094 cm³ g⁻¹, and the average pore diameter is 3.0948 nm. The pore size distribution of RHA-700 is shown in Fig. 7b, which indicates that the materials are composed mainly of micropores with a broad pore size distribution in the range of 0.5–3.0 nm. The presence of slit-shaped micropores in RHA-700 enables easier and faster penetration of electrolytes and diffusion of lithium ions.^{19,27} This is also an important reason why the material has much larger specific capacity than that of graphite.

As shown in Fig. 8a, there is a significant plateau voltage of 0.75 V in the first cycle, which results in a decrease in specific capacity after the first cycle. The first discharge specific capacity is 673 mA h g⁻¹, corresponding to a coulombic efficiency of 61%. Large irreversible capacity occurs during the first cycle for the carbon, which is a phenomenon seen in the electrodes due to the formation of an SEI film.²⁸

Fig. 7. (a) N₂ adsorption/desorption isotherm and (b) pore size distribution of C/SiO₂ composites at 700°C.

Fig. 8. (a) Charge and discharge curves for the first three cycles at a current density of 100 mA g^{-1} at a voltage range of 0.01–3.0 V; (b) the differential charge/discharge capacity curve of the first three cycles at different voltages and a current density of 100 mA g^{-1} ; (c) the rate performance of the electrode at current densities of 100 mA g^{-1} , 200 mA g^{-1} , 500 mA g^{-1} and 1000 mA g^{-1} , respectively; (d) the cycling performance of the electrode at a current density of 100 mA g^{-1} and a voltage range of 0.01–3.0 V (100th).

In fact, the SEI layer is advantageous, as it prevents the electrolyte from undergoing decomposition on the active electrode. However, the reversible capacity of the material becomes stable in the subsequent cycles.⁷ Fig. 8b shows the differential charge/discharge capacity of the electrode. Two main reduction peaks appear at around 0.3 V and 0.7 V during the first reduction process for the RHA-700 specimen. The peak at 0.3 V is due to the reductive reaction of the electrode and Li^+ to form Si, thus enhancing the activity of the electrode to generate a reduction potential of silicon.¹⁰ We have seen similar peaks appearing in the second and third cycle moving to the left, which indicates that the reductive reaction occurring at this voltage is reversible. At 0.7 V, SiO_2 and Li^+ undergo an irreversible reaction, and a stable SEI film is formed at this voltage, which is in accordance with the charge/discharge curve of the electrode.⁶ It has been reported that there is also a peak at 1.3 V due to the complex reaction between the electrolyte and the electrode, but this peak is not seen in the reduction curve, which means that our electrode has no reaction between the electrode and the electrolyte.³ On the oxidation curve, we can see a wide

peak between 0.6 V and 1.4 V, which is due to the formation of Li–C and Li–Si bonds during charging. The capacity differential diagrams of the second and third cycles almost coincide, so the main irreversible reaction occurs during the first cycle.⁹ This is also an important reason for the decrease in specific capacity after the first cycle. The rate performance of RHA-700 is investigated at various rates from 100 mA g^{-1} to 1000 mA g^{-1} (Fig. 8c). At a current rate of 1000 mA g^{-1} , the RHA-700 electrode shows a reversible capacity of 323 mA h g^{-1} . The reversible capacity of 418 mA h g^{-1} is restored when the current density is reversed to 100 mA g^{-1} , demonstrating the excellent rate performance of RHA-700. The reversible capacity increases dramatically when the current density is reversed to 100 mA g^{-1} , due to the activation process of anodes. Figure 8d is a graph of the cycling performance of the electrode. After 100 cycles, the discharge specific capacity is maintained at 425 mA h g^{-1} . The charge specific capacity first rises and then falls, finally remaining at 420 mA h g^{-1} . Coulombic efficiency also increases from 61% to 99% and remains basically stable, so the electrode stability of the material is also good. This is related to the honeycomb

structure of the material, the close packing of the carbon layer and the supporting action of the silica. It has also been suggested that the material has good cycling performance because the carbon in the material can prevent the SEI film from breaking.

CONCLUSIONS

In this work, we mainly explored the optimal temperature for carbonization of RHs to biomass C/SiO₂ composites and the influence of temperature on the degree of graphitization and functional groups, which affected the stacking of sp² hybridized carbon and indirectly influenced the properties of the electrode material. Based on the exploration, we determined that the optimal carbonization temperature was 700°C. At this temperature, according to the TGA, XRD, FTIR and Raman spectroscopy, RHs were completely decomposed, in which the amorphous carbon had been stacked, and the oxygen functional groups containing the sp² hybridized carbon substantially disappeared. sp² hybridized carbon was stacked in a honeycomb structure to enhance the stability of the material. Silica in the composites as a skeleton also contributed to the stability of the material. Our material had a first discharge specific capacity of 673 mA h g⁻¹ and an initial coulombic efficiency of 61%, which was a good result in similar materials. After 100 cycles, the coulombic efficiency was maintained at 99%, and the stability of the material was better. When the current density changed from small to large and was restored to the initial current density, the discharge specific capacity was restored to 425 mA h g⁻¹, which meant that the material's rate performance was also important. After the BET measurement, the data showed that the average pore diameter of the material was 3.0948 nm, showing the existing micropores. It had a specific surface area of 270.63 m² g⁻¹ and total pore volume of 0.2094 cm³ g⁻¹, which provided more active Li⁺ intercalation sites and also accelerated the Li⁺ transport rate because the transport distance was shortened. In short, the C/SiO₂ composites obtained by carbonization of RHs illustrate the use of a simple technique with raw materials that are easy to obtain. This is a method worth promoting.

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