FIG. 1

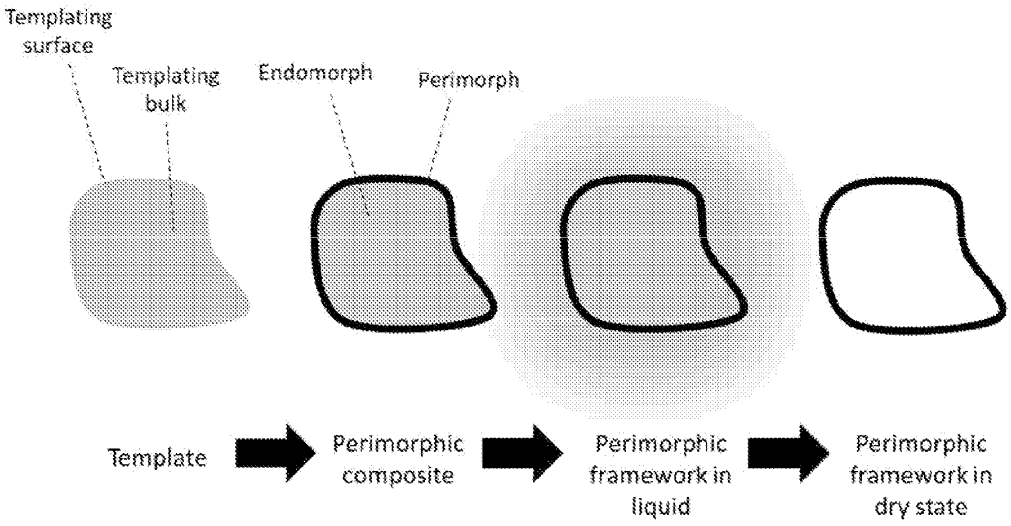
Templating surface
Templating bulk
Endomorph
Perimorph
Template
Perimorphic composite
Perimorphic framework in liquid
Perimorphic framework in dry state

FIG. 2

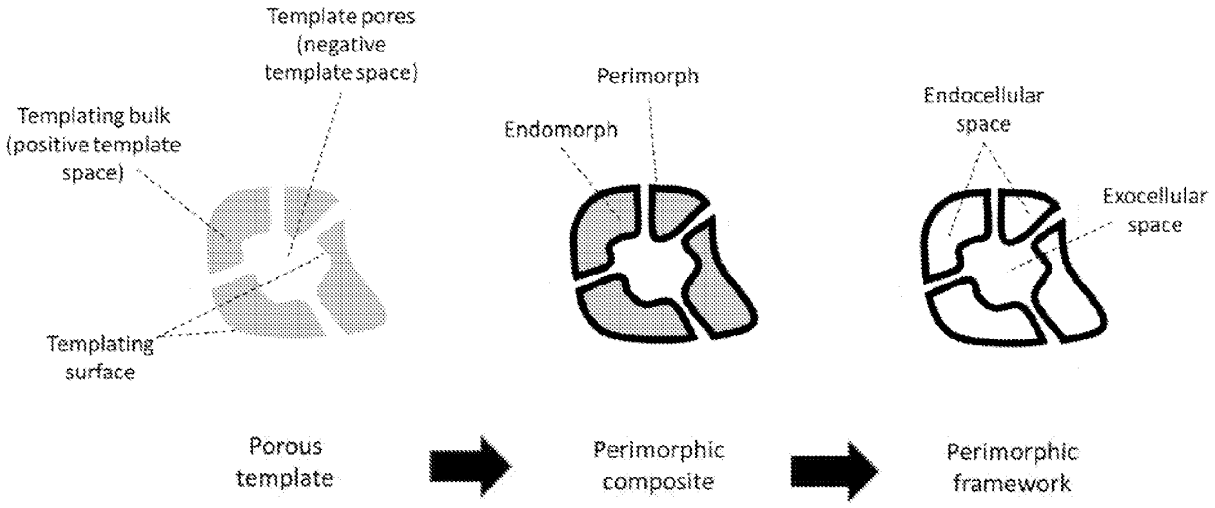
Template pores (negative template space)
Templating bulk (positive template space)
Templating surface
Perimorph
Endomorph
Endocellular space
Exocellular space
Porous template
Perimorphic composite
Perimorphic framework

FIG. 3

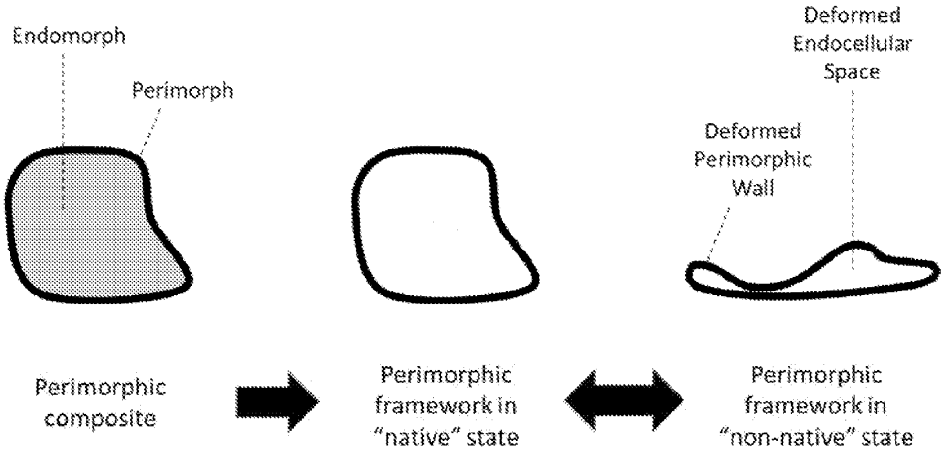
Endomorph
Perimorph
Deformed Endocellular Space
Deformed Perimorphic Wall
Perimorphic composite
Perimorphic framework in "native" state
Perimorphic framework in "non-native" state

FIG. 4

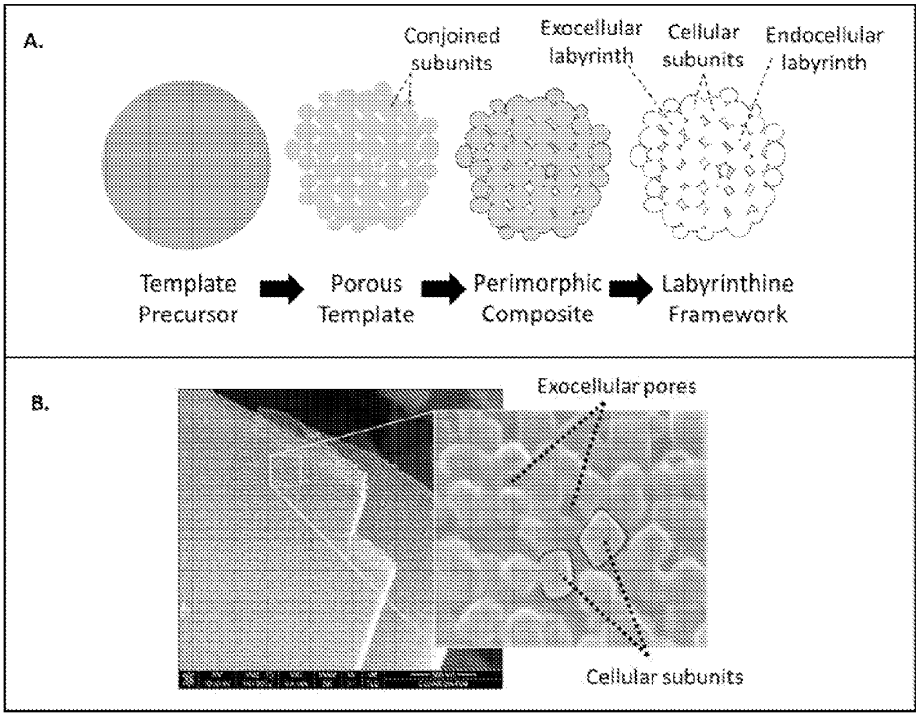
A.
Conjoined subunits
Exocellular labyrinth
Cellular subunits
Endocellular labyrinth
Template Precursor
Porous Template
Perimorphic Composite
Labyrinthine Framework
B.
Exocellular pores
Cellular subunits

FIG. 5

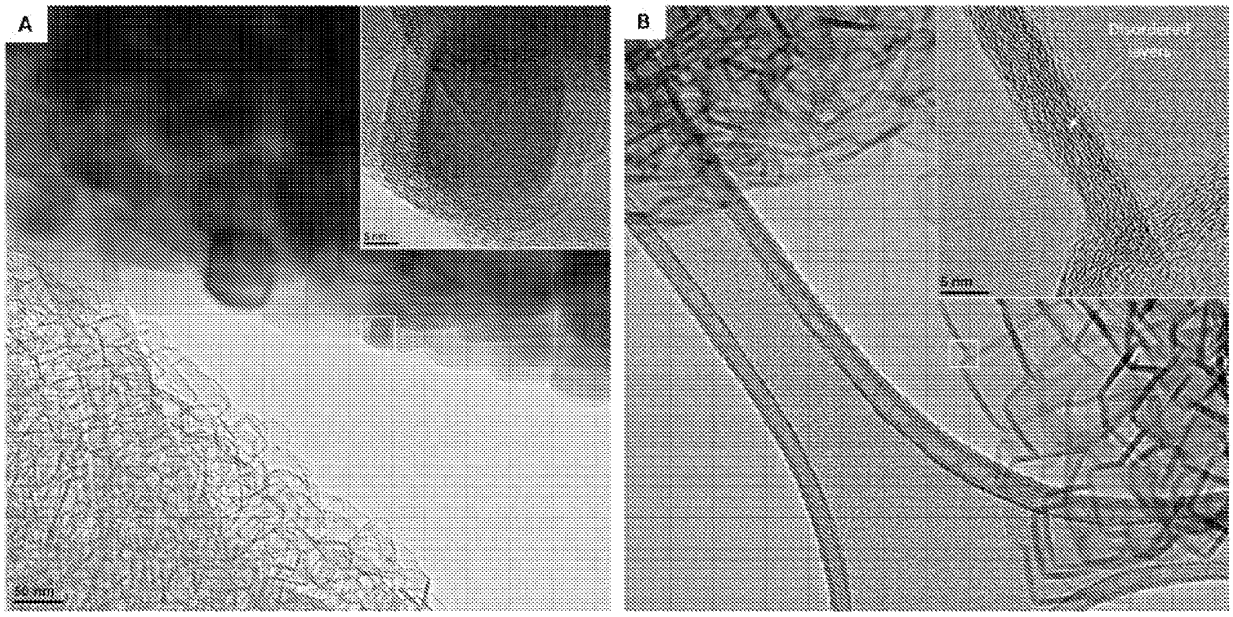

FIG. 6

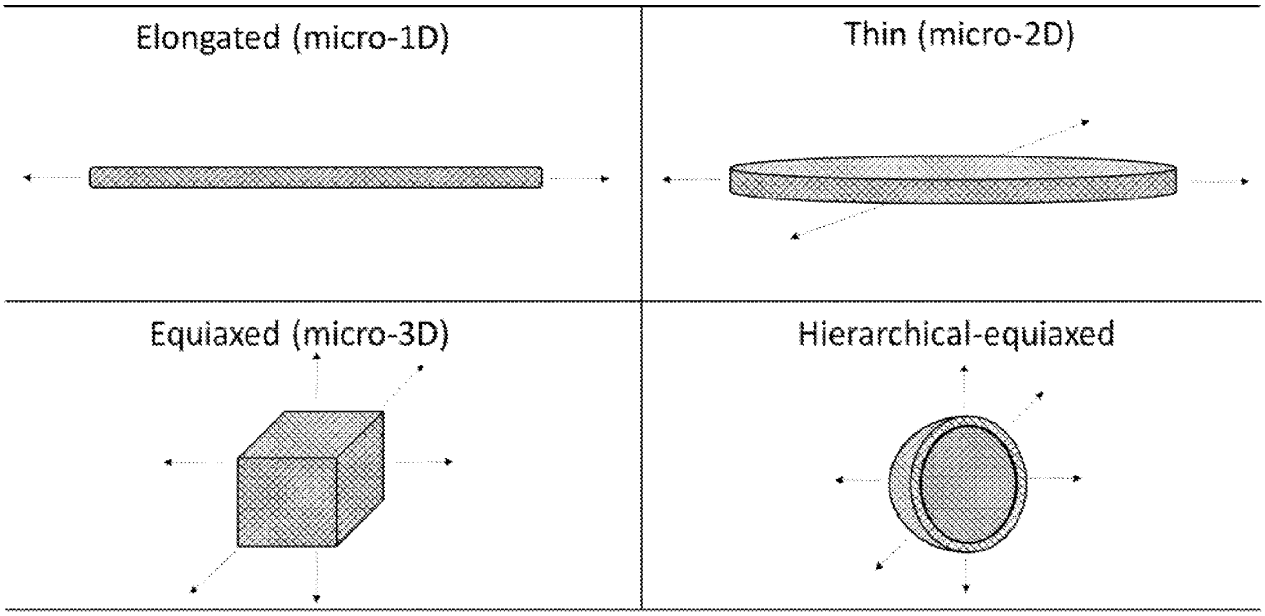
Elongated (micro-1D)
Thin (micro-2D)
Equiaxed (micro-3D)
Hierarchical-equiaxed

FIG. 7

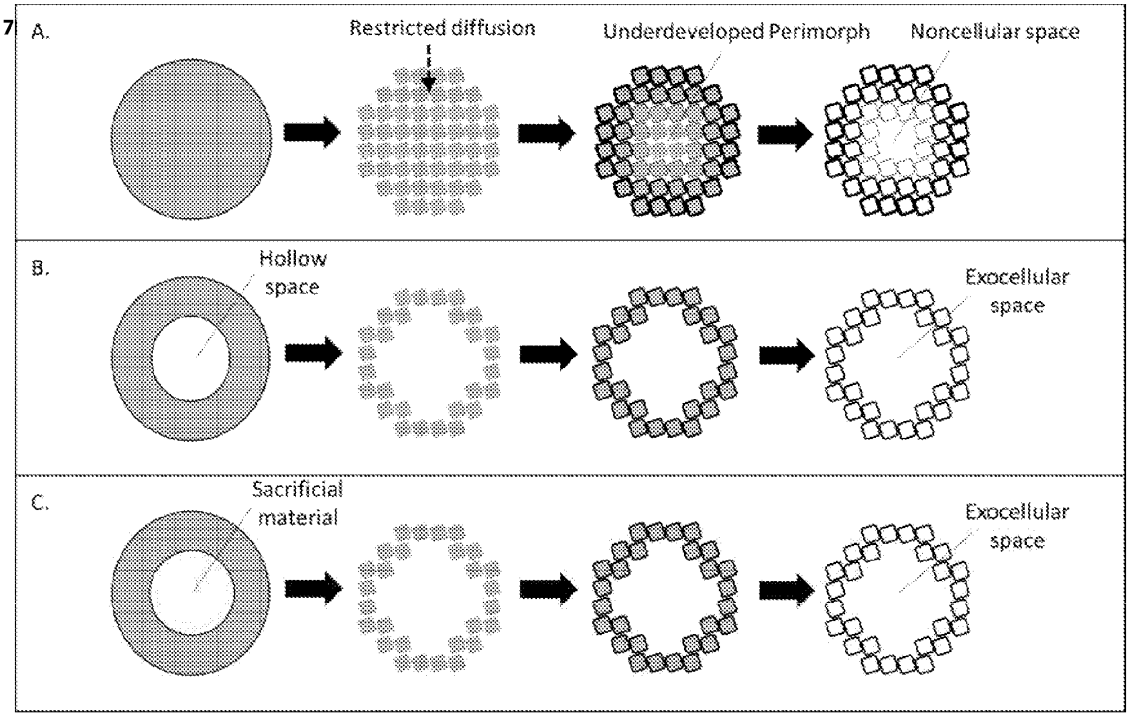
A.
Restricted diffusion
Underdeveloped Perimorph
Noncellular space
B.
Hollow space
Exocellular space
C.
Sacrificial material
Exocellular space

FIG. 8

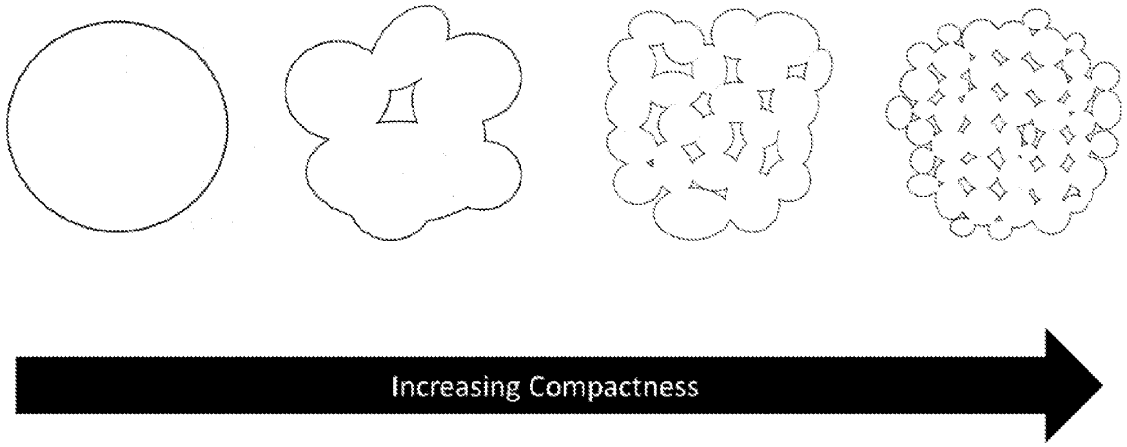

FIG. 9

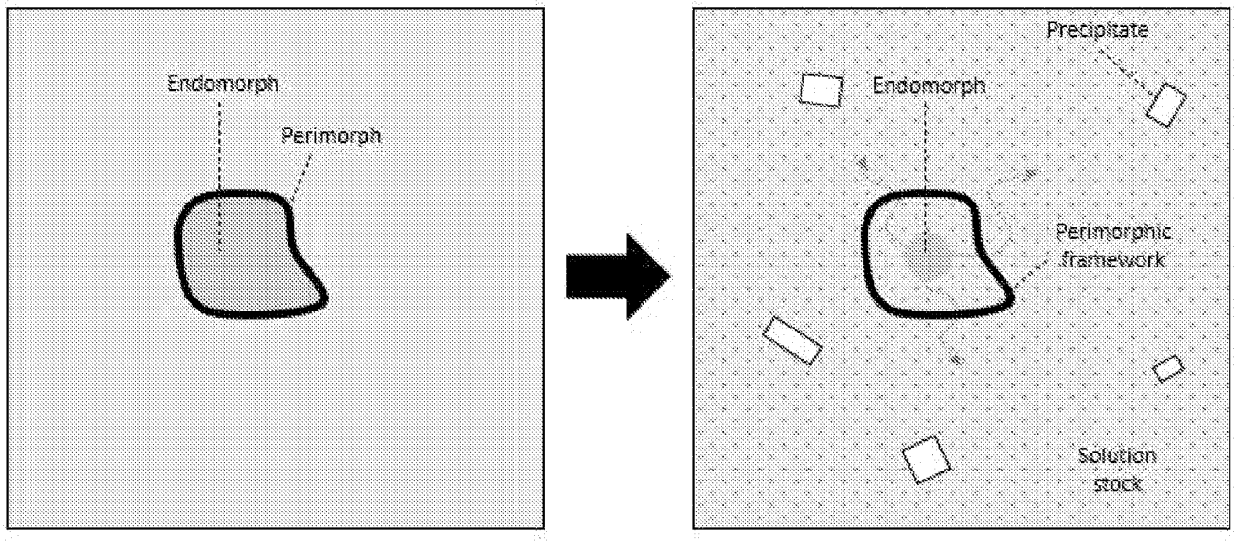
Endomorph
Perimorph
Precipitate
Endomorph
Perimorphic framework
Solution stock

FIG. 10

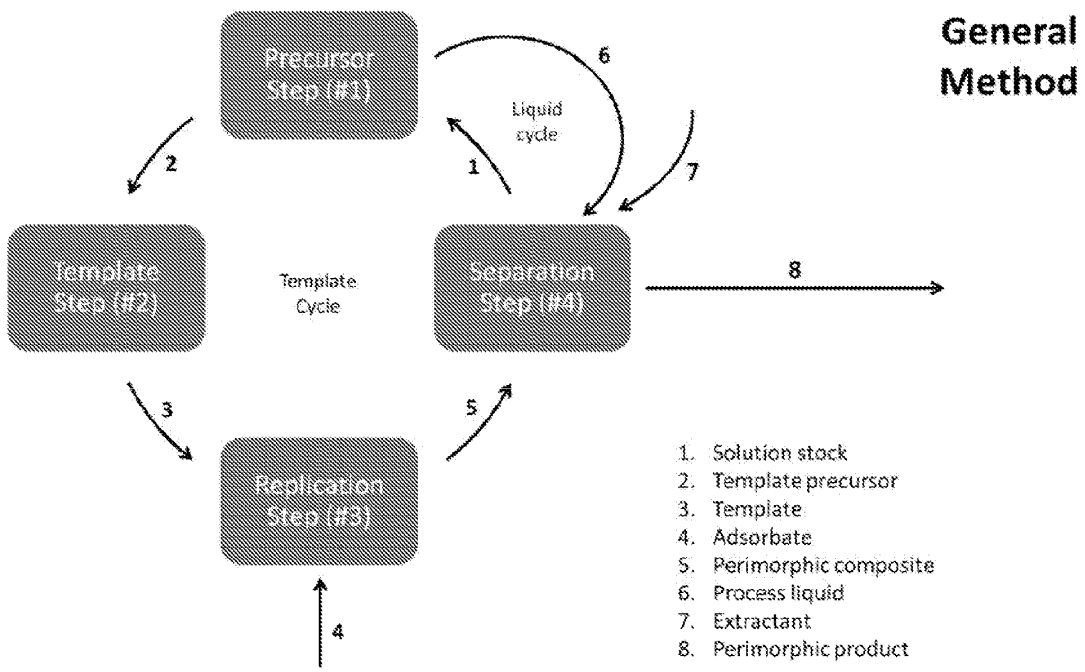
General Method
Precursor Step (#1)
Template Step (#2)
Replication Step (#3)
Separation Step (#4)
Template Cycle
Liquid cycle
1
2
3
4
5
6
7
8
1. Solution stock
2. Template precursor
3. Template
4. Adsorbate
5. Perimorphic composite
6. Process liquid
7. Extractant
8. Perimorphic product

FIG. 11

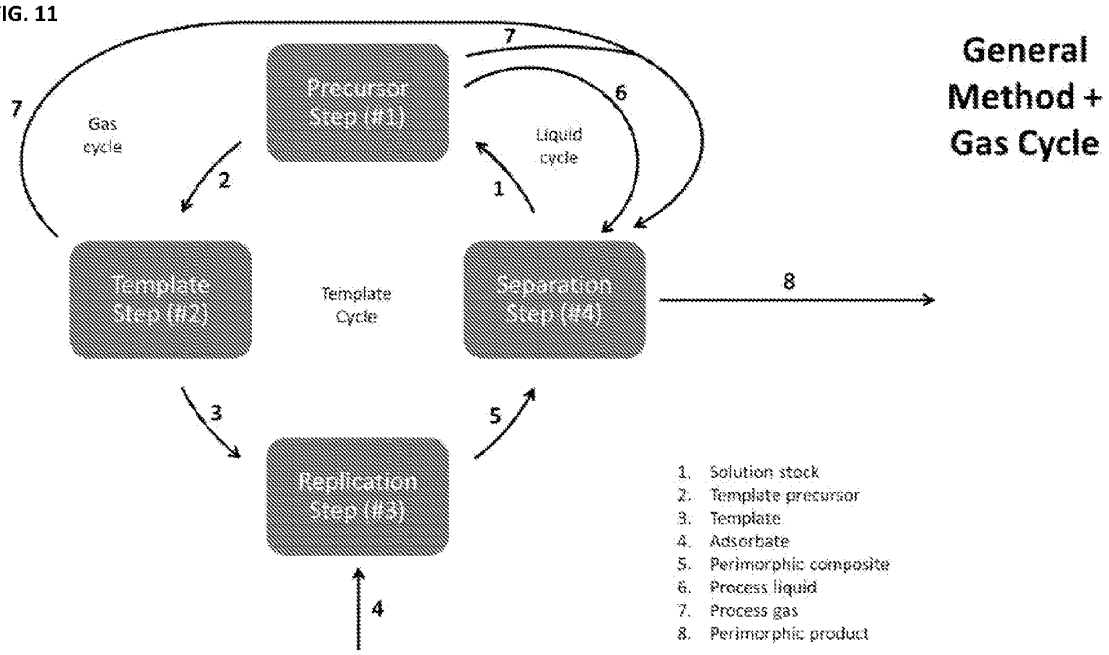
General Method + Gas Cycle
Precursor Step (#1)
Template Step (#2)
Replication Step (#3)
Separation Step (#4)
Gas cycle
Liquid cycle
Template Cycle
1
2
3
4
5
6
7
7
8
1. Solution stock
2. Template precursor
3. Template
4. Adsorbate
5. Perimorphic composite
6. Process liquid
7. Process gas
8. Perimorphic product

FIG. 12

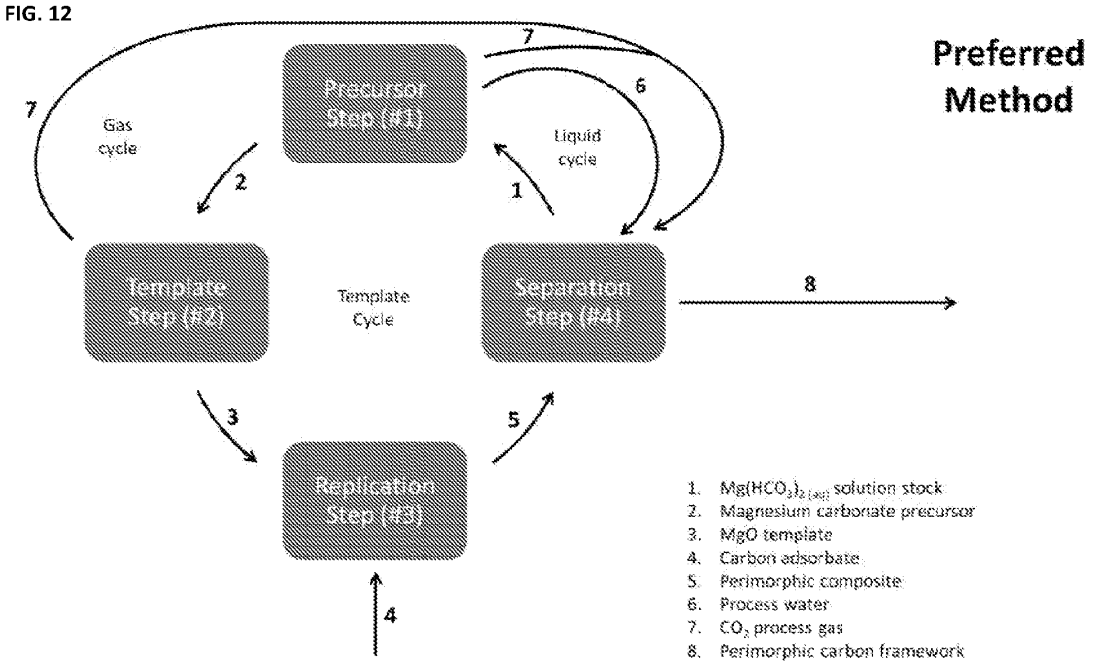
Preferred Method
Precursor Step (#1)
Template Step (#2)
Replication Step (#3)
Separation Step (#4)
Gas cycle
Liquid cycle
Template Cycle
1
2
3
4
5
6
7
8
1. $Mg(HCO_3)_{2\,(aq)}$ solution stock
2. Magnesium carbonate precursor
3. MgO template
4. Carbon adsorbate
5. Perimorphic composite
6. Process water
7. CO_2 process gas
8. Perimorphic carbon framework

FIG. 13

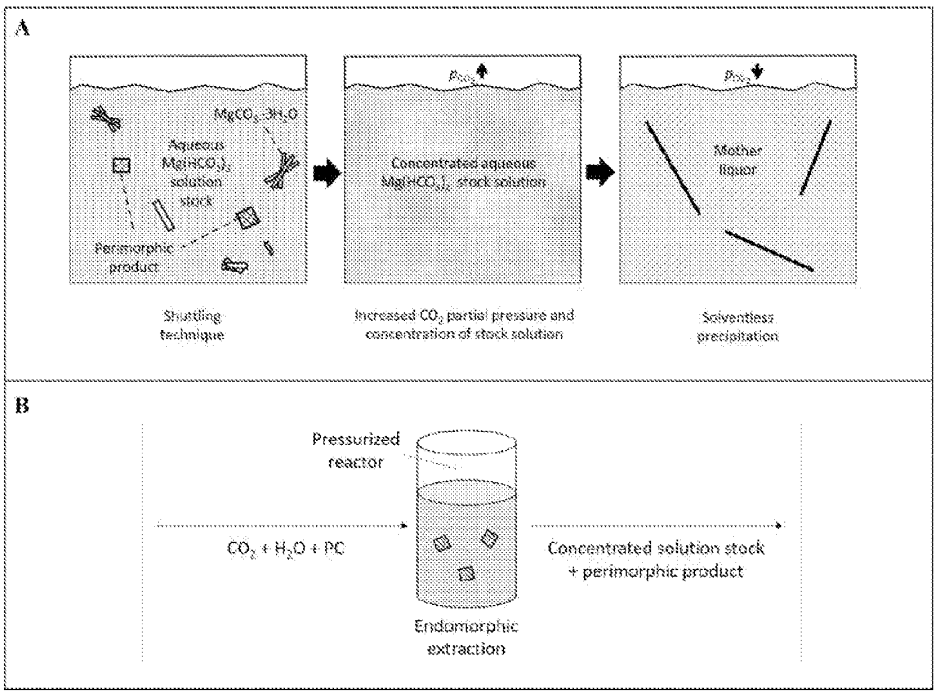
A
$MgCO_3 \cdot 3H_2O$
Aqueous $Mg(HCO_3)_2$ solution stock
Perimorphic product
Shuttling technique
Concentrated aqueous $Mg(HCO_3)_2$ stock solution
Increased CO_2 partial pressure and concentration of stock solution
Mother liquor
Solventless precipitation
B
Pressurized reactor
$CO_2 + H_2O + PC$
Endomorphic extraction
Concentrated solution stock + perimorphic product

FIG. 14

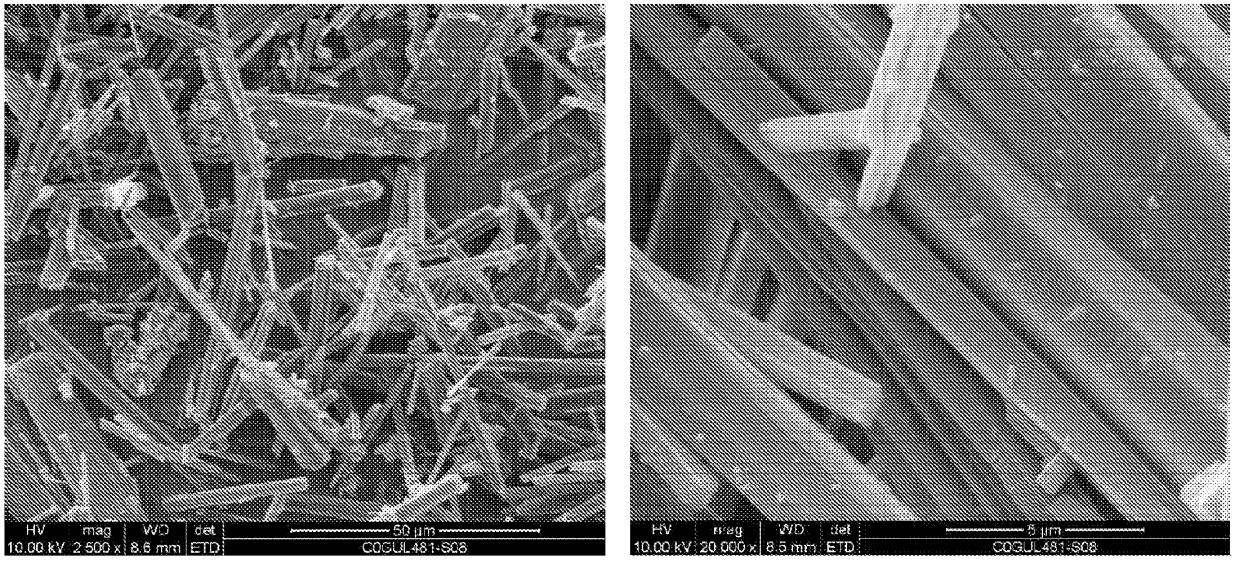
HV mag WD det
10.00 kV 2 500 x 8.6 mm ETD
50 µm
C0GUL481-S08
HV mag WD det
10.00 kV 20 000 x 8.5 mm ETD
5 µm
C0GUL481-S08

FIG. 15

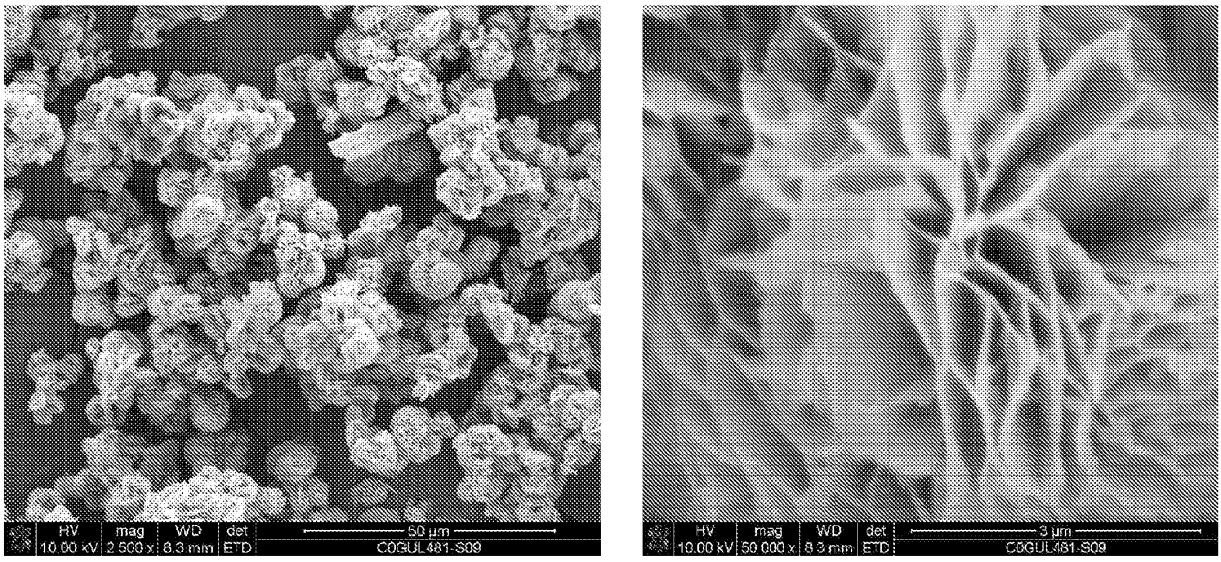
HV
mag
WD
det
50 µm
10.00 kV
2 500 x
8.3 mm
ETD
C0GUL481-S09
HV
mag
WD
det
3 µm
10.00 kV
50 000 x
8.3 mm
ETD
C0GUL481-S09

FIG. 16

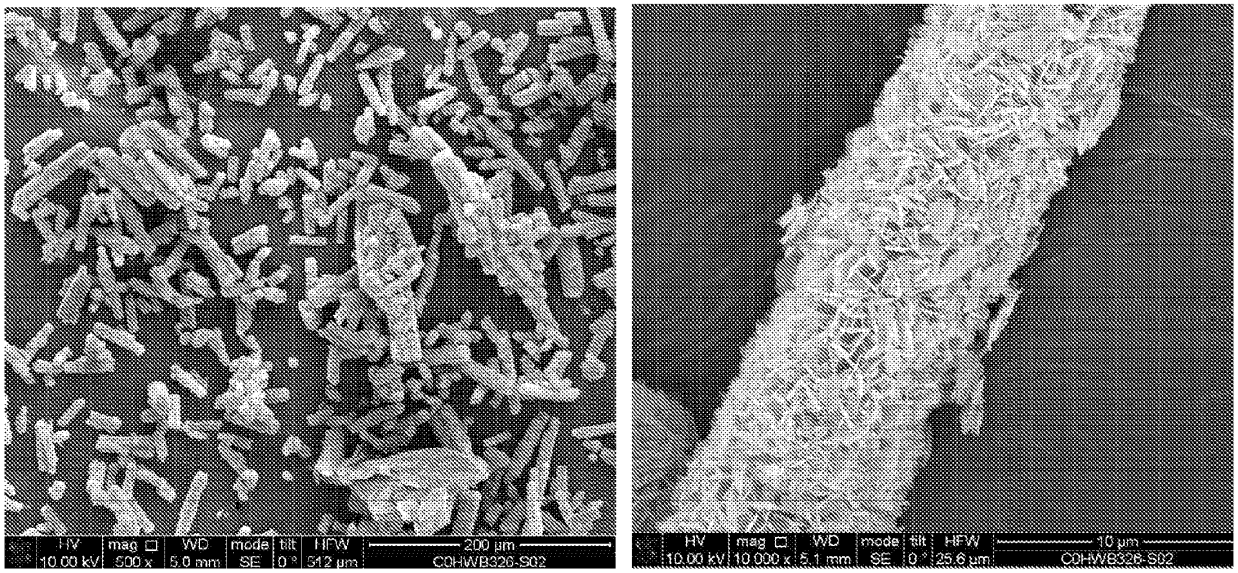
HV
10.00 kV
mag
500 x
WD
5.0 mm
mode
SE
tilt
0 °
HFW
312 µm
200 µm
C0HWB326-S02
HV
10.00 kV
mag
10 000 x
WD
5.1 mm
mode
SE
tilt
0 °
HFW
25.6 µm
10 µm
C0HWB326-S02

FIG. 17

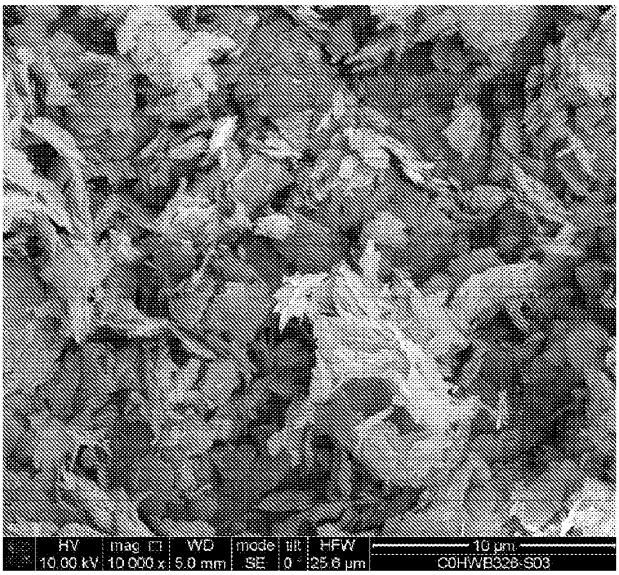
HV
10.00 kV
mag
10 000 x
WD
5.0 mm
mode
SE
tilt
0 °
HFW
25.6 µm
10 µm
C0HWB328-S03

FIG. 18

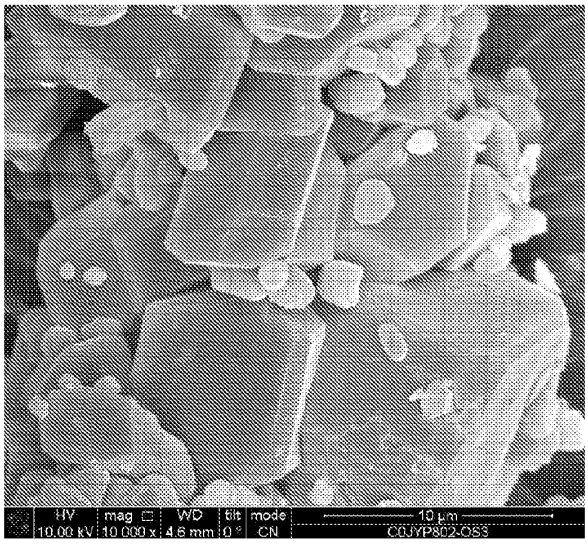

FIG. 19

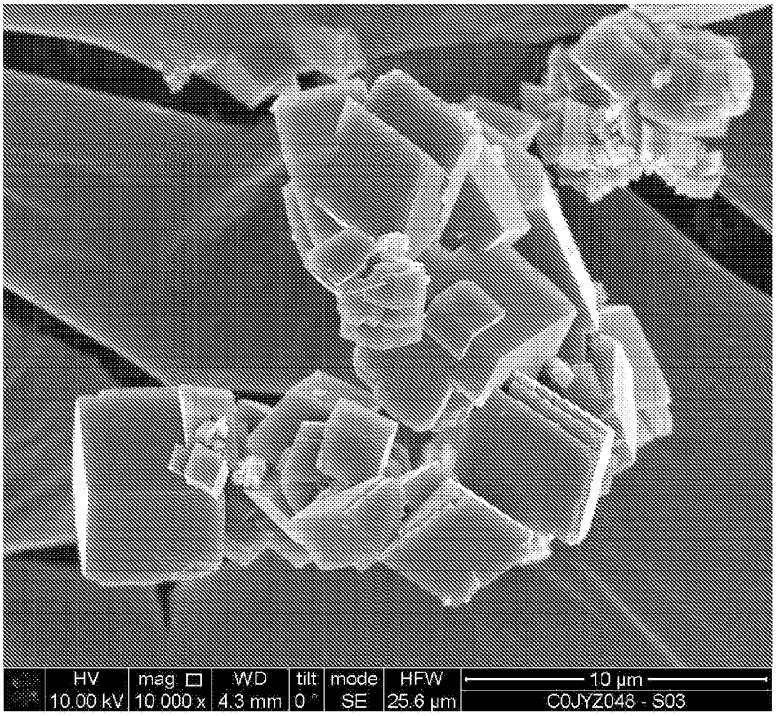
HV
10.00 kV
mag
10 000 x
WD
4.3 mm
tilt
0 °
mode
SE
HFW
25.6 µm
10 µm
C0JYZ048 - S03

FIG. 20

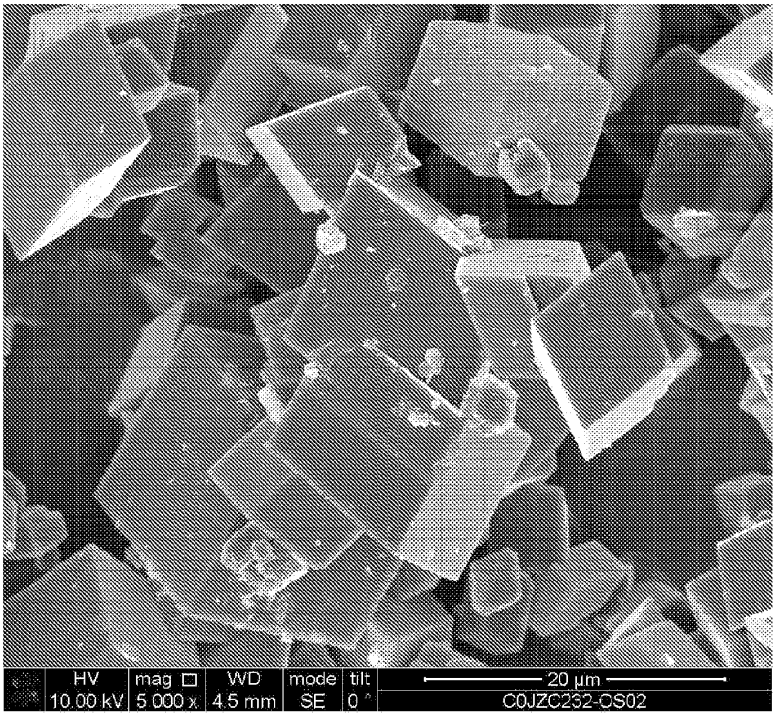

FIG. 21

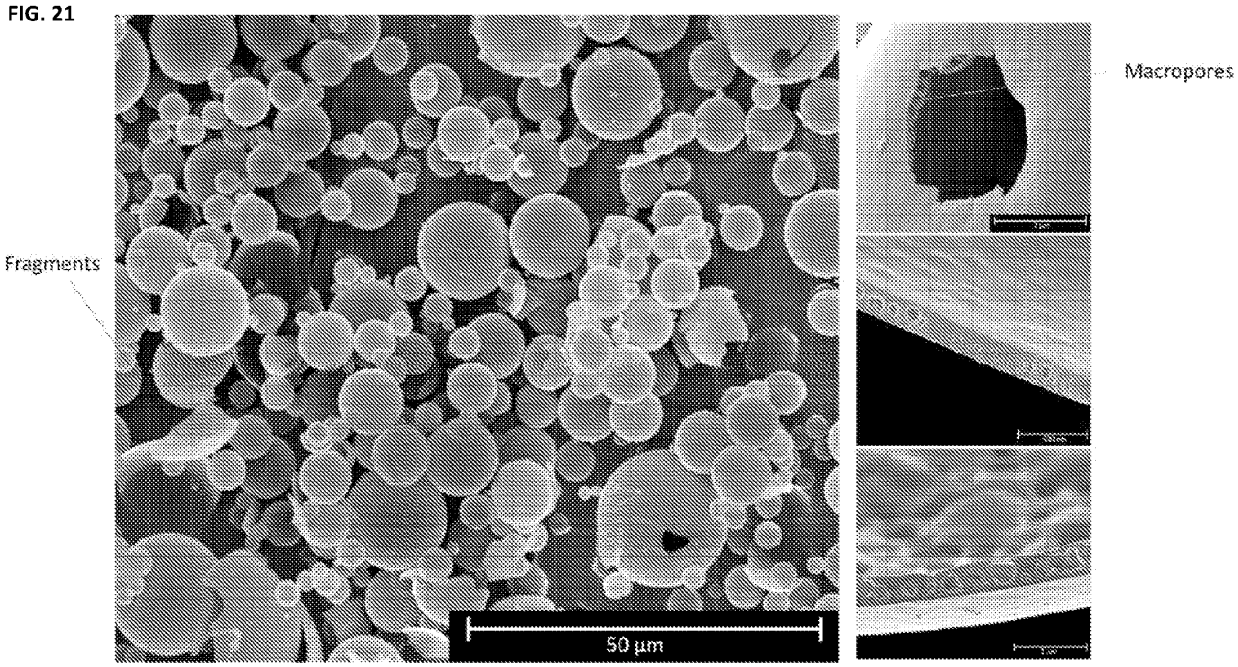

FIG. 22

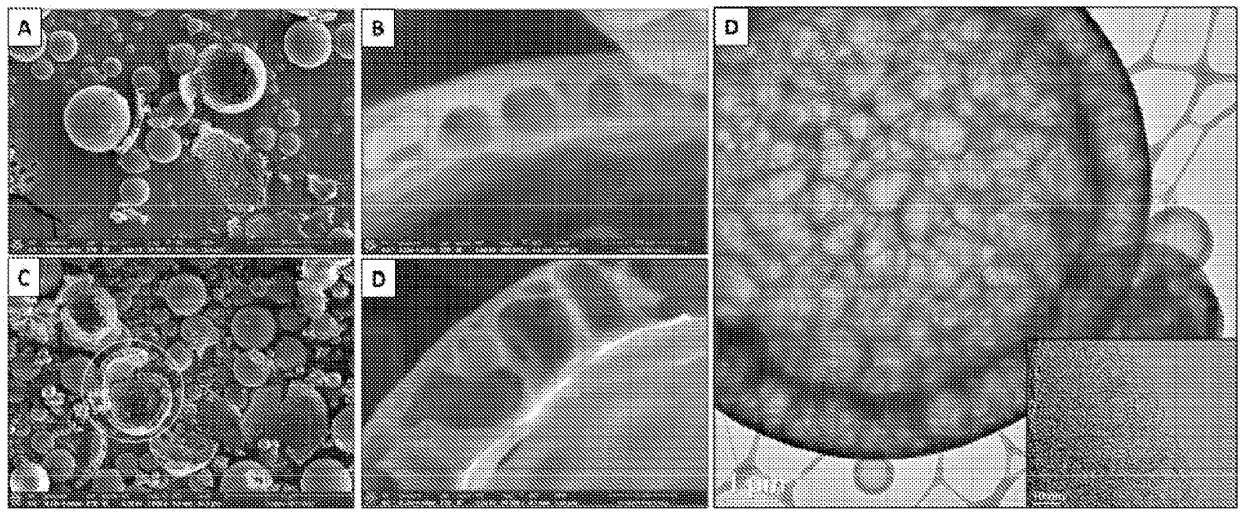

FIG. 23

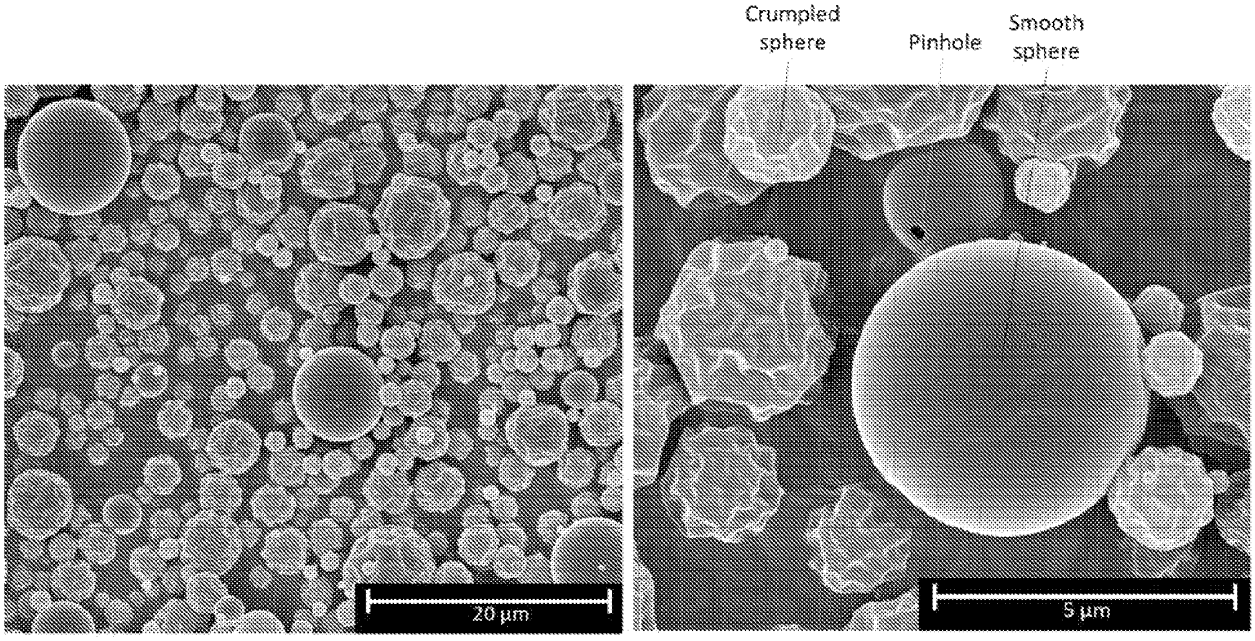

FIG. 24

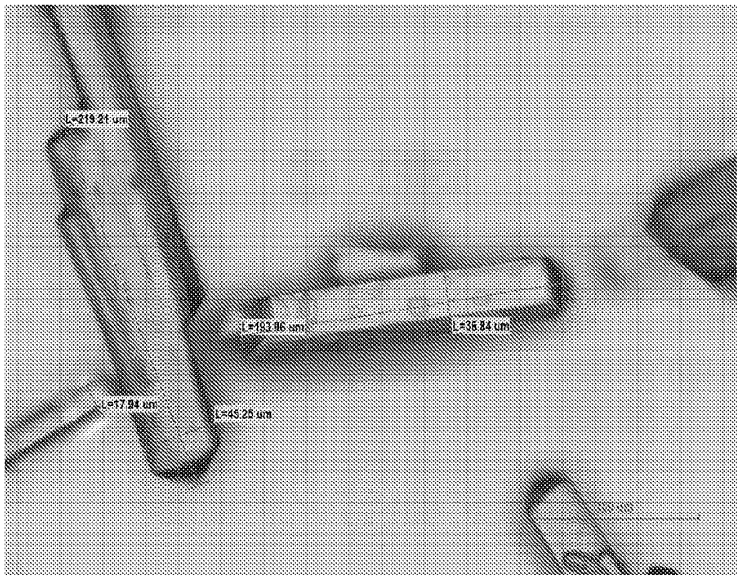

FIG. 25

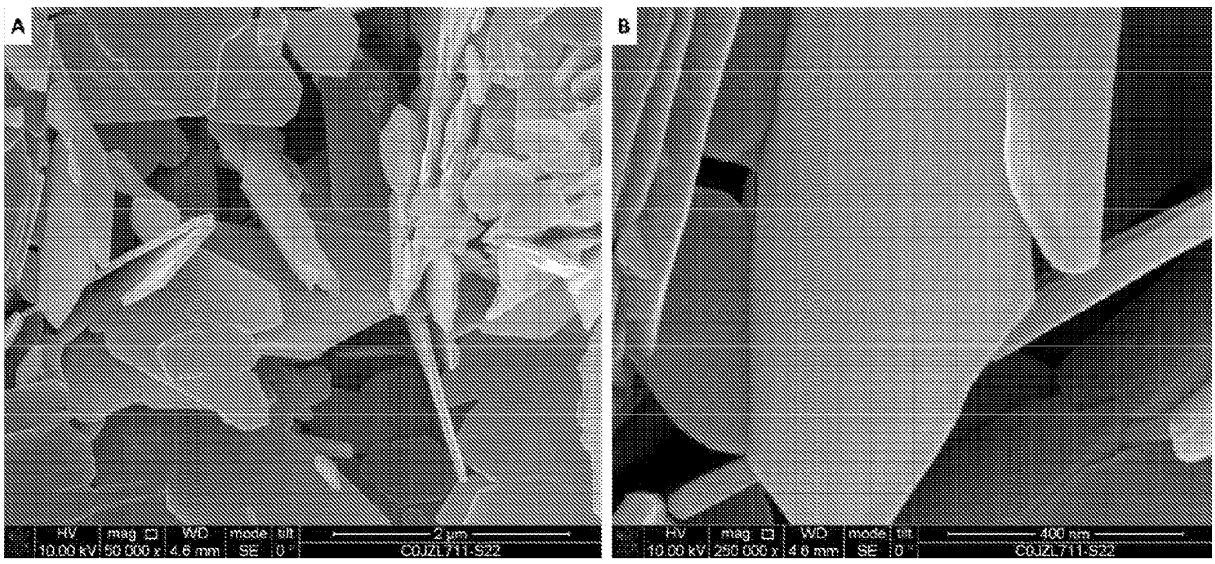
A
HV
mag
WD
mode
tilt
2 µm
10.00 kV
50 000 x
4.6 mm
SE
0 °
C0JZL711-S22
B
HV
mag
WD
mode
tilt
400 nm
10.00 kV
250 000 x
4.6 mm
SE
0 °
C0JZL711-S22

FIG. 26

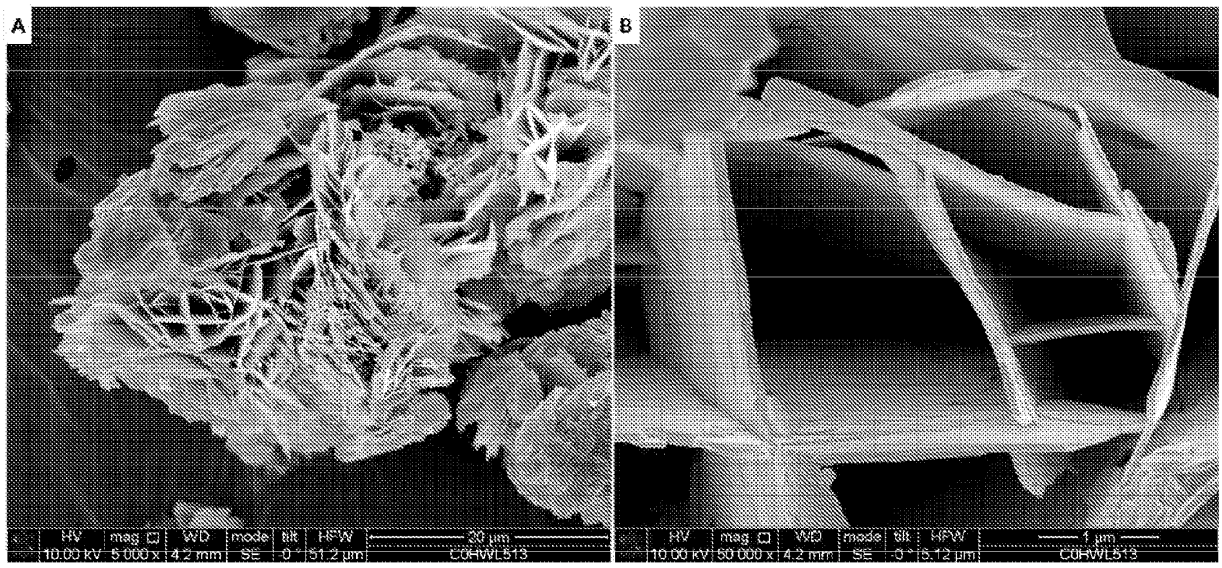
A
HV mag WD mode tilt HFW 20 µm
10.00 kV 5 000 x 4.2 mm SE 0 ° 51.2 µm C0HWL513
B
HV mag WD mode tilt HFW 1 µm
10.00 kV 50 000 x 4.2 mm SE 0 ° 5.12 µm C0HWL513

FIG. 27

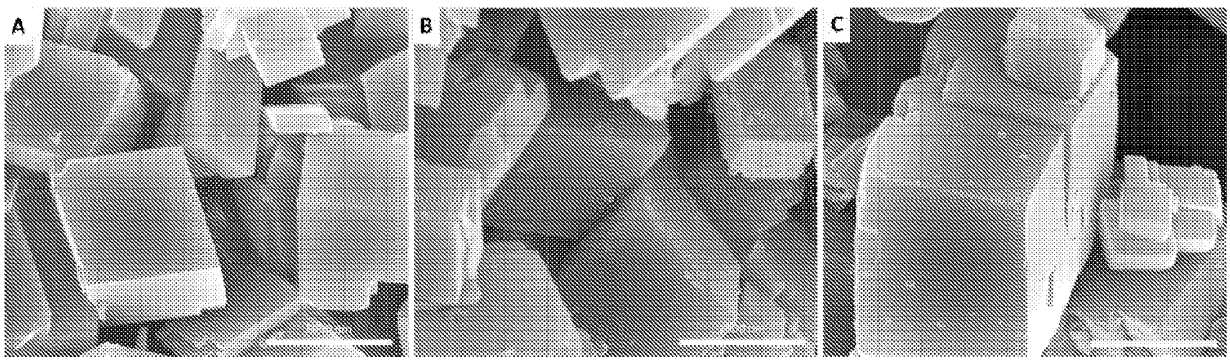

FIG. 28

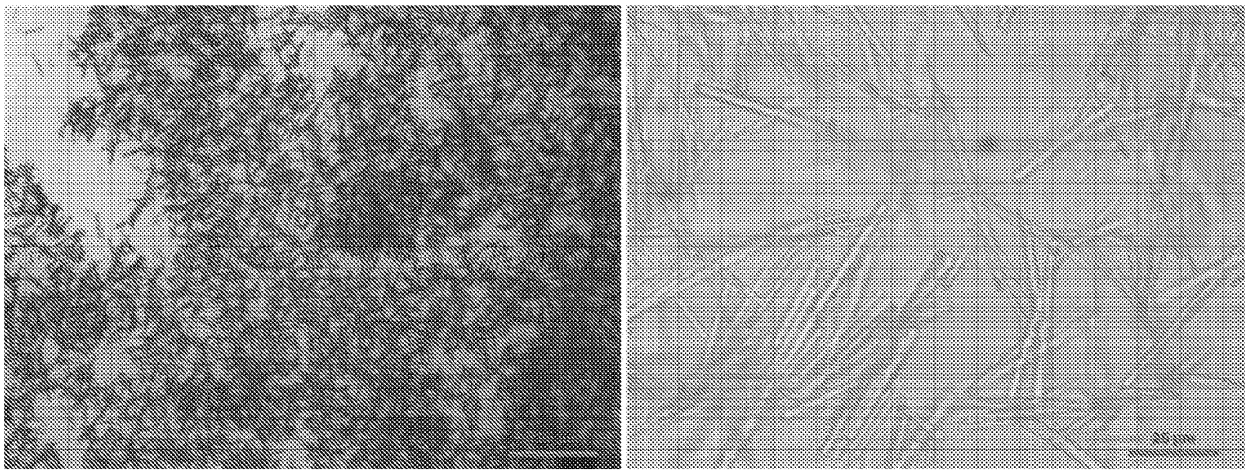

FIG. 29

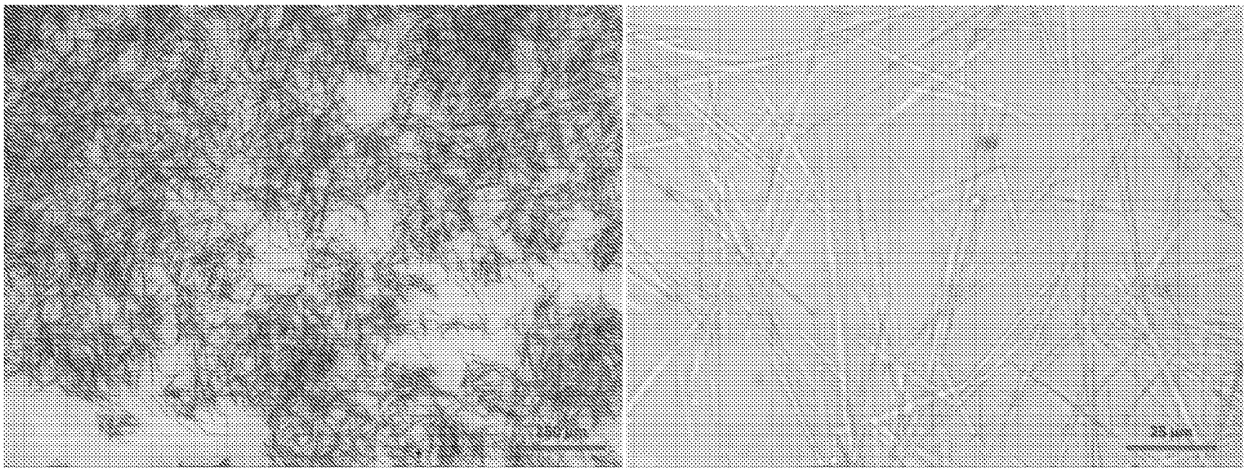

FIG. 30

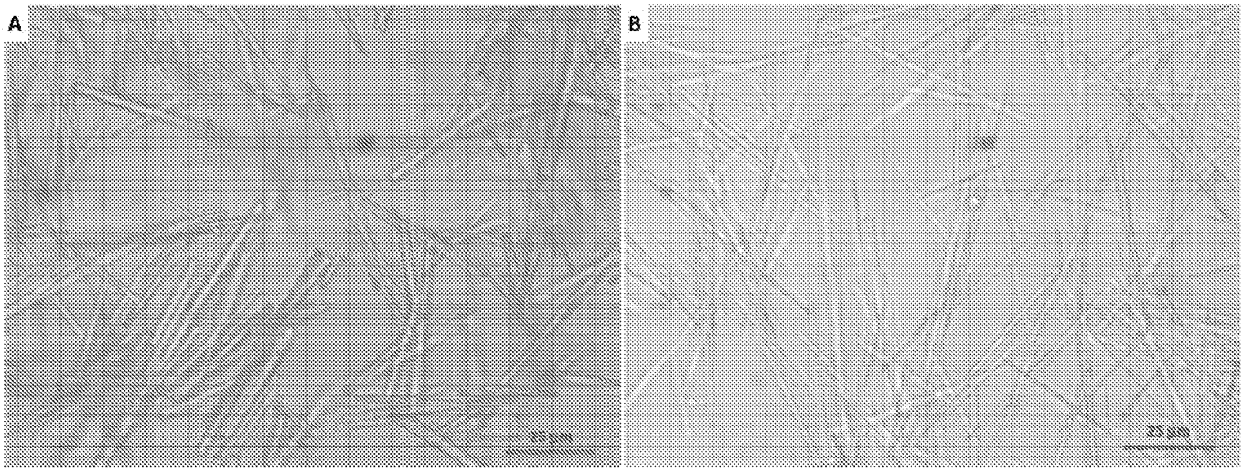

FIG. 31

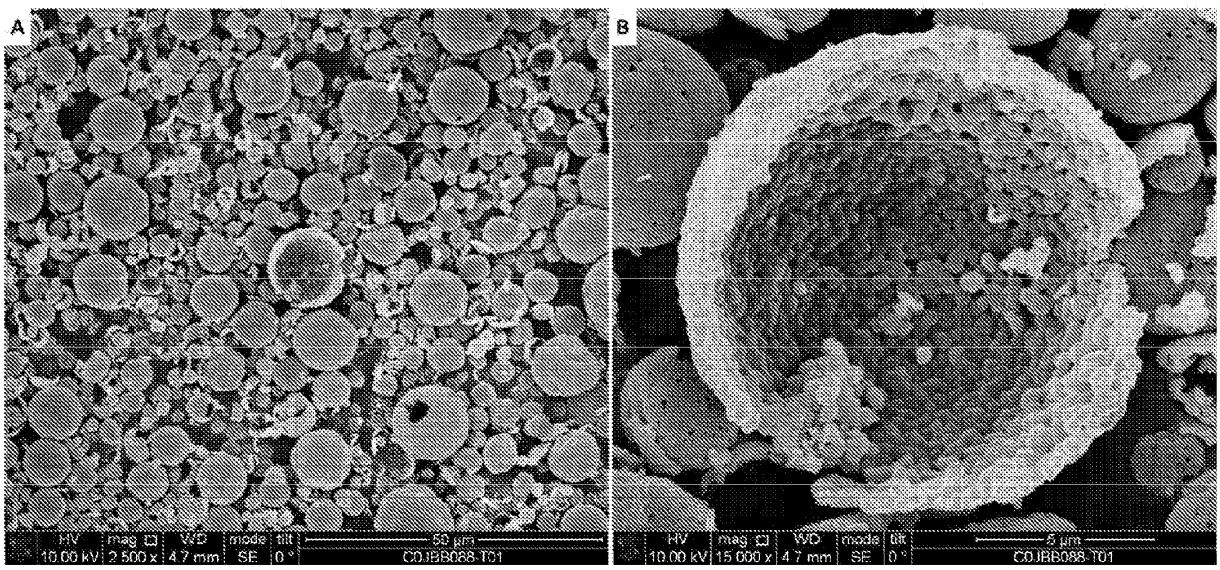
A
HV
10.00 kV
mag
2 500 x
WD
4.7 mm
mode
SE
tilt
0 °
50 µm
C0JBB088-T01
B
HV
10.00 kV
mag
15 000 x
WD
4.7 mm
mode
SE
tilt
0 °
5 µm
C0JBB088-T01

FIG. 32

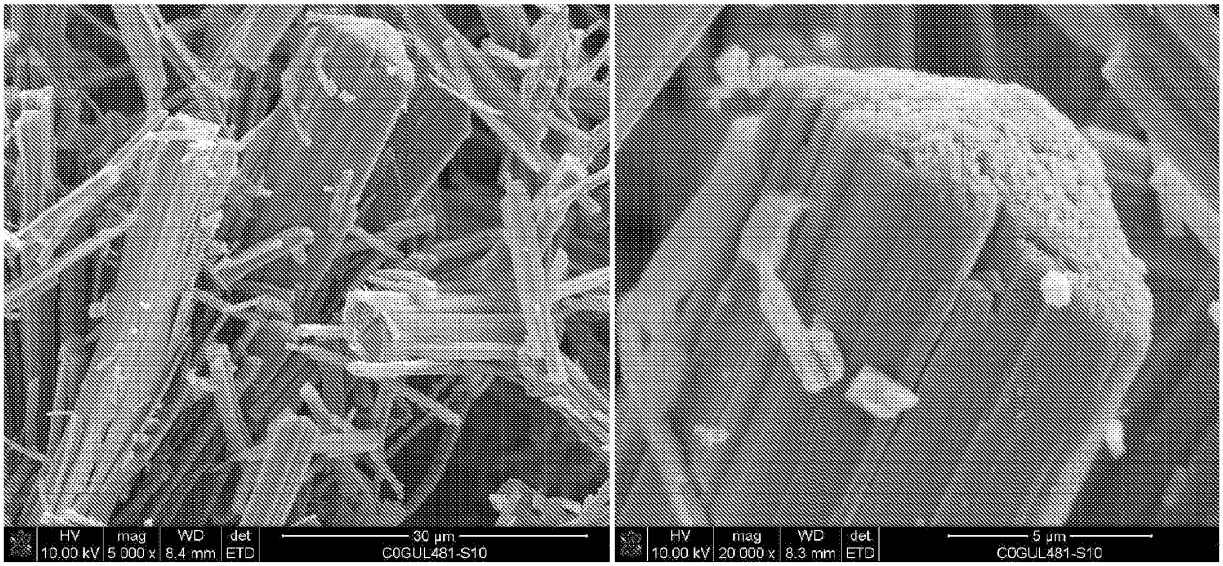
HV
10.00 kV
mag
5 000 x
WD
8.4 mm
det
ETD
30 µm
C0GUL481-S10
HV
10.00 kV
mag
20 000 x
WD
8.3 mm
det
ETD
5 µm
C0GUL481-S10

FIG. 33

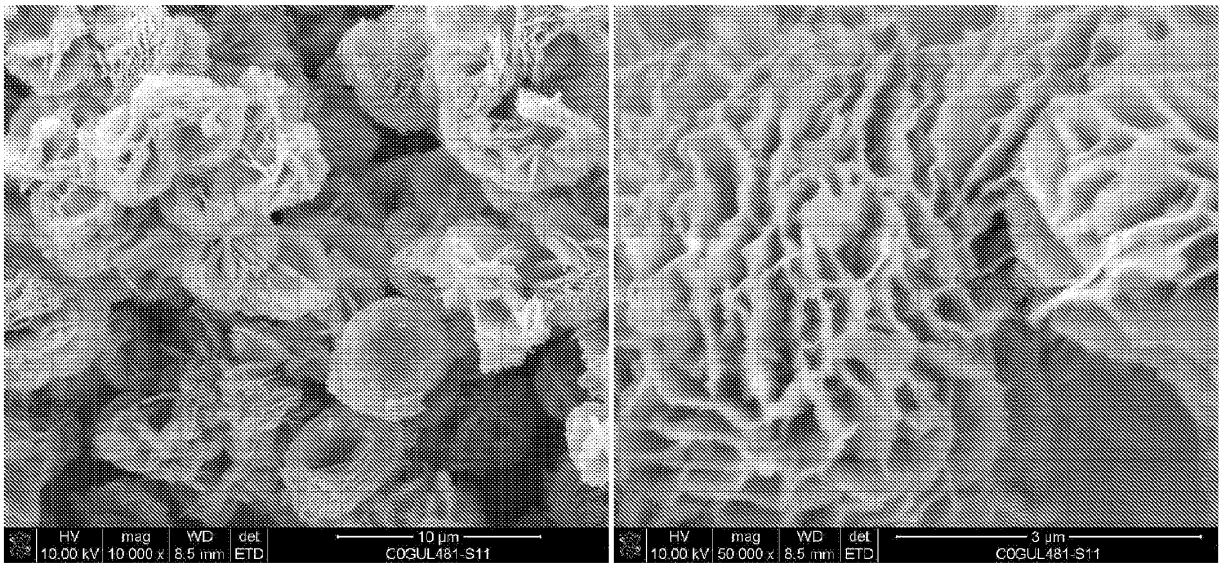
HV
10.00 kV
mag
10 000 x
WD
8.5 mm
det
ETD
10 µm
C0GUL481-S11
HV
10.00 kV
mag
50 000 x
WD
8.5 mm
det
ETD
3 µm
C0GUL481-S11

FIG. 34

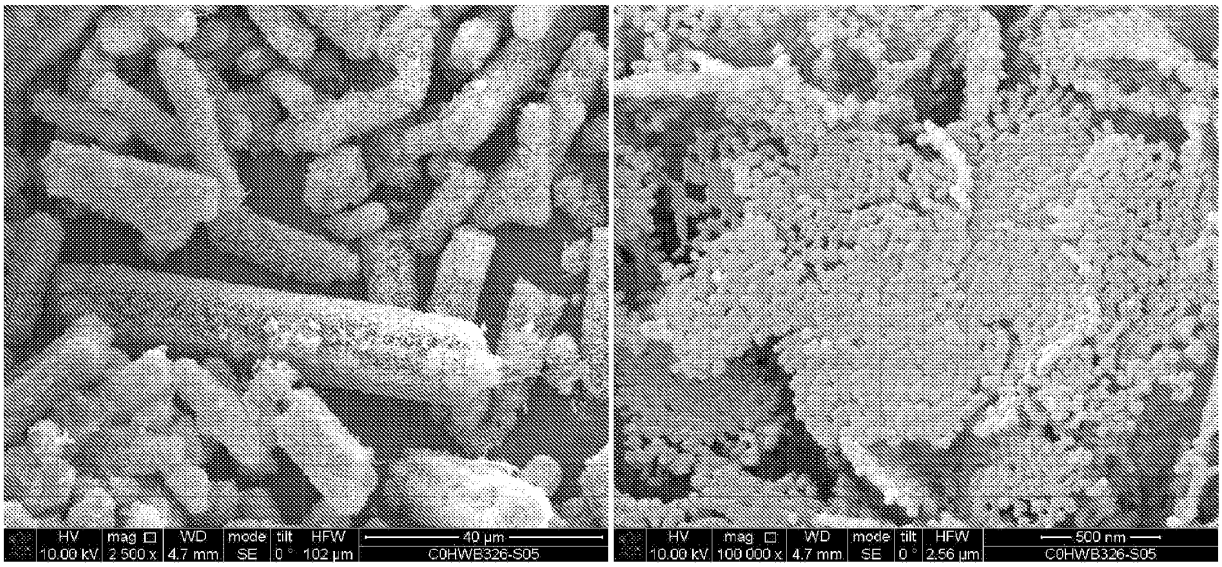
HV 10.00 kV
mag 2 500 x
WD 4.7 mm
mode SE
tilt 0 °
HFW 102 µm
40 µm
C0HWB326-S05
HV 10.00 kV
mag 100 000 x
WD 4.7 mm
mode SE
tilt 0 °
HFW 2.56 µm
500 nm
C0HWB326-S05

FIG. 35

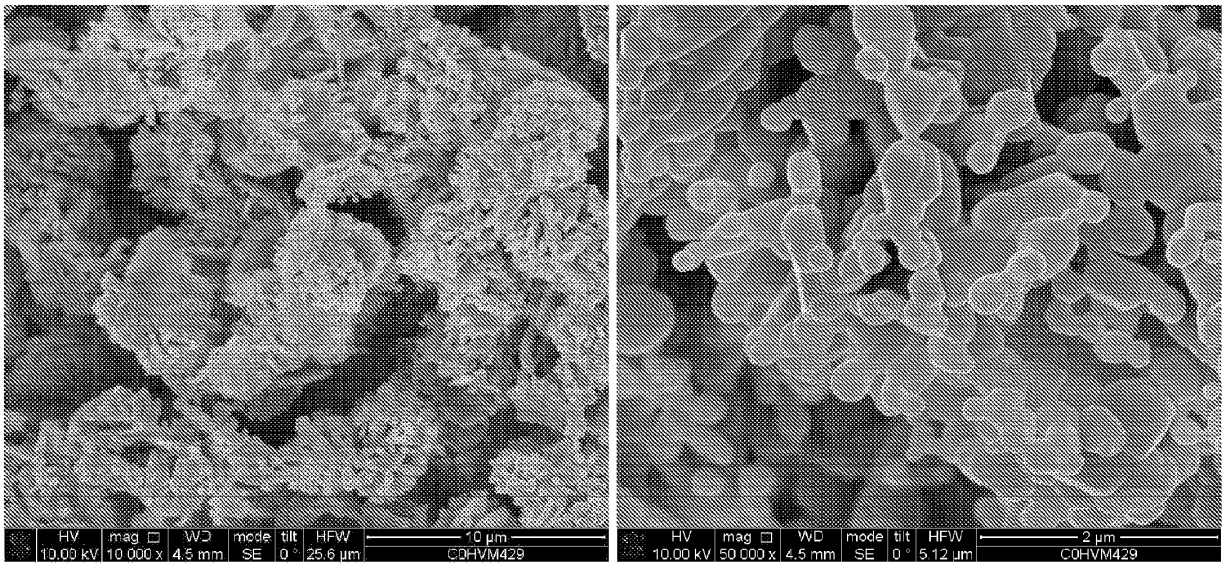
HV
10.00 kV
mag
10 000 x
WD
4.5 mm
mode
SE
tilt
0 °
HFW
25.6 µm
10 µm
C0HVM429
HV
10.00 kV
mag
50 000 x
WD
4.5 mm
mode
SE
tilt
0 °
HFW
5.12 µm
2 µm
C0HVM429

FIG. 36

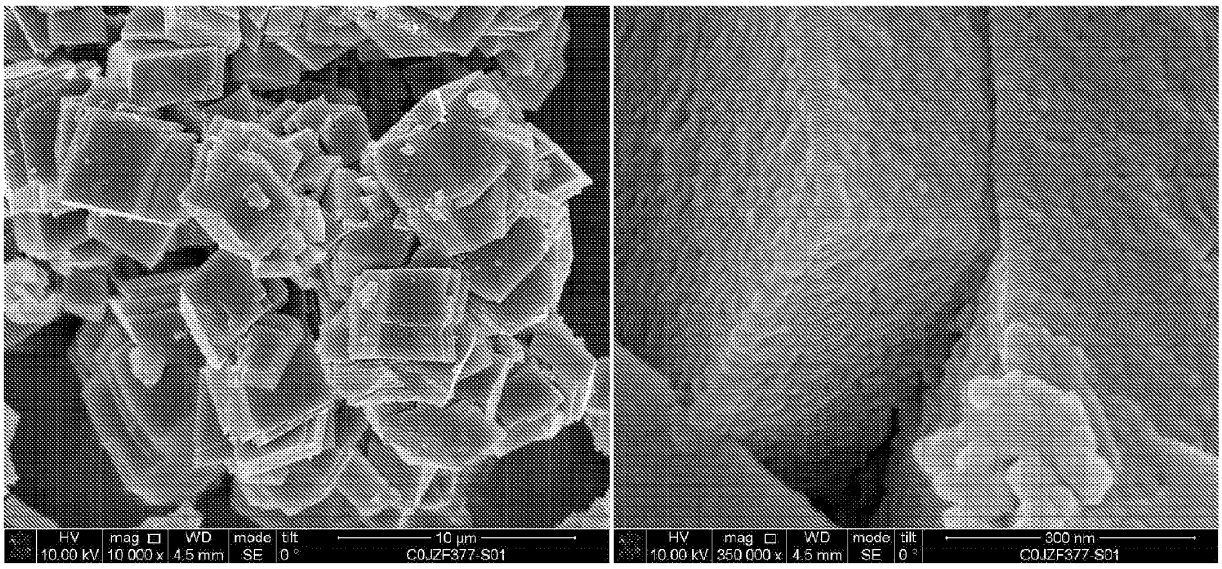
HV
10.00 kV
mag
10 000 x
WD
4.5 mm
mode
SE
tilt
0 °
10 µm
C0JZF377-S01
HV
10.00 kV
mag
350 000 x
WD
4.5 mm
mode
SE
tilt
0 °
300 nm
C0JZF377-S01

FIG. 37

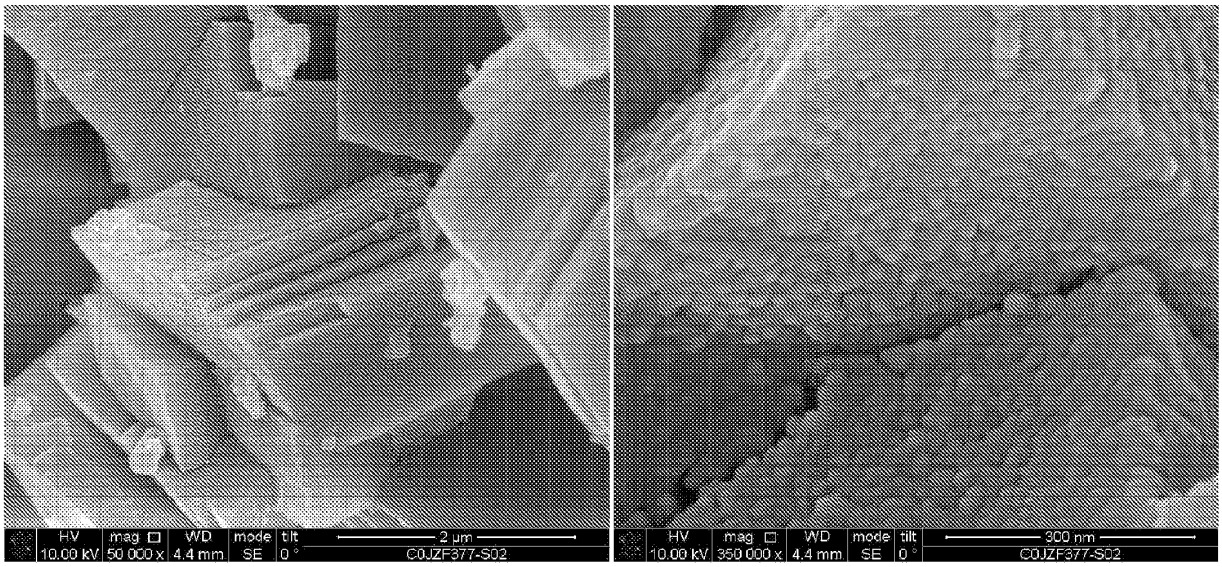
HV
10.00 kV
mag
50 000 x
WD
4.4 mm
mode
SE
tilt
0 °
2 µm
C0JZF377-S02
HV
10.00 kV
mag
350 000 x
WD
4.4 mm
mode
SE
tilt
0 °
300 nm
C0JZF377-S02

FIG. 38

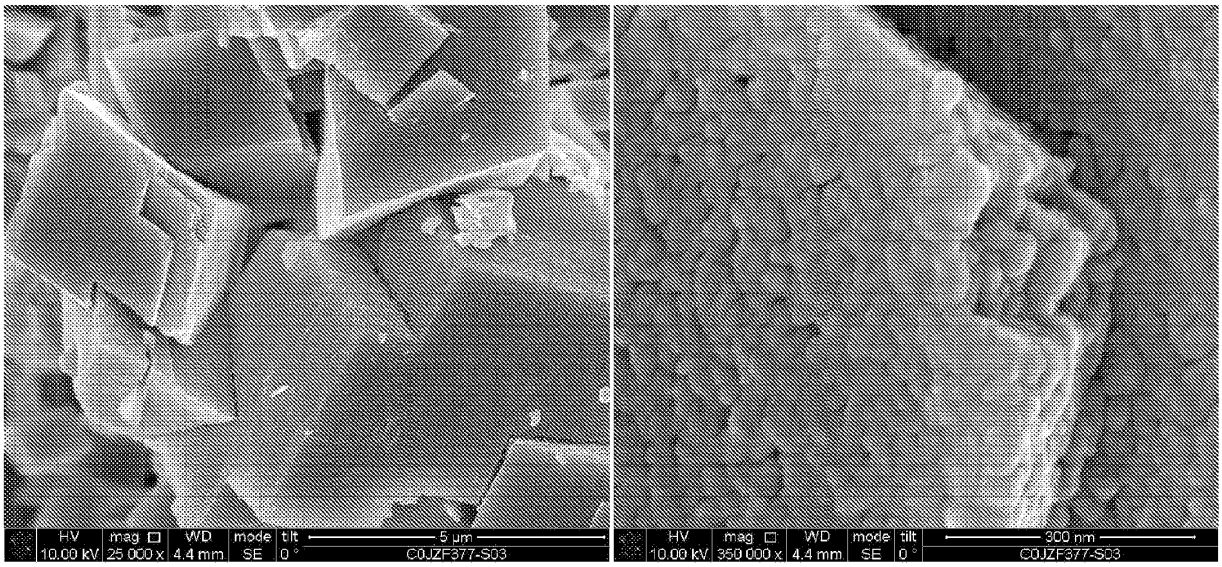
HV
10.00 kV
mag
25 000 x
WD
4.4 mm
mode
SE
tilt
0 °
5 µm
C0JZF377-S03
HV
10.00 kV
mag
350 000 x
WD
4.4 mm
mode
SE
tilt
0 °
300 nm
C0JZF377-S03

FIG. 39

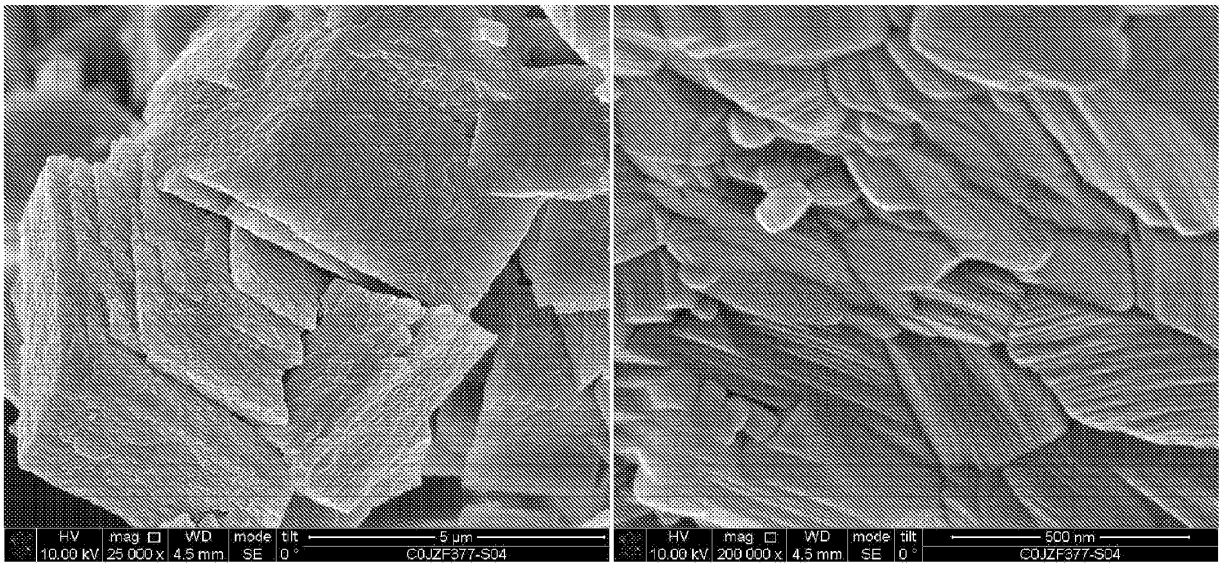
HV
10.00 kV
mag
25 000 x
WD
4.5 mm
mode
SE
tilt
0 °
5 µm
C0JZF377-S04
HV
10.00 kV
mag
200 000 x
WD
4.5 mm
mode
SE
tilt
0 °
500 nm
C0JZF377-S04

FIG. 40

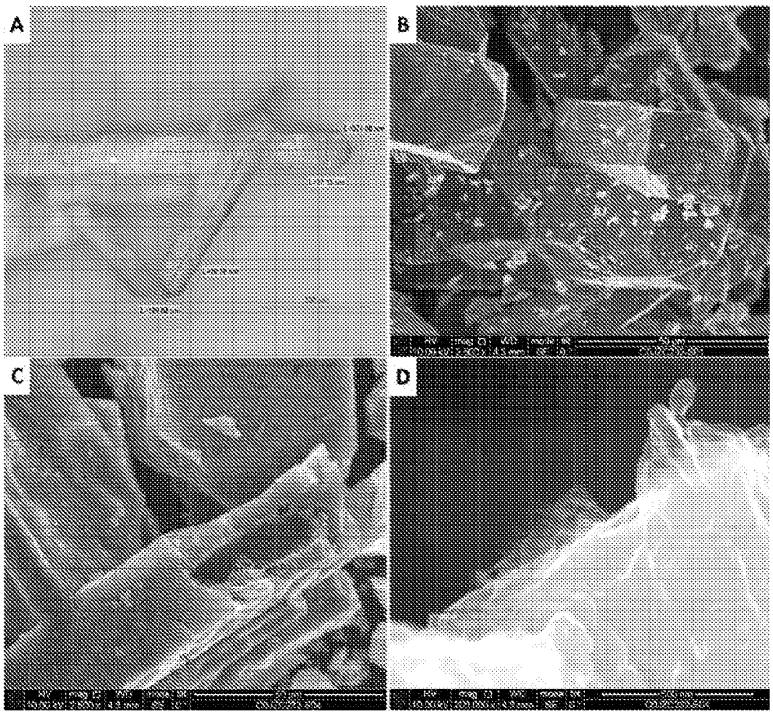

FIG. 41

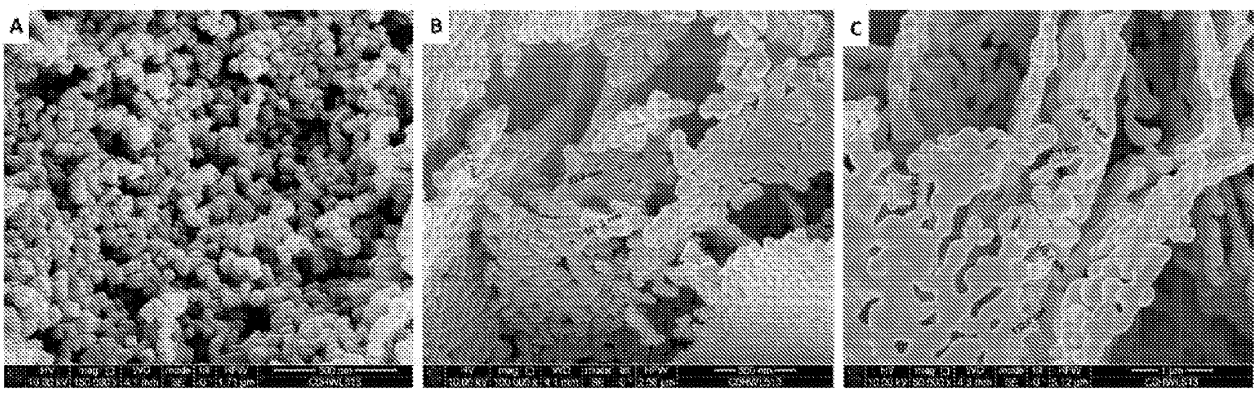

FIG. 42

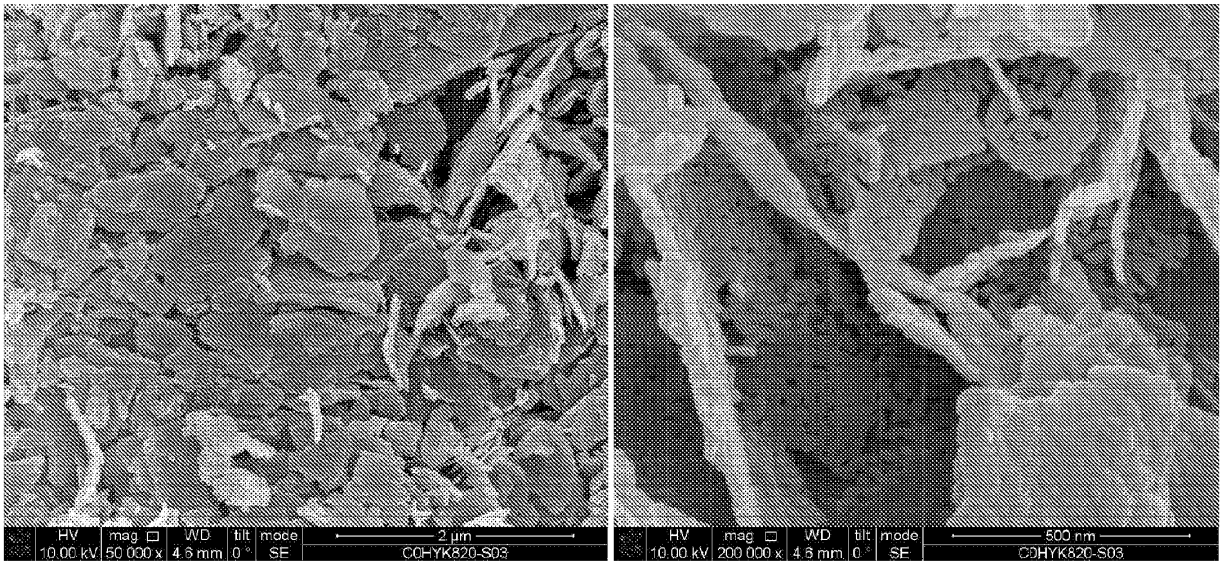
HV
10.00 kV
mag
50 000 x
WD
4.6 mm
tilt
0 °
mode
SE
2 µm
CDHYK820-S03
HV
10.00 kV
mag
200 000 x
WD
4.6 mm
tilt
0 °
mode
SE
500 nm
CDHYK820-S03

FIG. 43

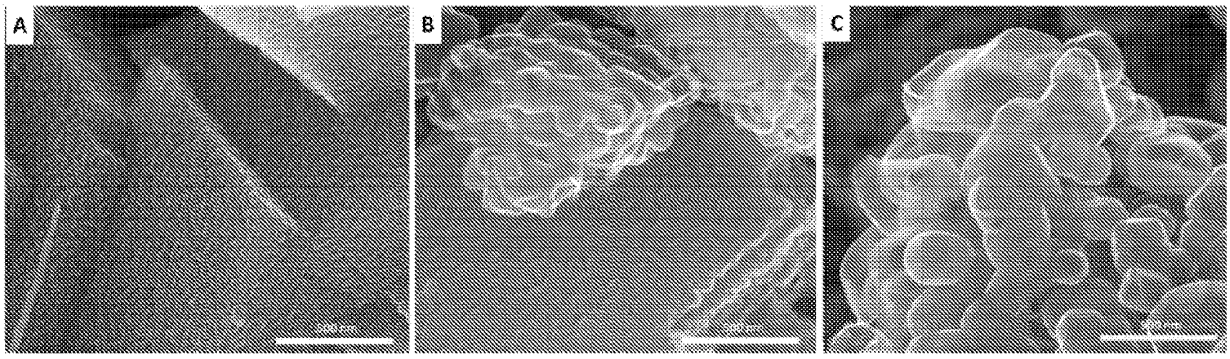

FIG. 44

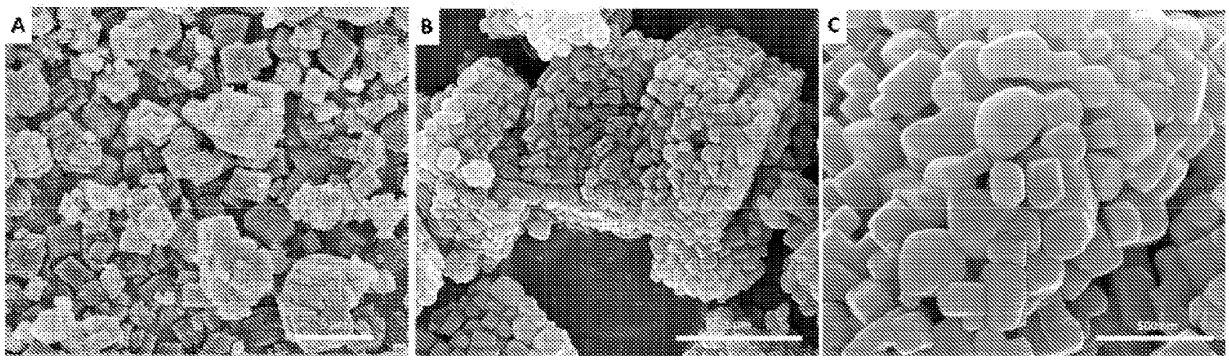

FIG. 45

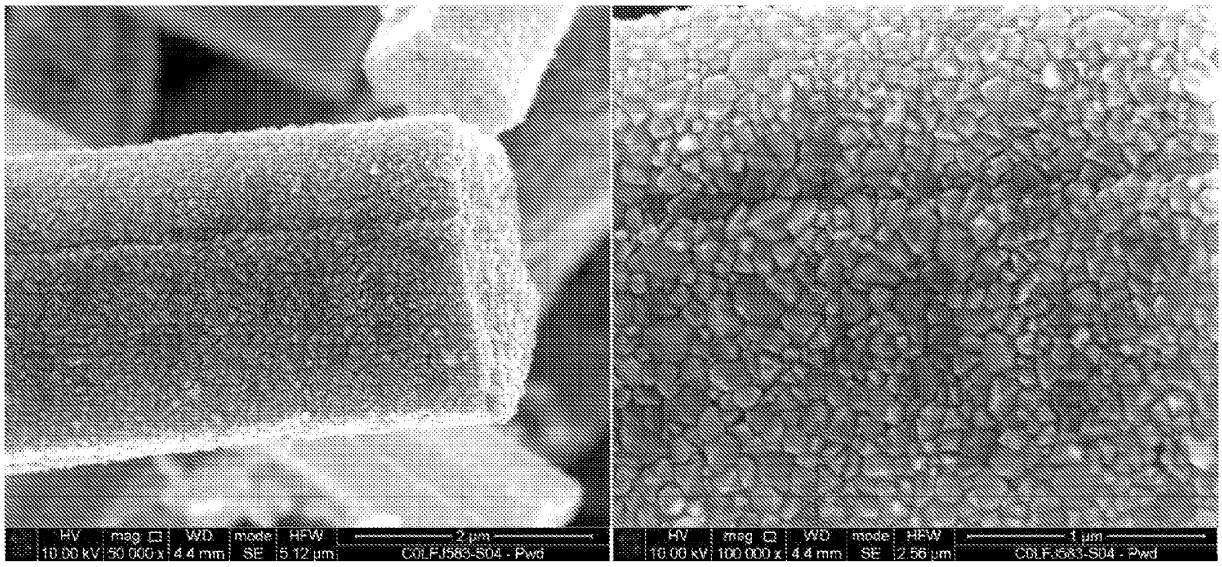
HV
10.00 kV
mag
50 000 x
WD
4.4 mm
mode
SE
HFW
5.12 µm
2 µm
CDLF-563-504 - Pwd
HV
10.00 kV
mag
100 000 x
WD
4.4 mm
mode
SE
HFW
2.56 µm
1 µm
CDLF-563-504 - Pwd

FIG. 46

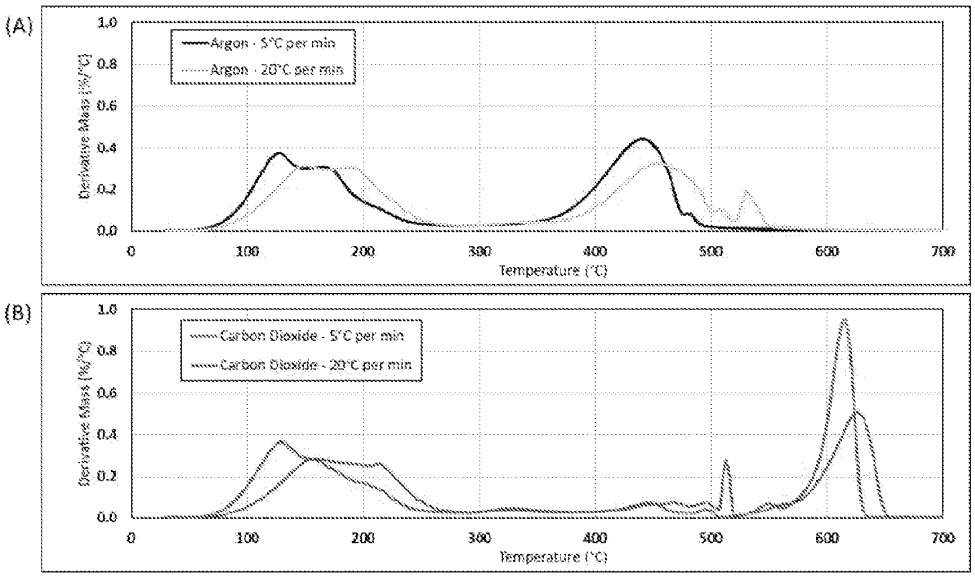
(A)
Argon - 5°C per min
Argon - 20°C per min
Derivative Mass (%/°C)
Temperature (°C)
(B)
Carbon Dioxide - 5°C per min
Carbon Dioxide - 20°C per min
Derivative Mass (%/°C)
Temperature (°C)

FIG. 47

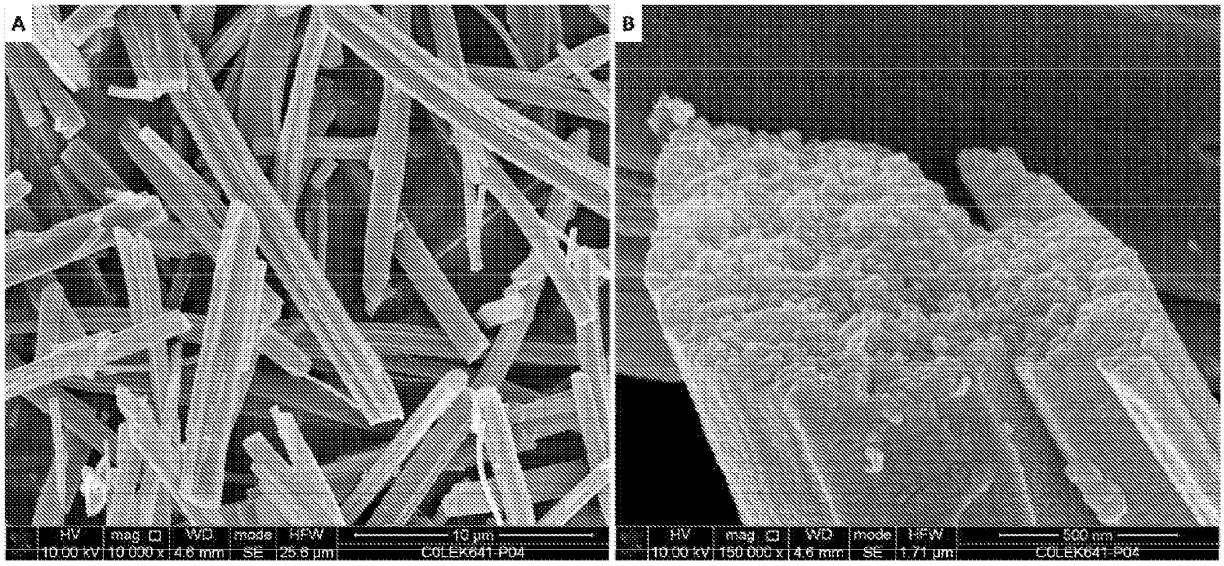
A
HV
mag
WD
mode
HFW
10 µm
10.00 kV
10 000 x
4.6 mm
SE
25.6 µm
C0LEK641-P04
B
HV
mag
WD
mode
HFW
500 nm
10.00 kV
150 000 x
4.6 mm
SE
1.71 µm
C0LEK641-P04

FIG. 48

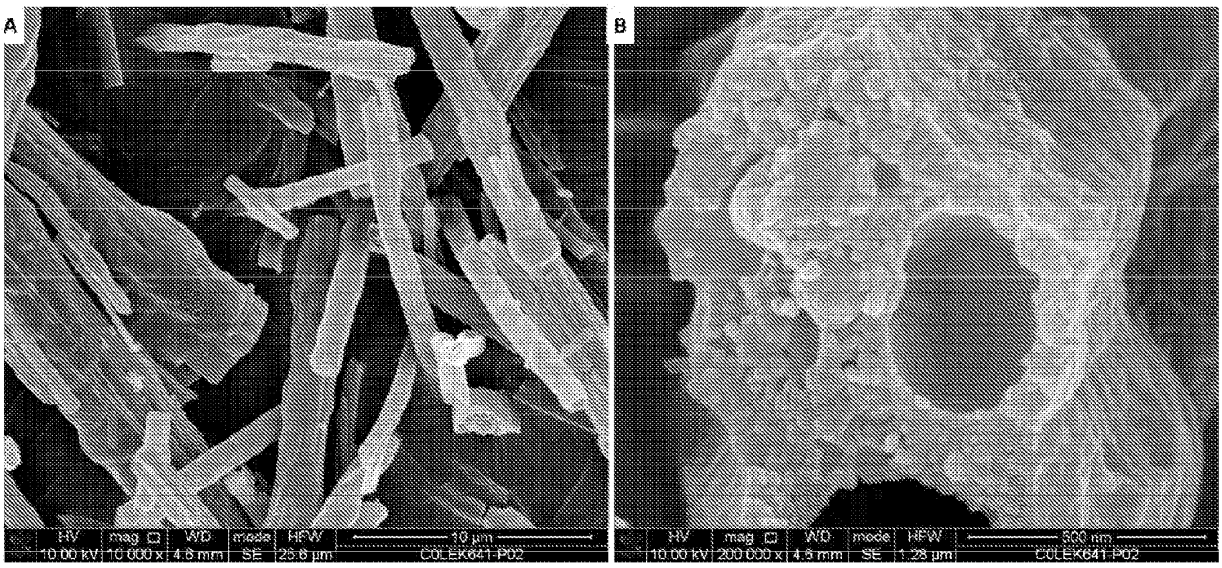
A
HV mag WD mode HFW 10 µm
10.00 kV 10 000 x 4.6 mm SE 25.6 µm C0LEK641-P02
B
HV mag WD mode HFW 500 nm
10.00 kV 200 000 x 4.6 mm SE 1.28 µm C0LEK641-P02

FIG. 49

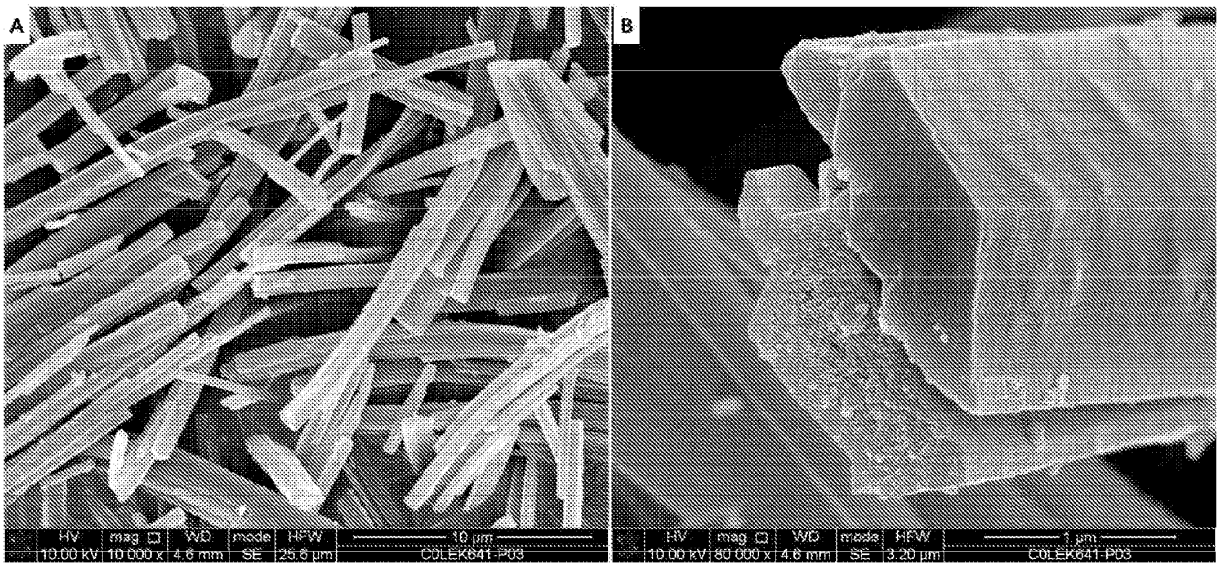
A
HV mag WD mode HFW
10.00 kV 10 000 x 4.6 mm SE 25.6 µm
10 µm
COLEK641-P03
B
HV mag WD mode HFW
10.00 kV 80 000 x 4.6 mm SE 3.20 µm
1 µm
COLEK641-P03

FIG. 50

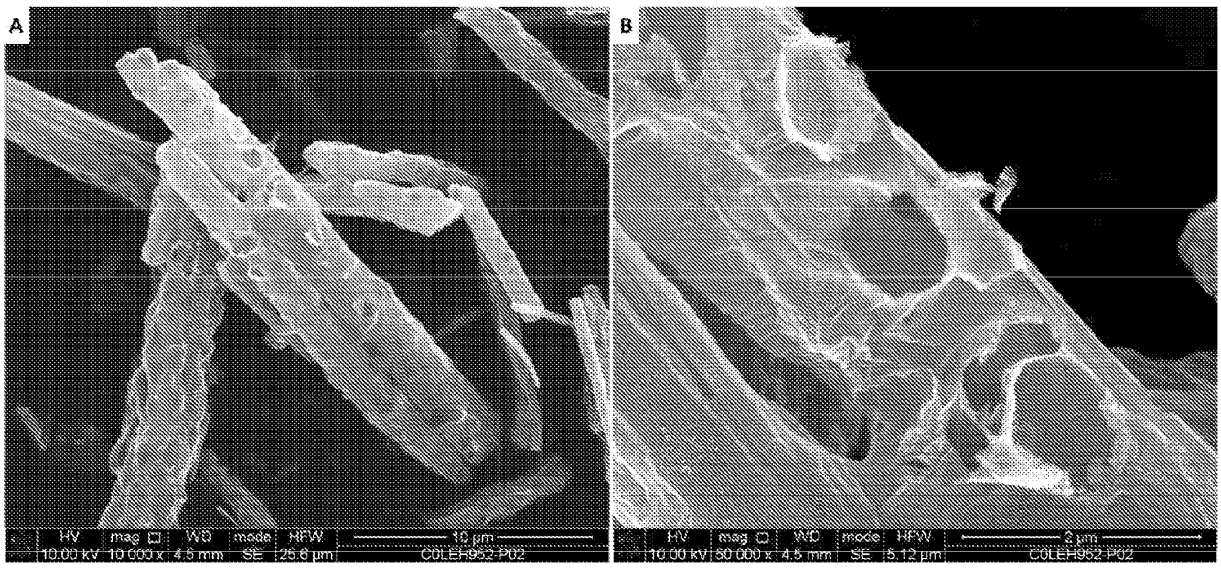
A
HV mag WD mode HFW
10.00 kV 10 000 x 4.5 mm SE 25.6 µm
10 µm
C0LEH962-P02
B
HV mag WD mode HFW
10.00 kV 50 000 x 4.5 mm SE 5.12 µm
2 µm
C0LEH962-P02

FIG. 51

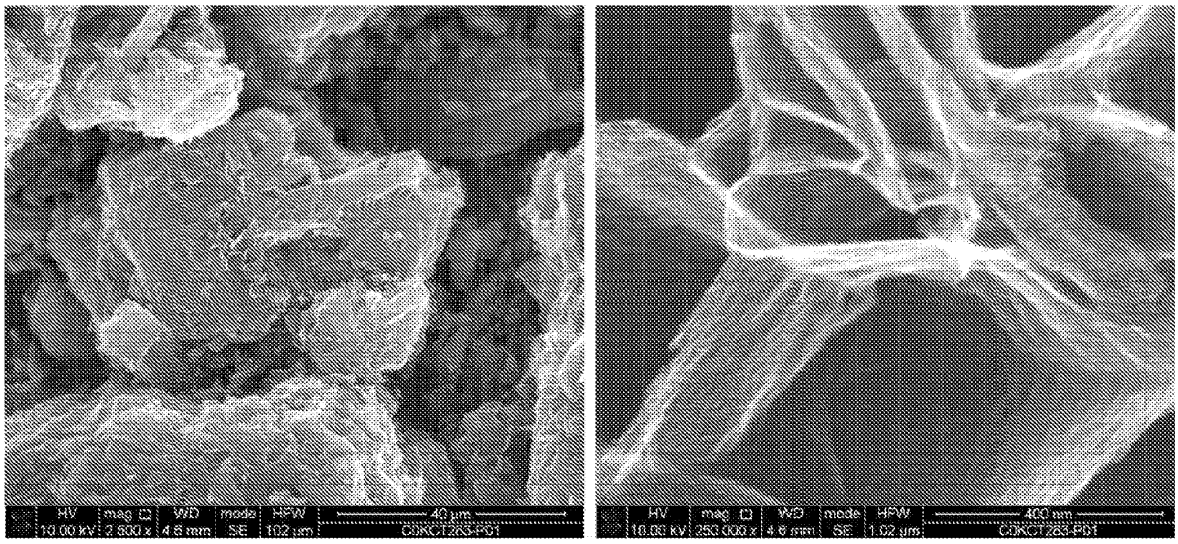
HV
10.00 kV
mag
2 000 x
WD
4.6 mm
mode
SE
HFW
102 µm
40 µm
CDKGT263-PD1
HV
10.00 kV
mag
250 000 x
WD
4.6 mm
mode
SE
HFW
1.02 µm
400 nm
CDKGT263-PD1

FIG. 52

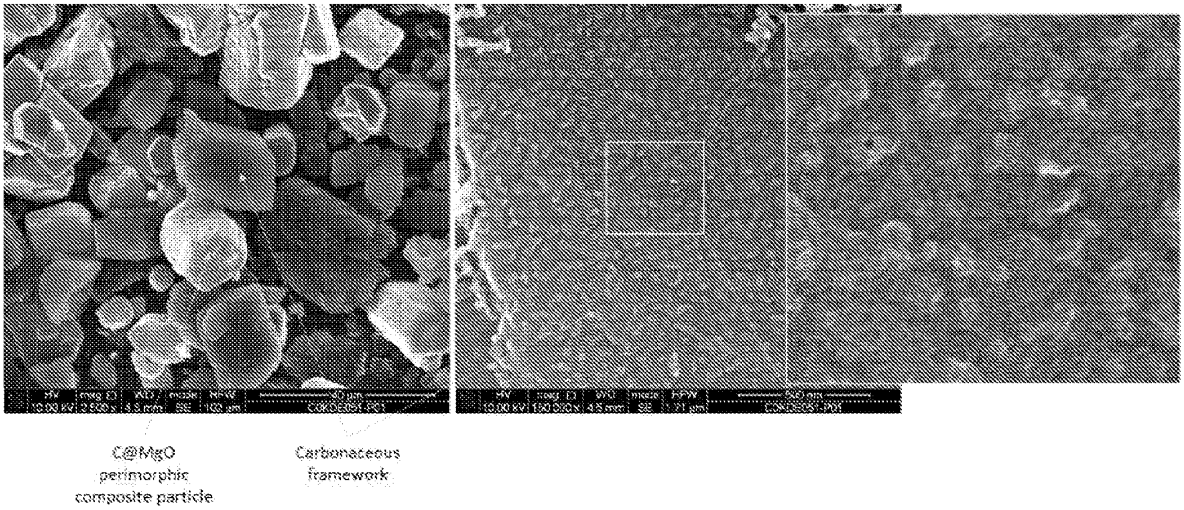
C@MgO
perimorphic
composite particle
Carbonaceous
framework

FIG. 53

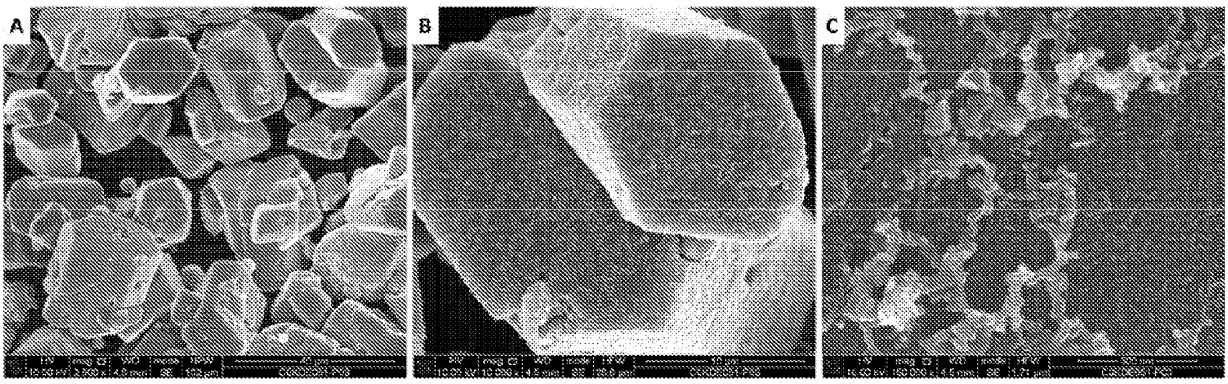

FIG. 54

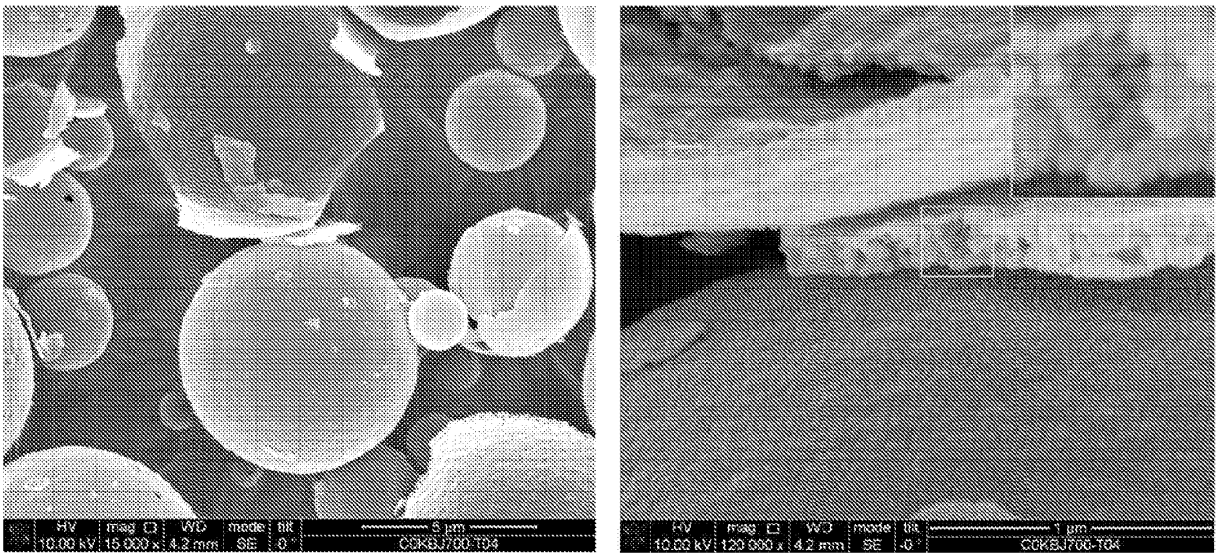
HV
mag
WD
mode
tilt
5 µm
10.00 kV
15 000 x
4.2 mm
SE
0 °
C0KBJ700-T04
HV
mag
WD
mode
tilt
1 µm
10.00 kV
120 000 x
4.2 mm
SE
-0 °
C0KBJ700-T04

FIG. 55

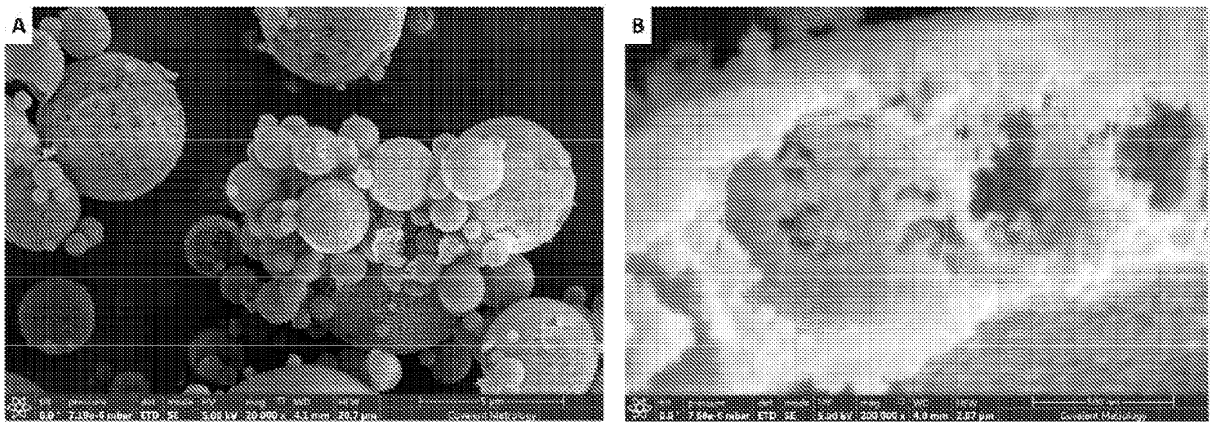

FIG. 56

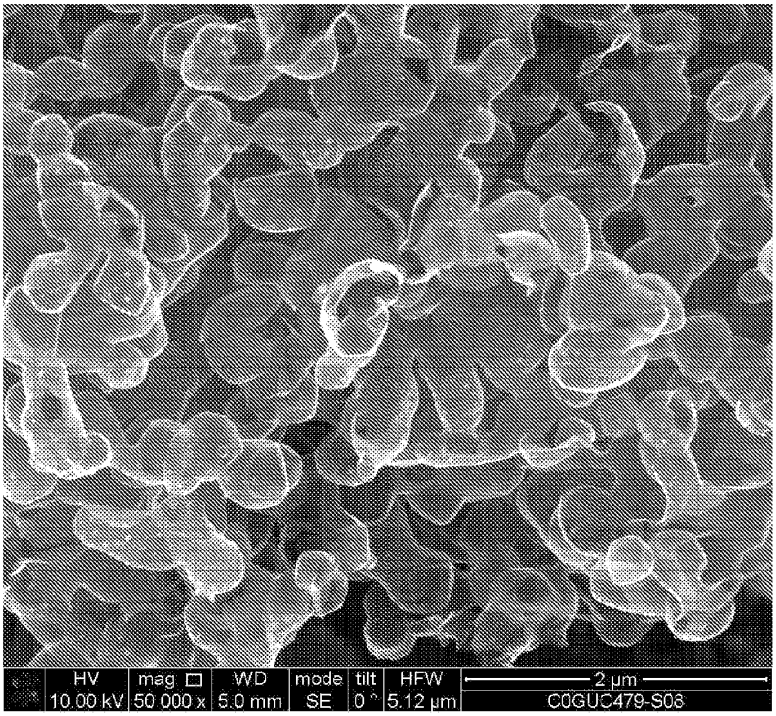
HV
10.00 kV
mag
50 000 x
WD
5.0 mm
mode
SE
tilt
0 °
HFW
5.12 µm
2 µm
C0GUC479-S08

FIG. 57

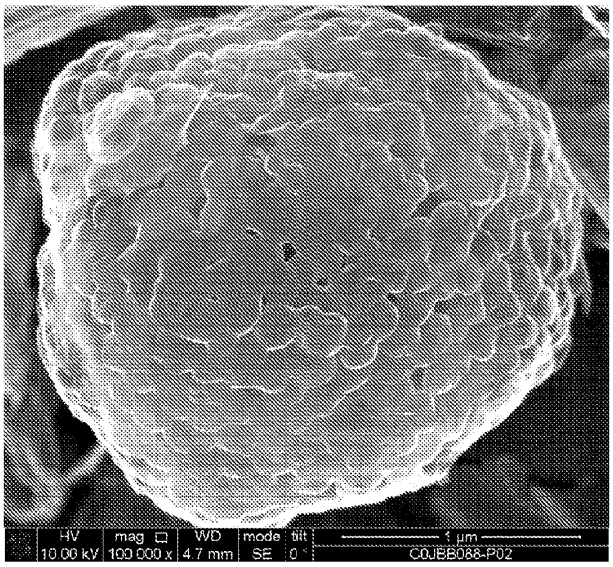

FIG. 58

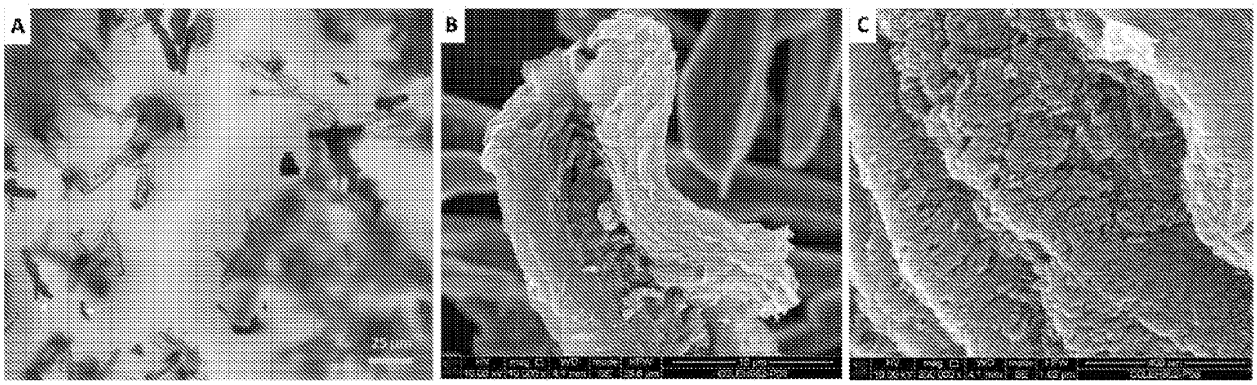

FIG. 59

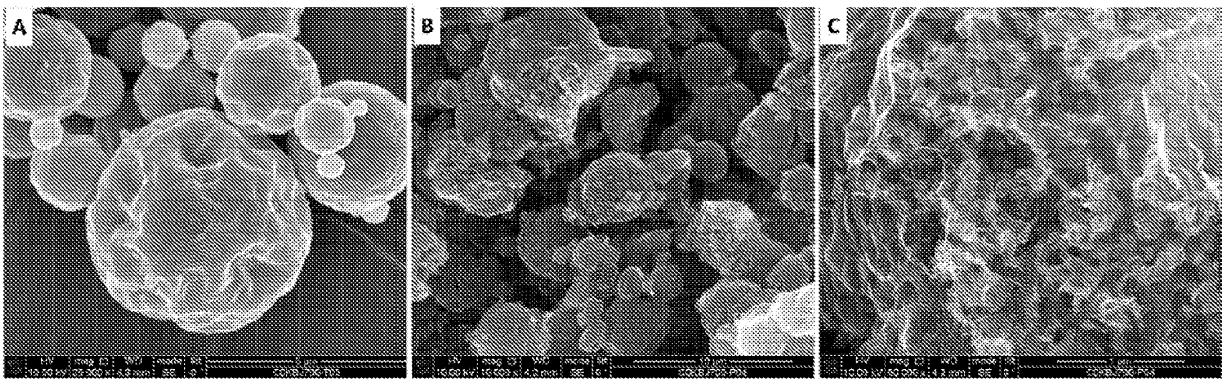

FIG. 60

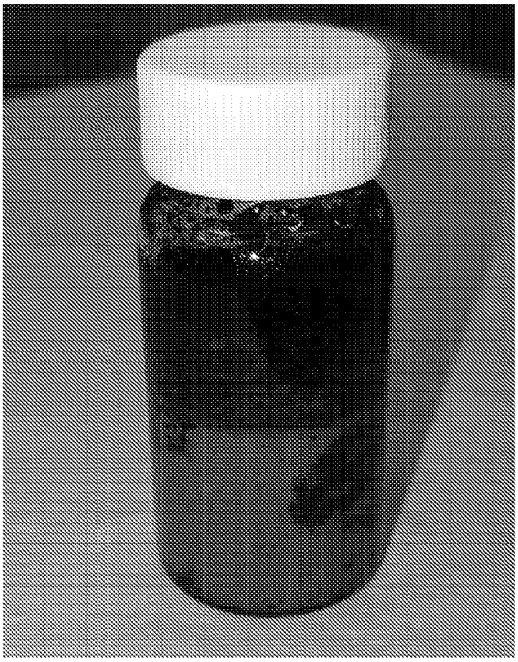

FIG. 61

Initial slurry Flotation

FIG. 62

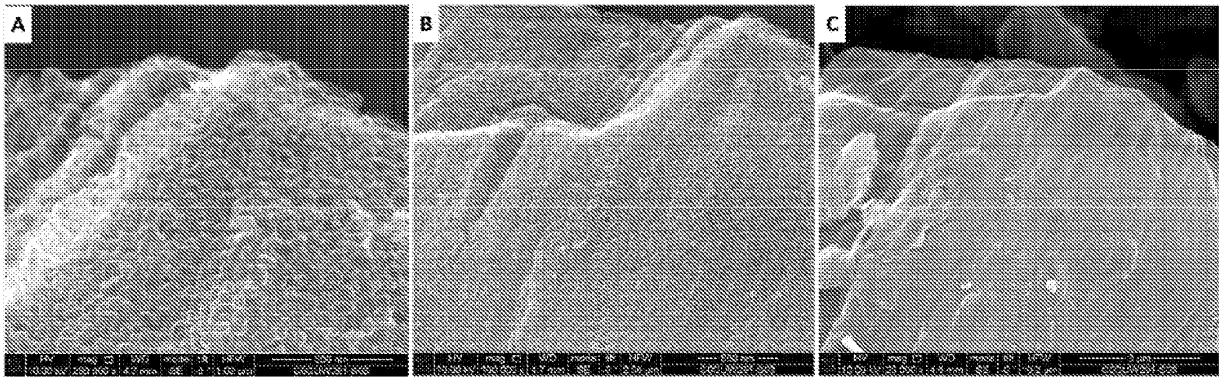

FIG. 63

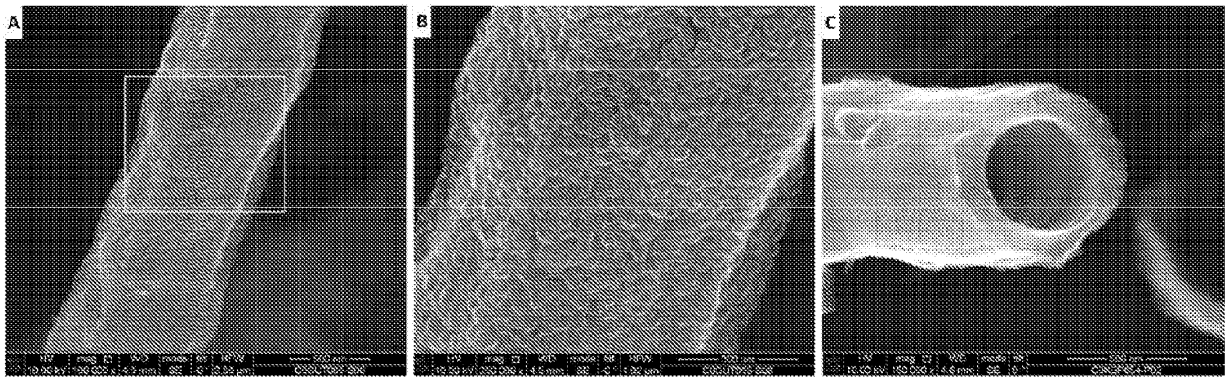

FIG. 64

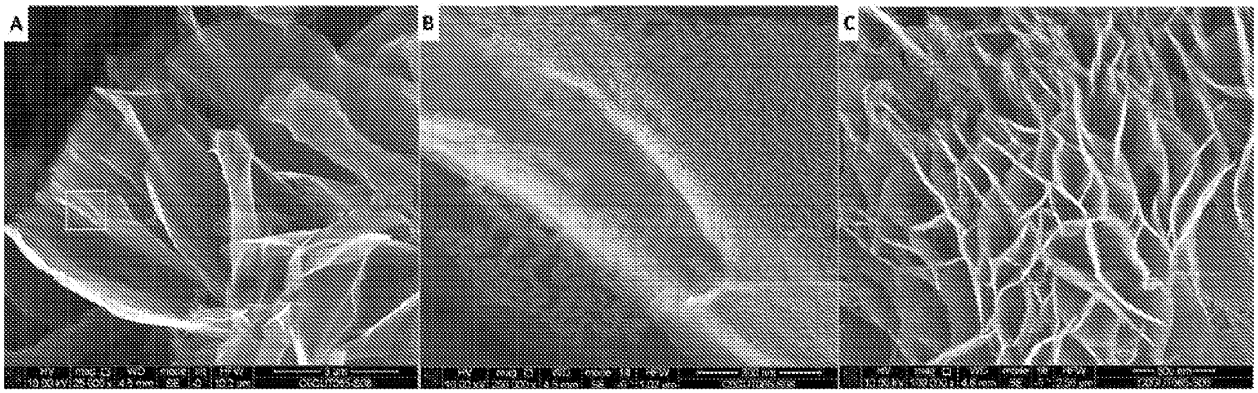

FIG. 65

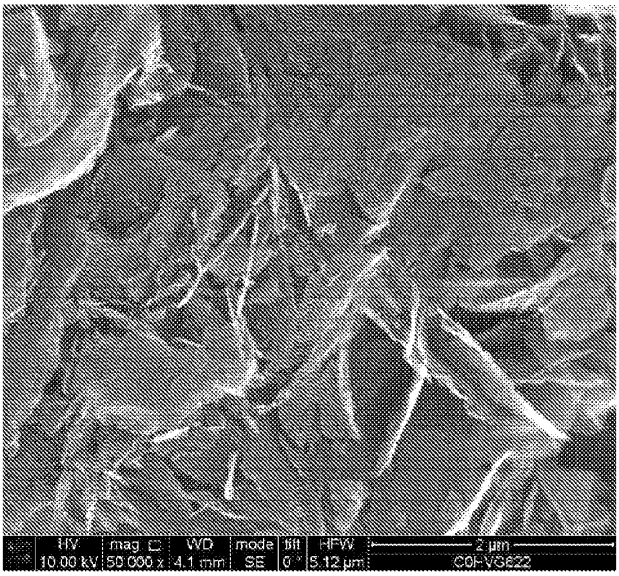
HV
10.00 kV
mag
50 000 x
WD
4.1 mm
mode
SE
tilt
0 °
HFW
5.12 µm
2 µm
C0H-VS622

FIG. 66

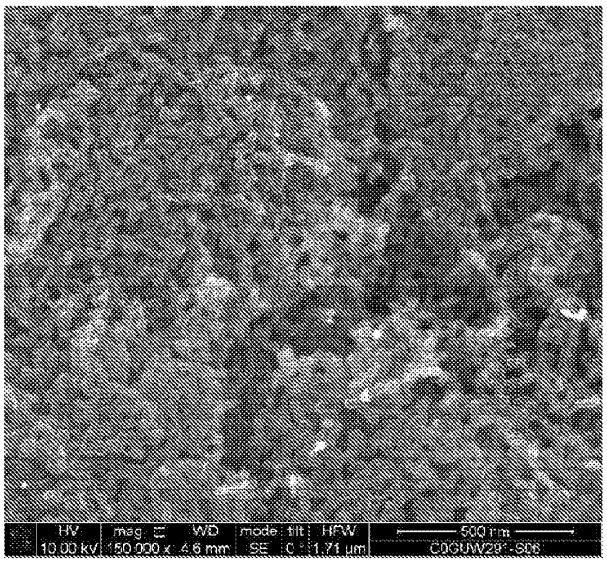

FIG. 67

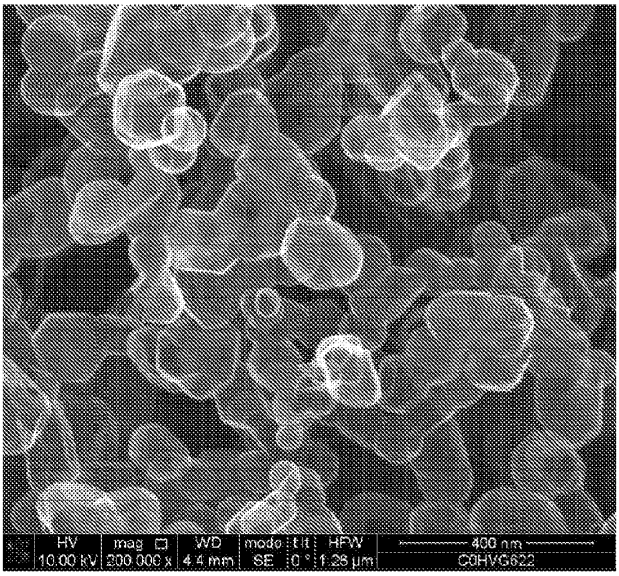
HV
10.00 kV
mag
200 000 x
WD
4.4 mm
mode
SE
tilt
0 °
HFW
1.28 µm
400 nm
C0HVG622

FIG. 68

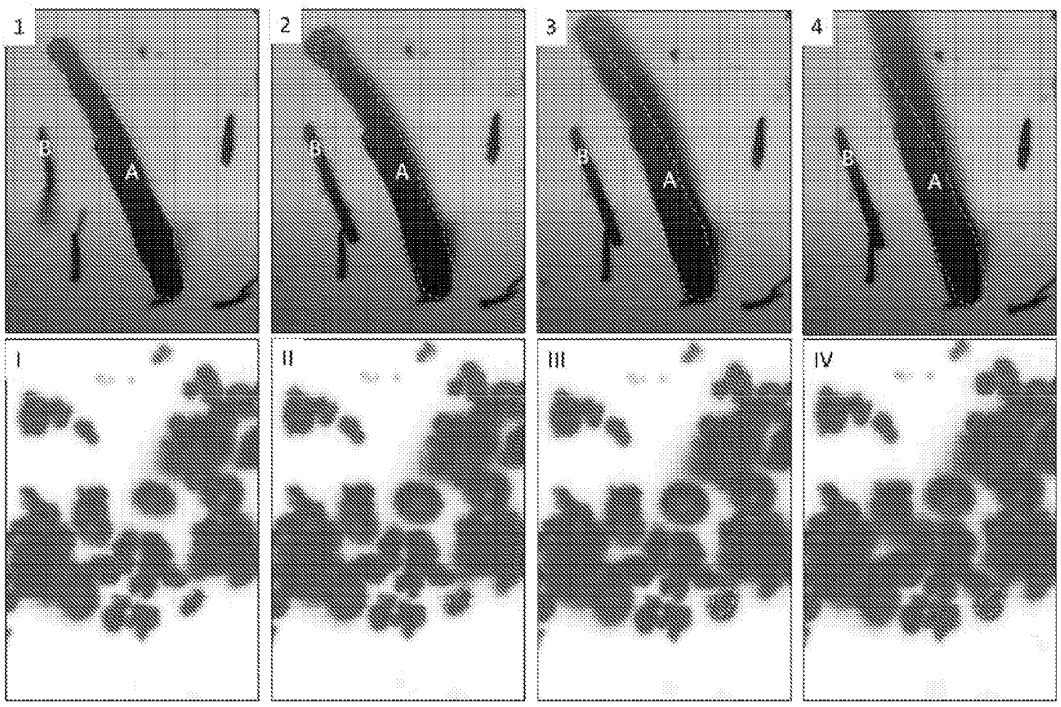

FIG. 69

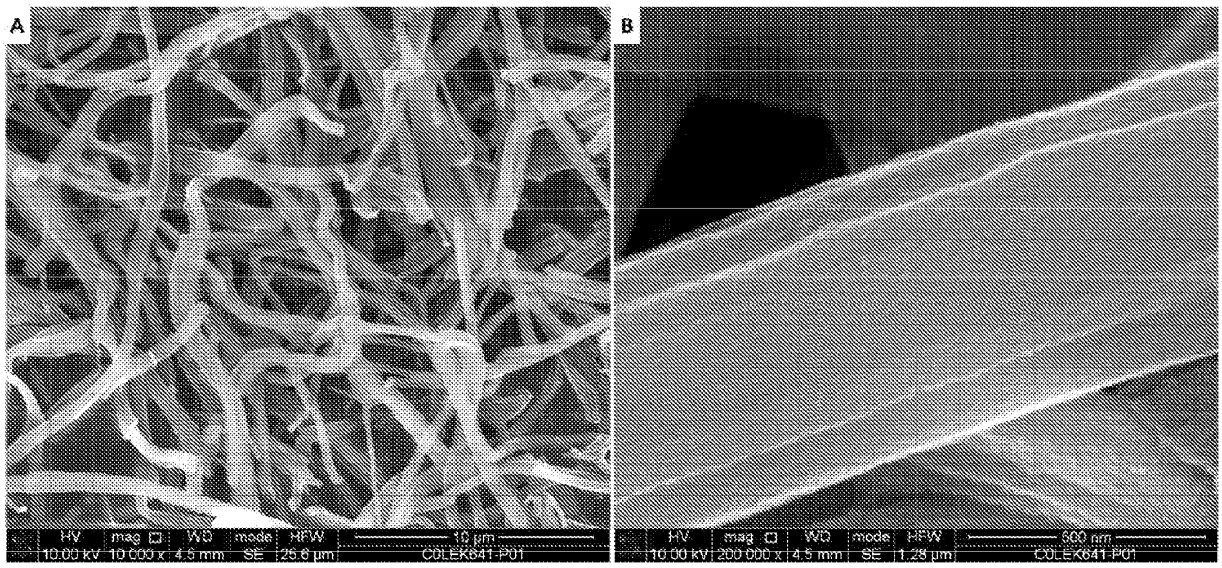
A
HV mag WD mode HFW
10.00 kV 10 000 x 4.9 mm SE 26.8 µm
10 µm
C0LEK641-P01
B
HV mag WD mode HFW
10.00 kV 200 000 x 4.5 mm SE 1.28 µm
500 nm
C0LEK641-P01

FIG. 70

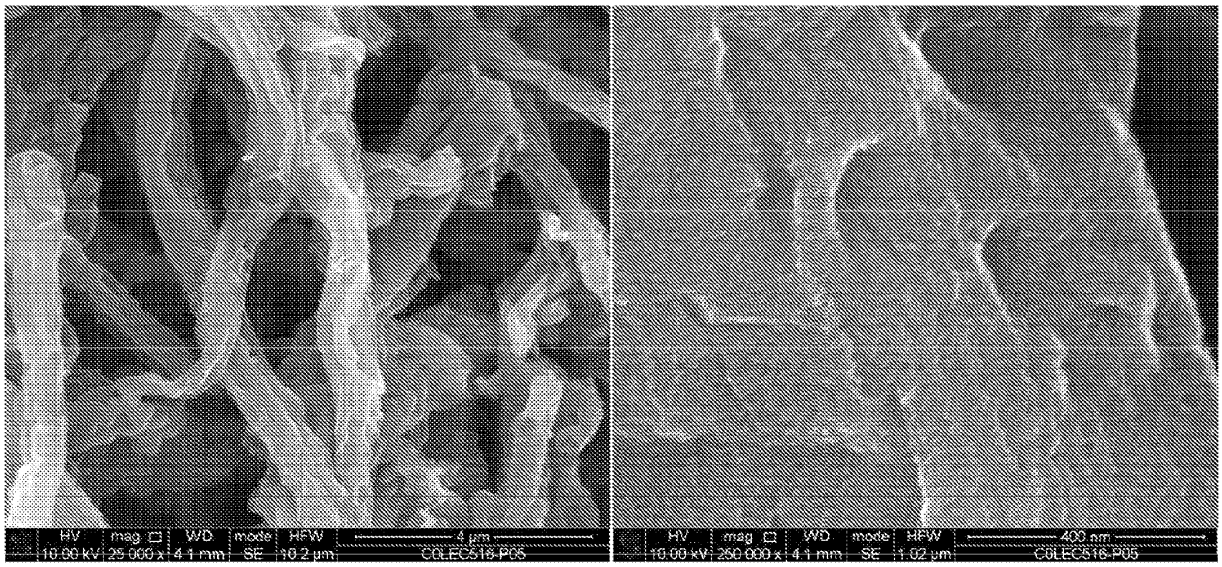
HV mag WD mode HFW 4 µm
10.00 kV 25 000 x 4.1 mm SE 10.2 µm C0LEC516-P05
HV mag WD mode HFW 400 nm
10.00 kV 250 000 x 4.1 mm SE 1.02 µm C0LEC516-P05

FIG. 71

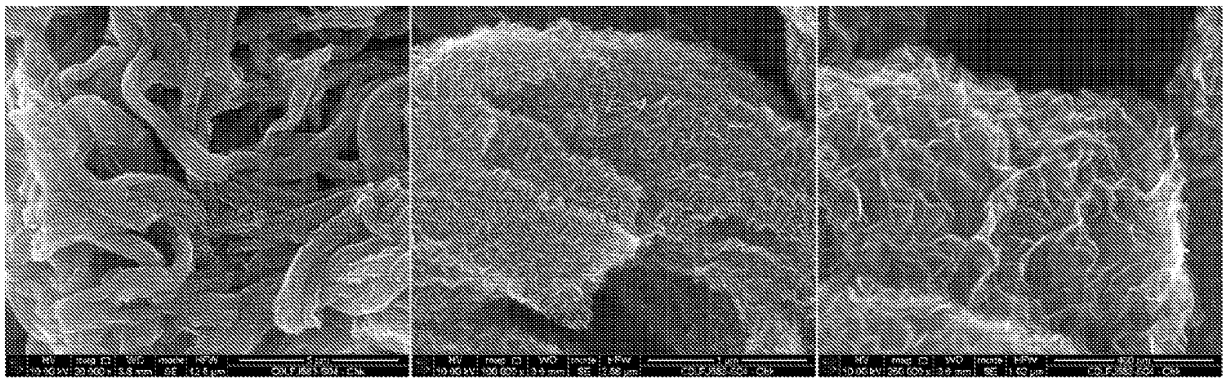

FIG. 72

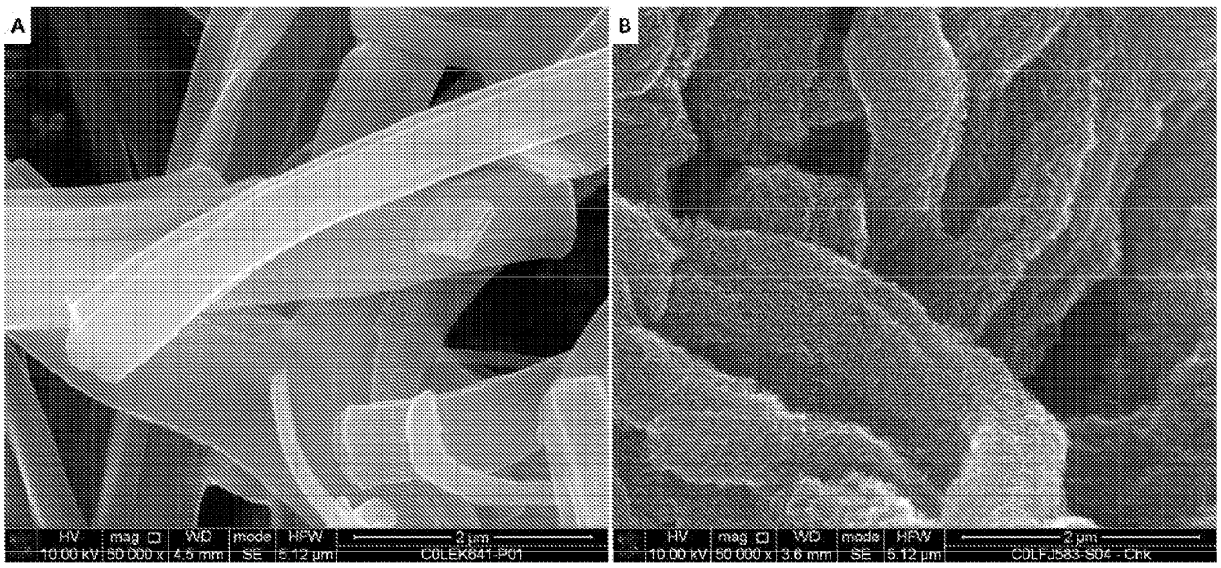
A
HV mag WD mode HFW 2 µm
10.00 kV 50 000 x 4.5 mm SE 5.12 µm C0LEK641-P01
B
HV mag WD mode HFW 2 µm
10.00 kV 50 000 x 3.6 mm SE 5.12 µm C0LFJ583-S04 - Chk

FIG.
73

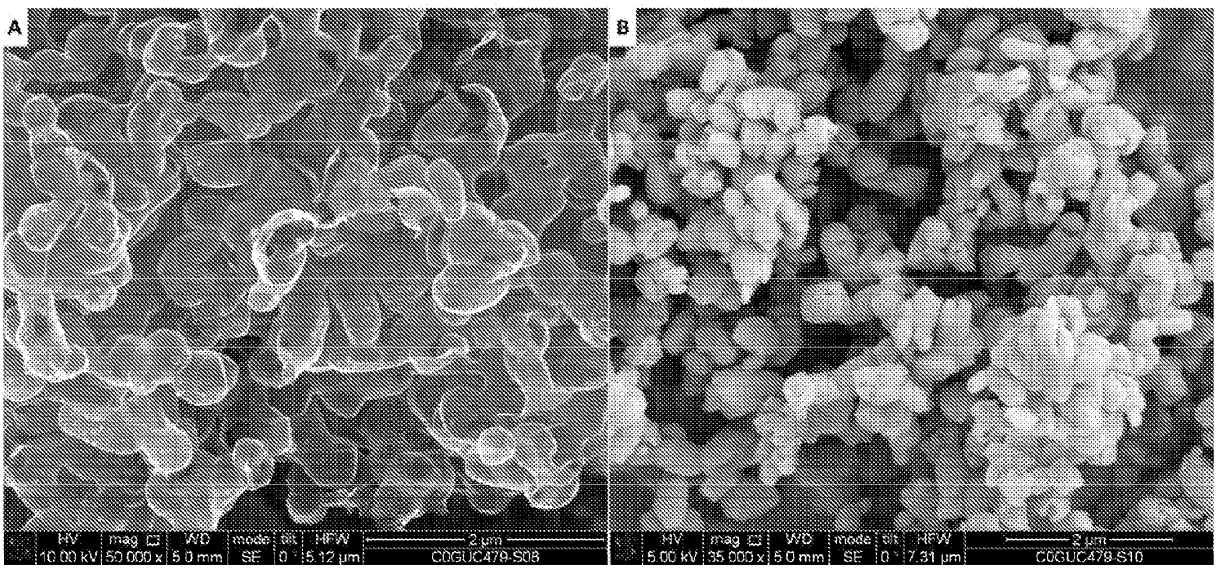
A
HV mag WD mode det HFW
10.00 kV 50 000 x 5.0 mm SE 0 5.12 µm
2 µm
C0GUC479-S08
B
HV mag WD mode det HFW
5.00 kV 35 000 x 5.0 mm SE 0 7.31 µm
2 µm
C0GUC479-S10

Table 1: Exemplary Materials Table

Template Precursor Material	Template Material	Peritemplate Composite Material	Peritemplate Material
H_1	H_1T_1	-	-
H_1	H_1T_2	-	-
H_1	H_1T_3	-	-
H_1	H_1T_3	-	-
H_1	H_1T_4	-	-
H_4	H_4T_1	$H_4T_1P_4$	P_4
H_4	H_4T_1	$H_4T_1P_7$	P_7
H_4	H_4T_1	$H_4T_1P_8$	P_8
H_4	H_4T_1	$H_4T_1P_8$	P_8
H_4	H_4T_1	$H_4T_1P_{16}$	P_{16}
L_1	-	-	-
L_1	L_1T_1	-	-
L_3	L_3T_1	$L_3T_1P_{11}$	P_{11}
L_3	L_3T_2	$L_3T_2P_{12}$	P_{12}
M_1	M_1T_1	-	-
M_1	M_1T_2	-	-
M_1	M_1T_3	-	-
M_1	M_1T_4	-	-
M_1	-	-	-
M_1	M_1T_1	$M_1T_1P_1$	P_1
M_1	M_1T_1	$M_1T_1P_2$	P_2
M_1	M_1T_1	$M_1T_1P_3$	P_3
M_1	M_1T_2	$M_1T_2P_3$	P_3
M_1	M_1T_2	$M_1T_2P_{31}$	P_{31}
M_4	M_4T_1	$M_4T_1P_{19}$	P_{19}
M_4	M_4T_2	-	-
M_5	M_5T_1	$M_5T_1P_{36}$	P_{36}
M_5	M_5T_2	-	-
A_1	A_1T_1	$A_1T_1P_{13}$	P_{13}
A_1	A_1T_1	$A_1T_1P_{14}$	P_{14}
A_2	-	-	-
A_2	A_2T_1	-	-
C_1	C_1T_1	$C_1T_1P_{15}$	P_{15}
E_1	E_1T_1	$E_1T_1P_{16}$	P_{16}
N_1	N_1T_1	-	-
N_1	N_1T_3	-	-
N_1	N_1T_4	$N_1T_4P_6$	P_6
N_1	N_1T_1	$N_1T_1P_{21}$	P_{21}
N_1	N_1T_3	-	-
N_1	N_1T_3	-	-
N_1	N_1T_4	-	-
N_1	N_1T_1	-	-
N_1	N_1T_4	$N_1T_4P_{21}$	P_{21}
N_1	-	-	-
Li_1	Li_1T_1	$Li_1T_1P_{18}$	P_{18}
Ca_1	Ca_1T_1	$Ca_1T_1P_{17}$	P_{17}

Table2

Table 2: Raman peak position and theoretical mass loss for magnesium carbonates				
	Lansfordite	**Nesquehonite**	**Hydromagnesite**	**Magnesite**
Raman Peak Position[†] (cm^{-1})	1083	1116	1094	1100
Theoretical mass loss (%)	76.9	70.9	56.9	52.2

[†] Raman characterization conducted as described in Section III

Table 3

Table 3: N_2 adsorption analysis of Na-doped template materials

Template Material	Template Precursor Material	Na Molality of Solution Stock† (mol/kg)	Furnace Scheme††	Treatment Temp. (°C)	BET Surface Area‡ (m^2/g)	BJH Pore Volume‡ (cm^3/g)	Template Space (%)	Porosity (%)
M_3T_1	M_3	-	D	1050	24.1	0.169	62.2%	37.8%
M_4T_1	M_4	$2.2 \cdot 10^{-3}$	D	1050	16.7	0.137	67.1%	32.9%
M_5T_1	M_5	$1.9 \cdot 10^{-1}$	D	1050	10.4	0.083	77.1%	22.9%
M_3T_2	M_3	-	D	900	56.6	0.309	47.5%	52.5%
M_4T_2	M_4	$2.2 \cdot 10^{-3}$	D	900	52.2	0.299	48.3%	51.7%
M_5T_2	M_5	$1.9 \cdot 10^{-1}$	D	900	12.3	0.078	78.2%	21.8%

Notes:

† The Na concentration of the brine from which precursor particles were crystallized

‡ Refer to Section III for description of gas adsorption analysis techniques

†† Refer to Section III for description of equipment schemes

Table 4

Table 4: N_2 adsorption analysis of templates coarsened with and without H_2O								
Template Material	**Template Precursor Material**	**Furnace Scheme**[††]	**Treatment Temp. (°C)**	**Treatment Atmosphere**	**BET Surface Area**[‡] **(m^2/g)**	**BJH Pore Volume**[‡] **(cm^3/g)**	**Template Space (%)**	**Porosity (%)**
N_2T_1	**N_2**	A	1000	Ar + H_2O(g)	13.3	0.084	76.9%	23.1%
N_2T_2	**N_2**	A	1000	Ar	32.7	0.111	71.5%	28.5%

Notes:

[‡] Refer to Section III for description of gas adsorption analysis techniques

[††] Refer to Section III for description of equipment schemes

Table 5

Table 5: Template Stage examples of precursors that may result in peapod formation

Template Material	Template Precursor Material	Furnace Scheme	Segment 1			Segment 2			Carrier Gas Type	Flow (sccm)
			Heating rate (°C/min)	Set temp. (°C)	Isotherm duration (min)	Heating rate (°C/min)	Set temp. (°C)	Isotherm duration (min)		
N_2T_3	N_2	B	5	640	120	-	-	-	Ar	1271
N_2T_4	N_2	B	20	640	120	-	-	-	Ar	1271
N_2T_5	N_2	B	20	350	0[††]	5	640	120	Ar	1271
N_2T_6	N_2	B	5	640	120	-	-	-	CO_2	815

Notes:

[†] Refer to Section III for description of equipment schemes

[††] This segment did not include an isotherm.

Table 6

Table 6: Template Stage precursor

Template Material	Template Precursor Material	Furnace Sequence	Segment 1			Segment 2			Segment 3			Carrier Gas Type	Flow rate
			Heating rate (°C/min)	Set temp. (°C)	Isothermal duration (min)	Heating rate (°C/min)	Set temp. (°C)	Isothermal duration (min)	Heating rate (°C/min)	Set temp. (°C)	Isothermal duration (min)		
N_1F_1	N_1	Li	10	1000	0	-	-	-	-	-	-	Ar	180
N_1F_2	N_1	Li	10	1200	10	-	-	-	-	-	-	Ar	180
N_1F_3	N_1	B	Max[1]	464	0	-	-	-	-	-	-	Ar	1271
N_2F_1	N_2	A	5	458	60	5	510	60	5	1000	60	Ar→H_2O	2360
N_2F_2	N_2	A	5	458	60	5	510	60	5	1000	60	Ar	2360
N_2F_3	N_2	B	5	640	120	-	-	-	-	-	-	Ar	1271
N_2F_4	N_2	B	20	640	120	-	-	-	-	-	-	Ar	1271
N_2F_5	N_2	B	20	350	0	5	640	120	-	-	-	Ar	1271
N_2F_6	N_2	B	5	640	120	-	-	-	-	-	-	UO_2	815
H_1F_1	H_1	Li	10	1000	0	-	-	-	-	-	-	Ar	180
H_1F_2	H_1	Li	10	1200	10	-	-	-	-	-	-	Ar	180
H_2F_1	H_2	B	20	1050	120	-	-	-	-	-	-	Ar	2000
H_2F_2	H_2	B	20	1050	20	-	-	-	-	-	-	Ar	2000
H_2F_3	H_2	B	20	1050	20	-	-	-	-	-	-	Ar	2000
H_3F_1	H_3	D	5	750	60	-	-	-	-	-	-	Ar[2]	N/A[3]
M_1F_1	M_1	Li	50	1050	1	-	-	-	-	-	-	Ar	180
M_1F_2	M_1	B	20	1050	240	-	-	-	-	-	-	Ar	2360
M_1F_3	M_1	Li	50	1200	1	-	-	-	-	-	-	Ar	180
M_1F_4	M_1	B	20	1200	240	-	-	-	-	-	-	Ar	2000
M_2F_1	M_2	D	5	580	60	5	1050	180	-	-	-	Ar[2]	N/A[3]
M_2F_2	M_2	D	5	580	60	5	910	60	-	-	-	Ar[2]	N/A[3]
M_2F_3	M_2	D	5	580	810	5	1050	60	-	-	-	Ar[2]	N/A[3]
M_3F_1	M_3	D	5	580	60	5	1050	60	-	-	-	Ar[2]	N/A[3]
M_3F_2	M_3	D	5	580	60	5	910	60	-	-	-	Ar[2]	N/A[3]
M_4F_1	M_4	D	5	580	60	5	1050	180	-	-	-	Ar[2]	N/A[3]
M_4F_2	M_4	D	5	580	60	5	910	60	-	-	-	Ar[2]	N/A[3]
L_1F_1	L_1	B	20	640	120	-	-	-	-	-	-	Ar	1220
L_1F_2	L_1	B	20	640	120	-	-	-	-	-	-	Ar	1220
L_2F_1	L_2	B	Max[1]	540	30	-	-	-	-	-	-	UO_2	815
A_1F_1	A_1	B	20	108	60	20	510	60	20	640	180	Ar	1271
A_2F_1	A_2	B	20	204	1	5	810	1	20	980	15	N_2	2480
C_1F_1	C_1	D	5	650	180	-	-	-	-	-	-	Ar[2]	N/A[3]
E_1F_1	E_1	B	Max[1]	580	N/A[4]	-	-	-	-	-	-	Ar	1102
Ca_1F_1	Ca_1	C	Max[1]	1050	N/A[4]	-	-	-	-	-	-	Ar	1102
La_1F_1	La_1	C	Max[1]	580	N/A[4]	-	-	-	-	-	-	Ar	1271

[1] "Max" denotes that the furnace was heated at the maximum power setting.
[2] "Flush" denotes that the sample was introduced into a preheated furnace.
[3] The procedure was performed in a fixed air recirculation oven with no active gas flow.
[4] The sequence did not include an anneal.

Table 7

Table 7: Exemplary Replication Stage procedures

Perimorphic Material	Perimorphic Composite Material	Template Material	Furnace Scheme	Primary Replication Stage Procedure - Segment 1						Primary Replication Stage Procedure - Segment 2							Annealing Segment					Secondary Replication Stage Procedure (If Applicable)
				Heating rate (°C/min)	Set temp. (°C)	Isotherm duration (min)	Reactive Gas	Reactive Gas Flow (sccm)	Carrier Gas	Carrier Gas Flow (sccm)	Heating rate (°C/min)	Set temp. (°C)	Isotherm duration (min)	Reactive Gas	Reactive Gas Flow (sccm)	Carrier Gas	Carrier Gas Flow (sccm)	Heating rate (°C/min)	Set temp. (°C)	Isotherm duration (min)	CR[‡] Type	CR[‡] Flow (sccm)	
P_1	$M_3T_1P_1$	M_3T_1	A	Max[‡]	640	960	C_2H_6	127	CO_2	1220	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_2	$M_3T_1P_2$	M_3T_1	A	Max[‡]	580	2400	C_2H_6	127	CO_2	1220	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_3	$M_3T_1P_3$	M_3T_1	A	Max[‡]	540	1050	C_2H_6	127	CO_2	1220	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_4	$H_6T_1P_4$	H_6T_1	B	Max[‡]	580	60	C_2H_2	276	CO_2	1220	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_5	$M_3T_2P_5$	M_3T_2	B	Max[‡]	1050	150	CH_4	27	Ar	2000	Max[‡]	1050	90	CH_4	54	Ar	2000	-	-	-	-	-	N/A
P_6	$N_3T_3P_6$	N_3T_3	B	N/A[***]	460	180	C_2H_2	43	Ar	1271	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_7	$H_6T_1P_7$	H_6T_1	B	Max[‡]	700	30	C_2H_6	1274	Ar	2000	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_8	$H_6T_1P_8$	H_6T_1	B	Max[‡]	700	30	C_2H_6	1274	Ar	2000	flash[‡‡]	1050	5	-	-	Ar	4000	-	-	-	-	-	N/A
P_9	$H_6T_1P_9$	H_6T_1	B	Max[‡]	580	180	C_2H_6	1274	Ar	2000	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{10}	$H_6T_1P_{10}$	H_6T_1	B	Max[‡]	580	180	C_2H_6	1274	Ar	2000	Max[‡]	1050	60	-	-	Ar	4000	-	-	-	-	-	N/A
P_{11}	$L_3T_2P_{11}$	L_3T_2	B	20	540	30	C_2H_6	812	CO_2	815	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{12}	$L_3T_2P_{12}$	L_3T_2	B	20	540	30	C_2H_6	812	CO_2	815	20	1050	30	-	-	Ar	2000	-	-	-	-	-	N/A
P_{13}	$A_1T_1P_{13}$	A_1T_1	A	20	580	240	C_2H_6	127	CO_2	1220	20	580	240	C_2H_6	127	CO_2	127	-	-	-	-	-	N/A
P_{14}	$A_1T_1P_{14}$	A_1T_1	A	20	580	240	C_2H_6	127	CO_2	1220	20	580	240	C_2H_6	127	CO_2	127	max	1050	30	Ar	1271	N/A
P_{15}	$C_1T_1P_{15}$	C_1T_1	B	Max[‡]	580	180	C_2H_6	127	CO_2	1220	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{16}	$E_1T_1P_{16}$	E_1T_1	B	N/A[***]	580	120	C_2H_6	1147	Ar	1102	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{17}	$Ca_1T_1P_{17}$	Ca_1T_1	C	N/A[***]	1050	15	CH_4	1027	Ar	1102	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{18}	$Li_1T_1P_{18}$	Li_1T_1	C	N/A[***]	580	870	C_2H_6	208	Ar	1271	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{19}	$M_4T_1P_{19}$	M_4T_1	B	Max[‡]	640	180	C_2H_6	255	CO_2	1220	Max[‡]	1050	30	-	-	Ar	2000	-	-	-	-	-	N/A
P_{20}	$M_4T_1P_{20}$	M_4T_1	B	Max[‡]	640	180	C_2H_6	255	CO_2	1220	Max[‡]	1050	30	-	-	Ar	2000	-	-	-	-	-	N/A
P_{21}	$N_2T_4P_{21}$	N_2T_4	A	20	540	8	C_2H_2	815	CO_2	812	20	540	8	C_2H_2	815	CO_2	812	max	1050	30	Ar	1271	N/A
P_{22}	$N_2T_4P_{22}$	N_2T_4	B	20	540	4.5	C_2H_2	815	CO_2	812	-	-	-	-	-	-	-	-	-	-	-	-	N/A
P_{23}	$M_3T_3P_{23}$	M_3T_3	A	20	580	1800	C_2H_6	127	CO_2	1220	Max[‡]	1050	30	-	-	Ar	2000	-	-	-	-	-	N/A

Notes:

[***] The Replication Stage procedure occurred directly upon completion of the Template Stage procedure and at the same temperature. Therefore, the furnace was already at temperature and did not require heating.

[‡] "Max" denotes that the furnace was heated at the maximum power setting.

[‡‡] "Flash" denotes that the sample was introduced into a preheated furnace.

Table 8

Table 8: Raman metrics for exemplary perimorphic carbons

Perimorphic Material	Replication Stage			Yield (%)	Raman laser power (mW)	I_D/I_G **	$I_{D'}/I_G$ ***	G Peak Position* (cm^{-1})	D Peak Position* (cm^{-1})	Interpeak Interval ** (cm^{-1})
	CVD Temp. (°C)	Total Growth Time (min)	HC† Type							
P_1	640	960	C_2H_6	18.3%	5.0	0.92	0.46	1592.0	1337.4	254.6
P_2	580	2400	C_2H_6	17.1%	5.0	0.86	0.43	1593.0	1330.7	262.3
P_3	540	1950	C_2H_6	15.8%	5.0	0.80	0.38	1596.6	1328.6	268.0
P_4	580	60	C_2H_2	19.0%	0.5	0.89	0.29	1603.3	1324.5	278.8
P_5	1050	240	CH_4	21.6%	5.0	1.29	0.17	1580.6	1337.4	243.2
P_6	460	180	C_2H_2	29.9%	0.5	0.80	0.32	1601.6	1332.7	268.9
P_7	700	30	C_2H_6	9.7%	5.0	0.88	0.55	1593.6	1334.3	259.3
P_8	700, 1050 ‡	30, 5 ‡	C_2H_6	9.7%	5.0	0.83	0.64	1590.7	1350.9	239.8
P_9	580	180	C_2H_6	7.7%	5.0	0.97	0.52	1592.7	1328.5	264.2
P_{10}	580, 1050 ‡	180, 60 ‡	C_2H_6	8.4%	5.0	0.99	0.63	1592.7	1346.8	245.9
P_{11}	540	30	C_2H_2	28.4%	0.5	0.85	0.25	1609.1	1331.8	277.3
P_{12}	540, 1050 ‡	30, 30 ‡	C_2H_2	9.2%	0.5	0.99	0.49	1603.0	1352.8	250.2
P_{13}	580	480	C_2H_6	19.3%	5.0	0.80	0.42	1593.6	1327.5	266.1
P_{14}	580, 1050 ‡	480, 30 ‡	C_2H_6	-	5.0	0.99	0.58	1593.0	1349.8	243.2
P_{15}	580	180	C_2H_6	11.8%	0.5	0.78	0.40	1605.4	1343.3	262.1
P_{16}	580	120	C_2H_6	5.7%	2.0	0.88	0.57	1584.3	1336.0	248.3
P_{17}	1050	15	CH_4	7.5%	2.0	1.24	0.45	1592.5	1340.6	251.9
P_{18}	580	870	C_2H_6	1.9%	0.5	0.80	0.35	1602.1	1341.0	261.2
P_{19}	640, 1050 ‡	180	C_2H_6	8.0%	2.0	0.96	0.47	1591.3	1367.4	223.9
P_{20}	640, 1050 ‡	180	C_2H_6	3.8%	0.5	0.94	0.64	1591.8	1360.0	231.8
P_{21}	540, 1050 ‡	16	C_2H_2	1.9%	2.0	0.99	0.57	1598.3	1353.6	244.7
P_{22}	540	4.5	C_2H_2	9.8%	2.0	0.93	0.53	1597.8	1324.9	272.9
P_{23}	580, 1050 ‡	1800	C_2H_6	14.4%	5.0	1.01	0.54	1589.5	1347.0	242.5

Notes:

† Hydrocarbon gas

†† I_D/I_G is a Raman metric indicating a ratio of I_D to I_G peak height

††† $I_{D'}/I_G$ is a Raman metric indicating a ratio of $I_{D'}$ to I_G peak height

* Raman peak position of the D and G bands

** Defined as the spread between the G Peak position and the D Peak position

‡ The Replication Stage procedures utilized to make these exemplary perimorphic materials involved a growth segment and an annealing segment hence there are two temperatures and times associated with these perimorphic materials.