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Optimized Electrochemical Performance of Si@C Prepared by Hydrothermal Reaction and Glucose Carbon Source

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 $\begin{array}{r} \text{Si Chen, Song-Sheng Zheng',$ Si Chen, Song-Sheng Zheng* **E** *H*₂ (2022, 28(8), 2112221 (1 of 11)

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(an Zhang, Zhao-Lin Wang

(102, *P. R. China*)

Fration lithium-ion batteries (LIBs) for its high

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Si Chen, Song-Sheng Zheng', Lei-Ming Zheng, Ye-Han Zh (Article)
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 Hydrothermal Reaction and Glucose Carbon Source

Si Chen, Song-Sheng Zheng^{*}, Lei-Ming Zheng, Ve-Han Zhang, Zhao-Lin Wang

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Hydrothermal Reaction and Glucose Carbon Source**

Si Chen, Song-Sheng Zheng', Lei-Ming Zheng, Ye-Han Zhang, Zhao-Lin Wang
 $(Gollege of Energy, Nimen/ohree, Namen, American 361102, P. R. China)$

Abst **Pydrochermal Reaction and Glucose Carbon Source**

Si Chen, Song-Sheng Zheng', Lei-Ming Zheng, Ye-Han Zhang, Zhao-Lin Wang

College of Energy, Xiamen University, Xiamen 361102, P. R. China)
 Abstract: Silicon (S) has be **Hydrothermal Reaction and Glucose Carbon Source**
Si Chen, Song-Sheng Zheng', Lei-Ming Zheng, Ye-Han Zhang, Zhao-Lin Wang
(*College of Energy, Xiamen University, Xiamen 361102, P. R. Clima)*
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(College of Energy, Xiamen University, Xiamen 361102, P. R. China)
 Abstract: Silicon (S)) has been conidered as the potential material for the ne Si Chen, Song-Sheng Zheng', Lei-Ming Zheng, Ye-Han Zhang, Zhao-Lin Wang

(Colloge of Energy, Xiamen University, Xiamen 361102, P. R. China)
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Eversity, *Xiamen* 36/1/02, P . R. China)
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Silicon (Si) has been considered as the potential material for the next-generation lithium-ion batteries (L

mAh·g⁻¹, Li_zSi₅) and suitable w ge of Energy, Autumen Cutterstary, Autumen 301102, r . A. Cuttuty

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the potential material for the next-generation lithium-ion batteries (LIBs) for its high

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ial for the next-generation lithium-ion batteries (LIBs) for its high

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n (C) **the attention of the charge rate of the charge rate and huge volume variation** solid electroland huge volume variation solid electrolyte interphase as graphite, carbon spheres is anode, which guarantees of relatively goo **ETACE:** Silicon (Si) has been considered as the potential material for the next-generation lithium-ion ty (4200 mAh ·g⁻¹, Li₂₅Si₅) and suitable working voltage (about 0.25 V vs. Li/Li⁻). However, the cyclal perfo 1(Si) has been considered as the potential material for the next-generation lithium-ion batteries (LIBs): g^i , Li₂₅²i, Li₂₅²i, Li₂₅²i, Li₂₅²i, Li₂₅²i, Li₂5²i, Li₂₅²i, Li₂₅²i, Li₂²i, L considered as the potential material for the next-generation lithium-ion batteries (LIBs) for its high
d suitable working voltage (about 0.25 V vs. Li/Li). However, the cycling stability and electro-
become significant ch the potential material for the next-generation lithium-ion batteries (LIBs) for its high cing voltage (about 0.25 V vs. Li/Li²). However, the cycling stability and electrocant challenges because of low intrinsic conduct terrial for the next-generation lithium-ion batteries (LIBs) for its high
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Li⁺). However, the cycling stability and electro-
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ges because of low intrinsic conductivity and huge volume variation
ated fo **Abstract:** Silicon (Si) has been considered as the potential material for the next-generation fithium-ion hatteric (LHs) for its high-
conperint (4200 mAh· g^2 , Li-Si) and saintible vonking voltage (absort 0.25 V vs. L eapscity (4200 mAh- g², 1.i.₅Si.) and suitable vortking voltage (about 0.25 V vs. 1.i/1.j⁵). However, the cycling stability and electro-
cheorish performance of Si ande become significant challenges because of fore

Sometime in power was sense in a matterial performance. In this study, gluesse was taken as the carbon source, using the presenting conditions to abeliev tided electrochemical performance. In this study, gluesse was taken as is wate from the photovoltaic industry as raw materials to prepare SigiC core-shell structure by hydrothermal process. The preparing

arounced rando-time around tophimical candomized around the medium control incompara parameters have been evaluated and optimized, including temperature, reaction time, raw material composition, and mass ratio.

The optimal resparaing process was proceeded in the solution with a glucose concentration of 0 The optimal preparing process was proceeded in the solution with a glucose concentration of 0.5 mol -1." and a Sitylucose mass

was toted. Then, it was treated in a hydrothermal reactor at 190 C for 9b. The obtined Sig(C mito of 0.3. Then, it was trented in a hydrothermal reactor at 190 °C for 9 h. The obtained SiffeC anode candidate (Sample CS190-3)
was tested with a coin alti-cell. The specific espacity after the first cycle reached 316 was tested with a coin half-cell. The specific capacity after the first cycle reuched 3369.5 mAh- g' , and the remaining capacity after
500 cycles 1495.0 mAh- g' in a current density of 655 mAh- g' . Moreover, for the ra ferred to perform a high capacity and relatively good cycle sta-

Si@C anodes for LIBs, therefore, it is significant to optimize

I. In this study, gluoose was taken as the carbon source, using the
 $\overline{\omega}C$ core-shell s Si@C anodes for LIBs, therefore, it is significant to optimize

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a glucose concentration of 0.5 go conservant suctuare by nynotontian process. The papering

recention time, raw material composition, and mass ratio.

a glucose concentration of 0.5 mol L^1 and a Si/glucose mass

or 9 h. The obtained Si@C anode candi **Example 12**
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1307.7 mAh·g⁻¹ and 937.1 mAh·g⁻¹ at the charge rates of 655
d 6550 mA·g⁻¹, respecti OU eyes a 60.00 many ² in a current desired by 655. Damage, *I*n converse, for the rate testing, it reduned the estange appearing conditions x^2 , $x^2(329.8 \text{ mA} + g^2$, $2029.8 \text{ mA} + g^2$, $2030 \text{ mA} + g^2$, $2030 \text{ mA$ Ahe y , 22008 $\text{MmA} + y$, 2007.) I mAhe y , 1792. That y , 1797. That μ is the change missel of 655 mA y , 1800 mA y , and its was recovered to 168 $mA \cdot g^{-1}$, 1310 mA $\cdot g^{-1}$, 2620 mA $\cdot g^{-1}$, 3930 mA $\cdot g^{-1}$, 5240 mA $\cdot g^{-1}$, and 6550 mA $\cdot g^{-1}$, respectively. And it was recovered to 1683.0 mAh g^{-1} when the current density was restored to 655 mA g^{-1} . In addition, the EIS data revealed that the half-circle radius of the chemical performance of Si anode become significant challenges because of low intrinsic conductivity and hage volume
(about 400%) during cyling processes. In addition, the repeated formation and edstruction of surface sol (about 400%) during cycling process.s. In addition, the reposted formal destroction of starkets colid electrolye interplate
(SEI) film will confiniously consume the electrolyte and cause damage to LIBs. Carbon C) material

1 Introduction with stable capacity and reversibility. However, gra-Example obtained by using the optimal conductions (Sample CS190-3) in the low-frequency region was greatly reduced. And the Warshurg inpediance became the smallest. This work can provide an important approach, and make a

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in Si is inevitable during the lithium intercalation, good electron channels^[31]. The hydrothermal reaction

which will cause high internal stress, electrode pul-

verization, and consequently loss of el $\mathbb{E}(\mathbb{E}^{\#}(L \text{ Electrochem.}) 2022, 28(8), 2112221 (2 of 11)$
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In Si is inevitable during the lithium intercalation,

in Si is inevitable during the lithium intercalation, good electron channels^[30]. The hydrothermal reaction

which will cause high internal stress, el \pm *f*/ \pm ²/*k Electrochem.*) 2022, 28(8), 2112221 (2 of 11)

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which will cause high internal stress, electrode pulcoritions are an i Si is inevitable during the littim intercalation, good electron channels^{[201}]. The hydrothermal reaction
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ing approaches to minimize the negative effect of the

volume expanse. However, the nanomaterials prepare

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2.1 Materials Synthestis

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SiC c volume expanse. However, the nanomaterials prepare **2. Experimental**

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and as orc-shell materials ^{maxp}, the Si vaste block ration usually needs a complex production process

Firstly, the Si waste block was ball milled for 10 h

and high cost.

Firstly, the Si waste block was ball milled for 10 h

Si W.c composites, such as core-shell material and high cost.

Firstly, the Si waste block was ball milled for 10 h

SiC composites, such as core-shell materials¹⁹²²¹, at the rate of 200 r-min', and then cleaned by deio-

ananowires¹⁹³, nanotubes¹⁹⁴³, lakes¹⁹ Si/C composites, such as core-shell materials 1820 , at the rate of 200 r·min⁴, and then cleaned by deion-
nanowires^{pa}, matoluses^{pac}, flakes¹⁹⁸, alset are one of the pointing between to be available proven to b nanowires⁽²⁴¹⁾, nanotubes⁽²⁴²⁾, flakes⁽²⁸¹, and spheres^[2621],

are wone of the potential solutions. Processes of elec-

are one of the potential solutions. Processes of elec-

trochemical deposition^{ra}, laser py are one of the potential solutions. Processes of elec-

undly, the typical hydrofohrmal process was as fol-

trochemical deposition¹²¹, laser prolyisis¹²¹, laser irra-

lows by taking the sample CS190-3 as an example: trochemical deposition⁽³²⁾, laser pyrolysis^[30], laser irra-

lows by taking the sample CS190-3 as an example:

diation⁸⁴¹, thermal pyrolysis^[4], chemical varior deposed variors assissione was station of Successiv diation^{24,53}, thermal pyrolysis³⁸¹, chemical vapor depo-
stino^{24,53}, thermical etching^{35,38}, are usatily applied and 1.35 g bull-milled Si powder was added. After
stino³³⁷, or chemical etching³⁵³⁸, are usati sition^[19], or chemical etching^{19], an} are usually applied and 1.35 g ball-milled Si powder was added. After the fabrican of Si/C composites by using nano ultrasonic stirring for 20 min, the mixture was trans-
Si as a for the fabrication of Si/C composites by using nano
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ferred into a Teflon-sealed autoclave and p

diverse, such as cellulosc^{ion}, glucosc^{ion}, starch, dopa-

minneration cond at a constant temperature for 9 h,

minneature, diverse, such as cellulose¹⁰⁸¹, glucose²⁰¹, starch, dopa-
nime¹⁴⁸, etc. However, the above methods samulo cooled naturally to room temperature. The solid was
novid the hasts requirements, including equipment,
separat mine^{126, 24}, etc. However, the above methods cannot
cooled naturally to room temperature. The solid was
evolt the harst requirements, including equipment, separated by suecion filtration and washed with
environment, or avoid the harsh requirements, including equipment,
eventuade by suction filtration and washed with
environment, or raw materials, thus resulting in ex-
decising in ex-
essively high cost or meager yields. As a compari-
for environment, or raw materials, thus resulting in ex-

desionized water, and then dried in an oven at 80 °C

eessively high cost or meager yields. As a compari-

for 12 h. Finally, the precursor was further ca-

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conditions are an important part of influencing these
factors. It is, therefore, significant to optimize the
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preparing conditions of the hydrothermal process to
achi

2 Experimental

which will cause high internal stress, cleetrode pul-

conditions are an important part of influencing these

verization, and consequently loss of electrical condet factors. It is, therefore, significant to opinize the

b verization, and consequently loss of electrical contact

between the active multial and current collector^[34], perparing conditions of the hydrothermal process to

between the active multial and current collectrolential between the active material and current collector^{39,11}. proparing conditions of the hydrothermal process to

What is worse, solid electrolyte interphase (SEI) achieve ideal electrochemical performance.

Effins will be c What is worse, solid electrolyte interphase (SEI) achieve ideal electrochemical performance.

films will be constantly generated, resulting in rapid In this paper, the submicron is recovered from the

neart equality loses films will be constantly generated, resulting in rapid In this paper, the submicron Si recovered from the composity decay, low cycling efficiency, and perma-
entrapactive decay. In organism of the parameters of the photov eapacity decay, low cycling efficiency, and perma-
earneat carbot the photovoltaic industry was taken as
the rank material. This ¹⁰³⁰⁴³⁰, the rank material, and glueose was used as the carbon
Termendous efforts have nent equacity losses of LIBs^{10:34}.

The raw material, and glucose was used as the carbon

Thermedous efforts have been made to solve this source. The Si@C electrodes were prepared by hy-

volume expansion issue. Nanostr Tremendous efforts have been made to solve this

source. The StiggC electrodes were prepared by hy-

volume expansion issue. Namothuches are promis-

pertatted ⁵⁴, and anothuches are promis-

pertangent permis-

impleme volume expansion issue. Nanostructures, such as nano-

aparticles¹⁹⁸, nanostructures, such as nano-

ing approaches to minimize the negroinis-

persuance, reaction time, and raw material emposi-

volume expanse. However particles¹⁰³, nanowires^{186, nay nanothes are promis-
parture, reaction time, and raw material composi-
ing approaches to mimize the negative effect of the time, were optimized.
The view optimized in the momental ration} conditions are an important part of influencing these
factors. It is, therefore, significant to optimize the
preparing conditions of the hydrothermal process to
achieve ideal electrochemical performance.
In this paper, th factors. It is, therefore, significant to optimize the
preparing conditions of the hydrothermal process to
achieve ideal electrochemical performance.
In this paper, the submicron Si recovered from the
kerf waste of the ph preparing conditions of the hydrothermal process to
achieve ideal electrochemical performance.
In this paper, the submicron Si recovered from the
kerf waste of the photovoltaic industry was taken as
the raw material, and achieve ideal electrochemical performance.

In this paper, the submicron Si recovered from the

kerf waste of the photovoltaic industry was taken as

the raw material, and glucose was used as the carbon

source. The Si@C e In this paper, the submicron Si recovered from the
kerf waste of the photovoltaic industry was taken as
the raw material, and glucose was used as the carbon
source. The Si@C electrodes were prepared by hy-
drothermal proc kerf waste of the photovoltaic industry was taken as
the raw material, and glucose was used as the carbon
source. The Si@C electrodes were prepared by hy-
drothermal process. The parameters, including tem-
perature, react the raw material, and glucose was used as the carbon
source. The Si@C electrodes were prepared by hy-
drothermal process. The parameters, including tem-
perature, reaction time, and raw material composi-
tion, were optimi source. The Si@C electrodes were prepared by hy-
drothermal process. The parameters, including tem-
perature, reaction time, and raw material composi-
tion, were optimized.
2. Experimental
2.1 Materials Synthesis Firs drothermal process. The parameters, including tem-
perature, reaction time, and raw material composi-
tion, were optimized.
2. Experimental
2.1 Materials Synthesis
Firstly, the Si waste block was ball milled for 10 h
 perature, reaction time, and raw material composi-
 2. Experimental
 2.1 Materials Synthesis

Firstly, the Si waste block was ball milled for 10 h

at the rate of 200 r·min⁻¹, and then cleaned by deion-

ized water **21 Experimental**
 2.1 Materials Synthesis
 2.1 Materials Synthesis

Firstly, the Si waste block was ball milled for 10 h

at the rate of 200 r·min⁻¹, and then cleaned by deion-

ized water to obtain pure submicron **2 Experimental**
 2.1 Materials Synthesis

Firstly, the Si waste block was ball milled for 10 h

at the rate of 200 r·min⁻¹, and then cleaned by deion-

ized water to obtain pure submicron Si particles. Sec-

ondly, t **2.1 Materials Synthesis**
Firstly, the Si waste block was ball milled for 10 h
at the rate of 200 r·min⁻¹, and then cleaned by deion-
ized water to obtain pure submicron Si particles. Sec-
ondly, the typical hydrotherma Firstly, the Si waste block was ball milled for 10 h
at the rate of 200 r·min⁻¹, and then cleaned by deion-
ized water to obtain pure submicron Si particles. Sec-
ondly, the typical hydrothermal process was as fol-
lows the rate of 200 r·min⁻¹, and then cleaned by deion-
d water to obtain pure submicron Si particles. Sec-
dly, the typical hydrothermal process was as fol-
sy by taking the sample CS190-3 as an example:
ig glucose was dis ized water to obtain pure submicron Si particles. Secondly, the typical hydrothermal process was as follows by taking the sample CS190-3 as an example: 4.5 g glucose was dissolved in 50 mL deionized water, and 1.35 g ballordly, the typical hydrothermal process was as fol-
lows by taking the sample CS190-3 as an example:
4.5 g glucose was dissolved in 50 mL deionized water,
and 1.35 g ball-milled Si powder was added. After
ultrasonic stirri lows by taking the sample CS190-3 as an example:
4.5 g glucose was dissolved in 50 mL deionized water,
and 1.35 g ball-milled Si powder was added. After
ultrasonic stirring for 20 min, the mixture was trans-
ferred into a 4.5 g glucose was dissolved in 50 mL deionized water,
and 1.35 g ball-milled Si powder was added. After
ultrasonic stirring for 20 min, the mixture was trans-
ferred into a Teflon-sealed autoclave and placed in an
oven at and 1.35 g ball-milled Si powder was added. After
ultrasonic stirring for 20 min, the mixture was trans-
ferred into a Teflon-sealed autoclave and placed in an
oven at a constant temperature for 9 h, and then
cooled natur

The carbon source seems

ferred into a Teflon-sealed autoclave and placed in an
 λ , glucose^[20], starch, dopa-

box enterhols cannot cooled naturally to room temperature for 9 h, and then

the above methods cannot co ultrasonic stirring for 20 min, the mixture was trans-
ferred into a Teflon-sealed autoclave and placed in an
oven at a constant temperature for 9 h, and then
cooled naturally to room temperature. The solid was
separated ferred into a Teflon-sealed autoclave and placed in an
oven at a constant temperature for 9 h, and then
cooled naturally to room temperature. The solid was
separated by suction filtration and washed with
deionized water, oven at a constant temperature for 9 h, and then
cooled naturally to room temperature. The solid was
separated by suction filtration and washed with
deionized water, and then dried in an oven at 80 °C
for 12 h. Finally, t cooled naturally to room temperature. The solid was
separated by suction filtration and washed with
deionized water, and then dried in an oven at 80 °C
for 12 h. Finally, the precursor was further car-
bonized under N₂ separated by suction filtration and washed with
deionized water, and then dried in an oven at 80 °C
for 12 h. Finally, the precursor was further car-
bonized under N₂ gas flow at 700 °C for 1.5 h. The
parameters for the deionized water, and then dried in an oven at 80 °C
for 12 h. Finally, the precursor was further car-
bonized under N₂ gas flow at 700 °C for 1.5 h. The
parameters for the other samples are listed in Table 1.
2.2 Mater

then the state of 1 mW.

incident power of 1 mW.

2.3 Electrochemical Measurements

2.3 Electrochemical Measurements

The as-prepared samples were mixed with sodium

The as-prepared samples were mixed with sodium

are sp **EVALUATE 1988** (*J. Electrochemical 2022, 28(8), 2112221 (3 of 11)*

incident power of 1 mW.

2.3 **Electrochemical Measurements** vs. Li⁷*Li.* Furthermore, the electrochemical imped-

The as-prepared samples were mixed **EVACULA Example 100** Example 100 Key and 1.2
 EXACULA Example 100 The cut-off voltage was set as 0.01 V and 1.2
 2.3 Electrochemical Measurements vs. Li⁷Li. Furthermore, the electrochemical imped-

The as-prepared **Example 12** the foil was assembled in an argon-filled glove box with the several and Resume of 1 mass cut in the experiment of the form **for the formulation**
 for the batter of 1 mW.
 for the batter of 1 mW.
 for the active of 1 mW.
 2.3 Electrochemical Measurements
 2.3 Electrochemical Measurements
 The separated samples were mixed with sodium (https://www.com/2022, 28(8), 2112221 (3 of 11)

Ident power of 1 mW.

30 °C. The cut-off voltage was set as 0.01 V and 1.2
 31 Electrochemical Measurements

17. Suitz. Furthermore, the electrochemical imped-

The as-pr the $\frac{4}{5}$ (Expresses) and $\frac{4}{5}$ (Expresses) and $\frac{4}{5}$ (Expresses) and $\frac{4}{5}$ (Expresses) and $\frac{4}{5}$ (Fig. and $\frac{4}{5}$ (Fi **institute power of 1 mW.**
 institute in an argon state in a separated an argon-filled in a mass ratio with safe are according a s

Example 1.1 matrix 1.1 matrix 1.1 matrix 3.0
 Example 1.1 mV. 3.0 °C. The cut-off volt

The as-prepared samples were mixed with sodium

algebrate and conductive carbo black in a mass ratio out on a CHI660E

of 8:1:1,

 $#E\# (J. Electron) 2022, 28(8), 2112221 (3 of 11)$ incident power of 1 mW.

30 °C. The cut-off voltage was set as 0

2.3 Electrochemical Measurements

The as-prepared samples were mixed with sodium

alginate and conductive carbon blac $# \ell \# (J. Electrochem.) 2022, 28(8), 2112221 (3 of 11)$ incident power of 1 mW.

2.3 Electrochemical Measurements

2.3 Electrochemical Measurements

2.3 Electrochemical Measurements

2.3 Electrochemical Measurements

2.3 Electrochemic The as-prepared samples were mixed with sodium **ELEVALUATE 1989**
 ELEVALUATE 1999
 ELEVALUATE of 8:1:1, dissolved in deionized water, and mixed for 28(8), 2112221 (3 of 11)
30 °C. The cut-off voltage was set as 0.01 V and 1.2
V vs. Li¹/Li. Furthermore, the electrochemical imped-
ance spectroscopic (EIS) measurements were carried
out on a CHI660E electrochemical wor 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 12221 (3 of 11)

he cut-off voltage was set as 0.01 V and 1.2

/Li. Furthermore, the electrochemical imped-

ctroscopic (EIS) measurements were carried

a CHI660E electrochemical workstation

ai Chenhua instrument co. Ltd. 28(8), 2112221 (3 of 11)
30 °C. The cut-off voltage was set as 0.01 V and 1.2
V vs. Li⁺/Li. Furthermore, the electrochemical imped-
ance spectroscopic (EIS) measurements were carried
out on a CHI660E electrochemical wor 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

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V vs. Li⁻/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

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V vs. Li⁻/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

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V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

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v. Li¹/Li. Furthermore, the electrochemical imped-

ce spectroscopic (EIS) measurements were carried

t on a CHI660E electrochemical workstation
 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li^{*}/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical $\frac{d\mathcal{L}}{dt}$ $\frac{d\mathcal{L}}{dt}$ (*J. Electrochem.*) 2022, 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2
 Surements V vs. Li⁺/Li. Furthermore, the electrochemical imped-

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algina **EVACTAL EXECT (EXECT 2300)**, 2112221 (3 of 11)

incident power of 1 mW.

200 °C. The cut-off voltage was set as 0.01 V and 1.2

2.3 **Electrochemical Measurements**

200 °C. The cut-off voltage was set as 0.01 V and 1.2
 ower of 1 mW.

30 °C. The cut-off voltage was set as 0.01 V and 1.2
 Etrochemical Measurements

V vs. Li^pLi. Furthermore, the electrochemical imped-

prepared samples were mixed with sodium

ance spectroscopic (EIS) m incident power of 1 mW.

30 °C. The cut-off voltage was set as 0.01 V and 1.2
 CB Electrochemical impediation

The as-prepared samples were mixed with sodium

ance spectroscopic (FIS) measurements were carried

algina 2.3 **Electrochemical Measurements** Vvs. Li⁷/L. Furthermore, the electrochemical imped-
The as-propared samples were mixed with sodium
aliginate and conductive carbon black in a mass ratio out on a CHI660E. lese
trochemi The as-prepared sumples were mixed with sodium

algrame and productive carbonate of 811 , disabled in deionized water, and mixed for (818) measurements were carried

algrame and conductive carbon black in a mass ratio alginate and conductive carbon black in a mass ratio out on a CHI660E electrochemical workst
of S:1:1, dissolved in deionized water, and mixed for (Shanghai Chenhua instrument co. Ltd., China) u
more than 10 h to obtina a 8:1:1, dissolved in deionized water, and mixed for

ere than 10 h to obtain a black viscous slurry. Then

a required y cange from 0.01 Hz to 100 kHz with an

slurry was coated on the copper foli with a thick-

slurry are more than 10 h to obtain a black viscous slurry. Then

the sultry was cost of 100 kHz with an

the sultry was coatd on the copper foil with a thick-

energy was colume of 5 mV.

The NRD and Raman spectra of the samples we the slury was coated on the copper foil with a thick-
maplitude of 5 mV.
ness of 100 μ m. After drying in a vacuum at 70 °C **3 Results and Discussion**
for 12 h, the foil was cut into 12 mm diameter discs **3.1. Structura** 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁻/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁺/Li. Furthermore, the electrochemical imped-

ance spectroscopic (EIS) measurements were carried

out on a CHI660E electrochemical 28(8), 2112221 (3 of 11)

30 °C. The cut-off voltage was set as 0.01 V and 1.2

V vs. Li⁷/Li. Furthermore, the electrochemical imped-

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V vs. Li⁷/Li. Furthermore, the electrochemical imped-
ance spectroscopic (EIS) measurements were carried
out on a CHI660E electrochemical workstation
(Shanghai Chenhu 30 °C. The cut-off voltage was set as 0.01 V and 1.2
V vs. Li⁺/Li. Furthermore, the electrochemical imped-
ance spectroscopic (EIS) measurements were carried
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(Shanghai Chenhu V vs. Li¹/Li. Furthermore, the electrochemical impedance spectroscopic (EIS) measurements were carried out on a CHI660E electrochemical workstation (Shanghai Chenhua instrument co. Ltd., China) under a frequency range f ance spectroscopic (EIS) measurements were carried
out on a CHI660E electrochemical workstation
(Shanghai Chenhua instrument co. Ltd., China) under
a frequency range from 0.01 Hz to 100 kHz with an
amplitude of 5 mV.
3. out on a CHI660E electrochemical workstation
(Shanghai Chenhua instrument co. Ltd., China) under
a frequency range from 0.01 Hz to 100 kHz with an
amplitude of 5 mV.
3 Results and Discussion
3.1 Structural Analyses
Th (Shanghai Chenhua instrument co. Ltd., China) under
a frequency range from 0.01 Hz to 100 kHz with an
amplitude of 5 mV.
3. Results and Discussion
3.1 Structural Analyses
The XRD and Raman spectra of the samples were
 a frequency range from 0.01 Hz to 100 kHz with an
amplitude of 5 mV.
3 Results and Discussion
3.1 Structural Analyses
The XRD and Raman spectra of the samples were
obtainedat 200 °C, and the results are shown in Figur amplitude of 5 mV.
 3 Results and Discussion
 3.1 Structural Analyses

The XRD and Raman spectra of the samples were

obtainedat 200 °C, and the results are shown in Figure 1.

As evident in Figure 1(a), the Si peaks The XRD and Raman spectra of the samples were

cal performance of

TR2025 coin half-

The XRD and the results are shown in Figure 1.

As evident in Figure 1(a), the Si peaks were clearly

ded glove box with

ded glove box ared anode samples, CR2025 coin half

As evident in Figure 1(a), the Si peaks were clearly

sembled in an argon-filled glove box with

the cautom of Clugard in dicated that the carbon in all the samples was

the sample in

	as assembled in an argon-filled glove box with m metal as the counter electrode and Celgard diaphragm as the separator. The electrolyte was $bl \cdot L^{-1}$ LiPF ₆ in ethylene carbonate (EC), dimethyl nate (DMC), and diethyl carbonate (DEC) (1:1:1 ume) with 10.0% fluoroethylene carbonate (FEC) 0% vinylene carbonate (VC) additives. The bat- as aged for 12 h before testing.		observed, and a broad carbon peak in $2\theta = 19^{\circ} \sim 22^{\circ}$ indicated that the carbon in all the samples was not well crystallized ^[20] . Simultaneously, the characteristic peaks of Si in the Raman spectra (Figure 1(b)) were lo- cated at 512 cm ⁻¹ and 925 cm ⁻¹ with the wide D (1337 cm^{-1}) and G bands (1594 cm ⁻¹), as well as the large intensity ratios of I_{D}/I_{G} as listed in Table 2, which re- flected the characteristics of amorphous carbon (or			
e galvanostatic charge/discharge performances			disorder carbon). There was no apparent difference			
	measured on a LAND-CT2001A battery test n (Wuhan Btrbts Technology Co. Ltd., China) at		among all the samples, indicating that the structures of the carbon and Si were similar. The differences in			
		Table 1 Preparation conditions of series samples				
Sample	Glucose weight (g)	Silicon weight (g)	Reaction temperature (°C)	Reaction time (h)		
CS170-1	2.25	0.9	170	9		
CS170-2	4.5	1.35	170	9		
CS180-1	2.25	0.9	180	9		
CS180-2	4.5	1.35	180	9		
CS190-1	2.25	0.9	190	9		
CS190-2	4.5	0.9	190	9		
CS190-3	4.5	1.35	190	9		
CS190-4	4.5	1.8	190	9		
CS190-5	4.5	1.35	190	6		
CS190-6	4.5	1.35	190	12		
CS200-1	4.5	1.35	200	6		
CS200-2	4.5	1.35	200	9		
CS200-3	2.25	0.9	$200\,$	9		

	Sample CS170-1 CS170-2 CS180-1 CS180-2 CS190-1 CS190-2 CS190-3 CS190-4 CS190-5 CS190-6									
$I_{\rm D}/I_{\rm G}$	0.85	0.85	0.83	0.82	0.84	0.83	0.82	0.84	0.82	0.84

Table 2 The I_3/I_0 values of the samples determined based on Raman

Tample CS170-1 CS170-2 CS180-1 CS180-2 CS190-1 CS190-2 CS190-3
 I_3/I_6 0.85 0.85 0.83 0.82 0.84 0.83 0.82

morphology and performance are due to the

Eigare 1 The structure analyses: (a) XRD patterns; (b) Raman spectra (color on line)
 Eigare 1 The structure analyses: (a) XRD patterns; (b) Raman spectra (color on line)
 Eigare 1 The structure analyses: (a) XRD pa **Eigure 1** The structure analyses: (a) XRD patterns; (b) Raman spectra (color on line)
 Eigure 1 The Internace analyses: (a) XRD patterns; (b) Raman spectra (color on line)
 Table 2 The I_p(I_0 tulus of the samples **Eigure 1** The structure analyses: (a) XRD patterns; (b) Raman spectra (color on line)
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Sample (S170-1 (S170-2 (S180-1 (S180-2 (S190-1 (S180-2 (S190-1 (S180-2 (S190-4 (S190-5 (S190-6
 l_6/l_6 0.85 0.83 0.82 0.84 0.82 0.84 0.82 0.84 0 Fraction (Sample CS190-2 in Figure 2) due to the basis ratio of Si to glucose was 20%, which was too low so that the basis ratio of Si to glucose was 40% (Sample CS190-4 in Figure 2) due to the lack of carbon. On the cont $\frac{\text{m}}{\text{20000}}$
 $\frac{\text{s}}{300\ \text{600}}$ 900 1200 1500 1800

Raman shift/cm⁻¹)

Raman shift/cm⁻¹)

Raman shift/cm⁻¹)

determined based on Raman data
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 when the mass ratio of Si to glucose was 20%, which or a color on line)

The actor of mine incomposite manners hittigram shiftigram is that the based on Raman data

1.1 CS190-2 CS190-3 CS190-4 CS190-5 CS190-6

0.83 0.82 0.84 0.82 0.84

that the best reaction temperature wa $\frac{64}{300}$ 600 900 1200 1500 1800

Raman shift/cm⁻¹)

ra (color on line)

determined based on Raman data
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0.83 0.82 0.84 0.82 0.84

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Raman shift)(cm⁻¹)

termined based on Raman data

CS190-2 CS190-3 CS190-4 CS190-5 CS190-6

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er, the coating on Si was i ra (color on line)

determined based on Raman data
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that the best reaction temperature was 190 °C. More-

over, the coating on Si was incompl

EXECUTE: EXECUTE: CALCUTE: Sample CS170-1 CS170-2 CS180-1 CS180-2 CS190-1 CS190-2 CS190-2 CS190-4 CS190-5 CS190-6
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that the best r stances appeared when the hydrothermal reaction morphology and performance are due to the distribu-
that the best reaction temperature was 190 °C. More-
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at action morphology and performance are due to the distribu-
that the best reaction temperature was 190 °C. More-
tion and thickness of the carbon shell, which will be
over, the coating on Si was incomplete when the mass
discussed morphology and performance are due to the distribu-
that the best reaction temperature was 190 °C. More-
tion and thickness of the carbon shell, which will be over, the coating on Si was incomplete when the mass
3.2 The tion and thickness of the carbon shell, which will be
over, the coating on Si was incomplete when the mass
sizeused later.
The influence of **Preparation Condi**
Figure 2) due to the lack of earbon. On the contrary,
tions discussed later.
 Comparison Condi- Figure 2) due to the lack of carbon. On the contrary,
 Comparison Morphology
 Comparison condi- Figure 2) when the mass ratio of Si to glueose was 20%, which

This SEM images of t 3.2 The influence of Preparation Condi-

Figure 2) due to the lack of carbon. On the contrary,

tions on Morphology

The SEM images of the as-prepared samples and

was too low so that the balls would combine and form

ThD **tions on Morphology** when the mass ratio of Si to glucose was 20%, which
The SEM images of the as-prepared samples and was too low on the the balls would combine and form
EDS date of Sample CS190-3 are shown in Figure 2. The SEM images of the as-prepared samples and

ust too low so that the balls would combine and form

EDS data of Sample CS190-3 are shown in Figure 2, a pranult-like streture (Sample CS190-2) Figure 2).

Among them, the S EDS data of Sample CS190-3 are shown in Figure 2.

Among them, the Si@C ball in Sample CS190-3 are parollologies were almost dentitived the base shorter and the more, then or

can be sticked a best shown as call when the Among them, the Si@C ball in Sample CS190-3 Furthermore, the morphologies were almost identi-
exhibited the best spherical morphology, which was call when the reaction time was longer than 9 h (Sam-
unitrom, smooth edge exhibited the best spherical morphology, which was

eal when the reaction time was longer than 9 h (Sam-

uniform, smooth edges, and very few excess floccu-

place CS1190-3 and CS190-6 in Figure 2), which indi-

eated tha determined based on Raman data
 -1 CS190-2 CS190-3 CS190-4 CS190-5 CS190-6
 0.83 0.82 0.84 0.82 0.84

that the best reaction temperature was 190 °C. More-

over, the coating on Si was incomplete when the mass

ratio o determined based on Raman data
 -1 CS190-2 CS190-3 CS190-4 CS190-5 CS190-6
 0.83 0.82 0.84 0.82 0.84

that the best reaction temperature was 190 °C. More-

over, the coating on Si was incomplete when the mass

ratio o ¹ CS190-2 CS190-3 CS190-4 CS190-5 CS190-6

0.83 0.82 0.84 0.82 0.84

that the best reaction temperature was 190 °C. More-

over, the coating on Si was incomplete when the mass

ratio of Si to glucose was 40% (Sample CS1 0.83 0.82 0.84 0.82 0.84

that the best reaction temperature was 190 °C. More-

over, the coating on Si was incomplete when the mass

ratio of Si to glucose was 40% (Sample CS190-4 in

Figure 2) due to the lack of carbon. that the best reaction temperature was 190 °C. More-
over, the coating on Si was incomplete when the mass
ratio of Si to glucose was 40% (Sample CS190-4 in
Figure 2) due to the lack of carbon. On the contrary,
when the ma that the best reaction temperature was 190 °C. More-
over, the coating on Si was incomplete when the mass
ratio of Si to glucose was 40% (Sample CS190-4 in
Figure 2) due to the lack of carbon. On the contrary,
when the ma that the best reaction temperature was 190 °C. More-
over, the coating on Si was incomplete when the mass
ratio of Si to glucose was 40% (Sample CS190-4 in
Figure 2) due to the lack of carbon. On the contrary,
when the ma over, the coating on Si was incomplete when the mass
ratio of Si to glucose was 40% (Sample CS190-4 in
Figure 2) due to the lack of carbon. On the contrary,
when the mass ratio of Si to glucose was 20%, which
was too low ratio of Si to glucose was 40% (Sample CS190-4 in Figure 2) due to the lack of carbon. On the contrary, when the mass ratio of Si to glucose was 20%, which was too low so that the balls would combine and form a peanut-lik Figure 2) due to the lack of carbon. On the contrary,
when the mass ratio of Si to glucose was 20%, which
was too low so that the balls would combine and form
a peanut-like structure (Sample CS190-2 in Figure 2).
Furtherm ne contrary,
20%, which
ne and form
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most identi-
n 9 h (Sam-
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Figure 2),
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 $^{-1}$ at 200 °C,
ces around when the mass ratio of Si to glucose was 20%, which
was too low so that the balls would combine and form
a peanut-like structure (Sample CS190-2 in Figure 2).
Furthermore, the morphologies were almost identi-
cal when the was too low so that the balls would combine and form
a peanut-like structure (Sample CS190-2 in Figure 2).
Furthermore, the morphologies were almost identi-
cal when the reaction time was longer than 9 h (Sam-
ples CS190a peanut-like structure (Sample CS190-2 in Figure 2).
Furthermore, the morphologies were almost identi-
cal when the reaction time was longer than 9 h (Sam-
ples CS190-3 and CS190-6 in Figure 2), which indi-
cated that th Furthermore, the morphologies were almost identi-
vhen the reaction time was longer than 9 h (Sam-
sc CS190-3 and CS190-6 in Figure 2), which indi-
ted that the reaction had been accomplished within
h. At the same time, t cal when the reaction time was longer than 9 h (Sam-
ples CS190-3 and CS190-6 in Figure 2), which indi-
cated that the reaction had been accomplished within
9 h. At the same time, the situation was different
when the reac

step[44].

gluceose would happen under the catalysis of hydro
generate a chain oligomer^{tel}.
generate a chain oligomer^{tel}.
(2) The chain oligomer continued to polymerize
and form macromolecular solid aromatic compounds
tetp¹⁴¹. gen ions provided by water at a high temperature and
generate a chain oligomer¹⁶⁴.
(2) The chain oligomer continued to polymerize
and form macromolecular solid aromatic compounds
following the Lamer model, which was the Example the polymerize

and the polymerize

and the polymerize

romatic compounds

and the mass fluctuation

scalid aromatic com-

Figure 3 The proposed process of hydrothermal carboniza-

tion. (color on line)

is unifac generate a chain oligomer¹⁴⁴.

(2) The chain oligomer continued to polymerize

and form macromolecular solid aromatic compounds

following the Lamer model, which was the control

step^{s41}.

(3) A coating process of the The shell was observed in Figure 4. The Sile of the content of the Shell was observed in Figure 4. The Sile of the carbon shell being about 100 nm.
The Sile of the carbon shell being about 100 nm.
Turnfrome, a clear bound Friendrich Contention

Contention

Trighted The distances of hydrothermal carbonization

Trighter 3 The proposed process of hydrothermal carboniza-

tion. (color on line)

time for 9 h.

The TEM images are shown in Figure Experimentation

Figure 3 The proposed process of hydrothermal carbonization

Dependention

Eigure 4 The TEM images are shown in Figure 4. The

Si(@C structure was identified in Figure 4 with the

Si(@C structure was ident Figure 3 The proposed process of hydrothermal carbonization. (color on line)

Trigation

time for 9 h.

The TEM images are shown in Figure 4. The

Si@C structure was identified in Figure 4 with the

thickness of the carbo

microstructure

alyses

mAh · g^{-1} with a current density of 655 mA · g^{-1} , which fringes of carbon and Si were partially staggered, in-

times 3 cycles at a sweep speed of 0.2 mV ·s¹ and a

dicating that he carbon lagre covered the Si tightly volutge range from 0.01 to 3.0 V are shown in Figure

wit dicating that the carbon layer covered the Si tightly

without voids. However, the carbon lattices fringes

were one correct two reduction pe

were only observed at the part of the rean neighbor to 0.52 V, which correspon without voids. However, the carbon lattices finiges

were only observed at the part of the area neighbor to 0.52 V, which corresponded to the formation of the

were only observed at the same and of the samples. SU, which were only observed at the part of the area neighbor to 0.52 V, which corresponded to the formation of the SEI film, and two coils Si compared Figure 4(c) and Si compared Figure H(si), thus, the SEI film, and two coilsti Si (compared Figure 4(c) and Figure 4(d)), thus, the

erspectively. If μ , relating to the hindion and delitibation of Li,

Si erystallization of the charge of the content and the ersectively. In addition, the rise of c erystallization of the carbon shell was limited

V, relating to the lithiation and delithiation of Li,Si
 alloy, respectively. In addition, the rise of current
 allows
 allows
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 allows 3.3 The Electrochemical Performance An-
alloy, respectively. In addition, the rise of current
alpses
for the second and third cycles was atthouted to
the galvanostatic charge/discharge cycle tests and electrode activation

28(8), 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating of 28(8), 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating of $28(8), 2112221$ (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
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was determined that a full coating of 28(8), 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating of $(28(8), 2112221)$ (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating 28(8), 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
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during the charge/discharge process. Therefore, it
was determined that a full coating of 28(8), 2112221 (6 of 11)

the first cycle was 66.8% (Figure 5(b)) and approached

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was determined that a full coating $28(8)$, 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating (8), 2112221 (6 of 11)

first cycle was 66.8% (Figure 5(b)) and approached

100% upon cycling, indicating good reversibility

ring the charge/discharge process. Therefore, it

s determined that a full coating of Si@C coul . 28(8), 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
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during the charge/discharge process. Therefore, it
was determined that a full coating o (6 of 11)
was 66.8% (Figure 5(b)) and approached
experime cycling, indicating good reversibility
arge/discharge process. Therefore, it
d that a full coating of Si@C could ef-
ove the electrochemical performance
h Si. A ca . 28(8), 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
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the first cycle was 66.8% (Figure 5(b)) and approached
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during the charge/discharge process. Therefore, it
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the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was deter

fictively improve the electrochemical performance
 FRIDED
 Example the partially staggered with Si. A carbon layer with moderate

the charge/discharge profiles of Sample CS190-3

at of Si m. + g^t in different equits **EVALUE CONDITE CONSTRANT THE CONDUCT THE CONDUCT THE CONDUCT CONDUCT AND THE CONDUCT CONDUCT THE CONDUCT CONDUCT THE CONDUCT CONDUCT THE CONDUCT CONDUCT THE CONDUCT THE CONDUCT CONDUCT THE CONDUCT CONDUCT THE CONDUCT CON** William and the component of the carbon lattices and a uniform distribution is more con-

where carbon distribution of the carbon distribution of SET film, and

the carbon distribution of SET film.

The carbon of SET film where the particle in the charge of Sample CS190-3

The charge disconfigure profiles of Sample CS190-3

at of S5 mA \cdot g¹ in different explices are presented in

Figure 5(c). It revealed a large capacity loss in the
 The charge/discharge profiles of Sample CS190-3
at 655 mA · ge' in different cycles are presented in
frigure 5(o.) It revealed a large capacity loss in the
figure 4 EIM images of Sample CS190-3 minute conding to the discha $28(8)$, 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
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was determined that a full coating $(28(8), 2112221)$ (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating $28(8)$, 2112221 (6 of 11)
the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating **Example 1982** (1991-1221) (1993) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating of Si@C could ef-
fectively improv the first cycle was 66.8% (Figure 5(b)) and approached
to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating of Si@C could ef-
fectively to 100% upon cycling, indicating good reversibility
during the charge/discharge process. Therefore, it
was determined that a full coating of Si@C could ef-
fectively improve the electrochemical performance
compared with S during the charge/discharge process. Therefore, it
was determined that a full coating of Si@C could ef-
fectively improve the electrochemical performance
compared with Si. A carbon layer with moderate
thickness and a unif s determined that a full coating of Si@C could ef-
tively improve the electrochemical performance
npared with Si. A carbon layer with moderate
ckness and a uniform distribution is more con-
tive to improving electrochemic fectively improve the electrochemical performance
compared with Si. A carbon layer with moderate
thickness and a uniform distribution is more con-
ducive to improving electrochemical performance.
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The charge/discharge profiles of Sample CS190-3
at 655 mA \cdot g⁻¹ in dif thickness and a uniform distribution is more con-
ducive to improving electrochemical performance.
The charge/discharge profiles of Sample CS190-3
at 655 mA ·g¹ in different cycles are presented in
Figure 5(c). It revea ducive to improving electrochemical performance.
The charge/discharge profiles of Sample CS190-3
at 655 mA \cdot g⁻¹ in different cycles are presented in
Figure 5(c). It revealed a large capacity loss in the
first cycle b The charge/discharge profiles of Sample CS190-3
at 655 mA \cdot g¹ in different cycles are presented in
Figure 5(c). It revealed a large capacity loss in the
first cycle because of the formation of SEI film. Ac-
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at 655 mA \cdot g⁻¹ in different cycles are presented in

Figure 5(c). It revealed a large capacity loss in the

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Expansion shell was like the correlation of SE Figure 5(e). It revealed a large eapacity loss in the
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term is Night microstructure (a), (b) microstr tween 0.25 V and 0.01 V, the hattery voltage de-
 Figure 4 TEM images of Sample CS190-3showing the carbon errorsed slowly with the increase of the specific ca-
 FRICH images showing the conseculator (a), (b) microstru **Eigure 4** TEM images of Sample CS190-3showing the carbon

sphere in SiggC microstructure (a), (b) microstructure; (c), (d) parend in this voltage range, which corresponds to

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The CV curres of the CS190-3 electroce in the

that the carbon l the process of lithium-ion intercalation in the negative electrode, that is, the process of forming Li, Si.

The CV curves of the CS190-3 electrode in the

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linges of earbon and Si were partially staggered, in-

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dicating that the carbon layer covered the Si tightly
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voltage range for 0.0 and 2 or shown in Fig n layer covered the Si tightly

voltage range from 0.01 to 3.0 V are shown in Figure

r, the carbon lattices fringes
 $5(e)$. There were two reduction peaks at 1.13 V and

the part of the area neighborto 6.2 V, which cor at 655 mA \cdot g⁻¹ in different cycles are presented in Figure 5(c). It revealed a large capacity loss in the first cycle because of the formation of SEI film. According to the discharge curve, in a voltage range betwee Figure 5(c). It revealed a large capacity loss in the
first cycle because of the formation of SEI film. Ac-
cording to the discharge curve, in a voltage range be-
tween 0.25 V and 0.01 V, the battery voltage de-
creased s first cycle because of the formation of SEI film. According to the discharge curve, in a voltage range be-
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creased slowly with the increase of the specific ca-
pacity, indi cording to the discharge curve, in a voltage range be-
tween 0.25 V and 0.01 V, the battery voltage de-
creased slowly with the increase of the specific ca-
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happened in tween 0.25 V and 0.01 V, the battery voltage de-
creased slowly with the increase of the specific ca-
pacity, indicating that the battery discharge mainly
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the process o creased slowly with the increase of the specific ca-
pacity, indicating that the battery discharge mainly
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tive ele pacity, indicating that the battery discharge mainly
happened in this voltage range, which corresponds to
the process of lithium-ion intercalation in the nega-
tive electrode, that is, the process of forming Li,Si.
The CV ppened in this voltage range, which corresponds to
 ϵ process of lithium-ion intercalation in the nega-
 ϵ electrode, that is, the process of forming Li, Si.

The CV curves of the CS190-3 electrode in the

st 3 cycl the process of lithium-ion intercalation in the negative electrode, that is, the process of forming Li, Si.

The CV curves of the CS190-3 electrode in the

first 3 cycles at a sweep speed of 0.2 mV ·s⁻¹ and a

voltage r tive electrode, that is, the process of forming Li, Si.

The CV curves of the CS190-3 electrode in the

first 3 cycles at a sweep speed of 0.2 mV · s⁻¹ and a

voltage range from 0.01 to 3.0 V are shown in Figure

5(e). g Li_xSi.

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here were two reduction peaks at 1.13 V and
which corresponded to the formation of : CS190-3 electrode in the
speed of 0.2 mV \cdot s⁻¹ and a
3.0 V are shown in Figure
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here were two reduction peaks at 1.13 V and
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n, and two oxidation peaks at 0.32 V a eed of 0.2 mV \cdot s⁻¹ and a

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peaks at 0.32 V and 0.52

and delithiation of Li_sSi

tion, the rise of current

d cycles was attributed to
 voltage range from 0.01 to 3.0 V are shown in Figure 5(e). There were two reduction peaks at 1.13 V and 0.52 V, which corresponded to the formation of the SEI film, and two oxidation peaks at 0.32 V and 0.52 V, relating t from 0.01 to 3.0 V are shown in Figure
ere two reduction peaks at 1.13 V and
corresponded to the formation of the
wo oxidation peaks at 0.32 V and 0.52
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mAh · g^{-1} , 2007.1 mAh · g^{-1} , 1769.2 mAh · g^{-1} , 1307.7 mAh \cdot g⁻¹ and 937.1 mAh \cdot g⁻¹ at the current densities $mA \cdot g^{-1}$, 5240 mA $\cdot g^{-1}$, and 6550 mA $\cdot g^{-1}$, respectively. There were two reduction peaks at 1.13 V and

V, which corresponded to the formation of the

lm, and two oxidation peaks at 0.32 V and 0.52

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Ah · g⁻¹ 0.52 V, which corresponded to the formation of the
SEI film, and two oxidation peaks at 0.32 V and 0.52
V, relating to the lithiation and delithiation of Li,Si
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peaks i SEI film, and two oxidation peaks at 0.32 V and 0.52
V, relating to the lithiation and delithiation of Li,Si
alloy, respectively. In addition, the rise of current
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ele V, relating to the lithiation and delithiation of Li,Si
alloy, respectively. In addition, the rise of current
peaks in the second and third cycles was attributed to
electrode activation. However, the curves of the first
a b the lithiation and delithiation of Li,Si
tively. In addition, the rise of current
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y the format samples.

^t the convenience of explanation, the most rep-

For the convenience of explanation, the most rep-

(solution resistance), while R_a the resistance of the

centative samples (i.e., CS170-2 and CS190-3, rep-

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resentative samples (i.e., CS170-2 and CS190-3, rep-
resentative samples (i.e., CS170-2 and CS190-3, rep-
charge transfer ⁴¹ *Heⁿ*</sup>(*J. Electrochem.*) 2022, 28(8), 2112221 (7 of 11)

For the convenience of explanation, the most rep-

respectively) were respectively) were respectively) were respectively) were respectively and the best pre **EXAMPLE 1999**
 EXAMPLE 1999 $\frac{d}{dt}\left(\frac{R}{dt}\right)$ Electrochem.) 2022, 28(8), 2112221 (7 of 11)

For the convenience of explanation, the most rep-

resentative samples (i.e., CS170-2 and CS190-3, rep-

charge transfer^{10.48}. R₄ (contact resistance) th (*k*^o)(*k Electrochem.*) 2022, 28(8), 2112221 (7 of 11)

For the convenience of explanation, the most rep-

(solution resistance), while R_a the resistance of the

resentative samples (i.e., CS170-2 and CS190-3, **EVALUATION EXAMOREL (Expression.** 1992, 28(8), 2112221 (7 of 11)

For the convenience of explanation, the most rep-

resentative samples (i.e., CS170-2 and CS190-3, rep-

charge transfer^{[0,4,6}]. *R_s* (contact resista 28(8), 2112221 (7 of 11)
(solution resistance), while R_{α} the resistance of the
charge transfer^[43, 45]. R_s (contact resistance) is generat-
ed by the interface between components inside the
battery, and mainly re 28(8), 2112221 (7 of 11)
(solution resistance), while R_{α} the resistance of the
charge transfer^[43, 45]. R_s (contact resistance) is generat-
ed by the interface between components inside the
battery, and mainly re charge transfer^[43, 45]. R_s (contact resistance) is generatwhile R_{α} the resistance of the
(contact resistance) is generat-
tween components inside the
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charge transfer^[43,45]. R_s (contact resistance) is generat-
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(solution resistance), while R_{α} the resistance of the
charge transfer^[43, 45]. R_s (contact resistance) is generat-
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(solution resistance), while R_{α} the resistance of the

charge transfer^[43, 45]. R_s (contact resistance) is generat-

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(solution resistance), while R_{α} the resistance of the
charge transfer^[43,45]. R_s (contact resistance) is generat-
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(solution resistance), while R_{α} the resistance of the

charge transfer^[43, 45]. R_s (contact resistance) is generated by the interface between components inside the

battery, and mainly r 28(8), 2112221 (7 of 11)

(solution resistance), while R_{α} the resistance of the

charge transfer^[43,45]. R_s (contact resistance) is generated by the interface between components inside the

battery, and mainly re 电化学(*J. Electrochem.*) 2022, 28(8), 2112221 (7 of 11)

unation, the most rep-

(solution resistance), while R_{α} the resistance of the

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charge transfer^[43, 45]. R_s (contact resistance) is gen

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Figure 6 SLM conserved to the cracks of SS-matrix (1983) and the SUM conserved with the cracks of the critical damage of SMM conserved with the cracks of the crack **Expansion of the volume expansion of the volume expansion of the volume of SiM magnet CS190-3 electrode shellow of the volume expansion of the volume expansion of the volume of the volume of the volume of the volume of t** Example of SEM images of Sample CS190-3 electrode before (a) and after (b) eyeling.
 Example 2019 and the checks of Sample CS190-3 electrode before (a) and after (b) eyeling.
 EXAM Characterizations Before and After th Figure 6 SEM images of Sample CS190-3 electrode still caused some and all the SIM final causes of Sample CS190-3 electrode some and AF-
 3.4 SEM Characterizations Before and AF- dates. It retained a reversible capacit Figure 6 SFM images of Sample CS190-3 electrode before (a) and after (b) cycling.
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 4.4 SEM Characterizations Before and Af- 3.4 SEM Characterizations Before and Af-
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 4.4 The electrode surface of Sample CS190-3 3.4 SEM Characterizations Before and Af-

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the reform of the signal and the signal and the signal and the residue and the electrode surface of Sample CS190-3 (Figure current density of 665 mA-g¹. As for the **3.4 SEM Characterizations Before and Af-**
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 **Encycling Environmentally of CS190-3 (Figure entrathally of 665 mA-g⁻¹, As for the rate perfor-

The electrode surface of Sample CS190-3 (Figure entrathal formed EXECUTE:** The electrode surface of Sample CS190-3 (Figure mAh \cdot g¹ after 500 cycles of channel cost (6(a)) had only minimal gaps. These gaps might be arrow are it retained the discharge care in the cyclic cost (if i 3) had only minimal gaps. These gaps might be armore, it retained the discharge equesties of 2328.7

icaly erceted during the prequation of current mAh rg¹, 2007. mAh rg¹, 2007. I mAh rg¹ (1769.2

electors and packa erically created during the preparation of current manking", 2007.8 making", 2007.1 making", 2007.1 making hat

solloctors and discharge cycles (Figure 6(b)), the current densities of 655 making¹, and 937.1 making¹ at collectors and packaging batteries. However, after mAh e g', 1307.7 mAh e "at the preparities of 655 mA e 2.17 mAh e 2.1820 solothare explose figure 6 (b)), the computer delectors of Sample CS1904-3 showed rela-
nary g¹ 500 charge and discharge cycles (Figure 6(b)), the current densities of 655 ms, Δt is Δt

4 Conclusions

shell well limited the volume expansion of Si. How-
was restored to 655 mA·g²,
even frenche bectorde surface became larg-

er, indicating that the Si expansion still caused some

or This study was funded by the National ever, the cnecks on the electrode surface became larg-
 Acknowledgements:

This study was finaded by the National Natural

damages to the clericode. Moreover, the surface of Science Foundation of China (21875199), the N er, indicating that the Si expansion still caused some

damages to the electrode Showed a morphology covered by dense

of Science Foundation of China (21875199), the Na-

the electrode showed a morphology covered by dense damages to the electrode. Moreover, the surface of Soviete Foundation of China (21875199), the Nate electrode showed a morphology covered by dense time alternal Touble First-class "Construction Special Funds material, whi the electrode showed a morphology covered by dense

ional "Double First-Class" Construction Special Funds

material, which was caused by the residual electrochemical work of the Niamen University - R & D Center Project of material, which was caused by the residual elec-

Project (0290-X2100520), the College of Energy at

trolyte and the SEI film formed on the electrode sur-

the Xiamen University - R. & D Center Project of

face during the

Figure 6 SEM images of Sample CS190-3 showed relations of \mathbf{S}_1 .

Figure 6 SEM images of Sample CS190-3 electrode before (a) and after (b) eyeling.

1.4 SEM Characterizations Before and After the some interest of any mAh · g^{-1} after 500 cycles of charge/discharge at a be capacity of 1405.0

be capacity of 1405.0

of charge/discharge at a

c¹. As for the rate perfor-

rrge capacities of 2328.7

2007.1 mAh · g⁻¹, 1769.2

ad 937.1 mAh · g⁻¹, 1769.2

of 1310 mA · g⁻¹, 2620 28(8), 2112221 (8 of 11)

19 10

19 11

19 10
 mAh · g^{-1} , 2209.8 mAh · g^{-1} , 2007.1 mAh · g^{-1} , 1769.2 Figure 1.1 220 (a) The set of the density of $\frac{1}{2}$ after 500 cycles of charged discharge at a density of 665 mA \cdot g⁻¹. As for the rate perforite retained the discharge capacities of 2328.7
⁻¹, 2209.8 mAh \cdot g⁻ Figure 1.1 and 937.1 mAh g^{-1} , 2007.1 mAh g^{-1} , 2009.1 and 937.1 mAh $g^{$ of 1405.0

arge at a

te perfor-

of 2328.7
 \cdot ₃⁻¹, 1769.2
 \cdot g⁻¹ at the
 \cdot g⁻¹, 2620

0 mA \cdot g⁻¹,

discharge mAh · g^{-1} , 1307.7 mAh · g^{-1} and 937.1 mAh · g^{-1} at the 1. It retained a reversible capacity of 1405.0

1, 14 after 500 cycles of charge/discharge at a

density of 665 mA · g⁻¹. As for the rate perfor-

it retained the discharge capacities of 2328.7

1, 2209.8 mAh · g⁻¹, 2 ersible capacity of 1405.0

ersible capacity of 1405.0

es of charge/discharge at a
 $4 \cdot g^{-1}$. As for the rate perfor-

scharge capacities of 2328.7
 g^{-1} , 2007.1 mAh $\cdot g^{-1}$, 1769.2
 g^{-1} and 937.1 mAh $\cdot g^{-1}$, 17 1405.0
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mA·g⁻¹, scharge
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The material of 655 mAt g⁻¹, 2007.

The set of 655 mAt g⁻¹, 2007.

The set of 65 mA g⁻¹, 2007.

The set of 65 mA g⁻¹, 2007.

The set of 655 mAt g⁻¹, 2007.

The set of $\frac{1}{2}$
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 $1⁻¹$ at the
mA $\cdot g^{-1}$, 2620
mA $\cdot g^{-1}$, scharge
density $mA \cdot g^{-1}$, 3930 mA $\cdot g^{-1}$, 5240 mA $\cdot g^{-1}$, and 6550 mA $\cdot g^{-1}$, 11 retained a reversible capacity of 1405.0

eyeling.

14 retained a reversible capacity of 1405.0

14 retained to subset of charge/discharge at a

14 density of 665 mA · g·l. As for the rate perfor-

2, it retained the d a reversible capacity of 1405.0

cycles of charge/discharge at a

65 mA · g⁻¹. As for the rate perfor-

he discharge capacities of 2328.7

Ah · g⁻¹, 2007.1 mAh · g⁻¹, 1769.2

Ah · g⁻¹ and 937.1 mAh · g⁻¹, 1769.2 Example:
 $\frac{1}{2}$
 $\frac{1}{2}$
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 -1 and -1 and -1 The could be respectively, and could be recovered to the discharge energies of 1405.0

mAh \cdot g⁻¹ after 500 cycles of charge/discharge at a

current density of 665 mA \cdot g⁻¹. As for the rate perfor-

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mAh \cdot g⁻¹ after 500 cycles of charge/discharge at a

current density of 665 mA \cdot g⁻¹. As for the rate perfor-

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i of charge/discharge at a
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and 937.1 mAh · g^{-1} , 1769.2

and 937.1 mAh · g^{-1} , 2620

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where (b) cycling.

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mAh · g^{-1} after 500 cycles of charge/discharge at a

current density of 665 mA · g^{-1} . As for the rate perfor-

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The Chiestan Constanting and the National Polenon Chies

Study of the Study of the Study of the Performe, it retained the discharge capacities of 2328.7

This g⁻¹, 2209.8 mAh · g⁻¹, 2007.1 mAh · g⁻¹, 1 Ther (b) cycling.

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mAh · g⁻¹ after 500 cycles of charge/discharge at a

current density of 665 mA · g⁻¹. As for the rate perfor-

mance, it retained the discharge ca ther (b) cycling.

dates. It retained a reversible capacity of 1405.0

mAh · g^{-1} after 500 cycles of charge/discharge at a

current density of 665 mA · g^{-1} . As for the rate perfor-

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mAh · g^{-1} after 500 cycles of charge/discharge at a

current density of 665 mA · g^{-1} . As for the rate perfor-

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mAh ·g⁻¹ after 500 cycles of charge/discharge at a

current density of 665 mA ·g⁻¹. As for the rate perfor-

mance, it retained the discharge capacities of 2328.7

m mAh · g^1 after 500 cycles of charge/discharge at a
current density of 665 mA · g^1 . As for the rate perfor-
mance, it retained the discharge capacities of 2328.7
mAh · g^1 , 2209.8 mAh · g^1 , 2007.1 mAh · g^1 , 1

Acknowledgements:

current collectors of Sample CS190-3 showed rela-
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trively large encake, and some intact spheres could be respectively and could be recovered to the dissinger
observed within the cracks, indicating that the car tively large cracks, and some intact spheres could be respectively and cond be recovered to the discharge
observed within the cracks, inclating that the carbon espaciol of S5 mA- g⁻¹,
ever, the cracks on the electrode s observed within the cracks, indicating that the carbon

shell limited the volume expansion of Si. How was restored to 655 mA-g¹

shell were, the cracks on the electrode surface became large.

NeXhowledgements:

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ecame larg-
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This study was funded by the National Natural

exparae of Science Foundation of China (21875199), the Na-

studied by dense

tional "Double First-class"C current density of 665 mA \cdot g⁻¹. As for the rate perfor-
mance, it retained the discharge capacities of 2328.7
mAh \cdot g⁻¹, 2209.8 mAh \cdot g⁻¹, 2007.1 mAh \cdot g⁻¹, 1769.2
mAh \cdot g⁻¹, 1307.7 mAh \cdot g⁻¹ mance, it retained the discharge capacities of 2328.7

mAh · g^{-1} , 2209.8 mAh · g^{-1} , 2007.1 mAh · g^{-1} , 1769.2

mAh · g^{-1} , 1307.7 mAh · g^{-1} and 937.1 mAh · g^{-1} at the

current densities of 655 mA · g^{-1} , mAh ·g⁻¹, 2209.8 mAh ·g⁻¹, 2007.1 mAh ·g⁻¹, 1769.2
mAh ·g⁻¹, 1307.7 mAh ·g⁻¹ and 937.1 mAh ·g⁻¹ at the
current densities of 655 mA ·g⁻¹, 1310 mA ·g⁻¹, 2620
mA ·g⁻¹, 3930 mA ·g⁻¹, 5240 mA ·g⁻¹, and 65 mAh · g^{-1} , 1307.7 mAh · g^{-1} and 937.1 mAh · g^{-1} at the
current densities of 655 mA · g^{-1} , 1310 mA · g^{-1} , 2620
mA · g^{-1} , 3930 mA · g^{-1} , 5240 mA · g^{-1} , and 6550 mA · g^{-1} ,
respectively, and could b current densities of 655 mA · g^{-1} , 1310 mA · g^{-1} , 2620
mA · g^{-1} , 3930 mA · g^{-1} , 5240 mA · g^{-1} , and 6550 mA · g^{-1} ,
respectively, and could be recovered to the discharge
capacity of 1683.0 mAh · g^{-1} .
A mA·g⁻¹, 3930 mA·g⁻¹, 5240 mA·g⁻¹, and 6550 mA·g⁻¹,
respectively, and could be recovered to the discharge
capacity of 1683.0 mAh·g⁻¹ when the current density
was restored to 655 mA·g⁻¹.
Acknowledgements:
This was restored to 655 mA·g¹.
 Acknowledgements:

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水热法制备锂电池 Si@C 负极材料的 工艺优化研究 _{电化学(*J. Electrochem.*) 2022, 28(8), 2112221 (11 of 11)
:**制备锂电池 Si@C 负极材料的**}

陈 思,郑淞生*,郑雷铭,张叶涵,王兆林

摘要: 水热法是广泛应用于锂离子电池 Si@C 电极材料的一种制备方法, 其反应条件是影响产物最终形貌和性 能的重要因素,采取最佳的反应工艺可以大大提升材料的电化学性能。本研究中,使用葡萄糖作为碳源,光伏切 割废料硅为硅源, 探究了水热法制备核壳结构 Si@C 电极材料的最优工艺, 分别研究了温度、原料浓度、反应时 间和原料比例对产物的形貌、性能的影响以及相互之间的关系,并得到最佳反应条件。在该条件下(葡萄糖浓度 电化学(*J. Electrochem.*) 2022, 28(8), 2112221 (11 of 11)
 水热法制备锂电池 Si@C负极材料
 工艺优化研究
 辉、恩、郑松生, 新雷铭,张叶涵, 王兆林
 库 恩, 郑松生, 新雷铭,张叶涵, 王兆林

《阿尔学能源学院,福建厦门361102)

横要: 水热法是广泛应用于锂离子电池 Si@C电极材料的一种制备方法, 其反应条件是影响
第四重要因素,采取最佳的医生 为 0.5 mol · L⁻¹, 硅与葡萄糖重量比为 0.3:1, 反应温度190 ℃, 反应时间 9 h), 得到了包覆完整、粒径适中的 ^袁 硅与葡萄糖重量比为 0.3:1^袁 反应温度¹⁹⁰ oC^袁 反应时间 9 h冤袁 得到了包覆完整^尧 粒径适中的 **大热法制备锂电池(322.288).2112221(11 of 11)

TOK热力用量量电池(Si@C负极材料】

TOK热力量量量速度电池(Si@C负极材料

(TOK等).8条件 10.5万元(TOK)

KB、外容生,并需络,张叶涵,王兆林(TOK)

(TOK等)

KB、多数法 (TOK等)

(TOK等)

KB技能量的 Si@C电极材料的电容平能。不断究中,使用葡萄糖作为紧张,光快时

AB度解决控制,整定了优势和机构** Si@C 电极材料(CS190-3), 对以该样品为负极的扣式半电池进行电化学测试, 在 655 mA·g⁻¹ 的电流密度下, 其 <u>电化学(*I. Electrochem.*) 2022, 28(8), 2112221 (11 of 11)</u>

 **水热法制备锂电池Si@C负极材料的

 三艺优化研究**

 - 修想,郑本生,郑雷铭,张叶涵,王兆林

 - 修想,郑本生,新雷铭,张叶涵,王兆林

 - 修理,采取最佳的反应工艺可以大大提升材料的电化学性能。不明究中,使用着葡萄作为破源,及应用

 - 前置要因素,采取最佳的反应工艺可以大大提升材料的电化学性 -1 -1 を(*L Electrochem.*)2022, 28(8), 2112221 (11 of 11)
 (A) 银白 电 1202, 28(8), 2112221 (11 of 11)

 (A) 银白 120 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 × 140 11)
11)
及材料的
地系件是影响产物最终形貌和性
中,使用葡萄糖作为碳源,光伏切
明察了温度、原料浓度、反应时研究了温度、原料浓度、反应时
30条件。在该条件下(葡萄糖浓度
在各55 mA·g⁻¹的电流密度下,其
在 655 mA·g⁻¹的电流密度下,其
在 655 mA·g⁻¹的电流密度下,其
油放电比容量仍可恢复至 1683.0
地放电比容量仍可恢复至 1683.0 \mathbf{r}^1 的 to the contract of \mathbf{r} **水热法制备锂电池 Si@C负极材料的工业系统的**
非常能量为减少,需要进行机制管理

**海里水热法是广泛用于埋离手电道 988C电极材料的一种制备方法,其反应条件是影响产物最终形象和性质的变更不能,(厦门大学能源学院、福建厦门361102)
能的重要因素,采取最佳的反应工艺可以大大提升材料的电化学性能,本研究中,使用葡萄糖作为破源,光伏切
间面感料料分产物的形象,性能量的是以下,有时间的是以下,以下,以下,以下,以下,以下,以下,** \pm ,当电流密度恢复至 655 mA·g \pm 时,电池放电比容量仍可恢复至 1683.0 **理电池 Si@C负极材料的**
正艺优化研究
A&生*,郑雷铭,张叶涵,王兆林
A&生*,郑雷铭,张叶涵,王兆林
HX^{字能源学院,福建厦门361102)

@C电极材料的一种制备方法,其反应条件是影响产物最终形貌和性
大大提升材料的电化学性能。本研究中,使用葡萄糖作为碳源,光伏切
结构 Si@C电极材料的最优工艺,分别研究了温度,原料液度,反应时
结构 Si@C电极材料的最优工艺,分别研究了温度,原料液度,反应时
5的成图加式半电池进行} $mAh·g⁻¹$ _o A -1 and 1 α \overline{a}

关键词: 水热反应;核壳结构 Si@C 材料;葡萄糖;锂离子电池负极材料