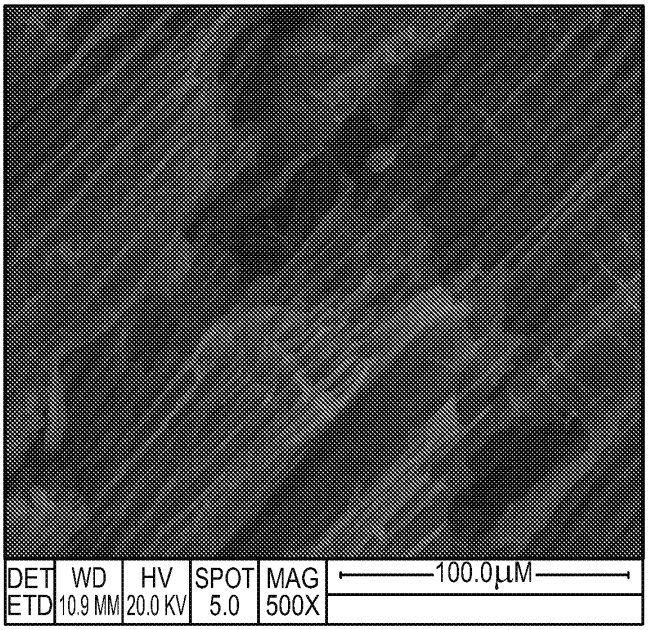

DET
ETD
WD
10.9 MM
HV
20.0 KV
SPOT
5.0
MAG
500X
100.0µM

FIG. 1A

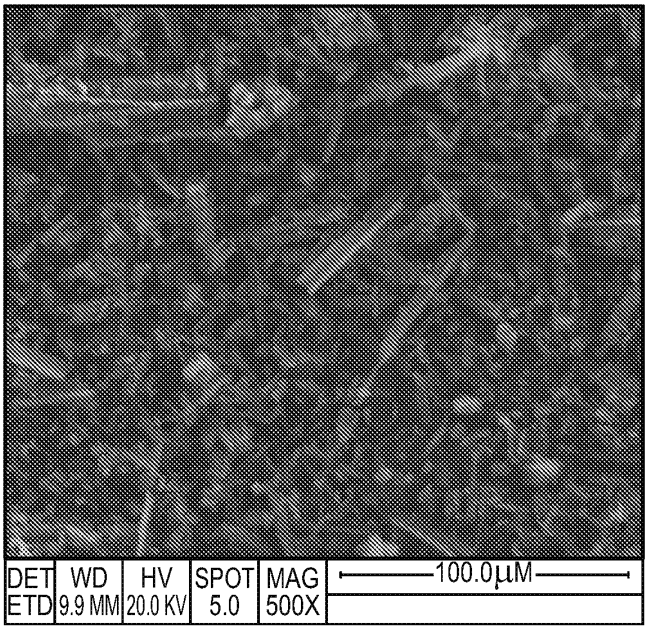

DET
ETD
WD
9.9 MM
HV
20.0 KV
SPOT
5.0
MAG
500X
100.0µM

FIG. 1B

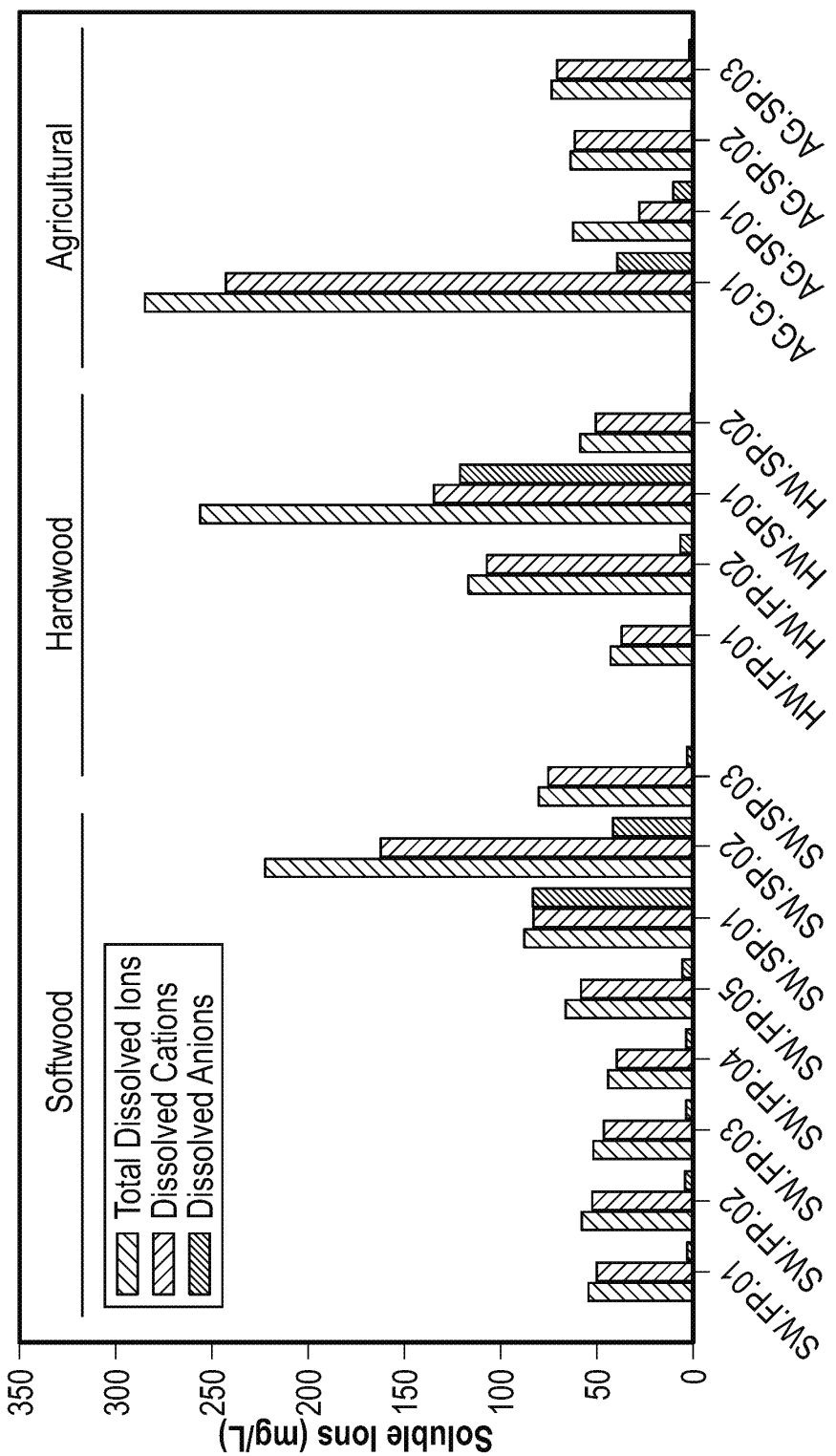

Soluble Ions (mg/L)
0
50
100
150
200
250
300
350
Total Dissolved Ions
Dissolved Cations
Dissolved Anions
Softwood
Hardwood
Agricultural
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 2

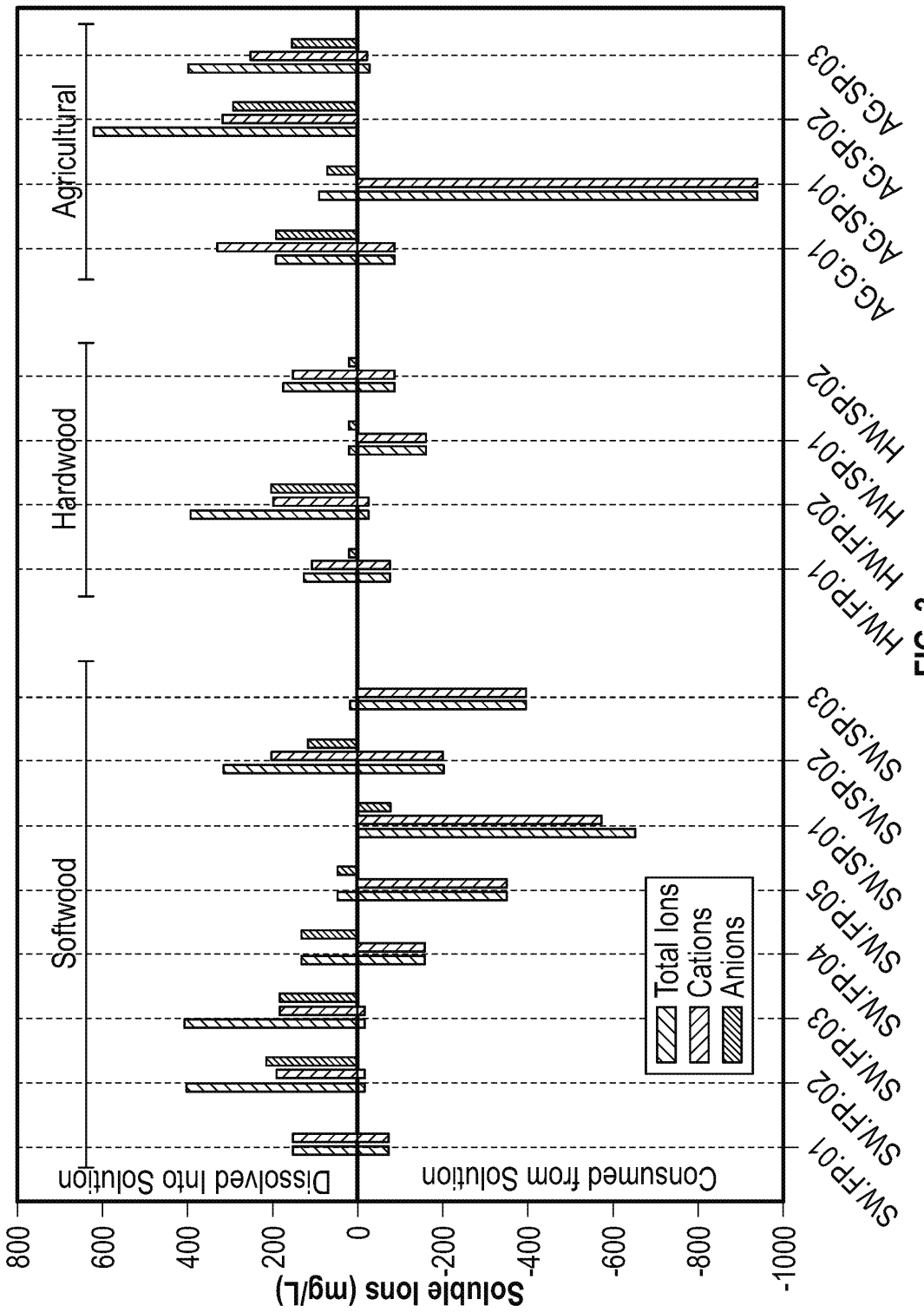

Soluble Ions (mg/L)
800
600
400
200
0
-200
-400
-600
-800
-1000
Dissolved Into Solution
Consumed from Solution
Total Ions
Cations
Anions
Softwood
Hardwood
Agricultural
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 3

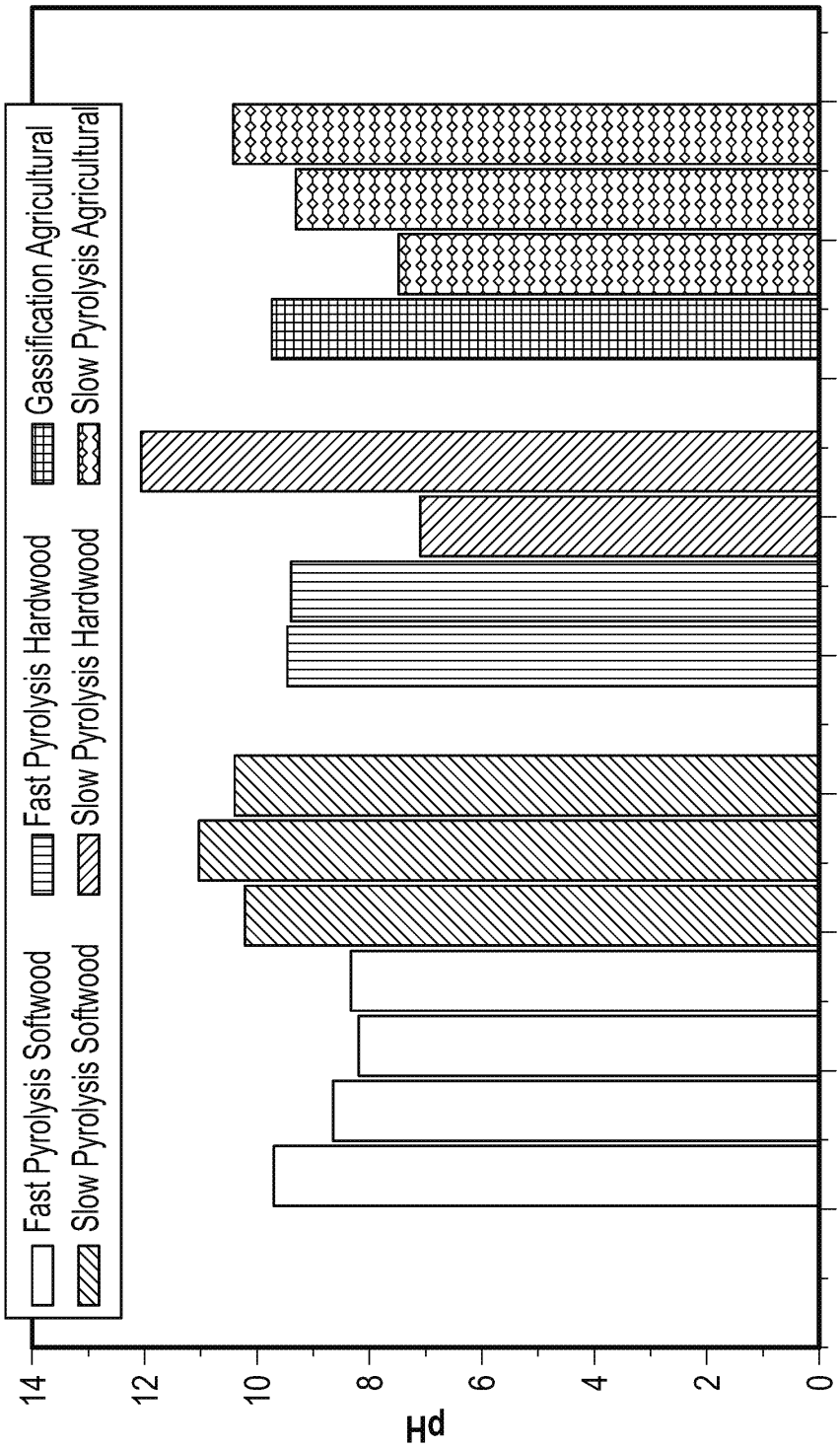

Fast Pyrolysis Softwood
Slow Pyrolysis Softwood
Fast Pyrolysis Hardwood
Slow Pyrolysis Hardwood
Gassification Agricultural
Slow Pyrolysis Agricultural
pH
0
2
4
6
8
10
12
14

FIG. 4

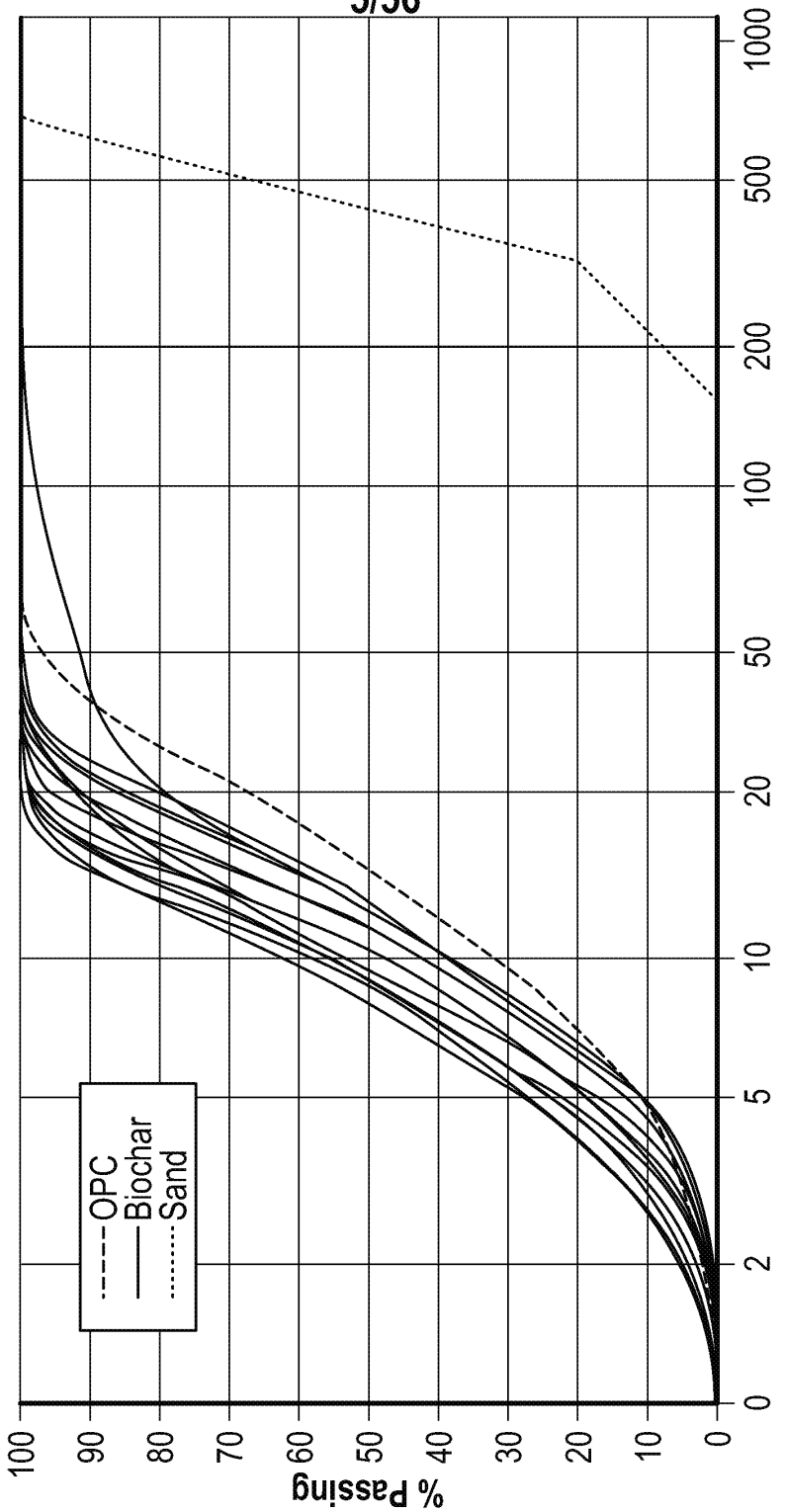

% Passing
100
90
80
70
60
50
40
30
20
10
0
Particle Size (μm)
0
2
5
10
20
50
100
200
500
1000
OPC
Biochar
Sand

FIG. 5

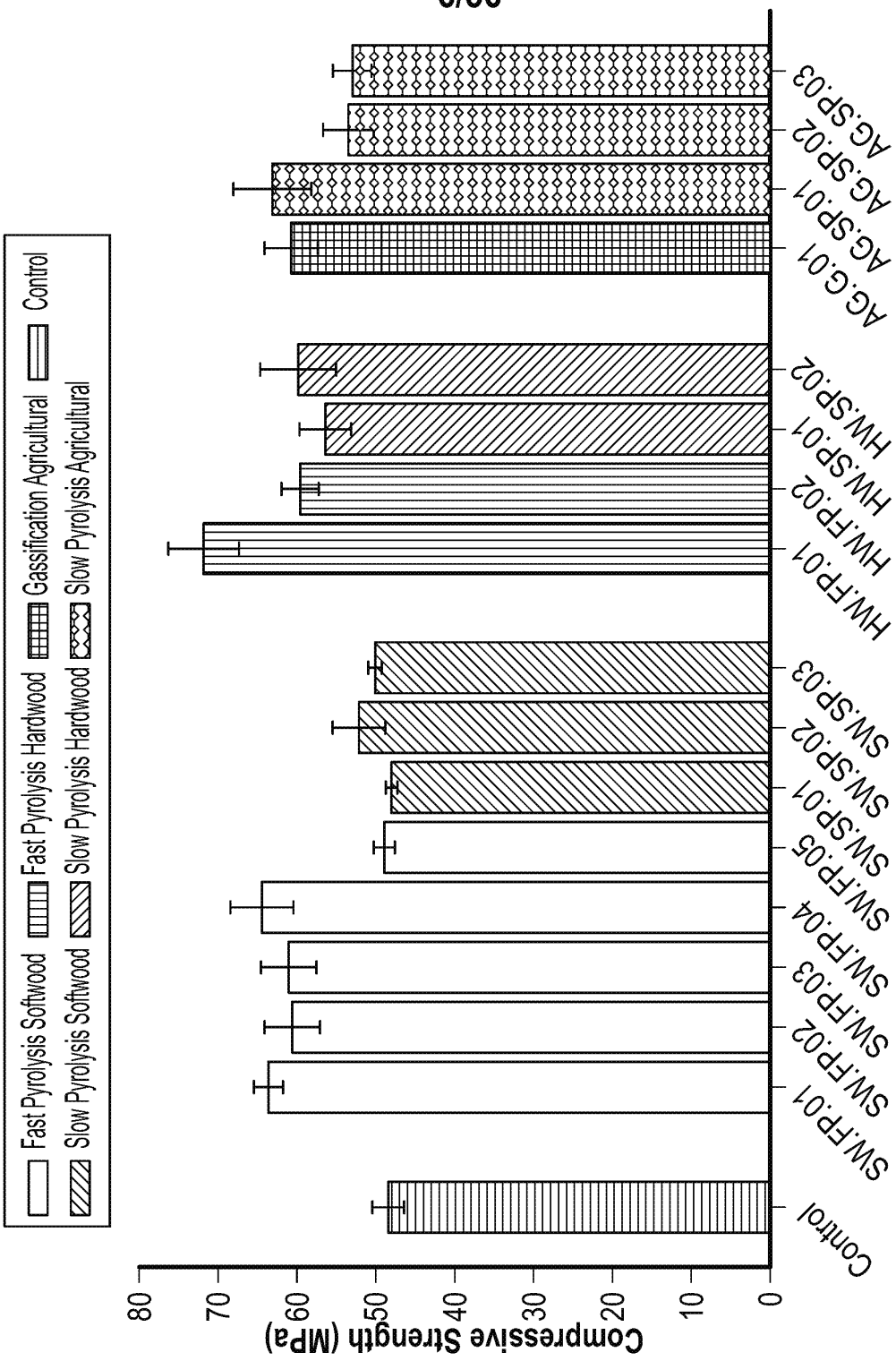

Fast Pyrolysis Softwood
Fast Pyrolysis Hardwood
Gassification Agricultural
Control
Slow Pyrolysis Softwood
Slow Pyrolysis Hardwood
Slow Pyrolysis Agricultural
Compressive Strength (MPa)
0
10
20
30
40
50
60
70
80
Control
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 6

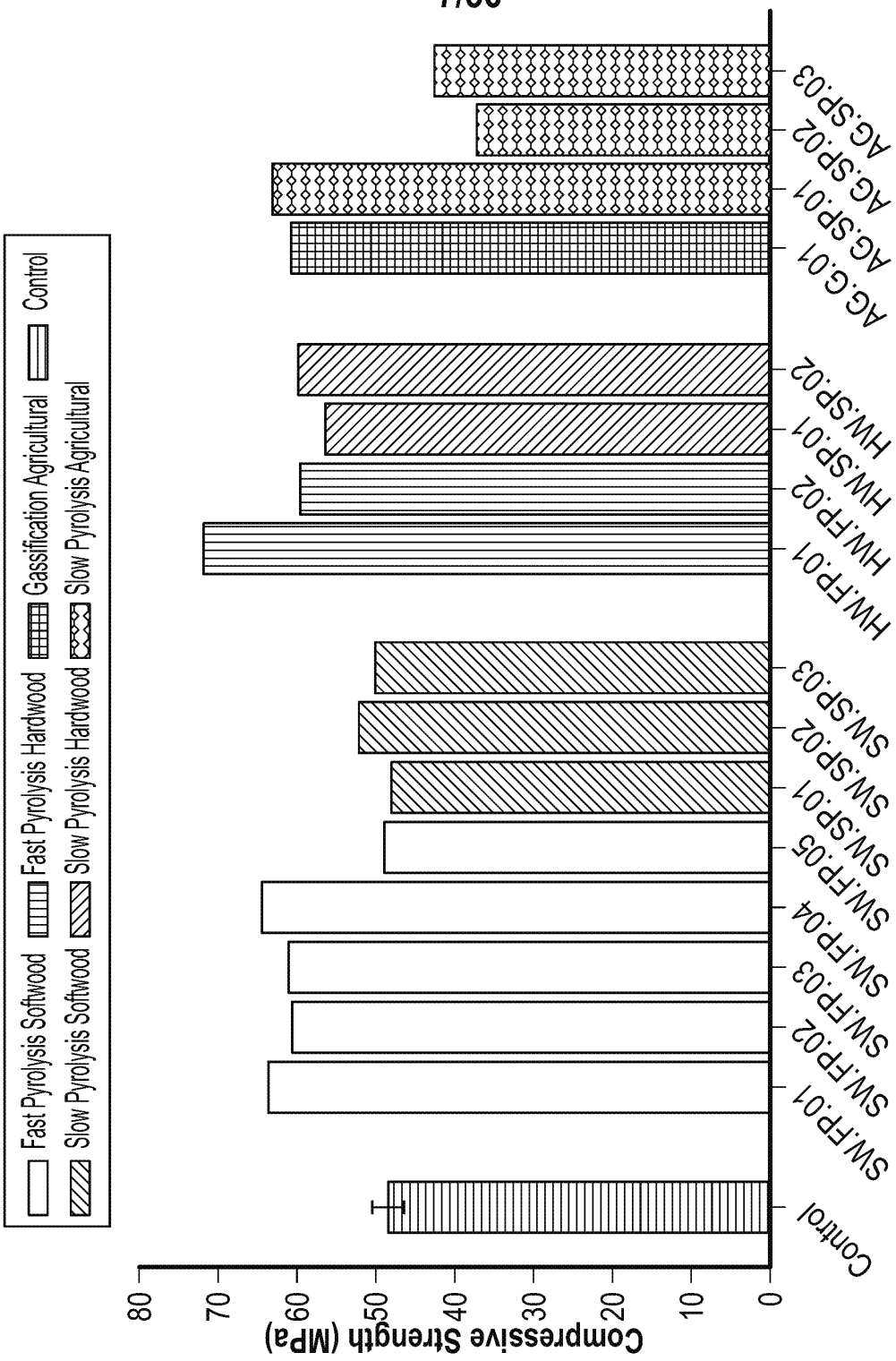

Fast Pyrolysis Softwood
Fast Pyrolysis Hardwood
Gassification Agricultural
Control
Slow Pyrolysis Softwood
Slow Pyrolysis Hardwood
Slow Pyrolysis Agricultural
Compressive Strength (MPa)
0
10
20
30
40
50
60
70
80
Control
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 7

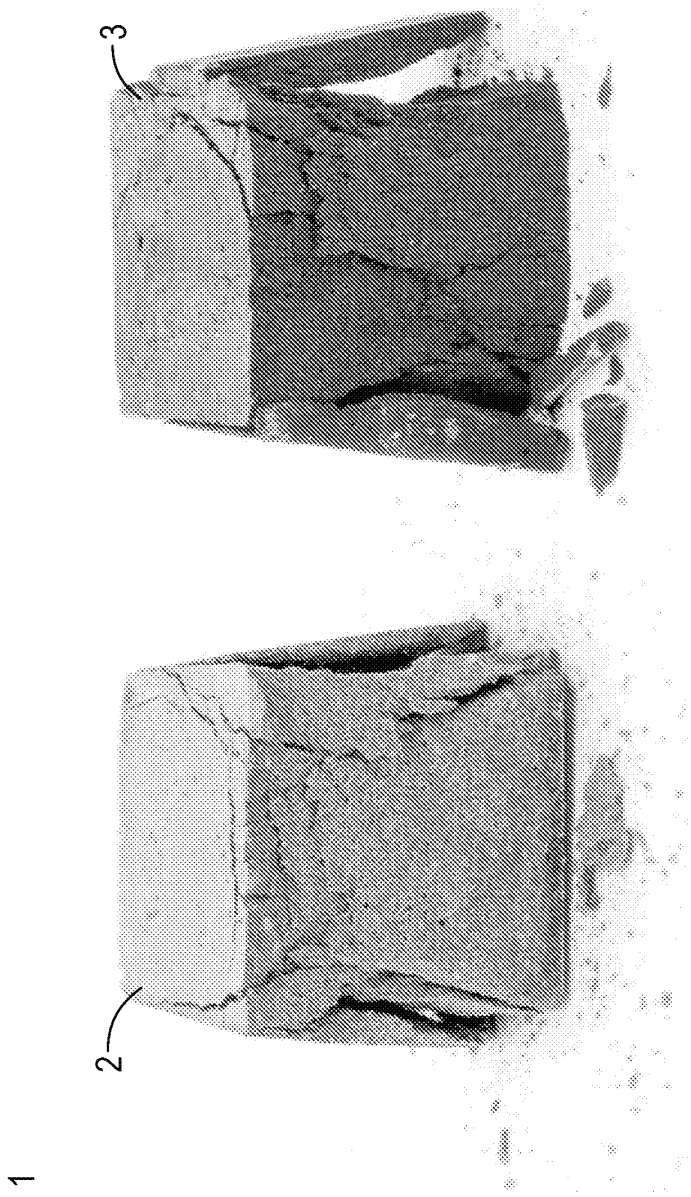


FIG. 8

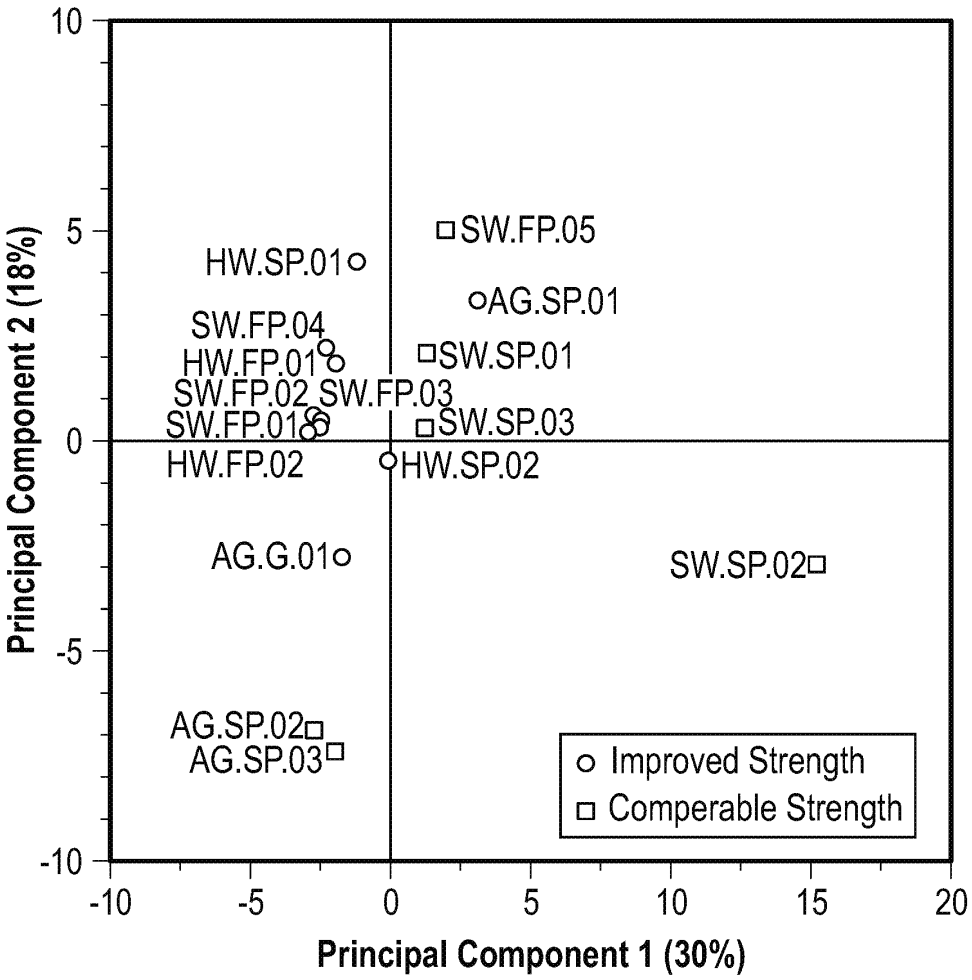

10
5
0
-5
-10
-10
-5
0
5
10
15
20
Principal Component 2 (18%)
Principal Component 1 (30%)
SW.FP.05
HW.SP.01
AG.SP.01
SW.FP.04
HW.FP.01
SW.SP.01
SW.FP.02
SW.FP.03
SW.FP.01
SW.SP.03
HW.FP.02
HW.SP.02
AG.G.01
SW.SP.02
AG.SP.02
AG.SP.03
Improved Strength
Comperable Strength

FIG. 9

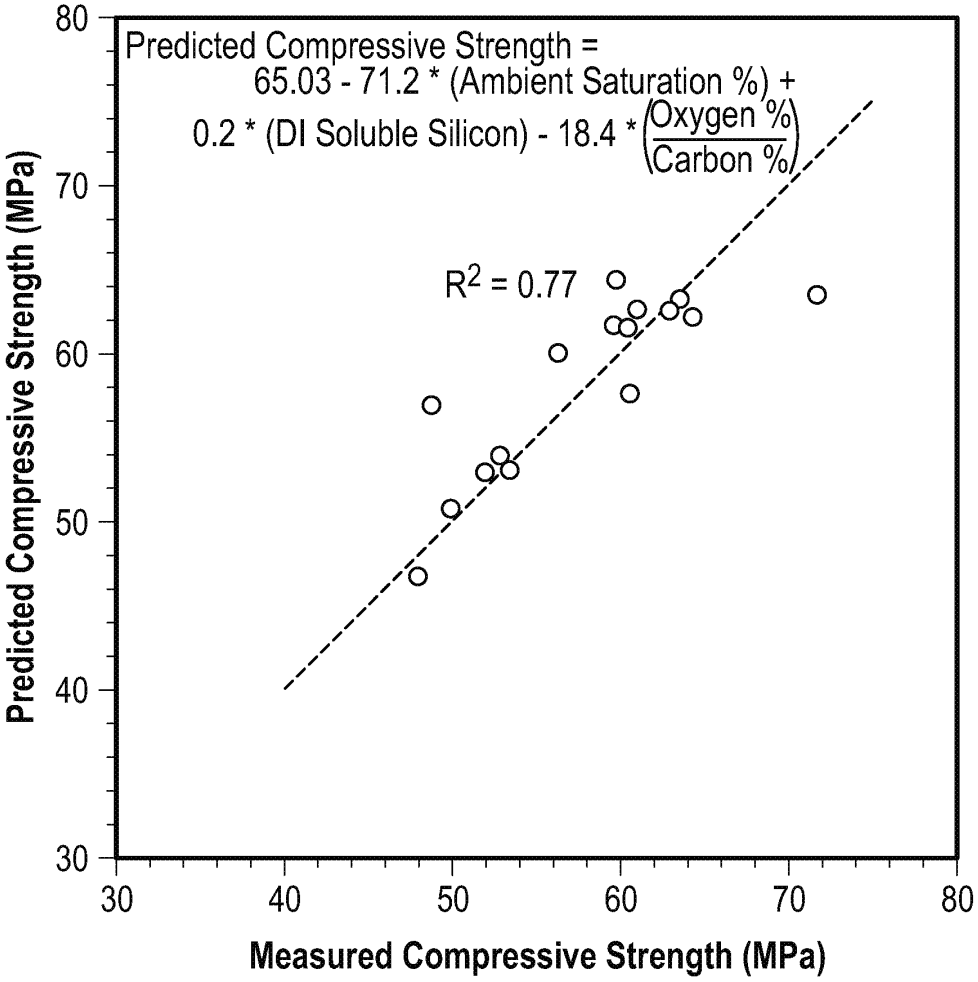

Predicted Compressive Strength =
65.03 - 71.2 * (Ambient Saturation %) +
0.2 * (DI Soluble Silicon) - 18.4 * (Oxygen % / Carbon %)
R2 = 0.77
Predicted Compressive Strength (MPa)
Measured Compressive Strength (MPa)
80
70
60
50
40
30
30
40
50
60
70
80

FIG. 10

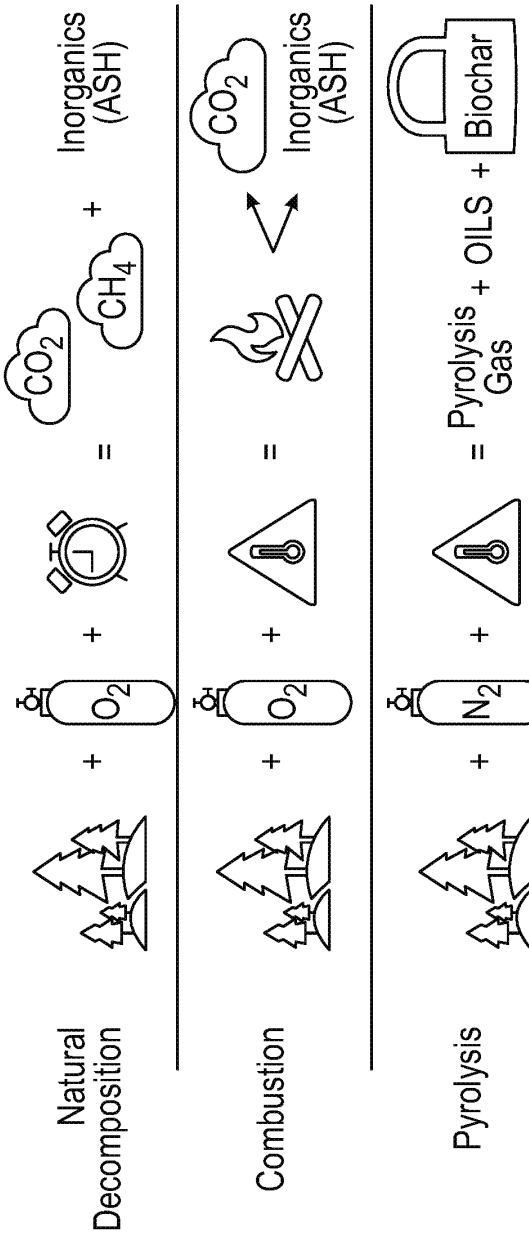

Natural Decomposition
Combustion
Pyrolysis
O_2
O_2
N_2
CO_2
CH_4
Inorganics (ASH)
CO_2
Inorganics (ASH)
Pyrolysis Gas
OILS
Biochar

FIG. 11

	Slow Pyrolysis	Fast Pyrolysis	Gasification
Temperature Range (°C)	350-800	400-800	700-1500
Heating Rate (°C/Min)	<10	~10,000	~100
Residence Time	Minutes-Hours	Seconds	Seconds-Minutes
Biochar Yield	~35%	~10%	~10%
Bio-Oil Yield	~30%	~70%	~5%
Pyrolysis Gas Yield	~35%	~20%	~85%
Typical Applications	Soil Remediation	Biofuel Production	Gas/Fuel Production

FIG. 12

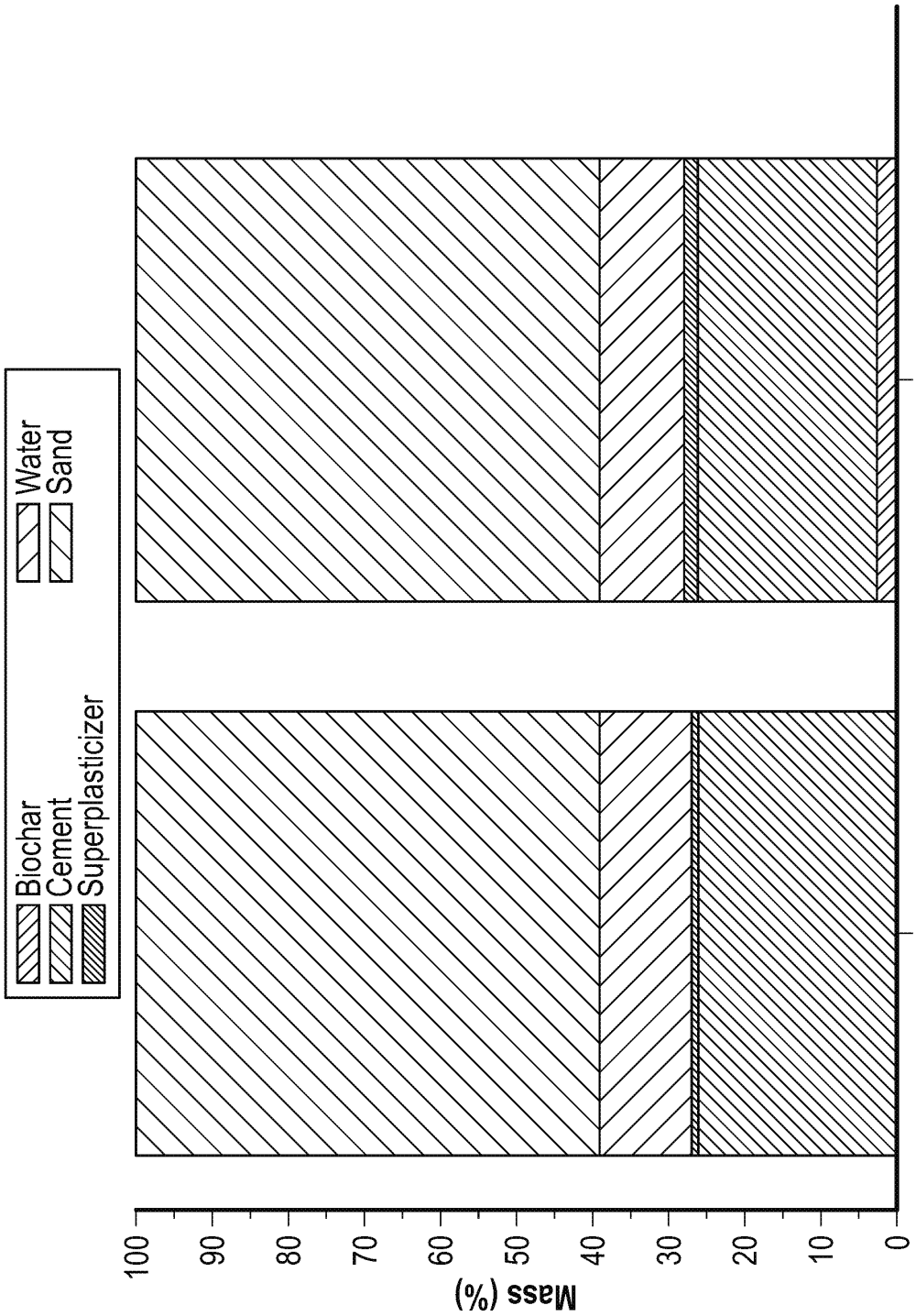

Biochar
Cement
Superplasticizer
Water
Sand
Mass (%)
100
90
80
70
60
50
40
30
20
10
0
Control
10% Biochar

FIG. 13

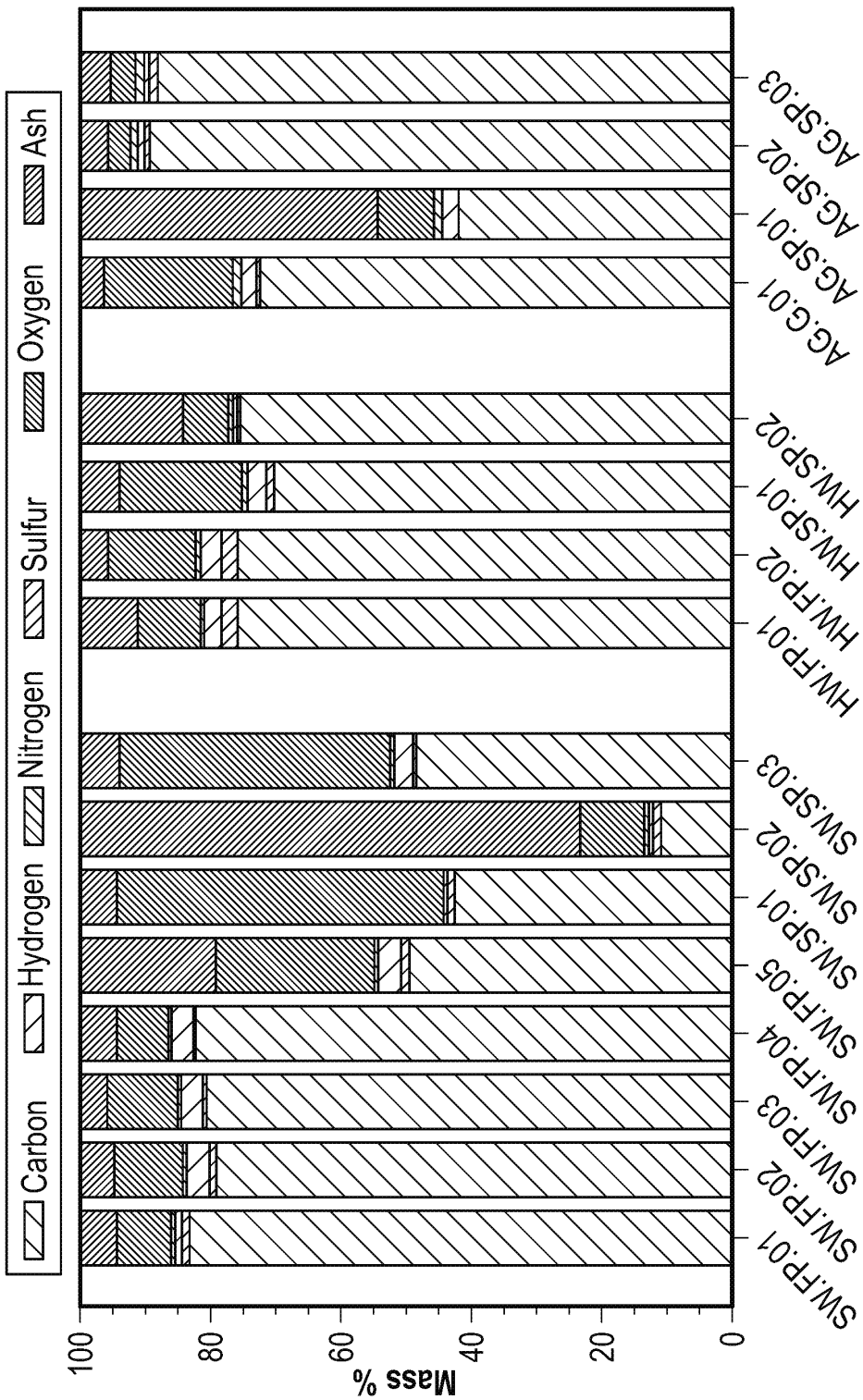

Carbon
Hydrogen
Nitrogen
Sulfur
Oxygen
Ash
Mass %
100
80
60
40
20
0
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 14

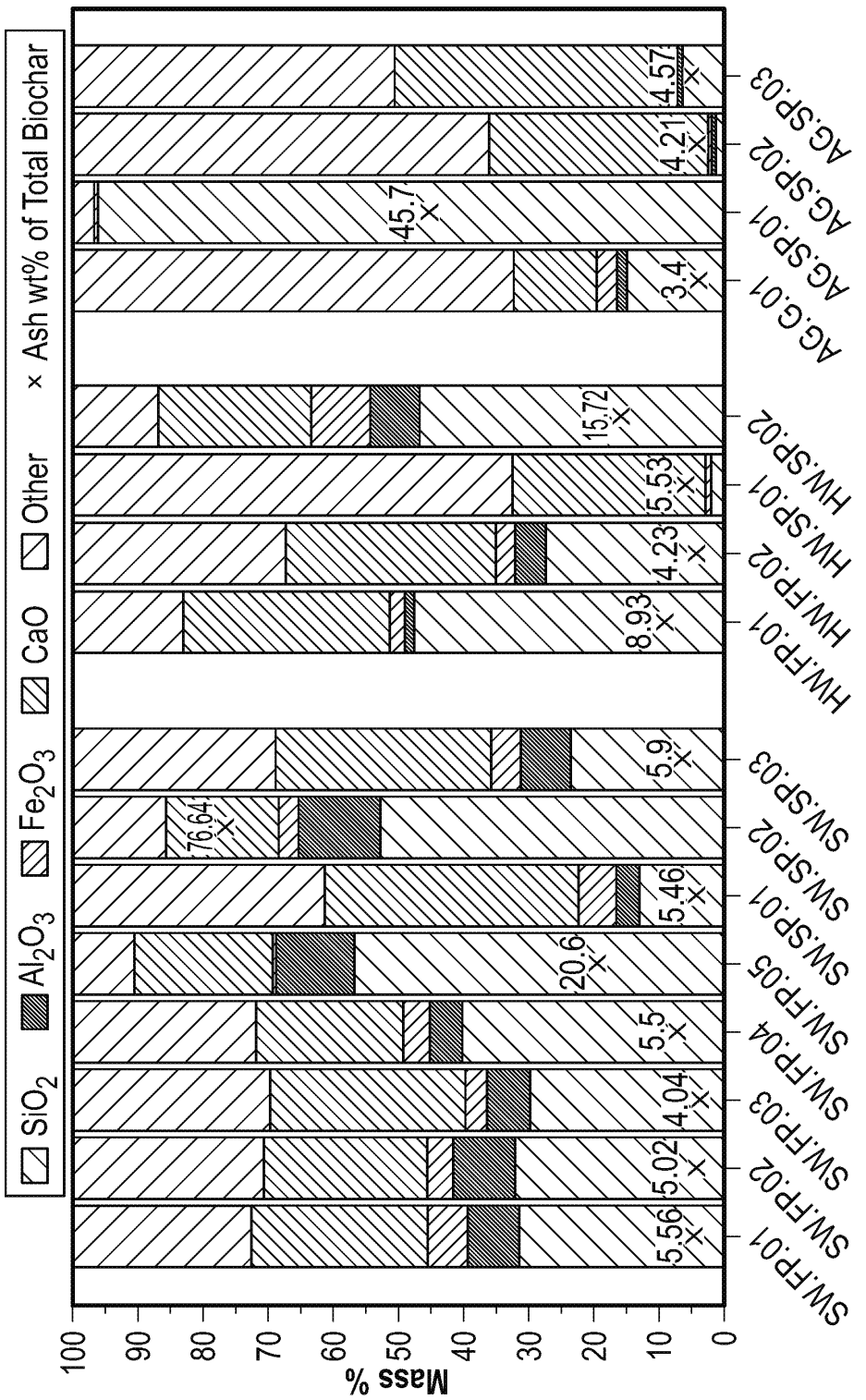

SiO2
Al2O3
Fe2O3
CaO
Other
× Ash wt% of Total Biochar
Mass %
100
90
80
70
60
50
40
30
20
10
0
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03
5.56
5.02
4.04
5.5
20.6
5.46
76.64
5.9
8.93
4.23
5.53
15.72
3.4
45.7
4.21
4.57

FIG. 15

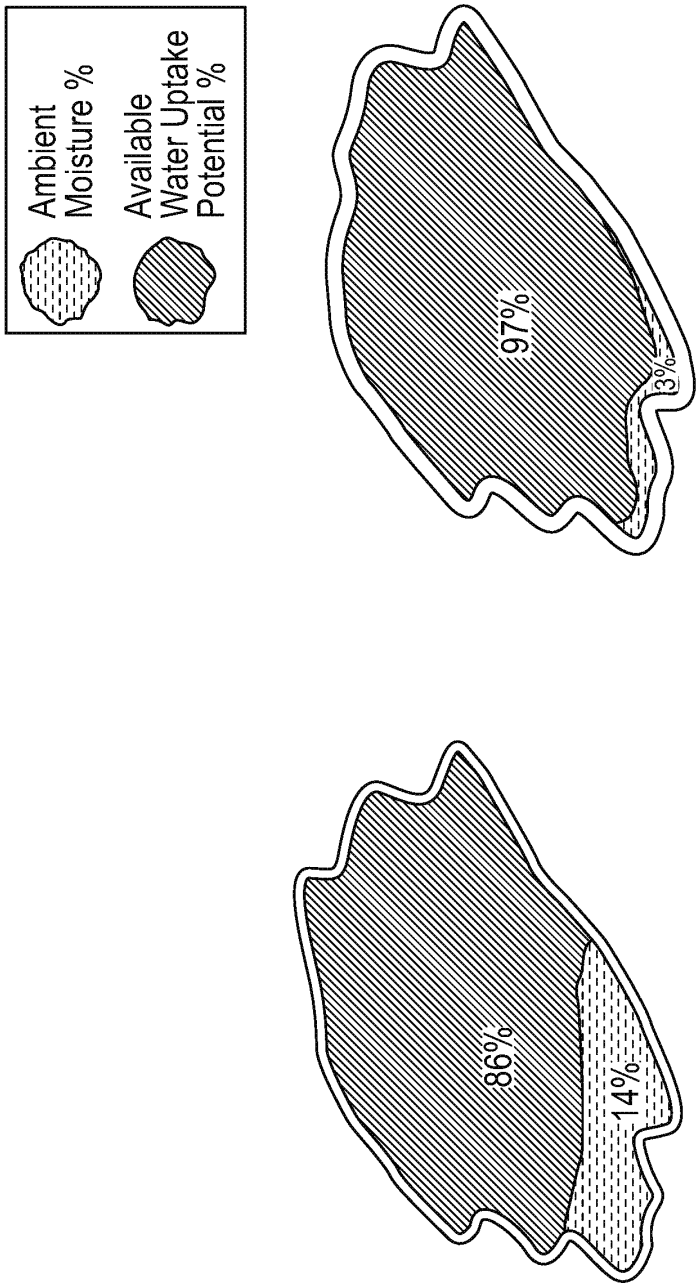

Ambient Moisture %
Available Water Uptake Potential %
97%
3%
86%
14%

FIG. 16

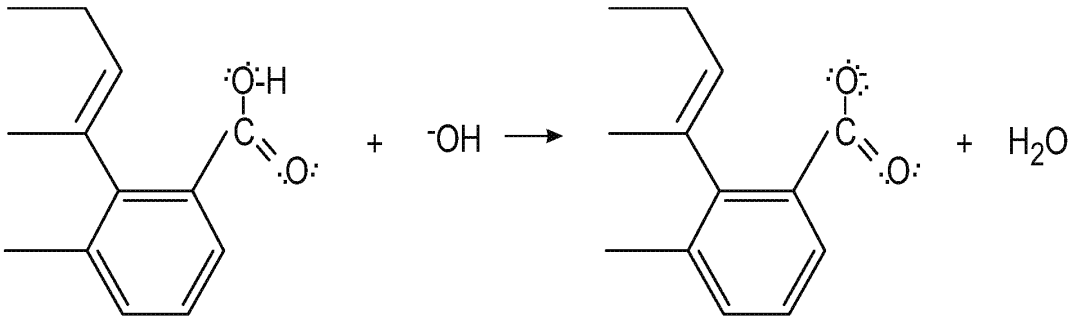


FIG. 17

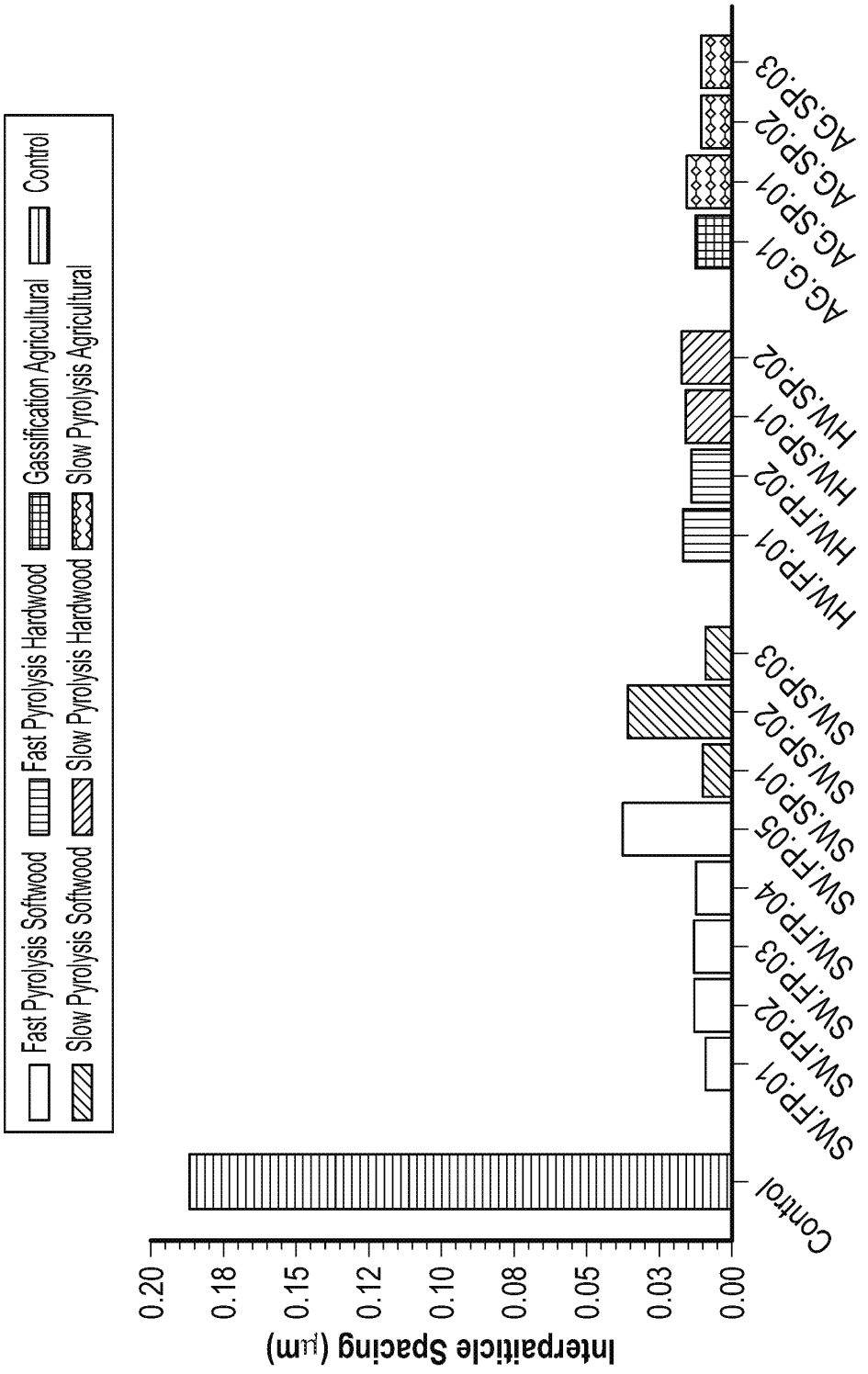

Fast Pyrolysis Softwood
Fast Pyrolysis Hardwood
Gassification Agricultural
Control
Slow Pyrolysis Softwood
Slow Pyrolysis Hardwood
Slow Pyrolysis Agricultural
Interparticle Spacing (μm)
0.20
0.18
0.15
0.12
0.10
0.08
0.05
0.03
0.00
Control
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 18

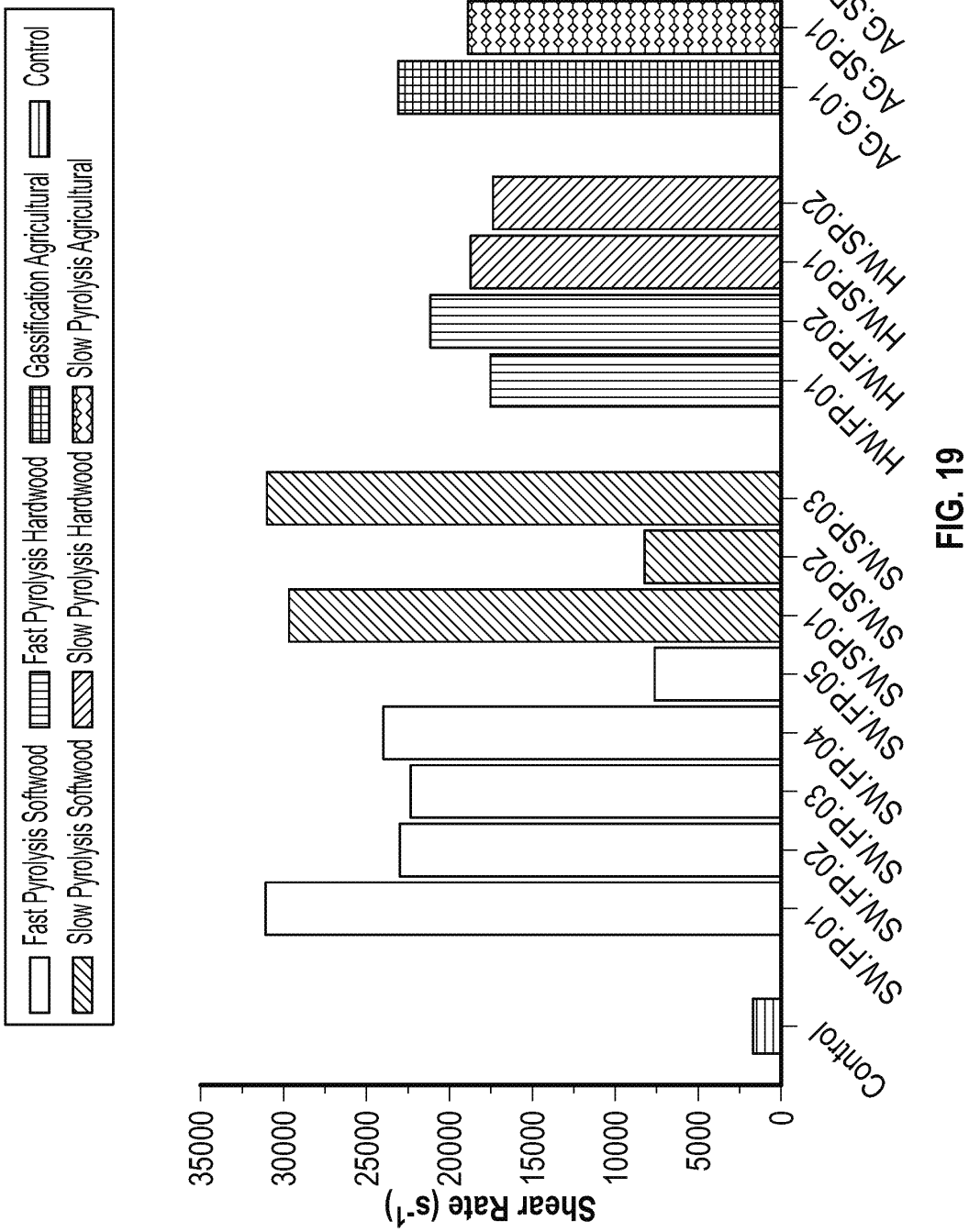

Fast Pyrolysis Softwood
Fast Pyrolysis Hardwood
Gassification Agricultural
Control
Slow Pyrolysis Softwood
Slow Pyrolysis Hardwood
Slow Pyrolysis Agricultural
Shear Rate (s-1)
0
5000
10000
15000
20000
25000
30000
35000
Control
SW.FP.01
SW.FP.02
SW.FP.03
SW.FP.04
SW.FP.05
SW.SP.01
SW.SP.02
SW.SP.03
HW.FP.01
HW.FP.02
HW.SP.01
HW.SP.02
AG.G.01
AG.SP.01
AG.SP.02
AG.SP.03

FIG. 19

Mix	Offset Method	Char Type	Proportions of Cement			MIX Recipe (in Grams)				
			OPC	Biochar	Fly Ash	Cement	Sand	Water	Char	Fly Ash
Control (no Char)	None	n/a	100%	0%	0%	954.58	2127.38	482.46	0.00	0.00
42% Filler BC18	Filler	BC18	100%	42%	0%	954.58	2127.38	474.76	400.93	0.00
42% Filler BC17	Filler	BC17	100%	42%	0%	954.58	2127.38	474.76	400.93	0.00
30% Replacement	Replacement	BC17	70%	30%	0%	698.16	2260.68	337.54	316.24	0.00
FA +BC17	Fly Ash + Replace	BC17	55%	25%	20%	482.23	2260.68	382.36	218.43	295.24
44% Replacement	Replacement	BC17	56%	44%	0%	570.46	2327.06	465.37	473.72	0.00
32% 0.6 W/C	Replacement	BC01	68%	32%	0%	508.19	1132.55	305.37	244.89	0.00
32% 0.55 W/C	Replacement	BC01	68%	32%	0%	508.19	1132.55	279.50	244.89	0.00
77% Replacement	Filler	BC17	100%	77%	0%	954.58	2127.38	482.46	735.03	0.00
FA + BC17 2.0	Fly Ash + Replace	BC17	39%	31%	30%	268.79	2265.33	332.49	213.66	206.76

Filler = Carbon Negative Additive (Does not Replace Cement)
Replacement = Mass Replacement of Cement Power
Fly Ash = Mass Replacement of Cement Power

FIG. 20

	Ratios		Carbon Calcs			
Superplasticizer	W/C	W/Binder	Kg CO2/Kg	Comared to OPC	Reduction to OPC	
0.00	0.51	0.51	0.922	100.00%	0.00%	
38.98	0.50	0.35	0.418	45.34%	54.66%	
38.30	0.50	0.35	0.418	45.34%	54.66%	
29.68	0.48	0.33	0.285	30.95%	69.05%	
20.98	0.49	0.38	0.207	22.46%	77.54%	
38.20	0.82	0.45	-0.012	-1.27%	101.27%	Carbon Negative
20.00	0.60	0.41	-0.077	-8.36%	108.36%	Carbon Negative
?	0.55	0.37	-0.077	-8.36%	108.36%	Carbon Negative
Not Yet Tested	0.51	0.29	-0.002	-0.22%	100.22%	Carbon Negative
Not Yet Tested	0.70	0.48	-0.012	-1.35%	101.35%	Carbon Negative

FIG. 20
(Continued)

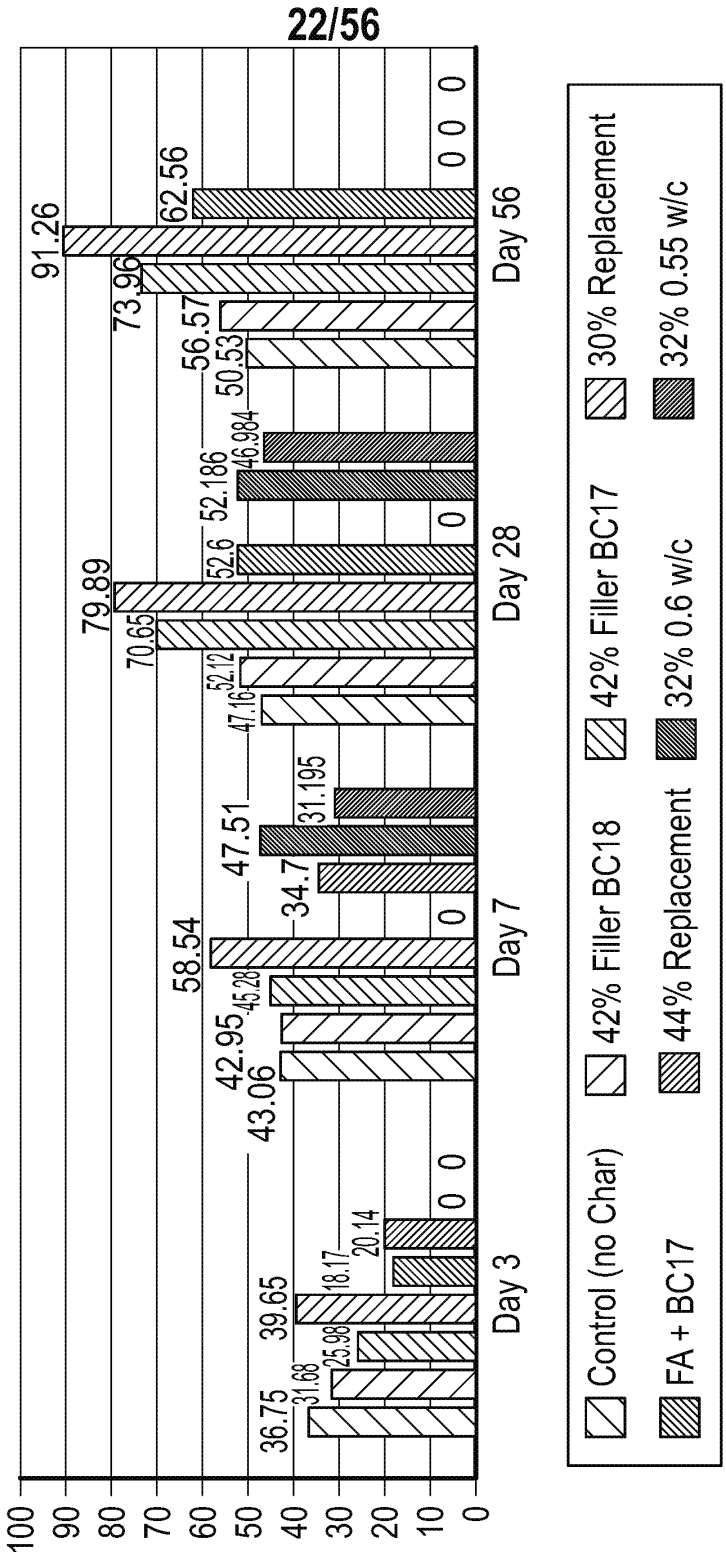

100
90
80
70
60
50
40
30
20
10
0
Day 3
Day 7
Day 28
Day 56
91.26
73.96
62.56
56.57
50.53
46.984
52.186
52.6
79.89
70.65
52.12
47.16
58.54
47.51
31.195
34.7
42.95
45.28
43.06
39.65
36.75
31.68
25.98
18.17
20.14
0
Control (no Char)
42% Filler BC18
42% Filler BC17
30% Replacement
FA + BC17
44% Replacement
32% 0.6 w/c
32% 0.55 w/c

FIG. 21

Compressive Strength Results (MPa)

	Day 3	Day 7	Day 28	Day 56
Control (no Char)	36.75	43.06	47.16	50.53
42% Filler BC18	31.68	42.95	52.12	56.57
42% Filler BC17	25.98	45.28	70.65	73.96
30% Replacement	39.65	58.54	79.89	91.26
FA + BC17	18.17 -		52.6	62.56
44% Replacement	20.14	34.7	Not Yet Tested	Not Yet Tested
32% 0.6 w/c	-	47.51	52.186 -	
32% 0.55 w/c	-	31.195	46.984 -	
77% Replacement	Not Yet Tested	Not Yet Tested	Not Yet Tested	Not Yet Tested
FA + BC17 2.0	Not Yet Tested	Not Yet Tested	Not Yet Tested	Not Yet Tested

FIG. 22

Embodied Carbon Values	kgCO2/kg
OPC	0.922
Biochar BC17 and BC18	-1.2
Biochar BC01	-2.2
Fly Ash	0
**BC17 Rice Hull Biochar	
**BC18 Pine Biochar	

FIG. 23

Mass Percent

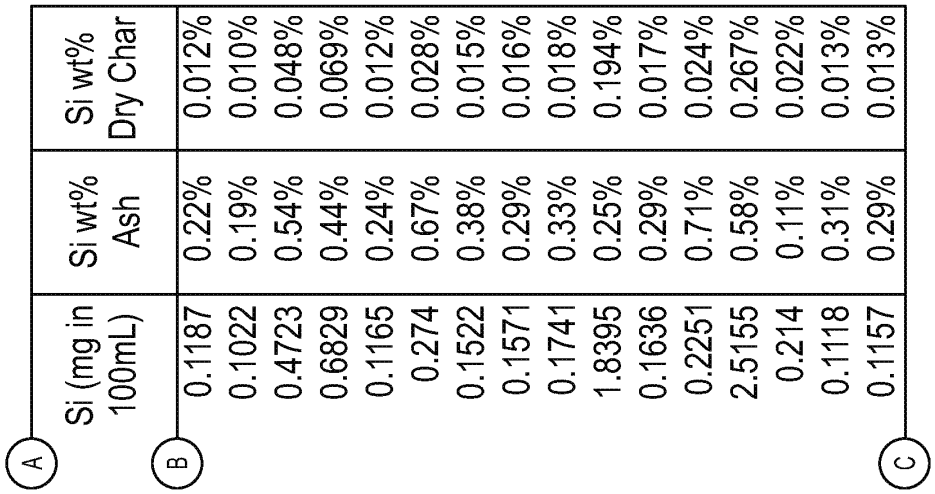
Biochar	Ambient Moisture wt%	Dry Char (g)	Dry Char (mg)	Ash wt%	ICP DI Total (mg/L)	ICP Total mg/100mL (Soluble Mass)	If Ash Was 100% Soluble (mg)	% Ash Soluble	% Dry Char Soluble	Ca (mg/L)	Ca (mg in 100mL)	Ca wt% Ash
BC-02	1.21%	0.9879	987.9	5.56%	55.009	5.5009	54.94206	10.0%	0.56%	2.835	0.2835	0.52%
BC-03	2.13%	0.9787	978.7	5.53%	258.17	25.817	54.07318	47.7%	2.64.%	55.864	5.5864	10.33%
BC-06	1.67%	0.9833	983.3	8.93%	43.205	4.3205	87.75953	4.9%	0.44%	4.999	0.4999	0.57%
BC-07	1.37%	0.9863	986.3	15.72%	59.151	5.9151	154.997	3.8%	0.60%	16.851	1.6851	1.09%
BC-09	2.84%	0.9716	971.6	5.02%	58.308	5.8308	48.77432	12.0%	0.60%	5.019	0.5019	1.03%
BC-10	2.94%	0.9706	970.6	4.23%	117.585	11.7585	41.05638	28.6%	1.21%	5.831	0.5831	1.42%
BC-11	1.50%	0.985	985.02	4.04%	52.244	5.2244	39.79481	13.1%	0.53%	4.978	0.4978	1.25%
BC-12	2.57%	0.9743	974.3	5.50%	44.761	4.4761	53.5865	8.4%	0.46%	5.042	0.5042	0.94%
BC-13	3.15%	0.9685	968.5	5.46%	87.961	8.7961	52.8801	16.6%	0.91%	6.248	0.6248	1.18%
BC-14	4.95%	0.9505	950.5	76.64%	223.896	22.3896	728.4632	3.1%	2.36%	14.167	1.4167	0.19%
BC-15	3.73%	0.9627	962.7	5.90%	80.621	8.0621	56.7993	14.2%	0.84%	2.541	0.2541	0.45%
BC-16	6.25%	0.9375	937.5	3.40%	286.155	28.6155	31.875	89.8%	3.05%	6.716	0.6716	2.11%
BC-17	5.69%	0.9431	943.1	45.70%	63.3	6.33	430.9967	1.5%	0.67%	1.1	0.11	0.03%
BC-19	2.76%	0.9724	972.4	20.60%	67.331	6.7331	200.3144	3.4%	0.69%	8.824	0.8824	0.44%
BC-20	13.40%	0.866	866	4.21%	64.308	6.4308	36.4586	17.6%	0.74%	2.355	0.2355	0.65%
BC-21	13.70%	0.863	863	4.57%	74.888	7.4888	39.4391	19.0%	0.87%	3.331	0.3331	0.84%

**Starting Biochar to Water Concentration = 1000mg Biochar/0.1L

FIG. 24

Ca wt% Dry Char	K (mg/L)	K (mg in 100mL)	K wt% Ash	K wt% Dry Char	Mg (mg/L)	Mg (mg in 100mL)	Mg wt% Ash	Mg wt% Dry Char	Na (mg/L)	Na (mg in 100mL)	Na wt% Ash	Na wt% Dry Char	Si (mg/L)
0.029%	42.489	4.2489	7.73%	0.430%	1.32	0.132	0.24%	0.013%	3.556	0.3556	0.65%	0.036%	1.187
0.571%	65.742	6.5742	12.16%	0.672%	9.458	0.9458	1.75%	0.097%	2.101	0.2101	0.39%	0.021%	1.022
0.051%	29.015	2.9015	3.31%	0.295%	1.026	0.1026	0.12%	0.010%	2.015	0.2015	0.23%	0.020%	4.723
0.171%	27.725	2.7725	1.79%	0.281%	0.924	0.0924	0.06%	0.009%	4.024	0.4024	0.26%	0.041%	6.829
0.052%	39.906	3.9906	8.18%	0.411%	0.578	0.0578	0.12%	0.006%	6.302	0.6302	1.29%	0.065%	1.165
0.060%	91.954	9.1954	22.40%	0.947%	1.849	0.1849	0.45%	0.019%	7.625	0.7625	1.86%	0.079%	2.74
0.051%	37.99	3.799	9.55%	0.386%	0.704	0.0704	0.18%	0.007%	2.515	0.2515	0.63%	0.026%	1.522
0.052%	30.731	3.0731	5.73%	0.315%	0.605	0.0605	0.11%	0.006%	1.992	0.1992	0.37%	0.020%	1.571
0.065%	70.305	7.0305	13.30%	0.726%	5.901	0.5901	1.12%	0.061%	1.155	0.1155	0.22%	0.012%	1.741
0.149%	140.393	14.0393	1.93%	1.477%	0.909	0.0909	0.01%	0.010%	6.045	0.6045	0.08%	0.064%	18.395
0.026%	42.245	4.2245	7.44%	0.439%	0.937	0.0937	0.16%	0.010%	29.393	2.9393	5.17%	0.305%	1.636
0.072%	224.704	22.4704	70.50%	2.397%	6.7	0.67	2.10%	0.071%	5.592	0.5592	1.75%	0.060%	2.251
0.012%	23.708	2.3708	0.55%	0.251%	1.464	0.1464	0.03%	0.016%	0.702	0.0702	0.02%	0.007%	25.155
0.091%	44.651	4.4651	2.23%	0.459%	4.024	0.4024	0.20%	0.041%	0.899	0.0899	0.04%	0.009%	2.14
0.027%	57.895	5.7895	15.88%	0.669%	0.656	0.0656	0.18%	0.008%	0.817	0.0817	0.22%	0.009%	1.118
0.039%	16.626	1.6626	4.22%	0.193%	0.752	0.0752	0.19%	0.009%	50.128	5.0128	12.71%	0.581%	1.157

FIG. 24
(Continued)



Si (mg in 100mL)	Si wt% Ash	Si wt% Dry Char
0.1187	0.22%	0.012%
0.1022	0.19%	0.010%
0.4723	0.54%	0.048%
0.6829	0.44%	0.069%
0.1165	0.24%	0.012%
0.274	0.67%	0.028%
0.1522	0.38%	0.015%
0.1571	0.29%	0.016%
0.1741	0.33%	0.018%
1.8395	0.25%	0.194%
0.1636	0.29%	0.017%
0.2251	0.71%	0.024%
2.5155	0.58%	0.267%
0.214	0.11%	0.022%
0.1118	0.31%	0.013%
0.1157	0.29%	0.013%

FIG. 24
(Continued)

Linear Model

Biochar	28Day Strength	DI_Soluble_Si_	NEW_O_C	Perc_Ambient
Units	MPa	mg/L	Atomic Ratio	wt%
BC02	63.51	1.187	0.074206172	1.097%
BC03	56.31	1.022	0.199050515	2.162%
BC06	71.71	4.723	0.09173124	1.391%
BC07	59.77	6.829	0.07001979	1.395%
BC09	60.43	1.165	0.099896495	2.741%
BC10	59.58	2.74	0.130962512	2.255%
BC11	60.98	1.522	0.100330696	1.390%
BC12	64.30	1.571	0.071662392	2.675%
BC13	47.98	1.741	0.858344532	4.213%
BC14	52.01	18.395	0.618256245	6.956%
BC15	49.91	1.636	0.642262383	3.992%
BC16	60.60	2.251	0.203721504	5.876%
BC17	62.99	25.155	0.160824272	7.497%
BC19	48.79	2.14	0.364456947	2.616%
BC-20	53.38	1.118	0.028033982	16.517%
BC-21	52.87	1.157	0.032207735	15.133%
Linear Model Coefficients:		0.2	-18.4	-0.71 65.03 (Constant)

FIG. 25

	A	B	C	D	E	F	G	H	I
1	Biochar	28Day Strength	O_N	AmbMoisture	AshNorm_XRF_CaO	AshNorm_XRF_Na2O	AshNorm_XRF_SiO2	AshNorm_XRF_SO3	C_N
2	BC02	63.51	24.36	1.21%	1.496	0.091	1.746	0.049	196.91
3	BC03	56.31	30.67	2.13%	1.643	0.044	0.108	0.048	119.32
4	BC06	71.71	40.52	1.67%	2.825	0.022	4.252	0.034	228.64
5	BC07	59.77	28.54	1.37%	3.688	0.162	7.337	0.077	126.65
6	BC09	60.43	34.39	2.84%	1.26	0.056	1.607	0.025	234.18
7	BC10	59.58	39.21	2.94%	1.364	0.079	1.16	0.033	228.64
8	BC11	60.98	32.64	1.50%	1.208	0.064	1.204	0.034	237.10
9	BC12	64.30	29.35	2.57%	1.247	0.072	2.205	0.032	241.47
10	BC13	47.98	242.7	3.15%	2.13	0.063	0.705	0.062	254.89
11	BC14	52.01	758.77	4.95%	13.466	0.498	40.328	0.284	141.15
12	BC15	49.91	139.6	3.73%	1.947	0.402	1.394	0.047	190.53
13	BC16	60.60	14.52	6.25%	0.43	0.05	0.51	0.17	60.83
14	BC17	62.99	49.49	5.69%	0.1371	0.10968	43.84001	0.00457	50.75
15	BC19	48.79	109.57	2.76%	4.33218	0.1648	11.67814	0	163.74
16	BC-20	53.38	2.952702	13.40%	1.41	0.03	0.05	0.04	105.33
17	BC-21	52.87	4.738736	13.70%	1.92	0.49	0.29	0.11	147.13
18									
19	Correlation		-0.407	-0.343	-0.319	-0.503	-0.017	-0.227	0.094

FIG. 26A

	J	K	L	M	N	O	P	Q
1	C_perc	CO2_SA_m2g	d10PartSize	d50PartSize	DI_ICP_AES_DslvAnions	DI_ICP_AES_DslvCations	DI_ICP_AES_SolMass	DI_Soluble_K_
2	84.40	271.05	4.236666667	11	3.169	50.654	55.009	42.489
3	71.60	151.25	4.31	11.665	121.773	135.374	258.17	65.742
4	78.40	164.84	2.867666667	8.703333333	0.869	37.614	43.205	29.015
5	76.00	148.29	4	10.85	1.005	51.318	59.151	27.725
6	80.30	190.68	4.26	12.37	4.571	52.572	58.308	39.906
7	78.40	176.21	4.12	13.53	6.991	107.853	117.585	91.954
8	81.30	191.94	4.1	11.1	3.475	47.247	52.244	37.99
9	82.80	201.5	4.21	11.84	4.037	39.153	44.761	30.731
10	43.70	241.22	3.57	9.6	2.414	83.807	87.961	70.306
11	12.10	67.54	2.6	8.24	42.368	163.133	223.896	140.393
12	49.00	297.56	2.77	7.38	3.03	75.955	80.621	42.245
13	73.00	177.2	5.16	13.71	39.509	244.395	286.155	224.704
14	42.15	146.27	4.14	8.24	10.243	27.902	63.3	23.708
15	50.78	56.31	3.57	8.81	6.186	59.005	67.331	44.651
16	90.29	218.52	3.29	8.01	0.98	62.21	64.308	57.895
17	89.55	213.8	3.83	8.73	2.519	71.213	74.888	16.626
18								
19	0.457	0.033	0.327	0.383	-0.096	-0.228	-0.191	-0.124

FIG. 26A
(Continued)

	R	S	T	U	V	W	X	Y	Z	AA	AB
1	DI_Soluble_Si_	Effwc_DI	Effwc_Pore	FixedCarbonDry	Flow	H_C	N_Perc	New_O_C	New_0_Perc	O_C	O_Perc
2	1.187		0.32429524	71.58	128	0.1691	0.5	0.07420617	8.34	0.124	13.9
3	1.022		0.27429867	59.88	99	0.5148	0.7	0.19905052	18.98	0.257	24.5
4	4.723		0.32362158	68.535	110	0.4095	0.4	0.09173124	9.58	0.177	18.5
5	6.829		0.32316678	71.8	112	0.0782	0.7	0.07001979	7.09	0.225	22.8
6	1.165		0.34289148	68.93	116	0.5331	0.4	0.0998965	10.68	0.147	15.7
7	2.74		0.31921238	79.49	104	0.5005	0.4	0.13096251	13.67	0.171	17.9
8	1.522		0.33620593	75.22	115	0.4973	0.4	0.1003307	10.86	0.138	14.9
9	1.571		0.33612057	70.7	124	0.4883	0.4	0.07166239	7.9	0.122	13.4
10	1.741		0.3649	70.65	136	0.1633	0.2	0.85834453	49.94	0.952	55.4
11	18.395		0.37871595	3.515	107	0.7862	0.1	0.61825625	9.96	5.376	86.6
12	1.636		0.3563	76	128	0.728	0.3	0.64226238	41.9	0.733	47.8
13	2.251		0.325	84.9	97	0.3584	1.4	0.2037215	19.8	0.239	23.2
14	25.155		0.32737864	36.4	140	0.6069	0.96886	0.16082427	9.03	0.975	54.72594
15	2.14		0.31722203	31.4	120	0.8456	0.361793	0.36445695	24.64	0.669	45.24231
16	1.118		0.3224	90.8	100	0.1475027	1	0.02803398	3.37	0.028033982	3.37
17	1.157		0.3461	88.19	96	0.1726232	0.71	0.03220774	3.84	0.032207735	3.84
18											
19	0.111	#DIV/0!	-0.332	0.180	-0.003	-0.165	0.213	-0.663	-0.563	-0.327	-0.434

FIG. 26A
(Continued)

	AC	AD	AE	AF	AG	AH
1	ParticleSpacing	Perc_ambient	Pore_ICP_AES_CnsmCations	Pore_ICP_AES_CnsmMass	PORE_ICP_AES_DslvCations	Pore_ICP_AES_DslvMass
2	0.009428122	1.097%	-75.216	-75.218	148.396	152.306
3	0.015487178	2.162%	-163.974	-163.974	0.29	20.911
4	0.016466932	1.391%	-78.719	-78.719	106.888	127.781
5	0.016791304	1.395%	-87.958	-87.958	152.656	173.255
6	0.0126709	2.741%	-19.327	-20.03	192.141	406.208
7	0.013768023	2.255%	-25.198	-25.353	197.139	398.367
8	0.013001298	1.390%	-18.568	-19.901	183.738	412.056
9	0.012036869	2.675%	-160.121	-160.121	0.355	133.285
10	0.009681361	4.213%	-574.614	-653.999	0.54	2.157
11	0.035889601	6.956%	-200.981	-200.981	201.651	320.161
12	0.009507794	3.992%	-396.443	-396.443	0.598	21.762
13	0.012690852	5.876%	-84.658	-84.658	334.307	193.13
14	0.015462511	7.497%	-939.816	-939.816	0.191	92.77
15	0.037697	2.616%	-355.283	-355.283	0.432	46.02
16	0.010546	16.517%	-0.212	-1.318	322.562	620.606
17	0.010247	15.133%	-21.6	-27.542	247.154	402.352
18						
19	-0.276	-0.371	0.221	0.245	0.098	0.037

FIG. 26A
(Continued)

	AI	AJ	AK	AL	AM	AN	AO	AP
1	Pore_Wash_Leach_Ca_	Pore_Wash_Leach_Mg_	Pore_Wash_Leach_Na_	PoreSolnSorpCpcty	ShearRate	Slow	WtrSorpCpcty	X.O.N.C
2	-75.214	-0.002	29.294	1.1192	30979.1881	0	1.0914	0.1287777
3	-100.579	0.061	-43.829	1.56	18651.3471	1	0.9639	0.2653895
4	-78.428	0.008	7.439	1.1207	17591.1477	0	1.1843	0.181609
5	-87.608	-0.006	21.05	1.1278	17438.2169	1	0.9686	0.233224
6	-19.326	0.019	85.218	0.9356	23002.0499	0	1.0076	0.1511218
7	-25.198	0.007	69.734	1.1477	21184.4945	0	1.2741	0.1758608
8	-18.559	0.014	83.268	1.0092	22387.4973	0	1.0625	0.1418721
9	-64.544	0.005	-9.588	0.9992	24104.3354	0	0.935	0.1256952
10	-146.647	0.01	-127.442	0.7342	29600.5393	1	0.7162	0.9561117
11	-200.979	0.001	19.692	0.5921	8229.81226	1	0.6621	5.3826862
12	-115.964	0.011	-55.784	0.8062	30883.785	1	0.8971	0.7379487
13	-84.632	0.031	25.215	1.0662	22998.5652	0	1.0011	0.2551443
14	-397.412	0.019	-128.134	1.0467	18757.5134	1	0.7021	0.9948102
15	-183.85	0.016	-50.942	1.1674	7664.478	0	1.0274	0.6752357
16	116.075	-0.043	73.247	1.0142	27485.5	1	0.6773	0.0375283
17	122.738	-0.144	-20.613	0.7978	28392.7	1	0.7683	0.0390044
18								
19	-0.028	0.205	0.325	0.379	-0.005	-0.538	0.535	-0.327

FIG. 26A
(Continued)

1	**NAMING CONVENTION KEY**	
2	O_N	OXYGEN/NITROGEN ATOMIC RATIO
3	AMBMOISTURE	AMBIENT MOISTURE%
4	ASHNORM_XRF_CAO	XRF WT% CAO
5	ASHNORM_XRF_NA2O	XRF WT% NA2O
6	ASHNORM_XRF_SIO2	XRF WT% SIO2
7	ASHNORM_XRF_SO3	XRF WT% SO3
8	C_N	CARBON/NITROGEN ATOMIC RATIO
9	C_PERC	CARBON WT%
10	CO2_SA_M2G	CO2 SURFACE AREA
11	D10PARTSIZE	D10 PARTICLE SIZE
12	D50PARTSIZE	D50 PARTICLE SIZE
13	DI_ICP_AES_DSLVANIONS	DISSOLVED ANIONS IN DI WATER
14	DI_ICP_AES_DSLVCATIONS	DISSOLVED CATIONS IN DI WATER
15	DI_ICP_AES_SOLMASS	DISSOLVED MASS IN DI WATER
16	DI_SOLUBLE__K_	K IONS SOLUBLE IN DI WATER
17	DI_SOLUBLE__SI_	SI IONS SOLUBLE IN DI WATER
18	EFFWC_DI	EFFECTIVE W/C WITH DI WATER
19	EFFWC_PORE	EFFECTIVE W/C WITH PORE SOLUTION
20	FIXEDCARBONDRY	FIXED CARBON CONTENT
21	FLOW	FLOW %
22	H_C	HYDROGEN/CARBON ATOMIC RATIO
23	N_PERC	NITROGEN WT%
24	NEW_O_C	NON-ORGANIC ORGANIC OXYGEN/CARBON WT%
25	NEW_O_PERC	NON-ORGANIC OXYGEN WT%
26	O_C	OXYGEN/CARBON ATOMIC RATIO
27	O_PERC	OXYGEN WT%
28	PARTICLESPACING	INTERPARTICLE DISTANCE
29	PERC_AMBIENT	AMBIENT SATURATION %
30	PORE_ICP_AES_CNSMCATIONS	CATION CONSUMED FROM PORE SOLUTION
31	PORE_ICP_AES_CNSMMASS	MASS CONSUMED FROM PORE SOLUTION
32	PORE_ICP_AES_DSLVCATIONS	CATION DISSOLVED INTO PORE SOLUTION
33	PORE_ICP_AES_DSLVMASS	MASS DISSOLVED INTO PORE SOLUTION
34	PORE_WASH_LEACH__CA_	CA ION CONCENTRATION IN PORE SOLUTION
35	PORE_WASH_LEACH__MG_	MG ION CONCENTRATION IN PORE SOLUTION
36	PORE_WASH_LEACH__NA_	NA ION CONCENTRATION IN PORE SOLUTION
37	PORESOLNSORPCPCTY	PORE SOLUTION SORPTION CAPCITY
38	SHEARRATE	PARTICLE SHEAR RATE
39	SLOW	SLOW PYROLYSIS (YES/NO)
40	WTRSORPCPCTY	DI WATER SORPTION CAPCITY
41	X.O.N.C	(NITROGEN+OXYGEN)/CARBON ATOMIC RATIO

FIG. 26B

Mix	Mass (kg/m3)	Density (kg/m3)	WA (%)	V (m3)	Dry
Cement	350	3100		0.1129032	350
Effective Water	158	1000		0.158	
Casting Water					159.80125
Holcim Coarse Aggregate	1100	2640	0.4305684	0.4166667	1095.2637
Ottawa Sand (Fine Aggregate)	845	2665		0.3170732	845
Total Mass	2453	Total Volume		1.004643	

FIG. 27A

Mix	Mass (kg/m3)	Density (kg/m3)	WA (%)	V (m3)	Dry
Cement	350	3100		0.1129032	350
Effective Water	158	1000		0.158	
Casting Water					159.46875
Holcim Coarse Aggregate	1100	2640	0.4305684	0.4166667	1095.2637
Ottawa Sand (Fine Aggregate)	845	2665		0.3170732	845
Biochar (BC-18) (wt% of Cement)	17.5	1280	**10**	0.0136719	15.75
Sika Viscocrete 2100	7	1080		0.006481481	
Total Mass	2434.064	Total Volume		1.004643	
Ottawa Sand (Fine Aggregate) After Replacing by Biochar	808.5645	2665	7.6	0.303401	747.1136

FIG. 27B

Mix	Mass (kg/m3)	Density (kg/m3)	WA (%)	V (m3)	Dry
Cement	350	3100		0.1129032	350
Effective Water	158	1000		0.158	
Casting Water					159.13625
Holcim Coarse Aggregate	1100	2640	0.4305684	0.4166667	1095.2637
Ottawa Sand (Fine Aggregate)	845	2665		0.3170732	845
Blochar (BC-18) (Wt% of Cement)	35	1280	**10**	0.0273438	31.5
Sika Viscocrete 2100	7	1080		0.006481481	
Total Mass	2415.128	Total Volume		1.004643	
Ottawa Sand (Fine Aggregate) After Replacing by Biochar	772.1289	2665	7.6	0.289729	713.4471

FIG. 27C

Mix	Mass (kg/m3)	Density (kg/m3)	WA (%)	V (m3)	Dry
Cement	350	3100		0.1129032	350
Effective Water	158	1000		0.158	
Casting Water					159.80325
Holcim Coarse Aggregate	1100	2640	0.4305684	0.4166667	1095.2637
Ottawa Sand (Fine Aggregate)	845	2665		0.3170732	845
Biochar (BC-18) (Wt% of Cement)	52.5	1280	**10**	0.0410156	47.25
Sika Visococrete 2100	7	1080		0.006481481	
Total Mass	2396.193	Total Volume		1.004643	
Ottawa Sand (Fine Aggregate) After Replacing by Biochar	735.6934	2665	7.6	0.276058	679.7807

FIG. 27D

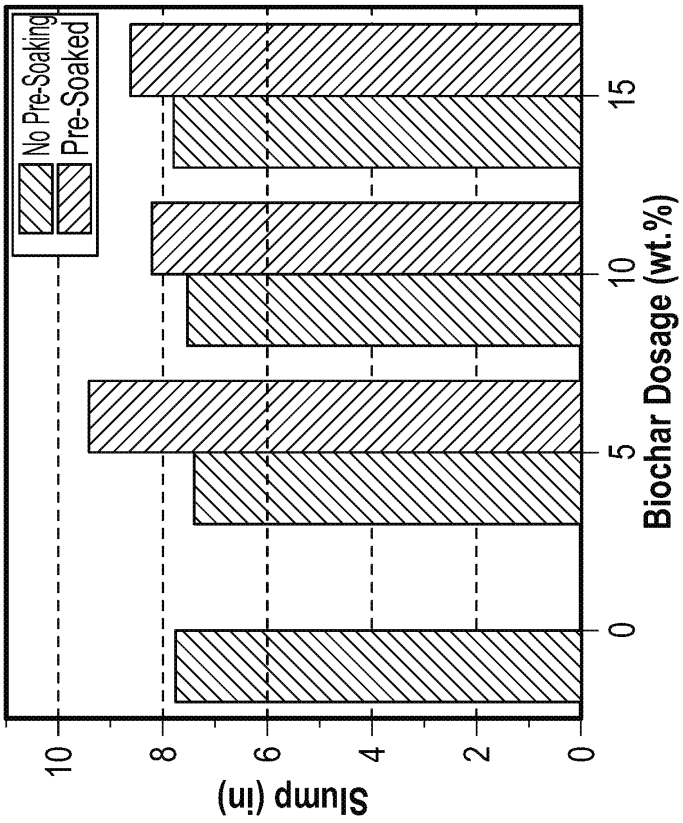


FIG. 28A

BC Dosage (wt.%)	MasterEase 3000(mL/100 kg Cement)	Mixing Time
0	150	4
5	400	5
10	450	4
15	800	8

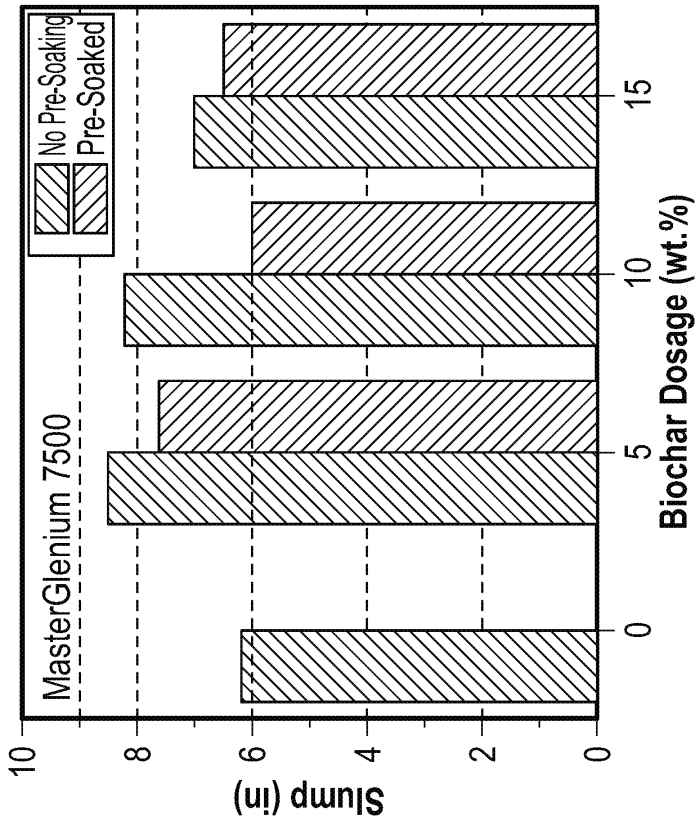


FIG. 28B

Bc Dosage (wt.%)	MasterGlenium 7500 (mL/100 kg Cement)	Mixing Time
0	130	8
5	380	8
10	430	8
15	800	8

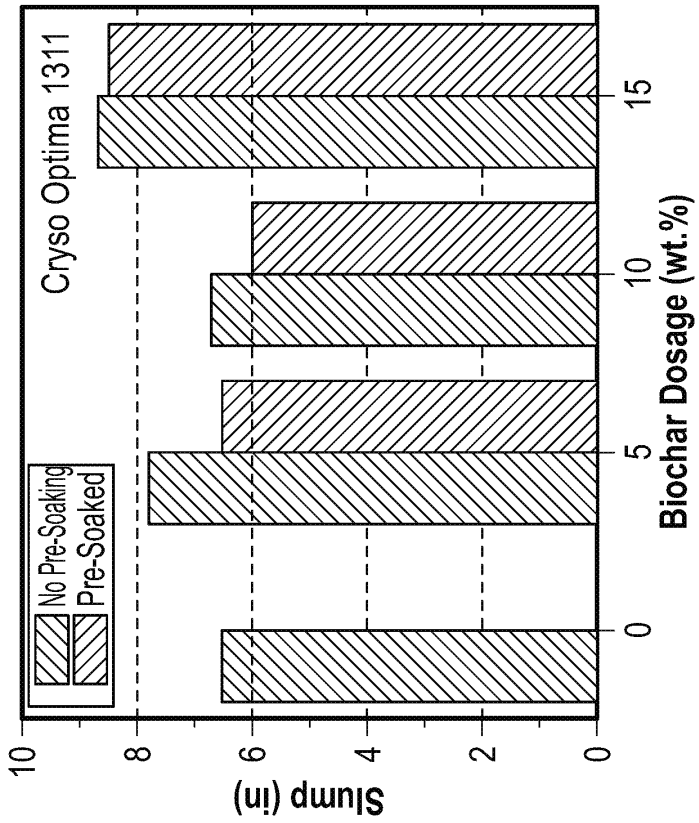


FIG. 28C

BC Dosage (wt. %)	Cryso Optima 1311 (mL/100 kg Cement)	Mixing Time
0	185	5
5	350	5
10	400	5
15	700	5

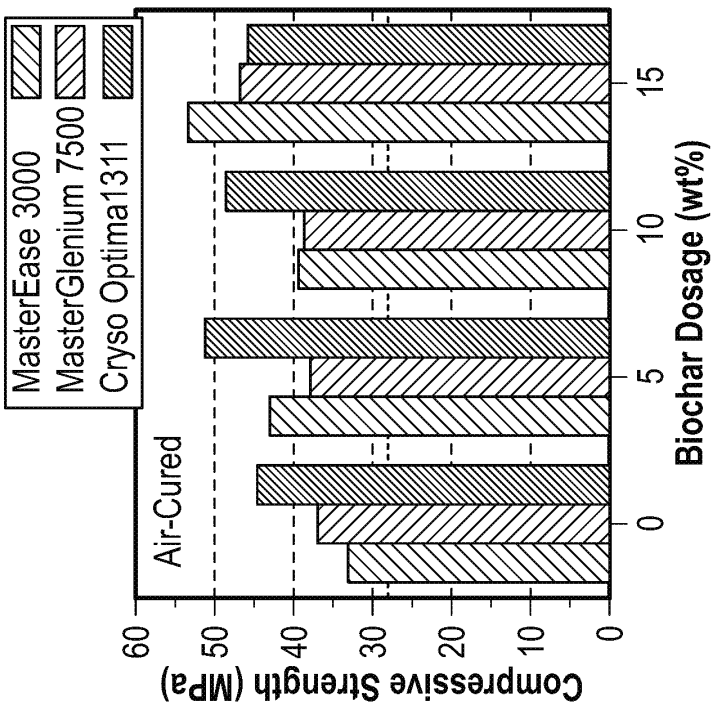


FIG. 29B

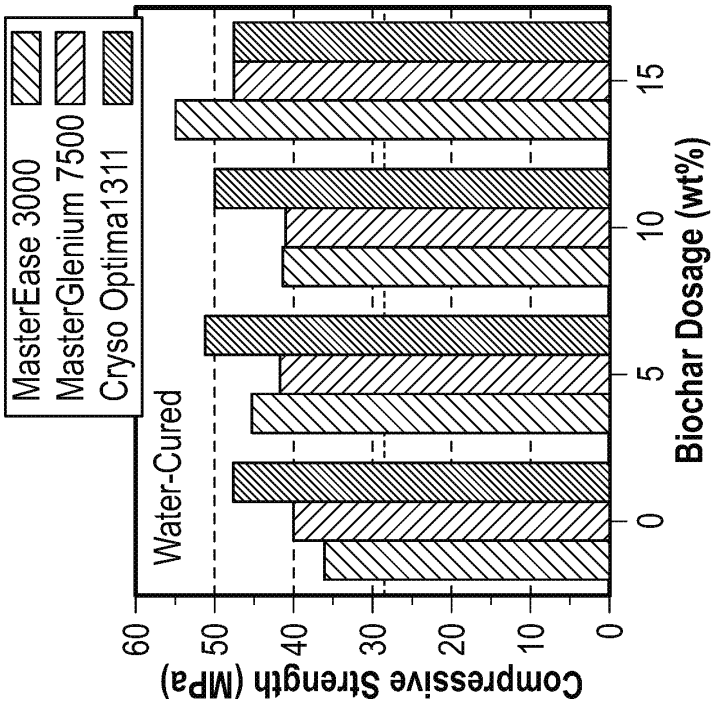


FIG. 29A

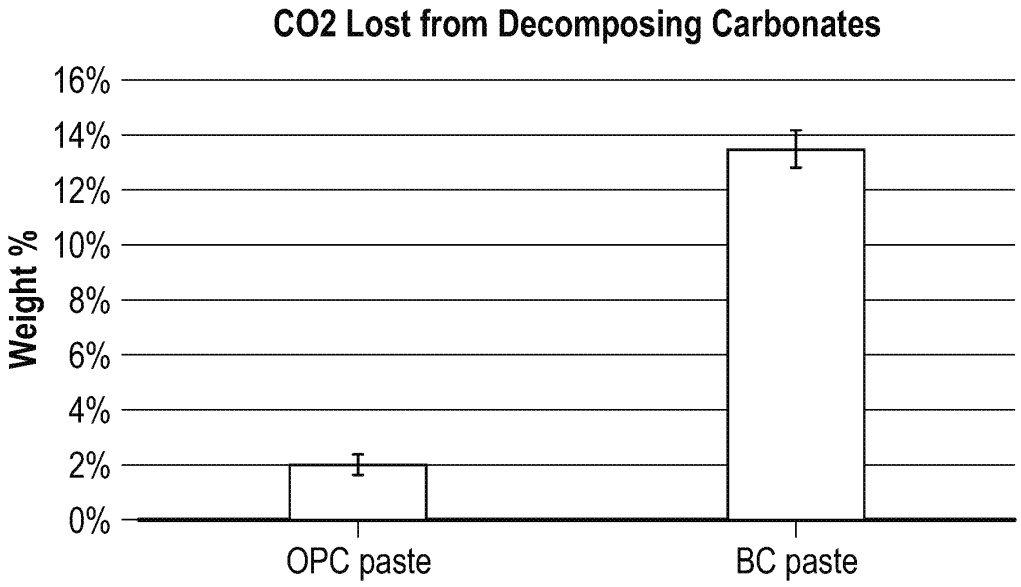

CO2 Lost from Decomposing Carbonates
Weight %
16%
14%
12%
10%
8%
6%
4%
2%
0%
OPC paste
BC paste

FIG. 30

	BC10	BC11
Ambient Saturation	2.2%	1.4%
Soluble Silica	2.74	1.52
O/C	0.13	0.10

FIG. 31

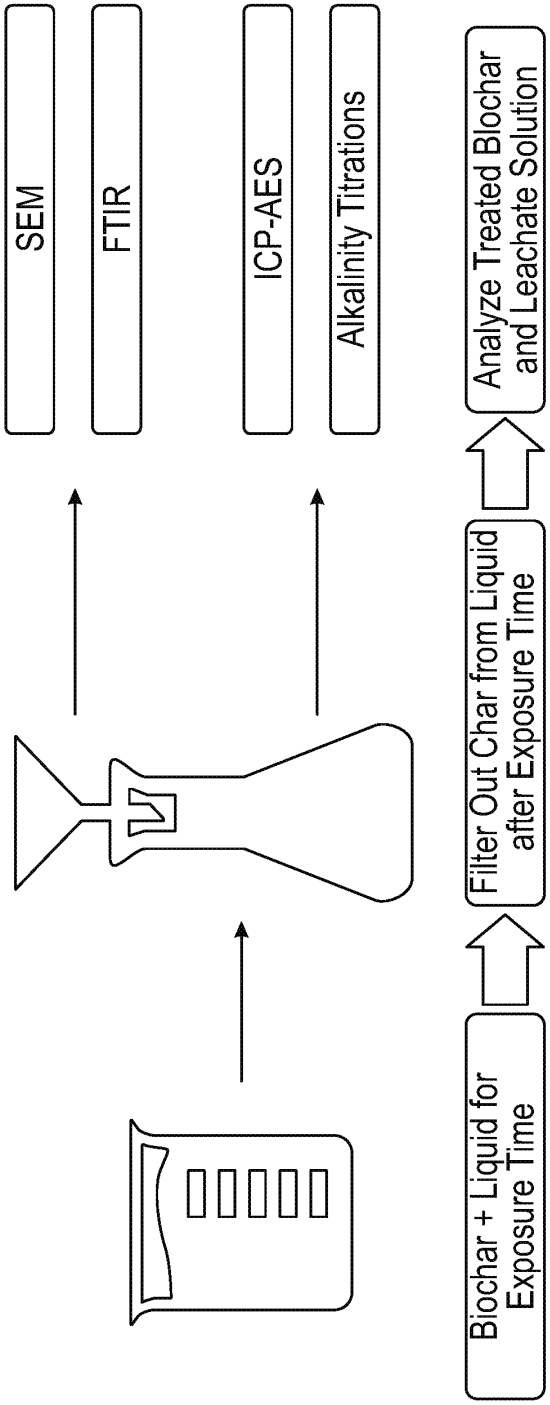

Biochar + Liquid for Exposure Time
Filter Out Char from Liquid after Exposure Time
Analyze Treated Biochar and Leachate Solution
SEM
FTIR
ICP-AES
Alkalinity Titrations

FIG. 32

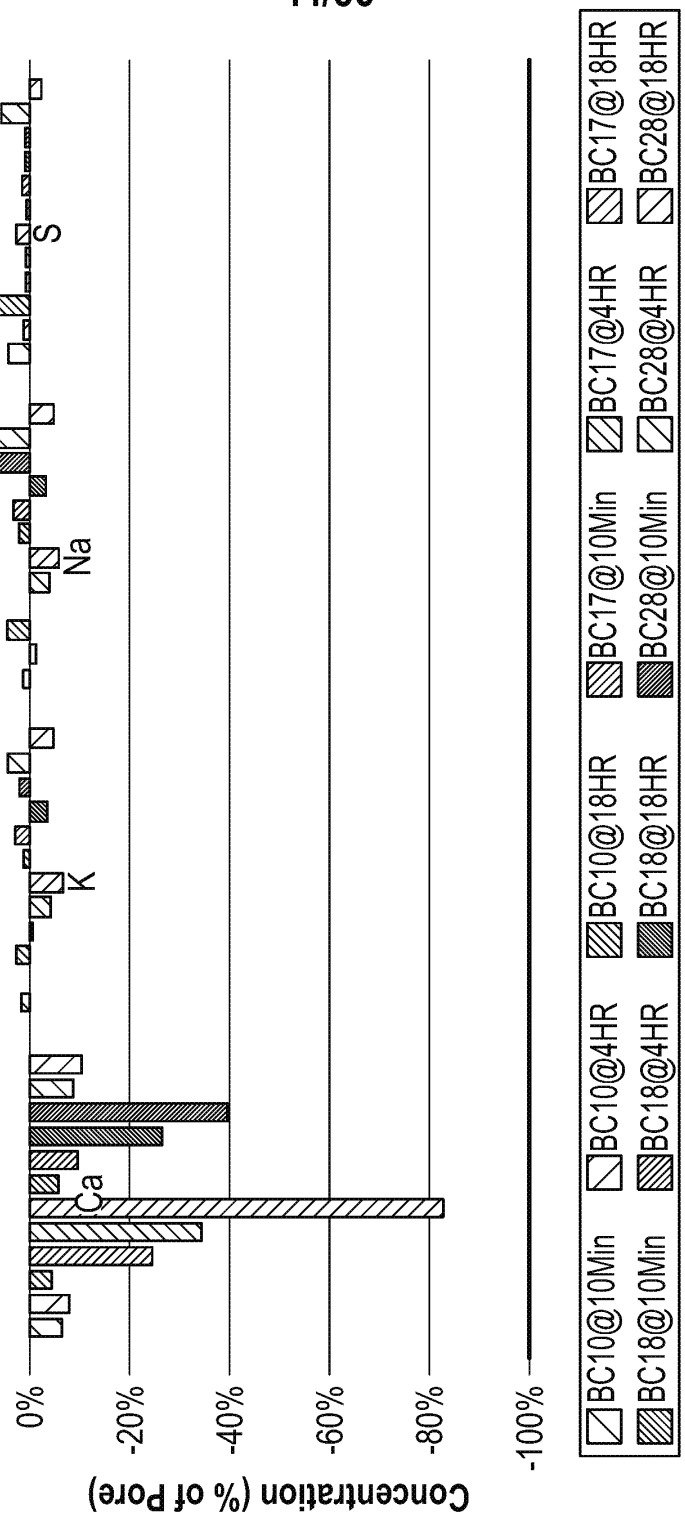

Concentration (% of Pore)
0%
-20%
-40%
-60%
-80%
-100%
Ca
K
Na
S
BC10@10Min
BC10@4HR
BC10@18HR
BC17@10Min
BC17@4HR
BC17@18HR
BC18@10Min
BC18@4HR
BC18@18HR
BC28@10Min
BC28@4HR
BC28@18HR

FIG. 33

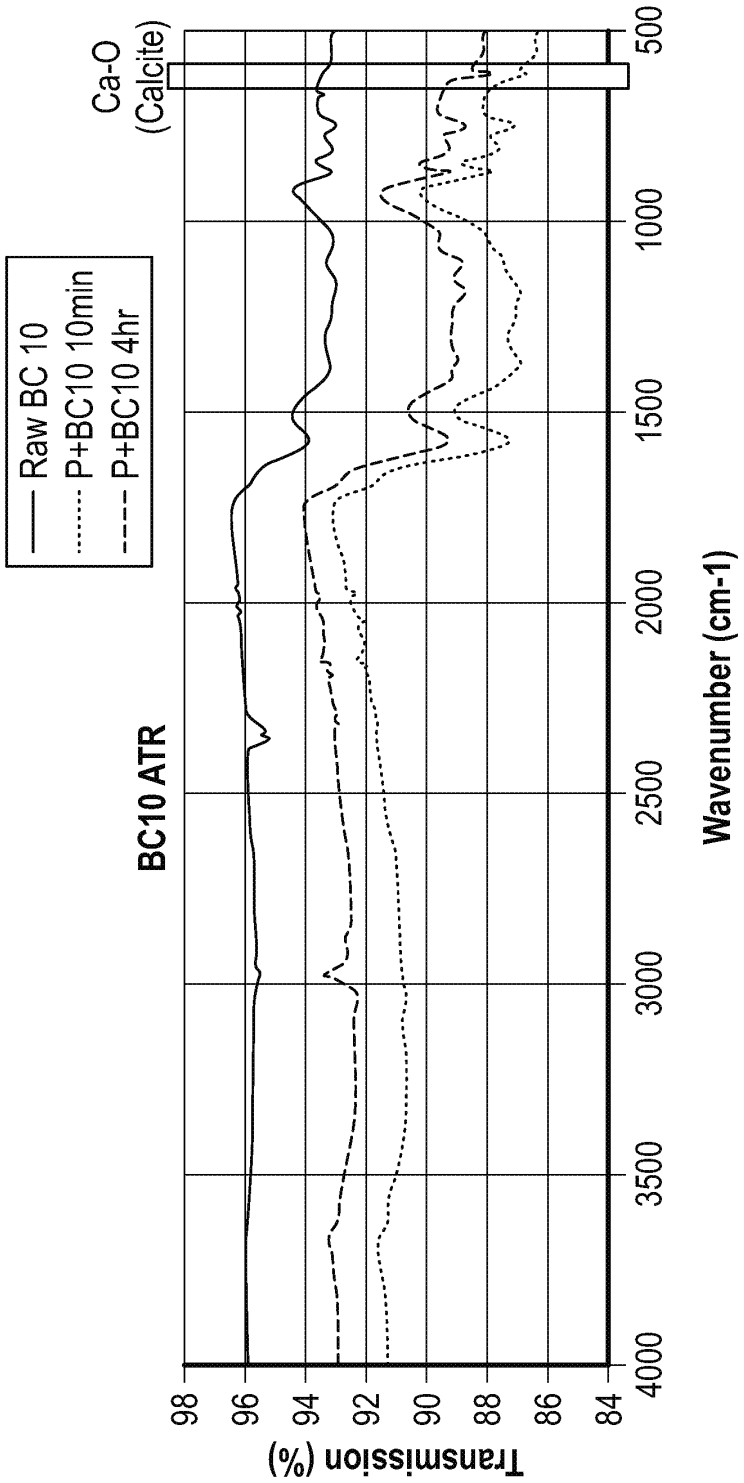

BC10 ATR
Raw BC 10
P+BC10 10min
P+BC10 4hr
Ca-O
(Calcite)
Transmission (%)
98
96
94
92
90
88
86
84
Wavenumber (cm-1)
4000
3500
3000
2500
2000
1500
1000
500

FIG. 34A

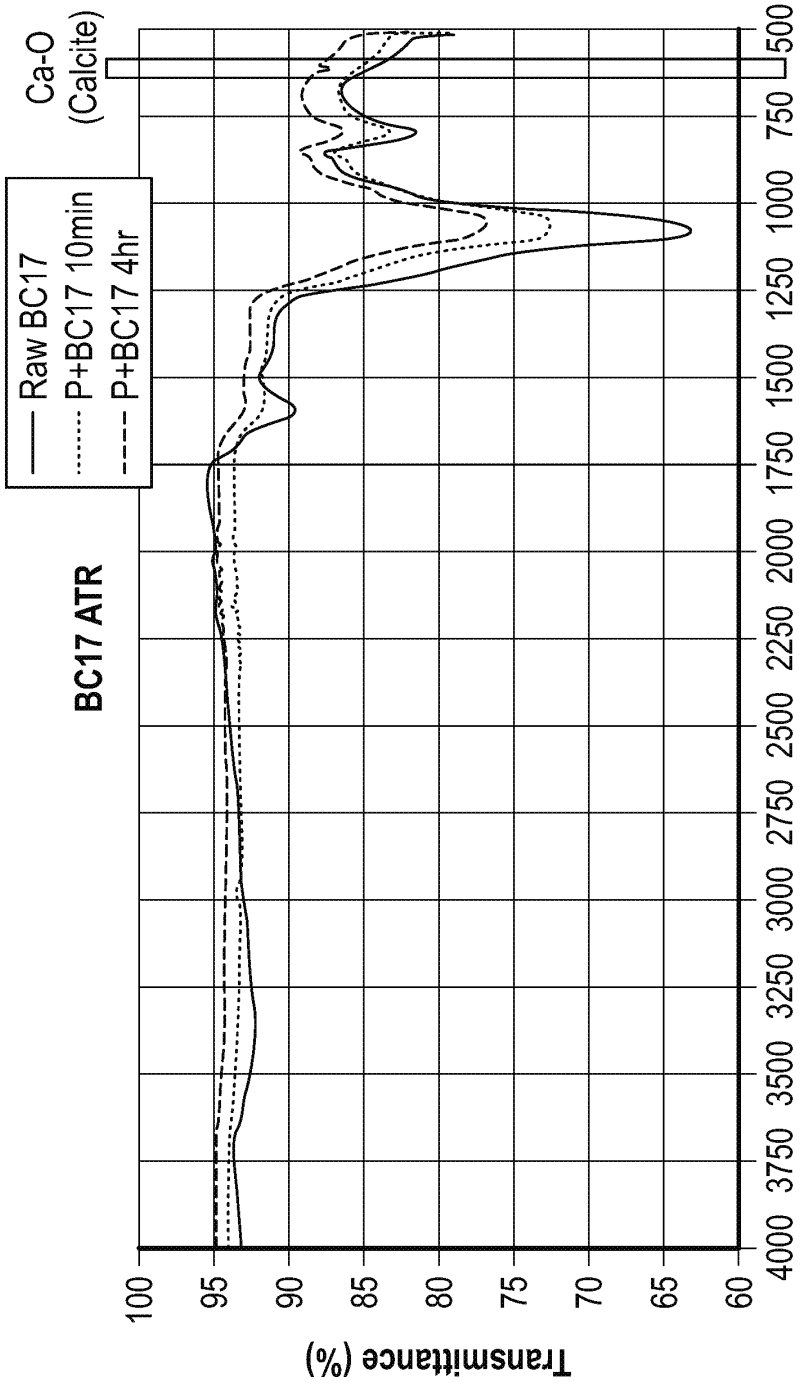

BC17 ATR
Raw BC17
P+BC17 10min
P+BC17 4hr
Ca-O
(Calcite)
Transmittance (%)
100
95
90
85
80
75
70
65
60
Wavenumber (cm-1)
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500

FIG. 34B

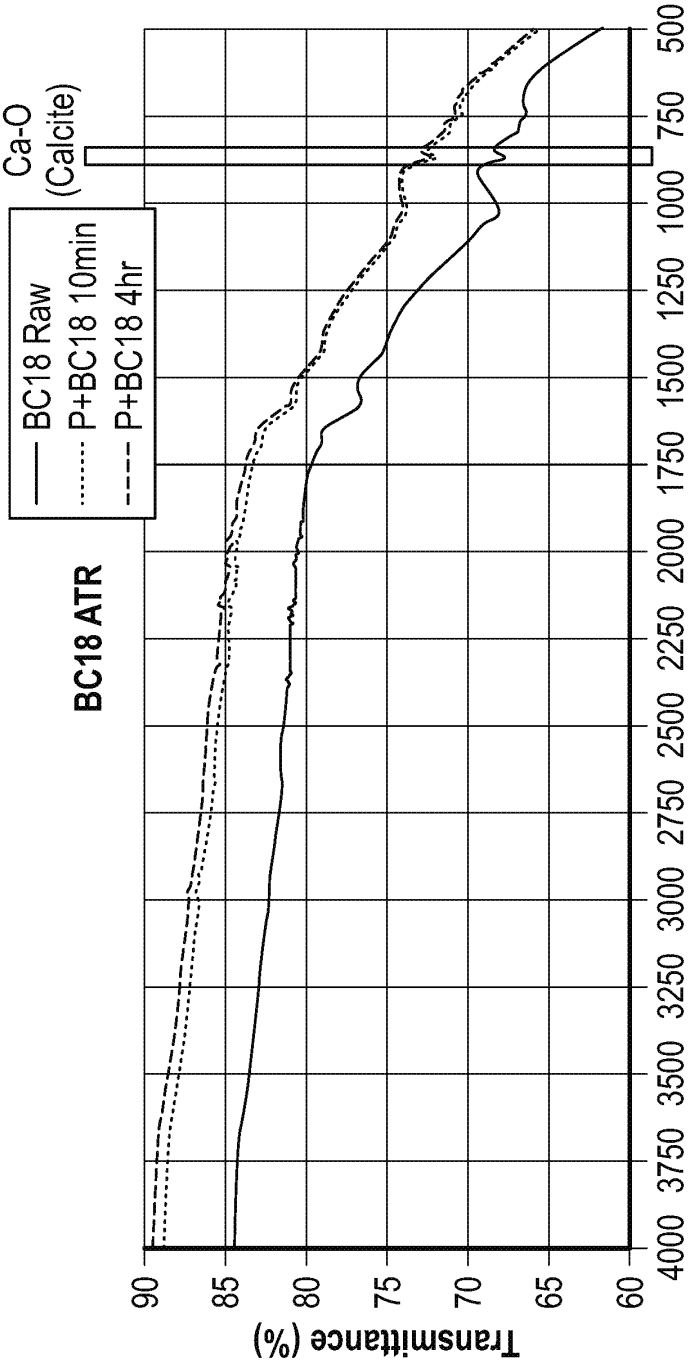

BC18 ATR
BC18 Raw
P+BC18 10min
P+BC18 4hr
Ca-O
(Calcite)
Transmittance (%)
90
85
80
75
70
65
60
Wavenumber (cm-1)
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500

FIG. 34C

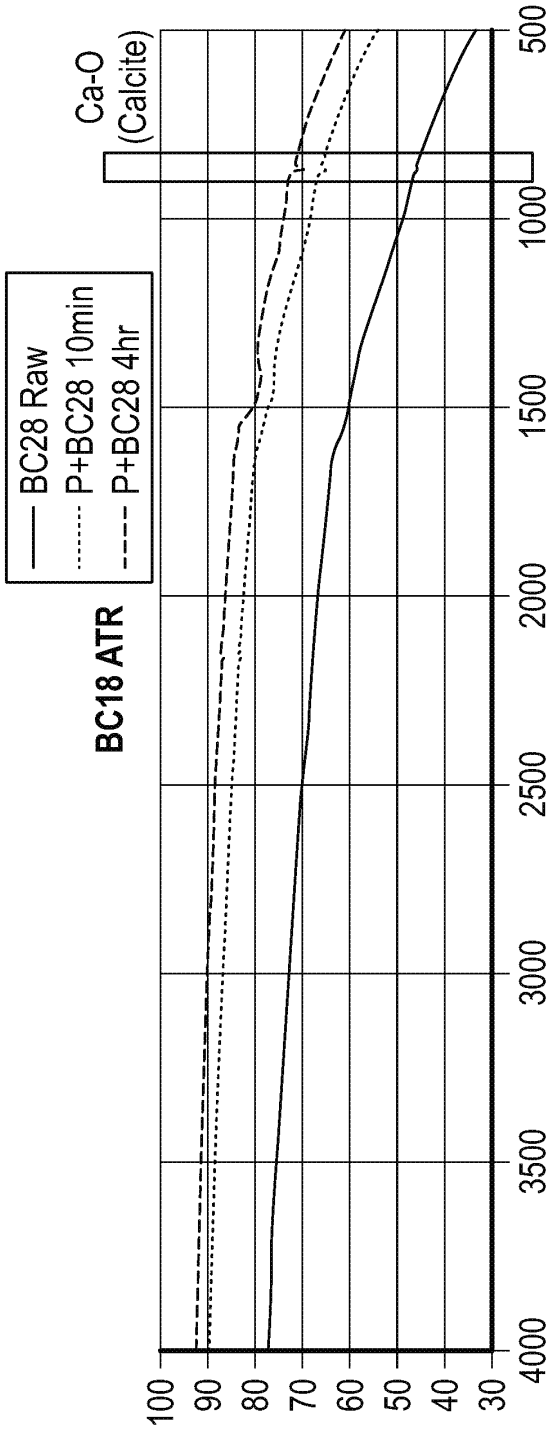

BC18 ATR
BC28 Raw
P+BC28 10min
P+BC28 4hr
Ca-O
(Calcite)
100
90
80
70
60
50
40
30
500
1000
1500
2000
2500
3000
3500
4000

FIG. 34D

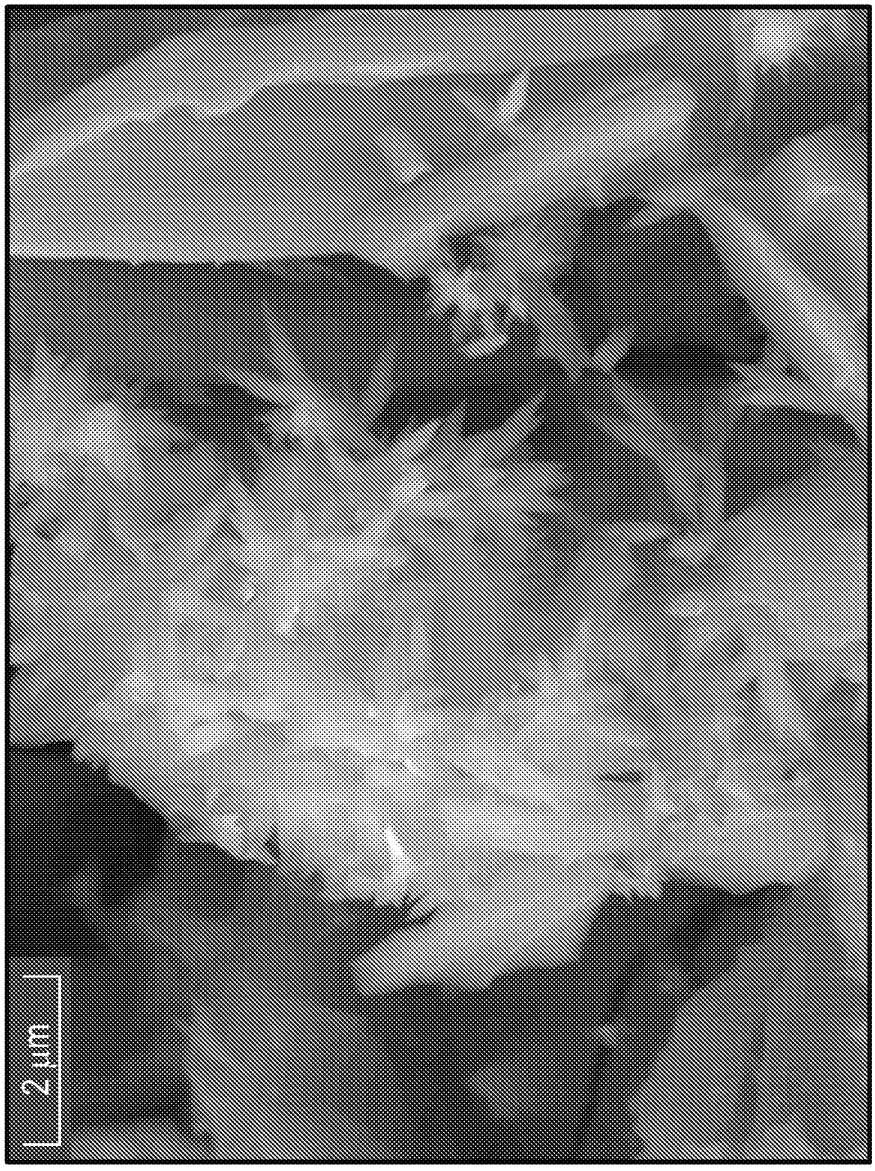


FIG. 35

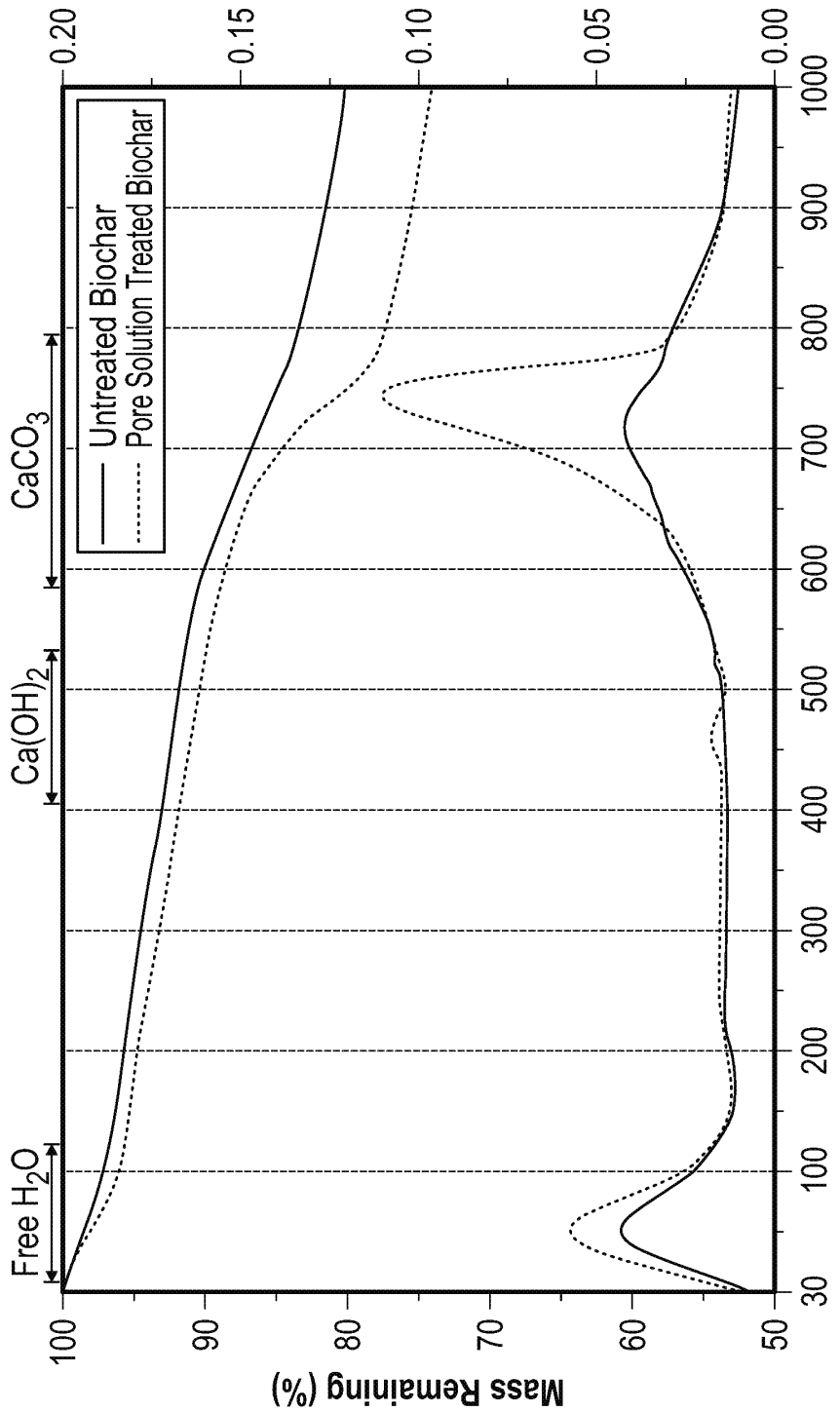

Rate of Mass Loss (dM/dT)
0.20
0.15
0.10
0.05
0.00
Untreated Biochar
Pore Solution Treated Biochar
$CaCO_3$
$Ca(OH)_2$
Free H_2O
Mass Remaining (%)
100
90
80
70
60
50
30
100
200
300
400
500
600
700
800
900
1000
Temperature (°C)

FIG. 36

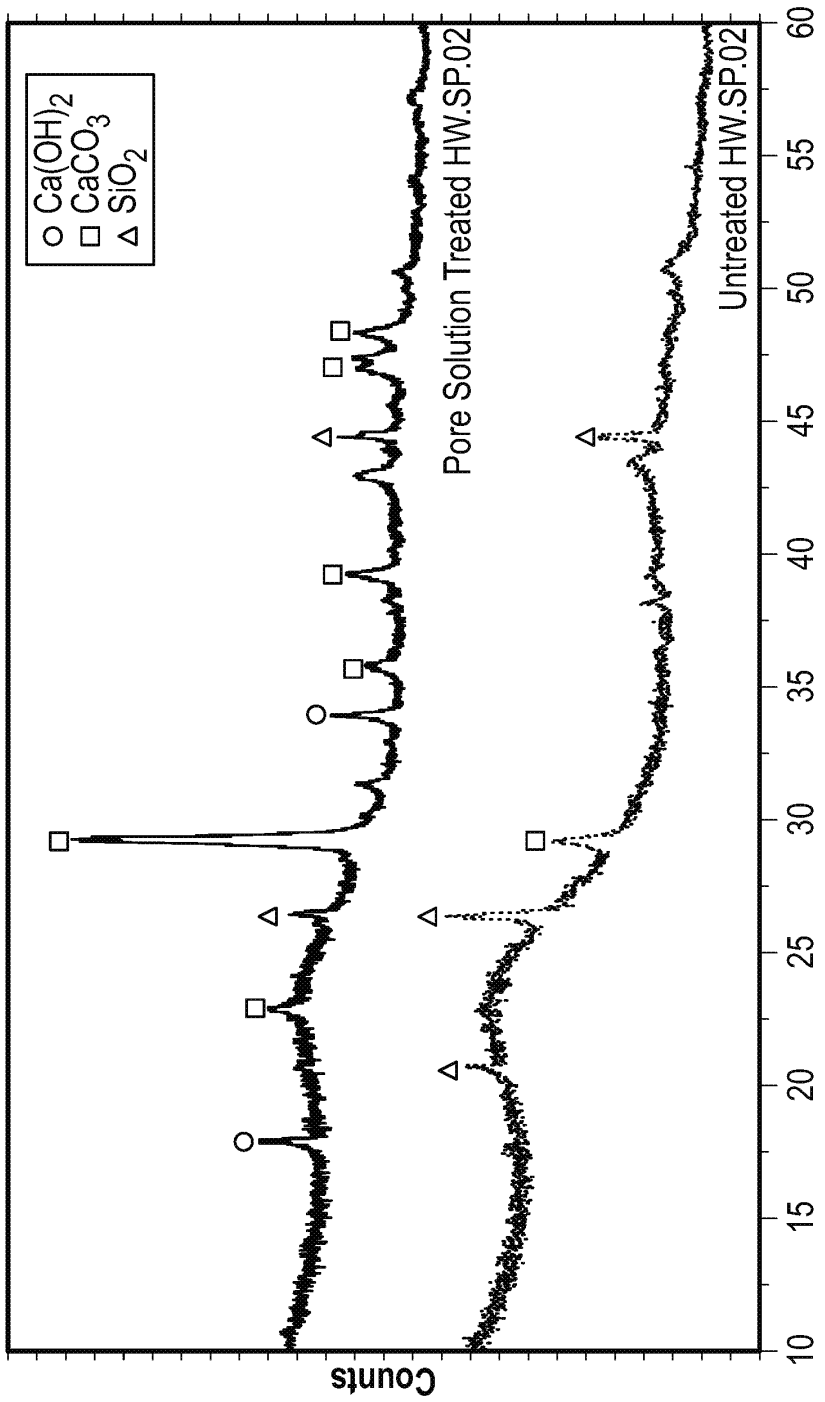

Ca(OH)2
CaCO3
SiO2
Pore Solution Treated HW.SP.02
Untreated HW.SP.02
Counts
2θ°
10
15
20
25
30
35
40
45
50
55
60

FIG. 37

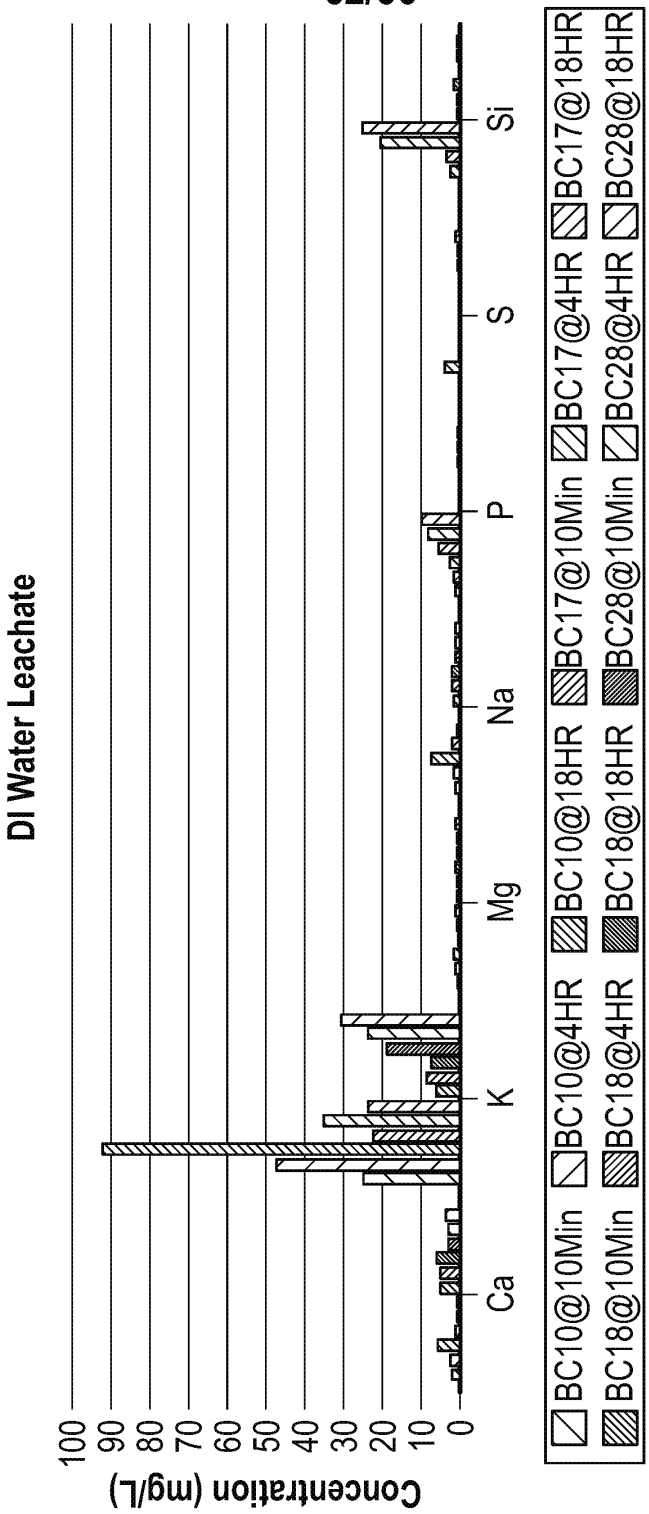

DI Water Leachate
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
Ca
K
Mg
Na
P
S
Si
BC10@10Min
BC10@4HR
BC10@18HR
BC17@10Min
BC17@4HR
BC17@18HR
BC18@10Min
BC18@4HR
BC18@18HR
BC28@10Min
BC28@4HR
BC28@18HR

FIG. 38

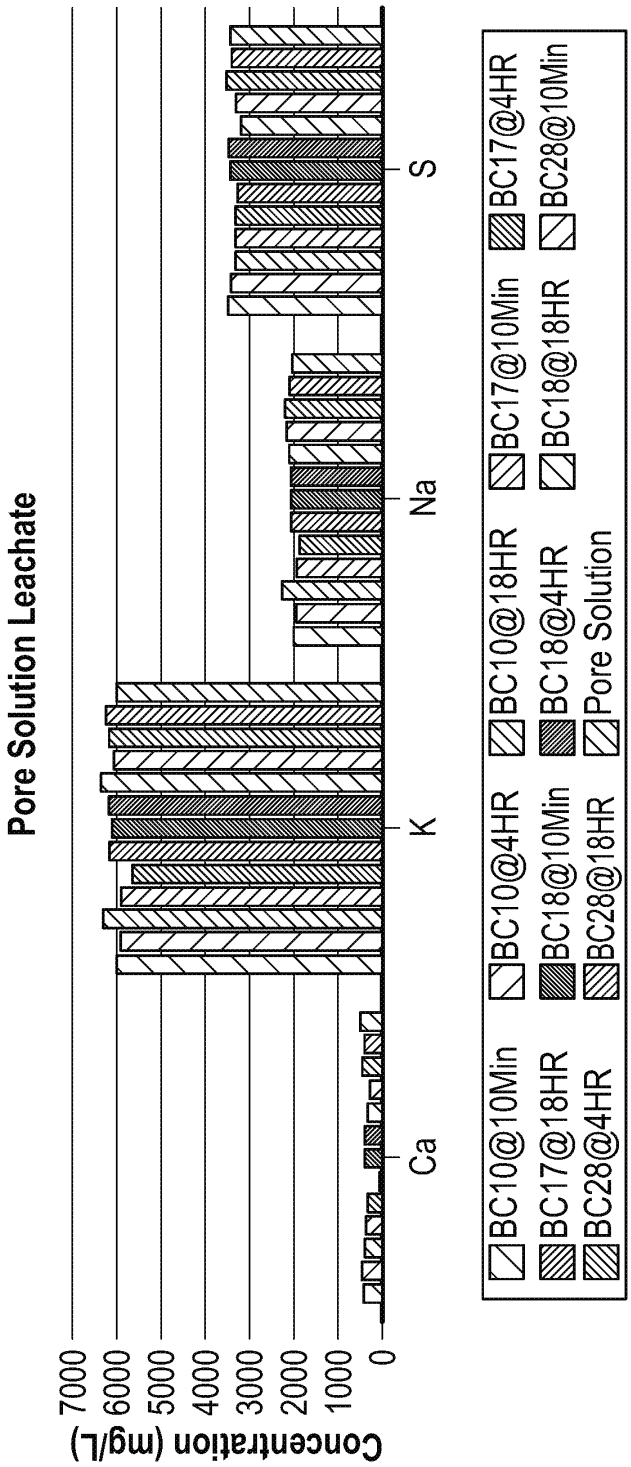

Pore Solution Leachate
Concentration (mg/L)
7000
6000
5000
4000
3000
2000
1000
0
Ca
K
Na
S
BC10@10Min
BC10@4HR
BC10@18HR
BC17@10Min
BC17@4HR
BC17@18HR
BC18@10Min
BC18@4HR
BC18@18HR
BC28@10Min
BC28@4HR
BC28@18HR
Pore Solution

FIG. 39

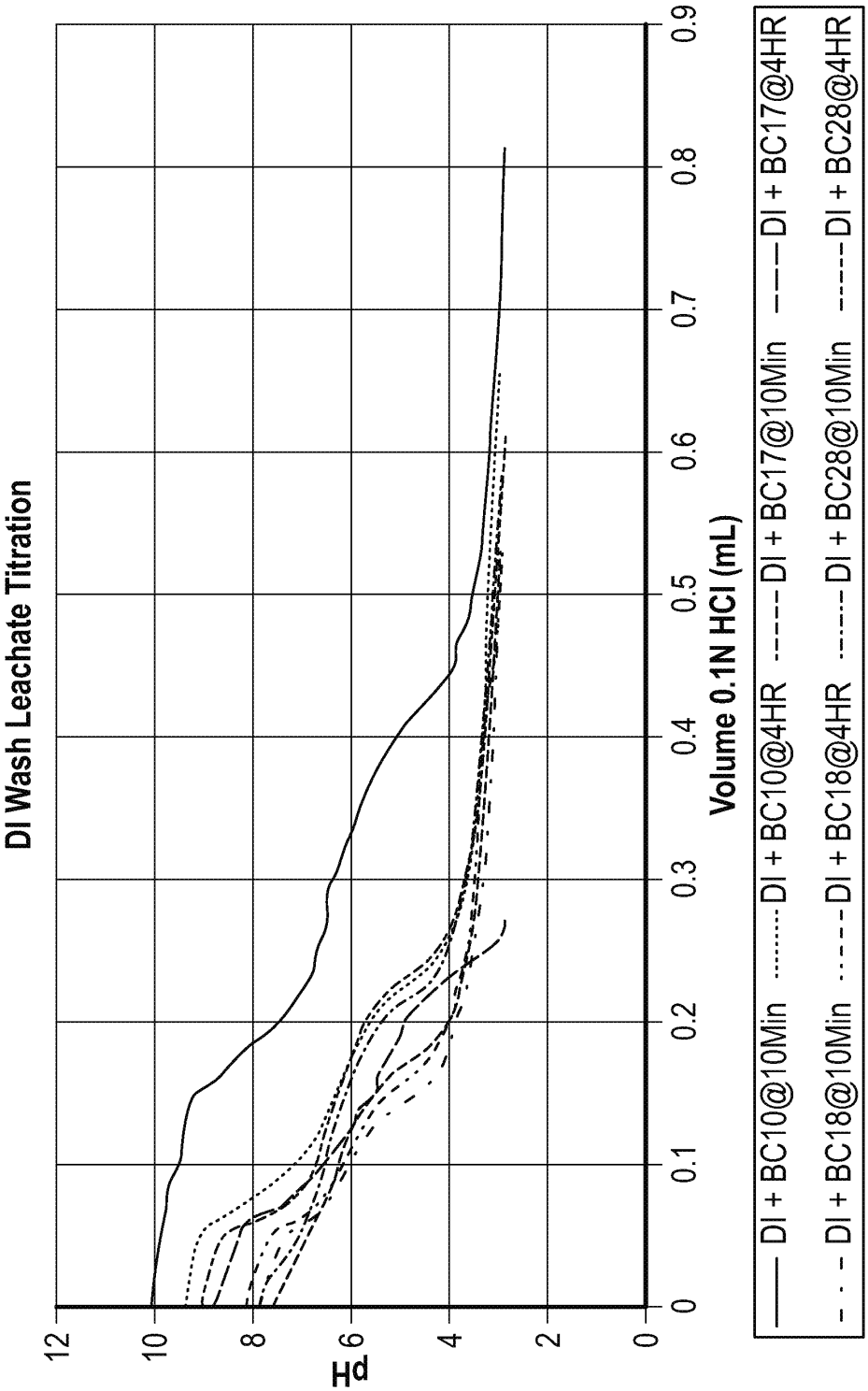

DI Wash Leachate Titration
pH
Volume 0.1N HCl (mL)
0
2
4
6
8
10
12
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
DI + BC10@10Min
DI + BC10@4HR
DI + BC17@10Min
DI + BC17@4HR
DI + BC18@10Min
DI + BC18@4HR
DI + BC28@10Min
DI + BC28@4HR

FIG. 40A

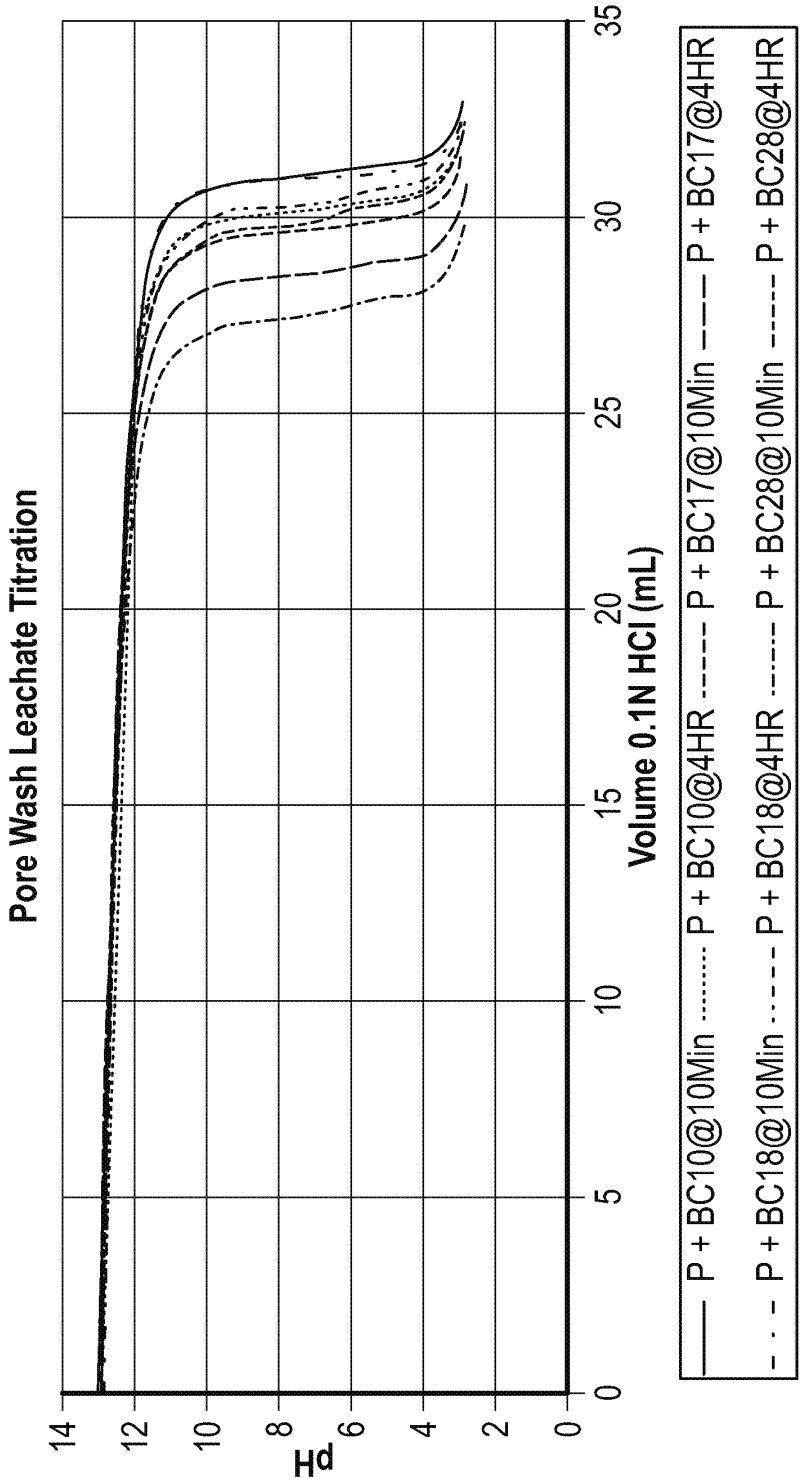

Pore Wash Leachate Titration
pH
Volume 0.1N HCl (mL)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
P + BC10@10Min
P + BC10@4HR
P + BC17@10Min
P + BC17@4HR
P + BC18@10Min
P + BC18@4HR
P + BC28@10Min
P + BC28@4HR

FIG. 40B

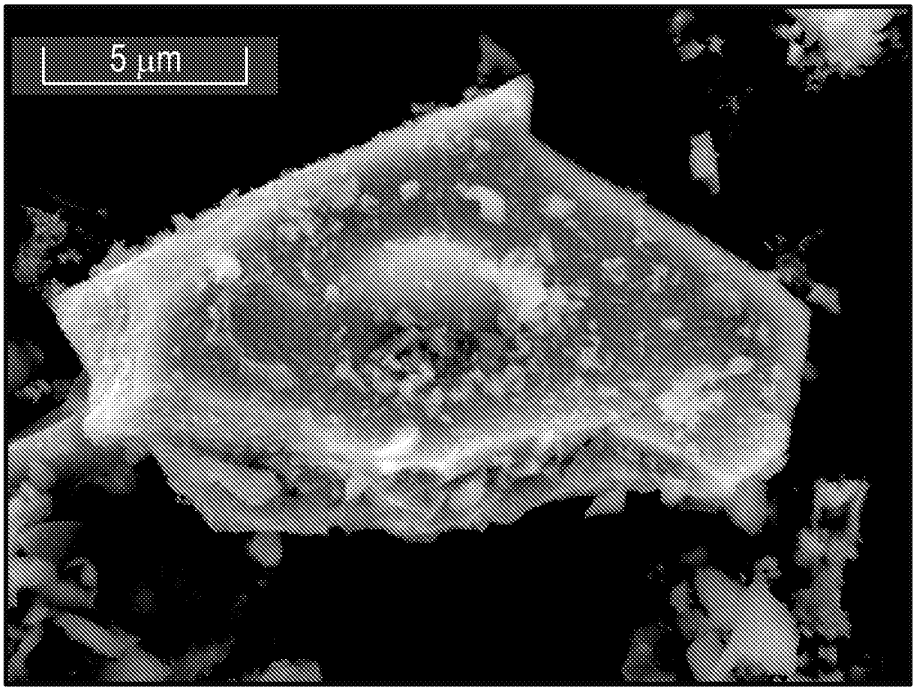


FIG. 41A

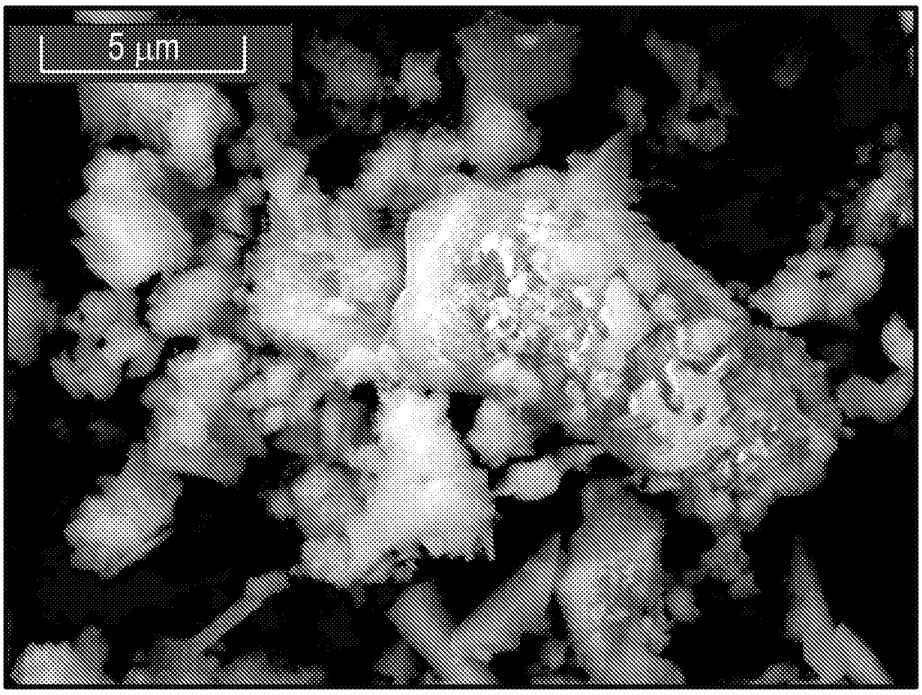


FIG. 41B