

1 Enhanced capacity of aluminum-ion batteries by
2 adjusting the average pore size of the porous carbon
3 cathodes

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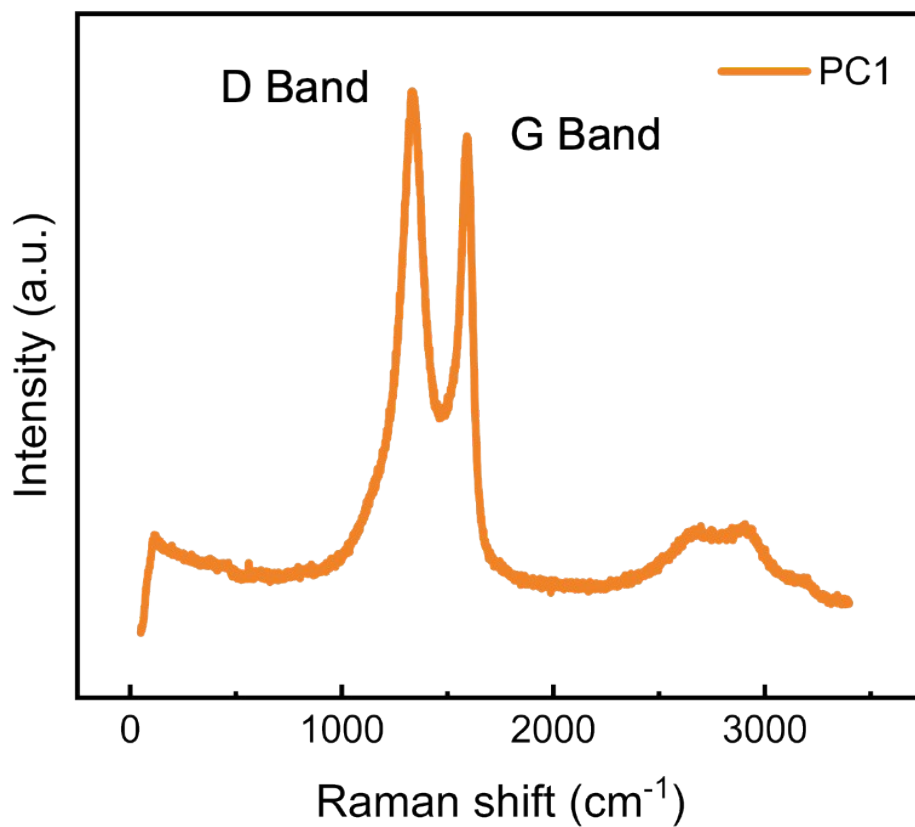
10 ^cSeiwa Electric Mfg. Co., Ltd., Kyoto 610-0192, Japan

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16 **Fig. S1** Raman spectra of PC1

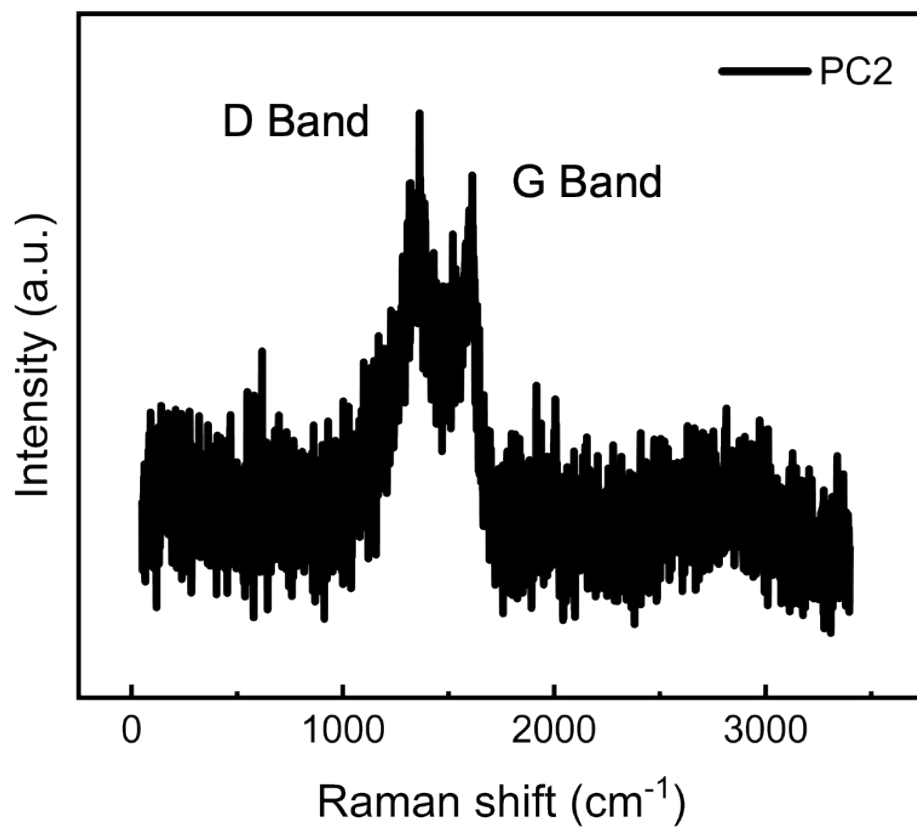
17 PC1 (YP50F) was commercially purchased and directly used as a cathode material

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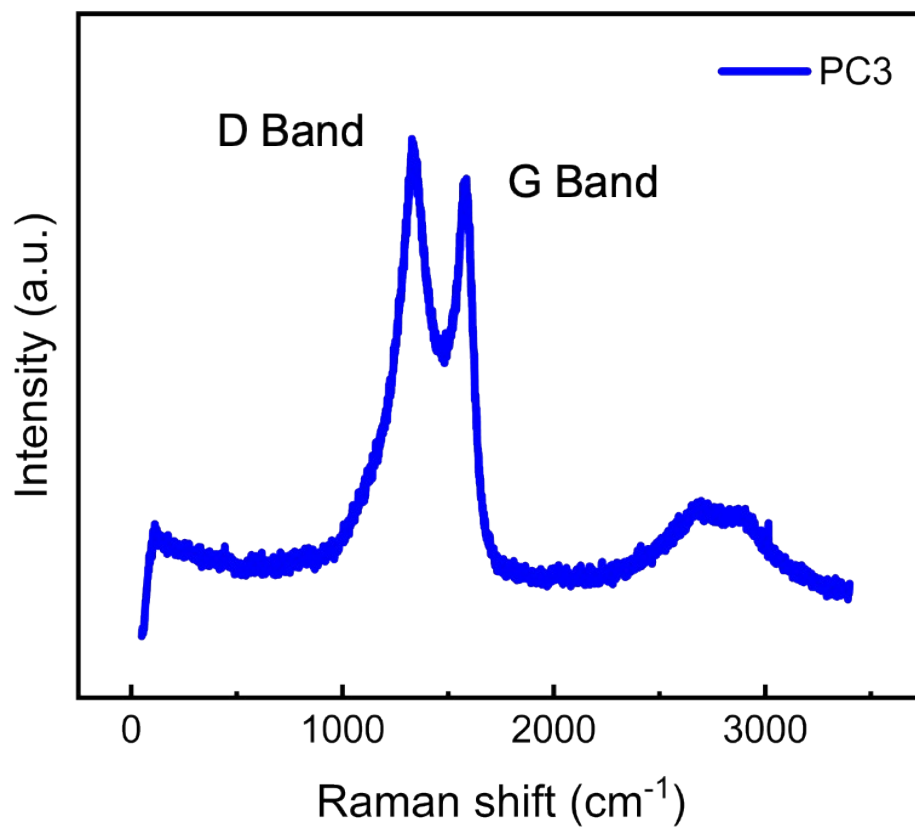
23 **Fig. S2** Raman spectra of PC2

24 PC2 (MSP-20) was commercially purchased and directly used as a cathode material

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29 **Fig. S3** Raman spectra of PC3

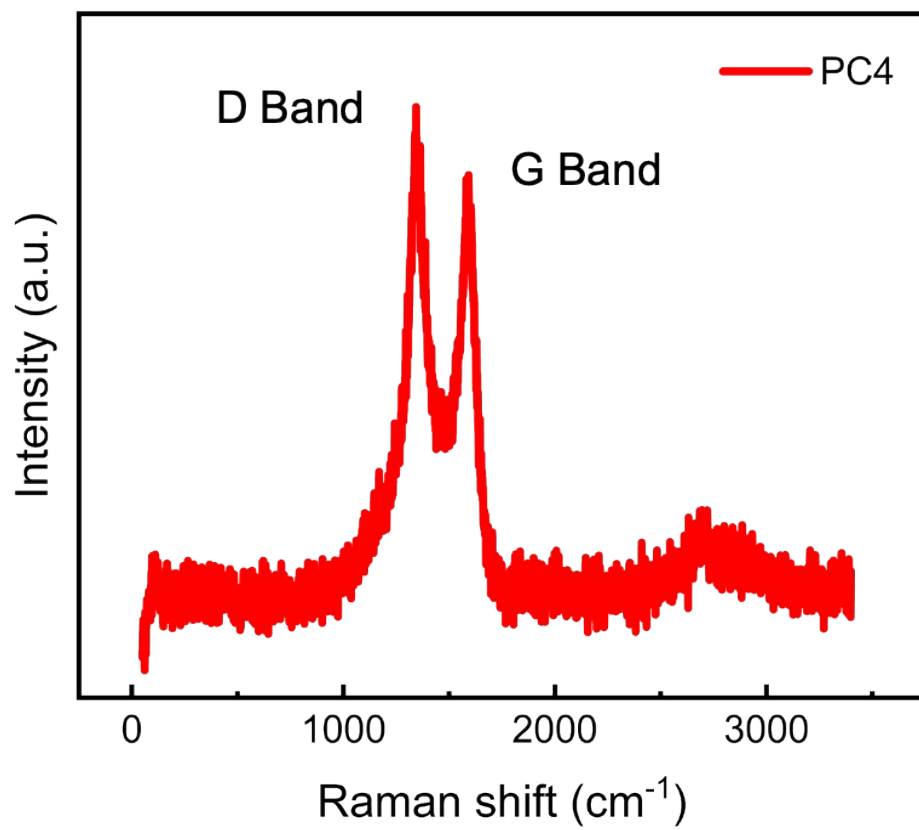
30 PC3 (MSA-20) was commercially purchased and directly used as a cathode material

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36 **Fig. S4** Raman spectra of PC4

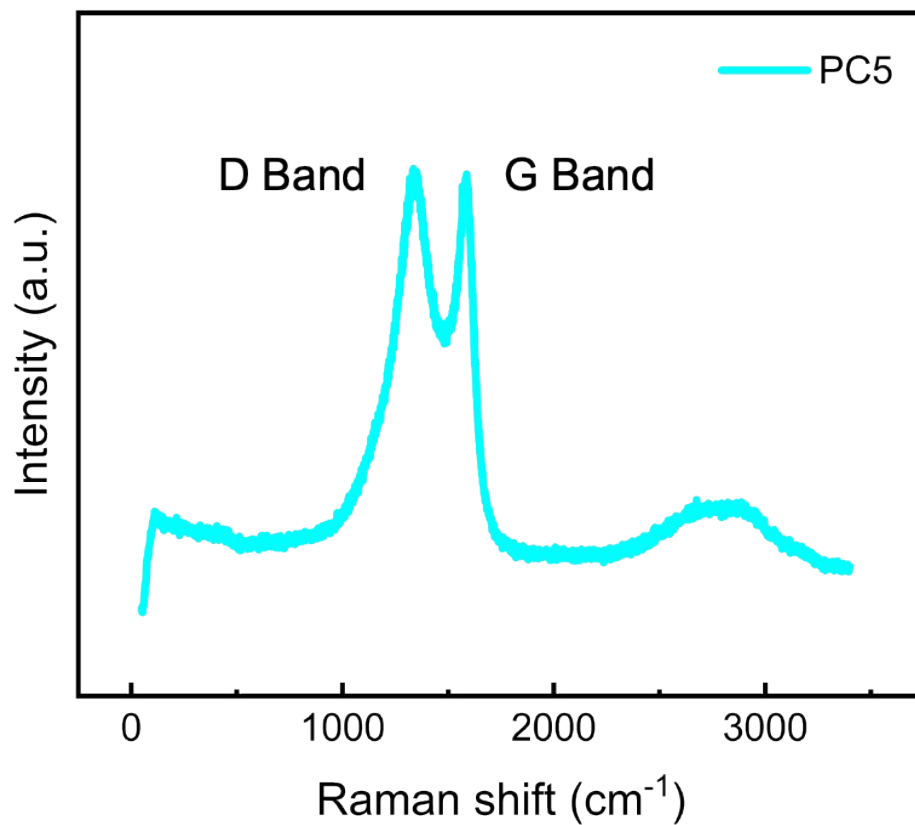
37 PC4 (MSC-30) was commercially purchased and directly used as a cathode material

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43 **Fig. S5** Raman spectra of PC5

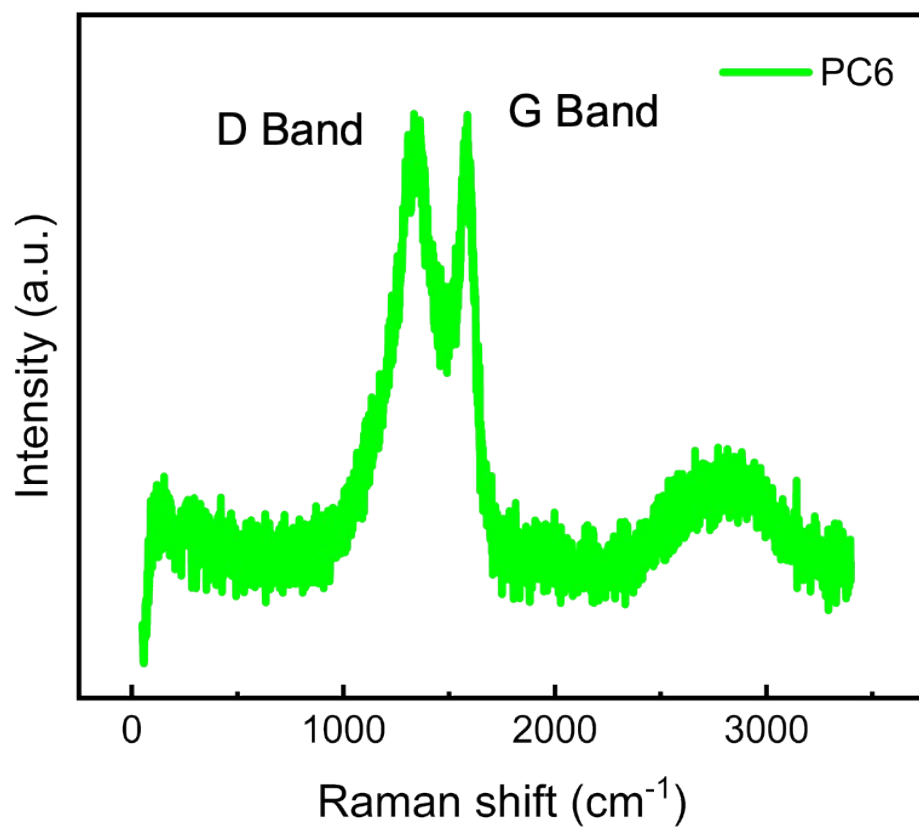
44 PC5 (CNovel 20 nm) was commercially purchased and directly used as a cathode material

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50 **Fig. S6** Raman spectra of PC6

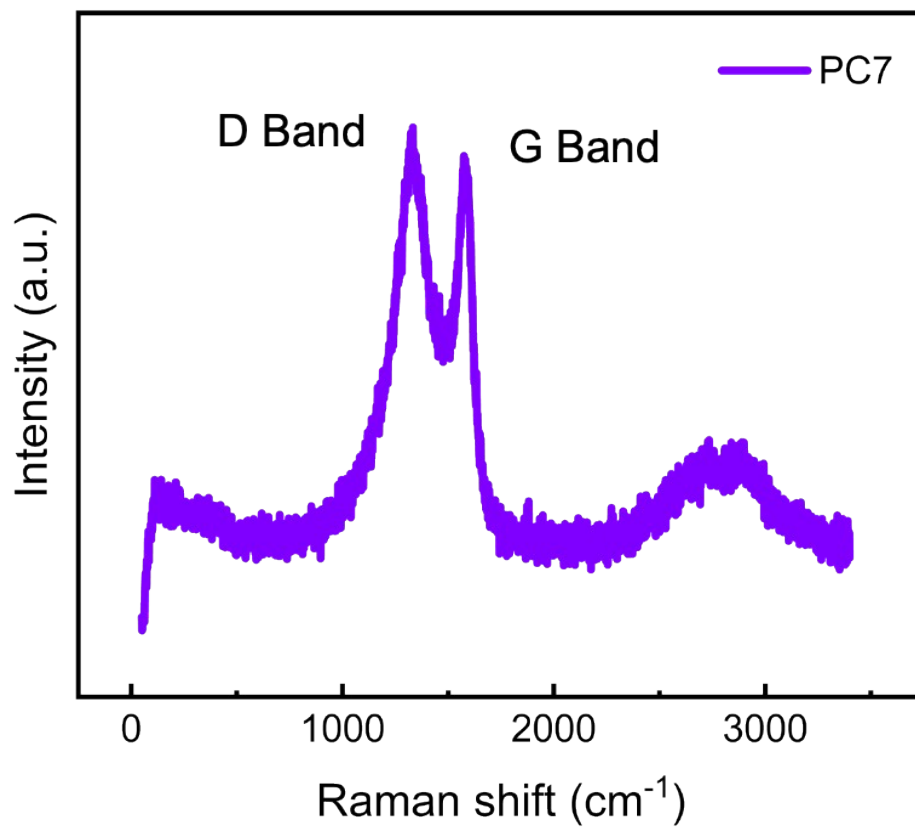
51 PC6 (CNovel MJ4 010-00) was commercially purchased and directly used as a cathode material

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57 **Fig. S7** Raman spectra of PC7

58 PC7 (CNovel MH-00) was commercially purchased and directly used as a cathode material

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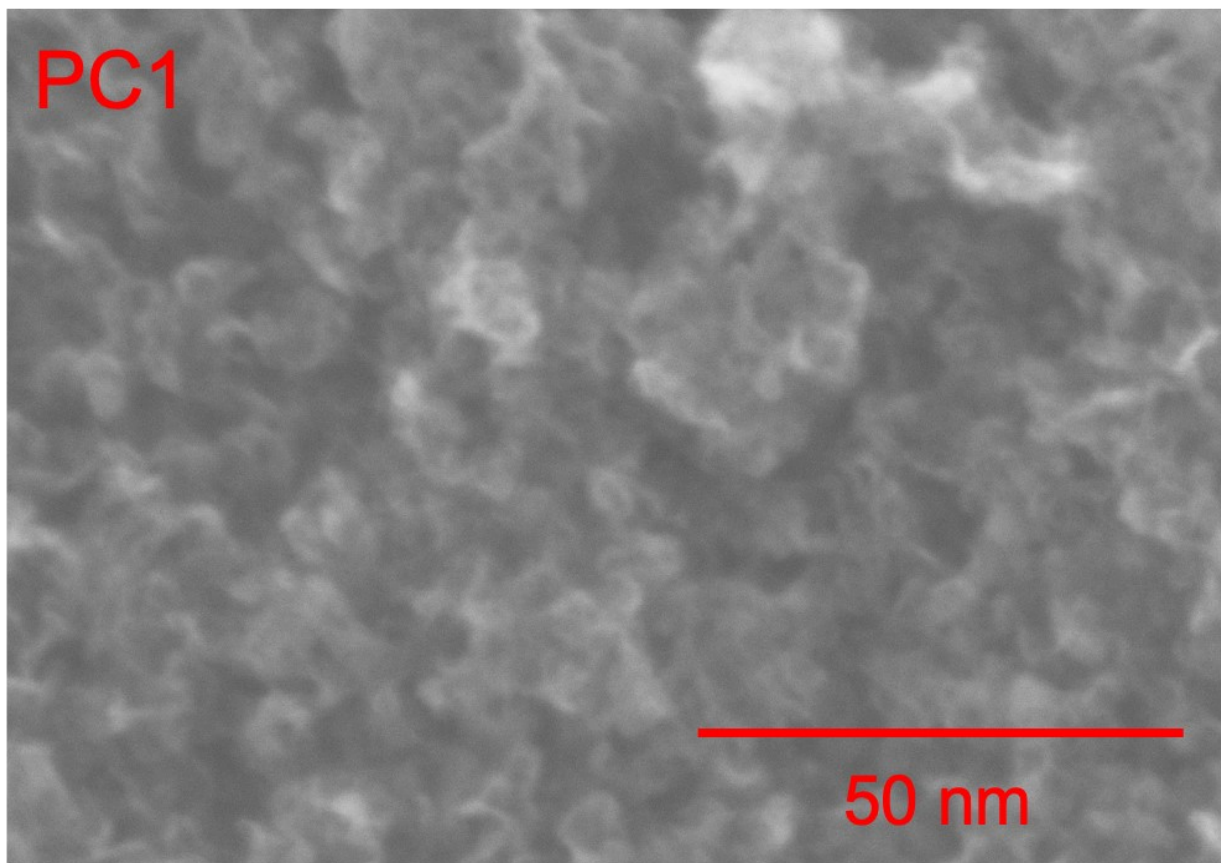
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66 **Fig. S8** Field emission scanning electron microscope image of the top view of PC1

67 PC1 (YP50F) was commercially purchased and directly used as a cathode material

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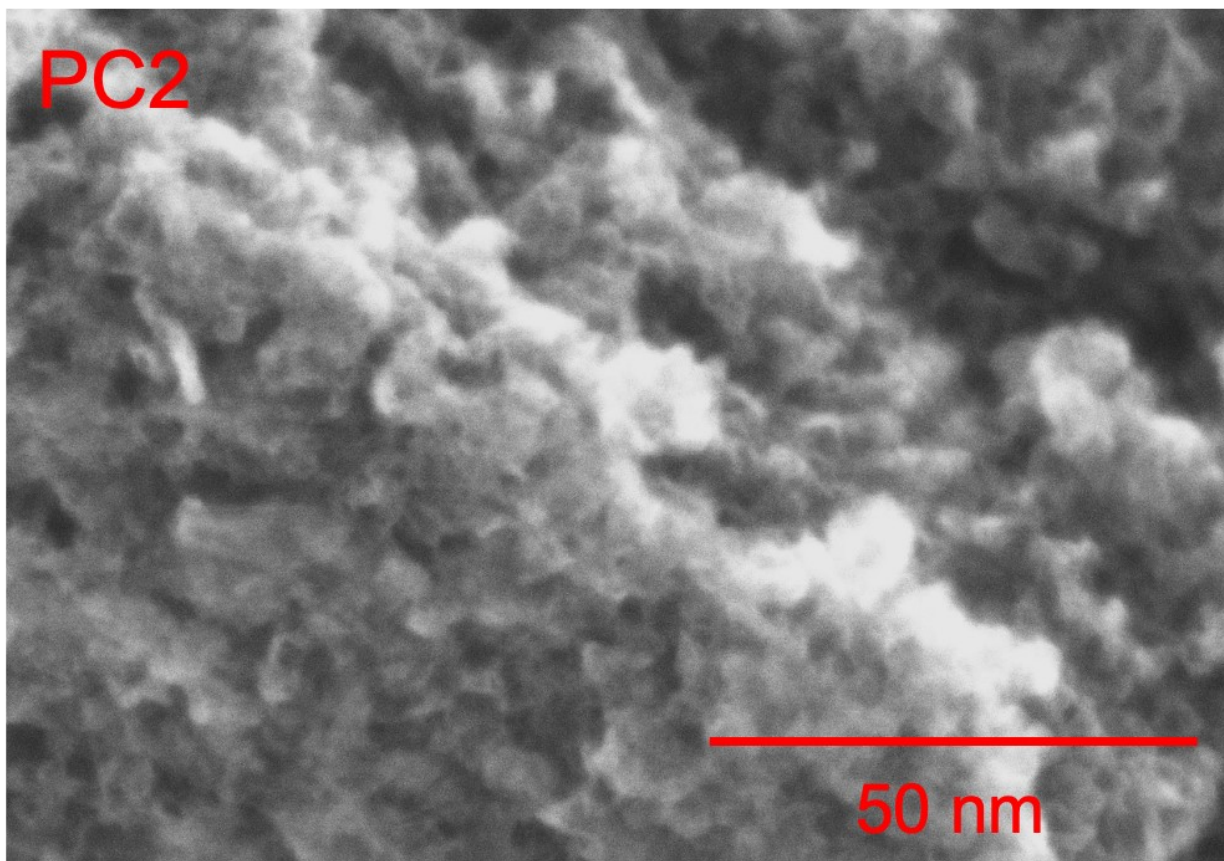
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75 **Fig. S9** Field emission scanning electron microscope image of the top view of PC2

76 PC2 (MSP-20) was commercially purchased and directly used as a cathode material

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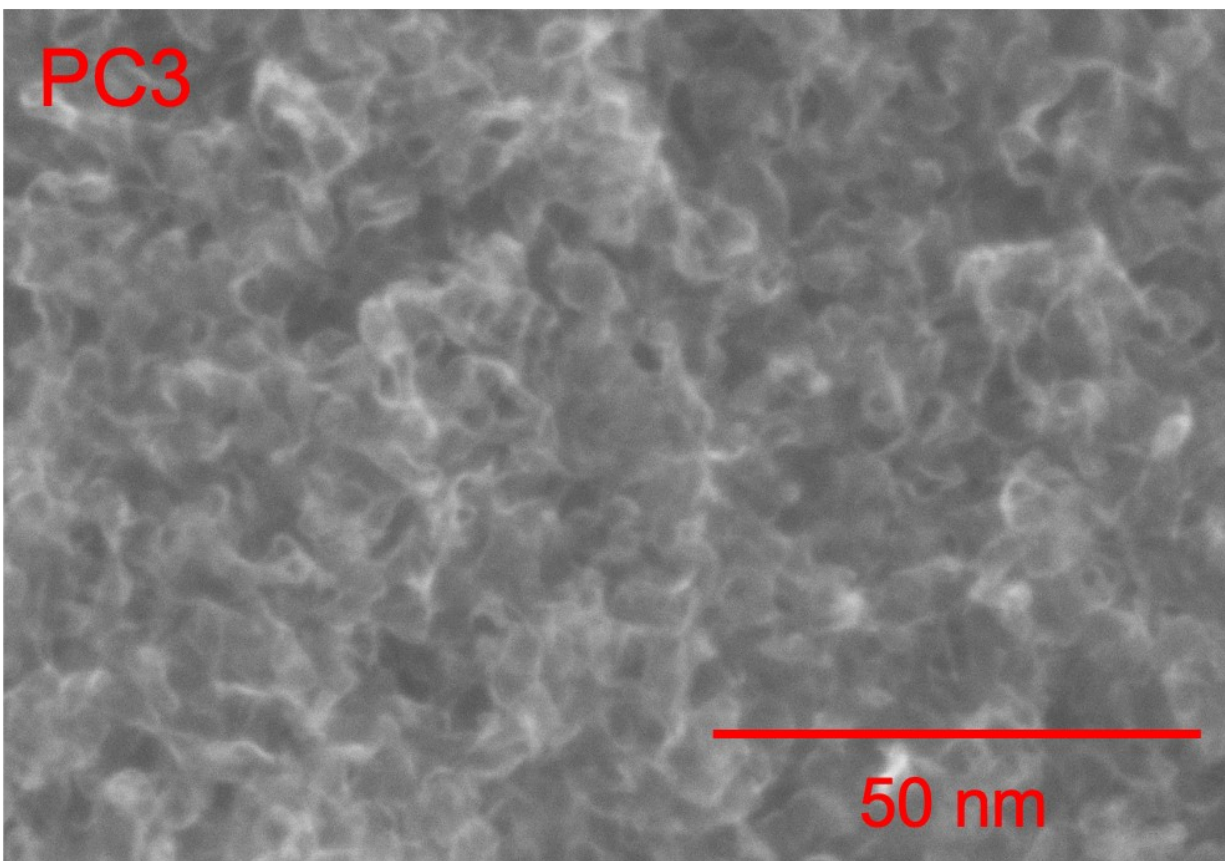
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84 **Fig. S10** Field emission scanning electron microscope image of the top view of PC3

85 PC3 (MSA-20) was commercially purchased and directly used as a cathode material

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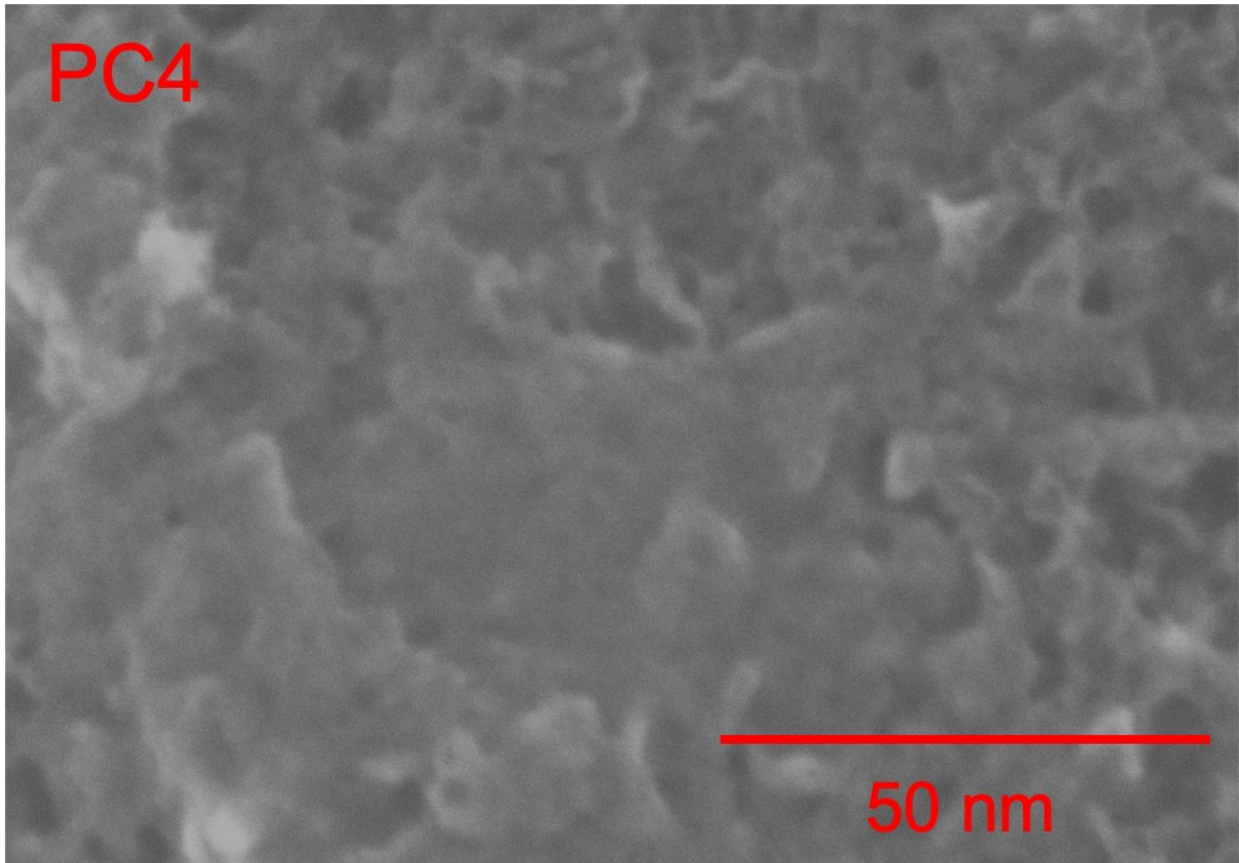
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93 **Fig. S11** Field emission scanning electron microscope image of the top view of PC4

94 PC4 (MSC-30) was commercially purchased and directly used as a cathode material

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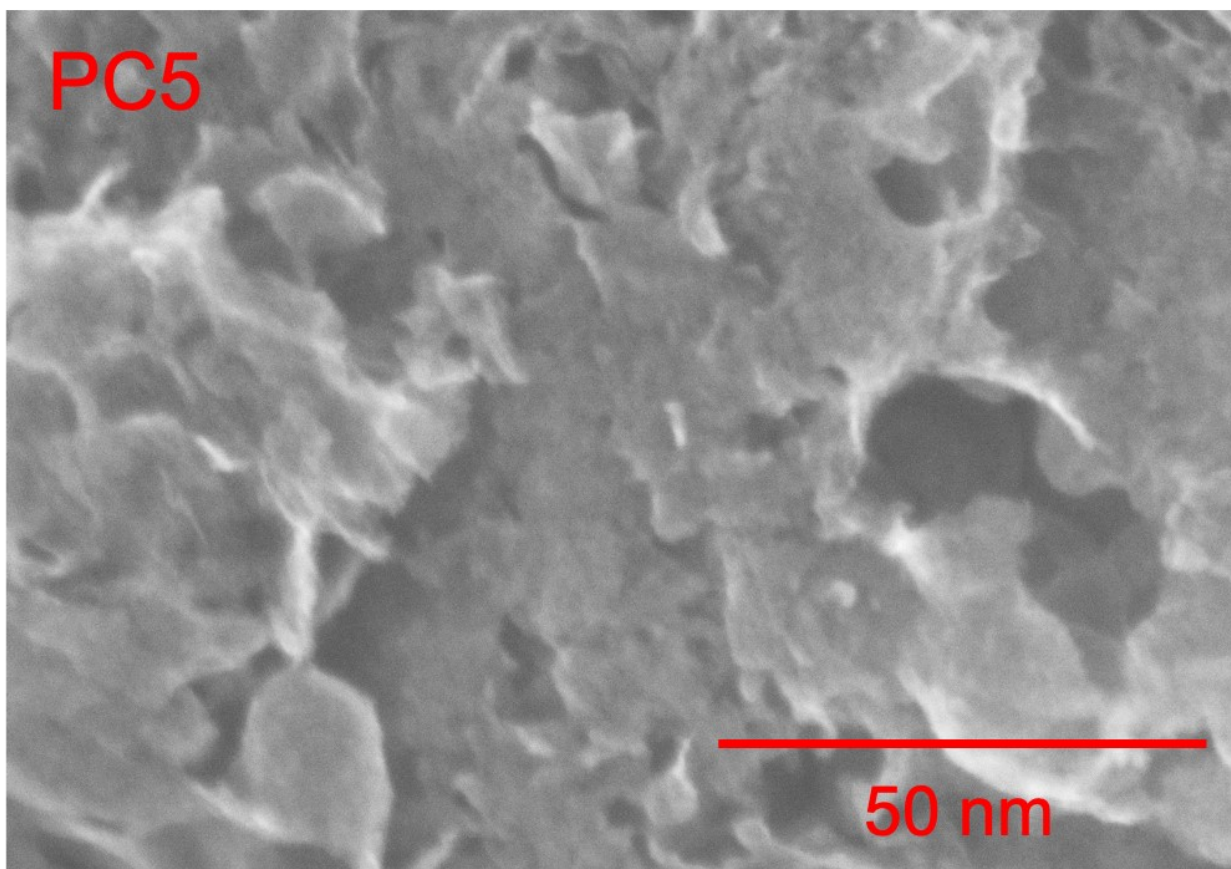
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102 **Fig. S12** Field emission scanning electron microscope image of the top view of PC5

103 PC5 (CNovel 20 nm) was commercially purchased and directly used as a cathode material

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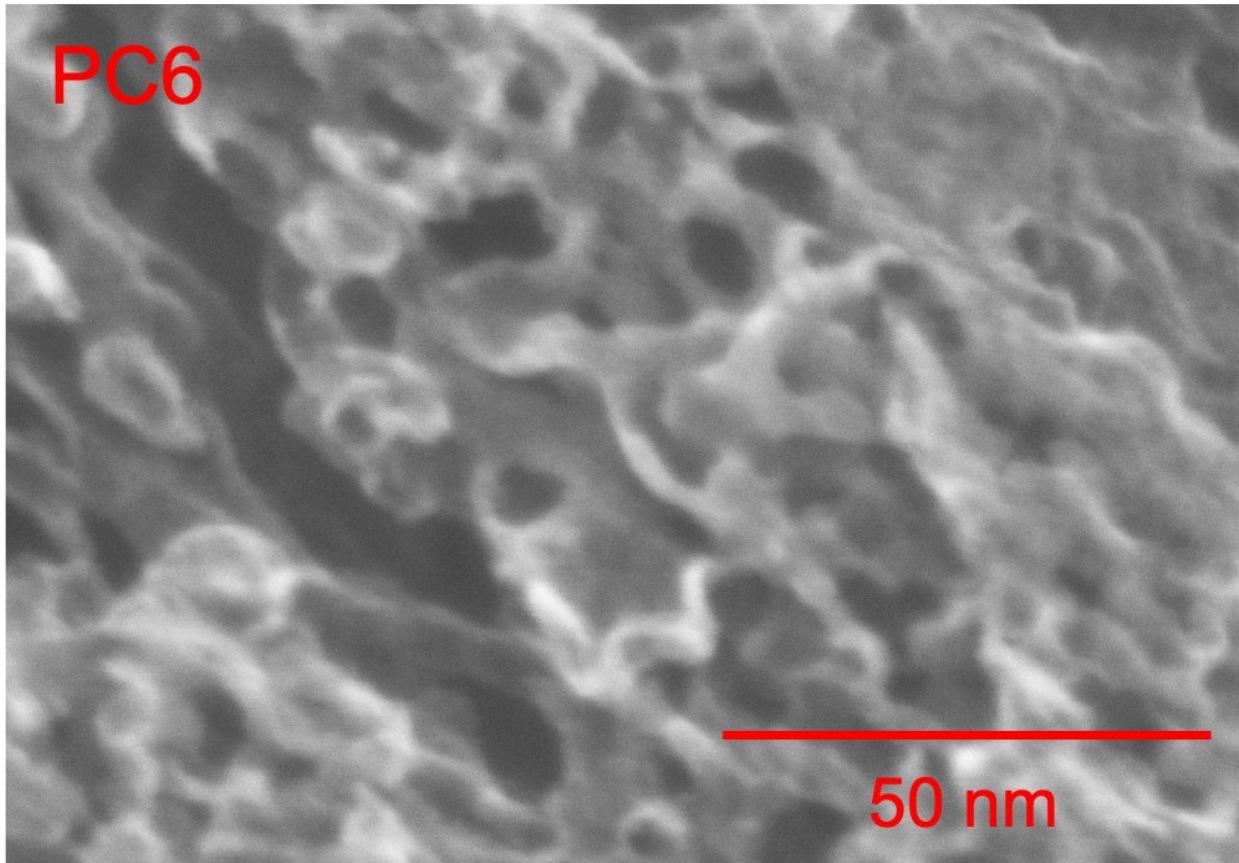
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111 **Fig. S13** Field emission scanning electron microscope image of the top view of PC6

112 PC6 (CNovel MJ4 010-00) was commercially purchased and directly used as a cathode material

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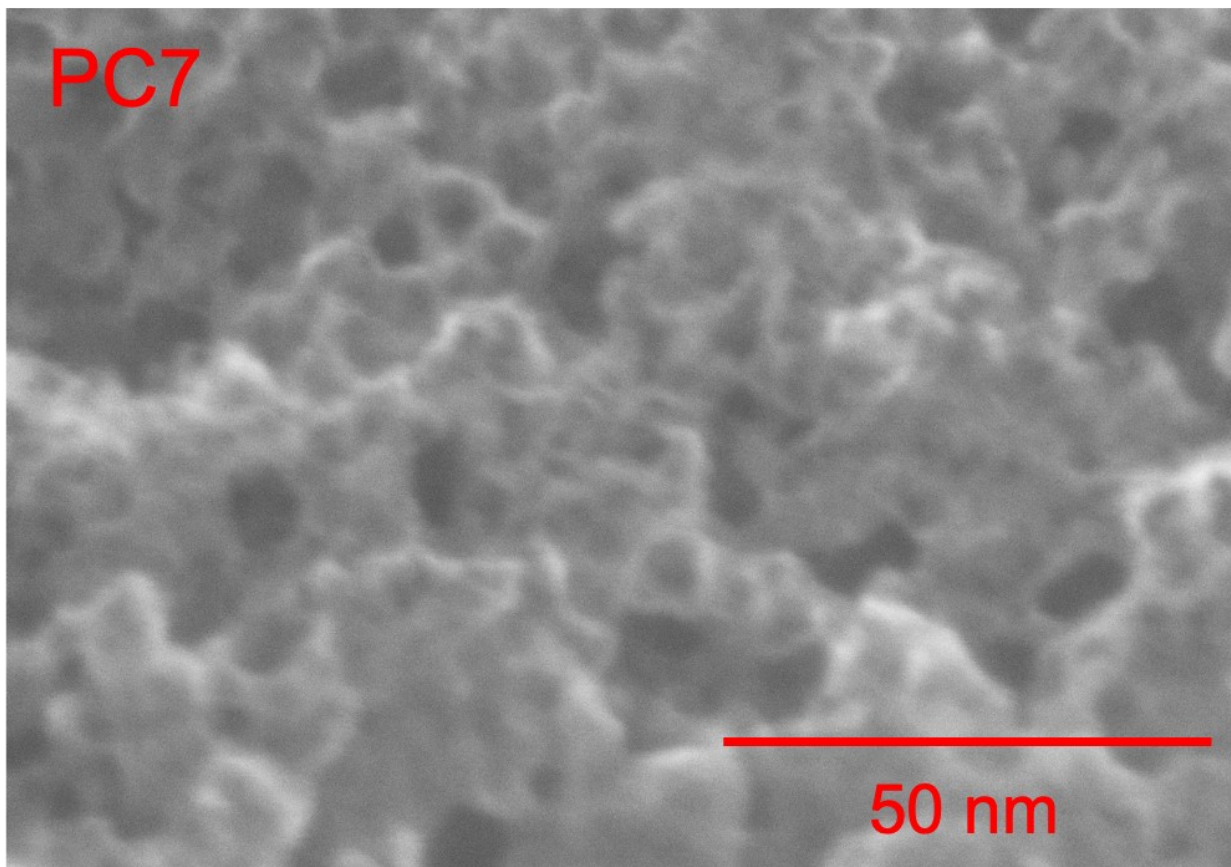
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120 **Fig. S14** Field emission scanning electron microscope image of the top view of PC7

121 PC7 (CNovel MH-00) was commercially purchased and directly used as a cathode material

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129 **Table S1** Specific surface area and pore structure characteristics of PC1, PC2, PC3, PC4, PC5,
130 PC6 and PC7, along with the capacity at a current density of 0.1 A/g and the ratio of capacity to
131 specific surface area.

Sample	Average pore width (nm)	Specific surface area (m ² /g)	Capacity at 0.1 A/g (mAh/g)	Capacity/Specific surface area
PC1	1.09	1616	44.48	0.03
PC2	1.09	2266	9.48	0.01
PC3	2.60	2514	103.66	0.04
PC4	2.48	3299	137.81	0.04
PC5	19.6	709	70.79	0.10
PC6	8.45	1031	118.81	0.12
PC7	4.43	1500	128.79	0.09

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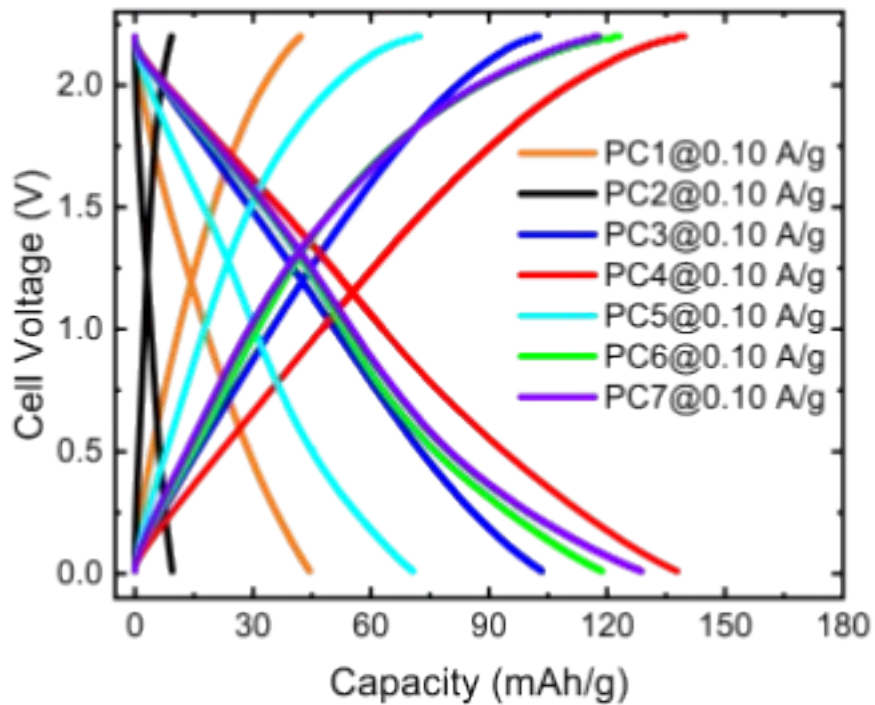
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142 **Fig. S15** Discharge capability of aluminum-ion batteries with PC1, PC2, PC3, PC4, PC5, PC6,

143 and PC7 as cathode materials at a current density of 0.10 A/g

144 PC1 (YP50F), PC2 (MSP-20), PC3 (MSA-20), PC4 (MSC-30), PC5 (CNovel 20 nm), PC6

145 (CNovel MJ4 010-00), and PC7 (CNovel MH-00) were commercially purchased and directly

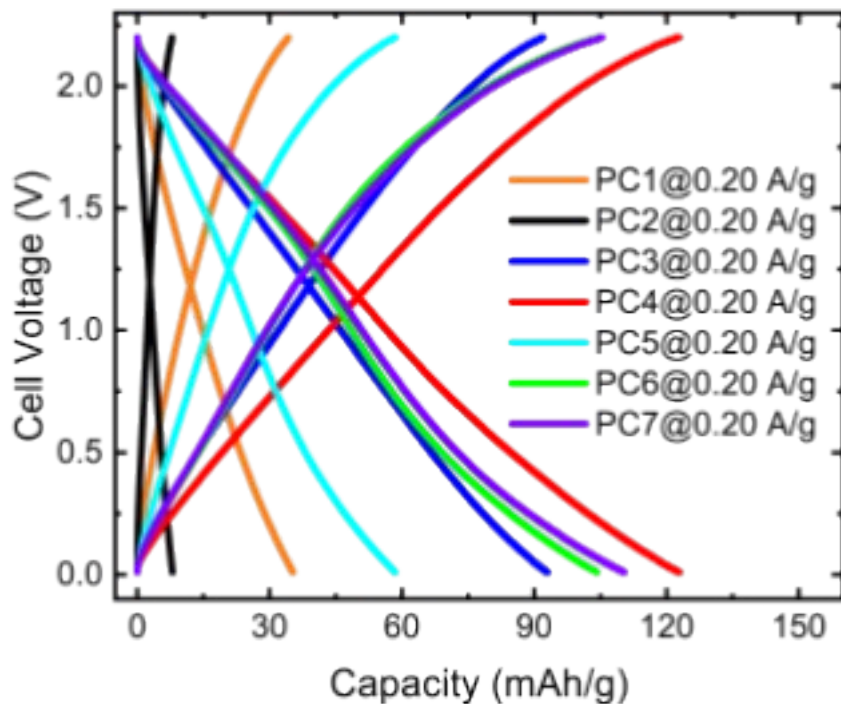
146 used as cathode materials

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152 **Fig. S16** Discharge capability of aluminum-ion batteries with PC1, PC2, PC3, PC4, PC5, PC6,
 153 and PC7 as cathode materials at a current density of 0.20 A/g

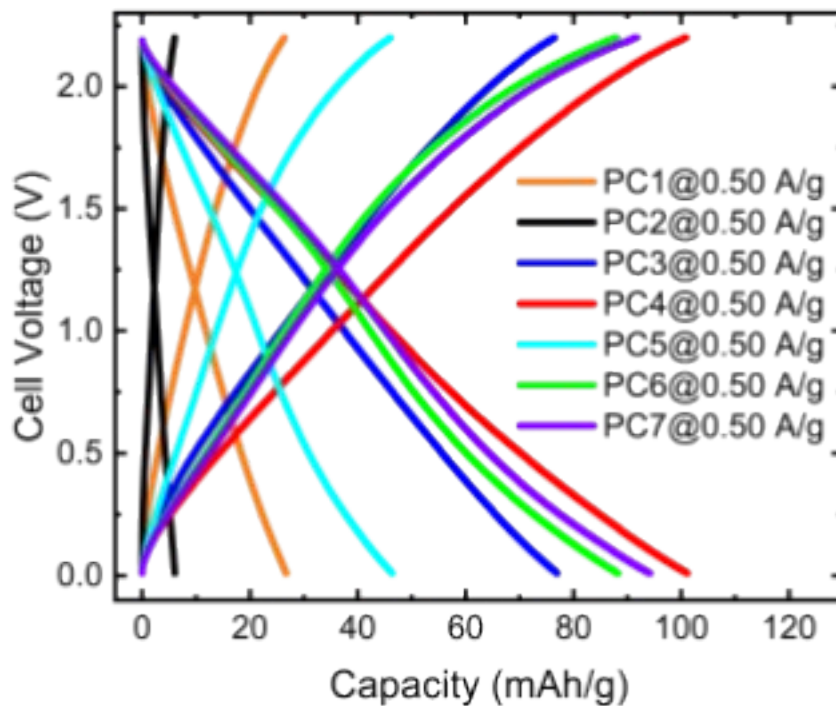
154 PC1 (YP50F), PC2 (MSP-20), PC3 (MSA-20), PC4 (MSC-30), PC5 (CNovel 20 nm), PC6
 155 (CNovel MJ4 010-00), and PC7 (CNovel MH-00) were commercially purchased and directly
 156 used as cathode materials

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162 **Fig. S17** Discharge capability of aluminum-ion batteries with PC1, PC2, PC3, PC4, PC5, PC6,
 163 and PC7 as cathode materials at a current density of 0.50 A/g

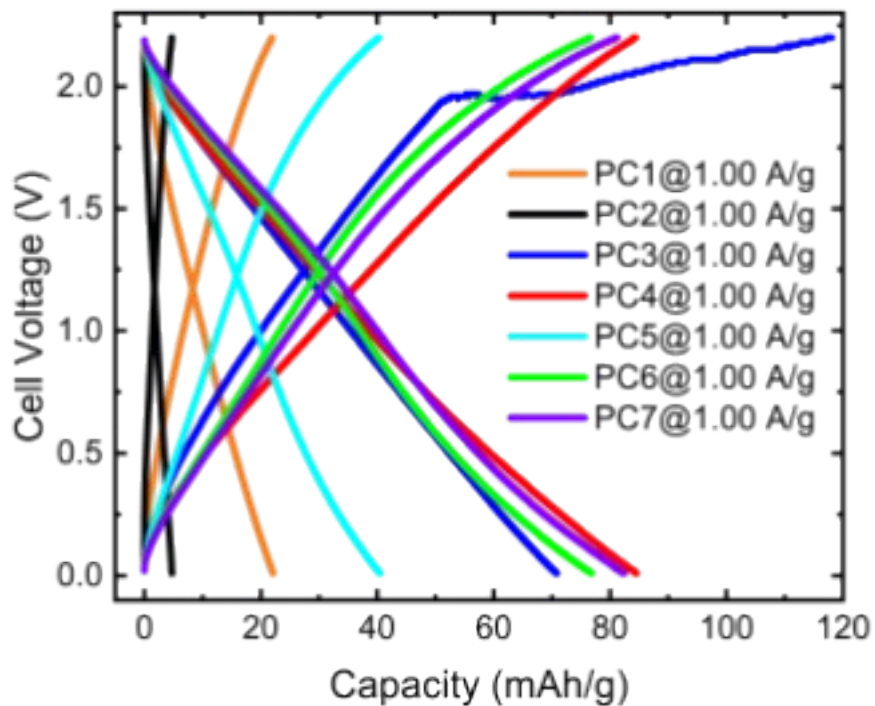
164 PC1 (YP50F), PC2 (MSP-20), PC3 (MSA-20), PC4 (MSC-30), PC5 (CNovel 20 nm), PC6
 165 (CNovel MJ4 010-00), and PC7 (CNovel MH-00) were commercially purchased and directly
 166 used as cathode materials

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172 **Fig. S18** Discharge capability of aluminum-ion batteries with PC1, PC2, PC3, PC4, PC5, PC6,
 173 and PC7 as cathode materials at a current density of 1.00 A/g

174 PC1 (YP50F), PC2 (MSP-20), PC3 (MSA-20), PC4 (MSC-30), PC5 (CNovel 20 nm), PC6
 175 (CNovel MJ4 010-00), and PC7 (CNovel MH-00) were commercially purchased and directly
 176 used as cathode materials

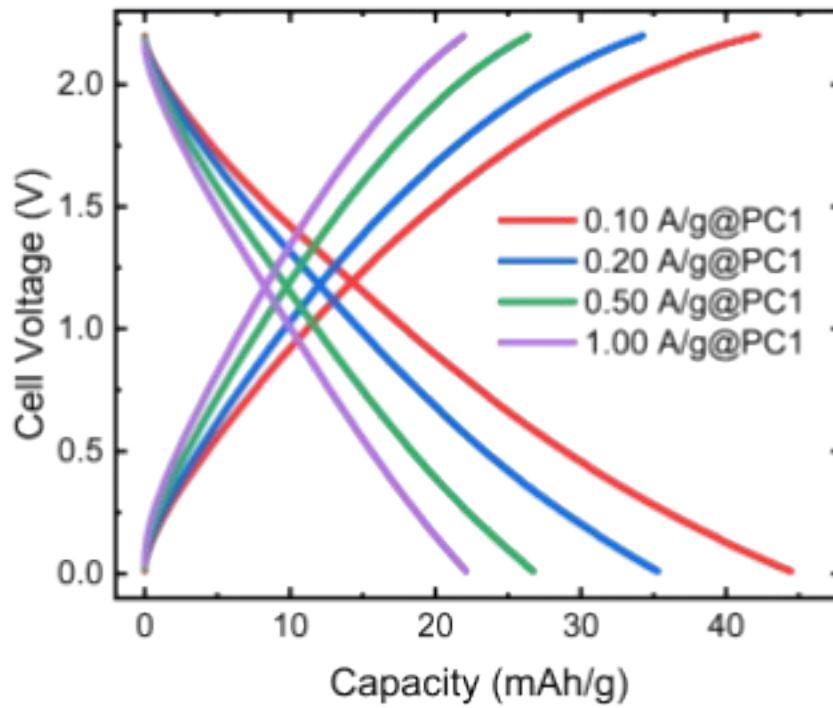
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183 **Fig. S19** Galvanostatic charge and discharge curves of an aluminum-ion battery with the cathode

184 material of PC1 at a series of current densities

185 PC1 (YP50F) was commercially purchased and directly used as a cathode material

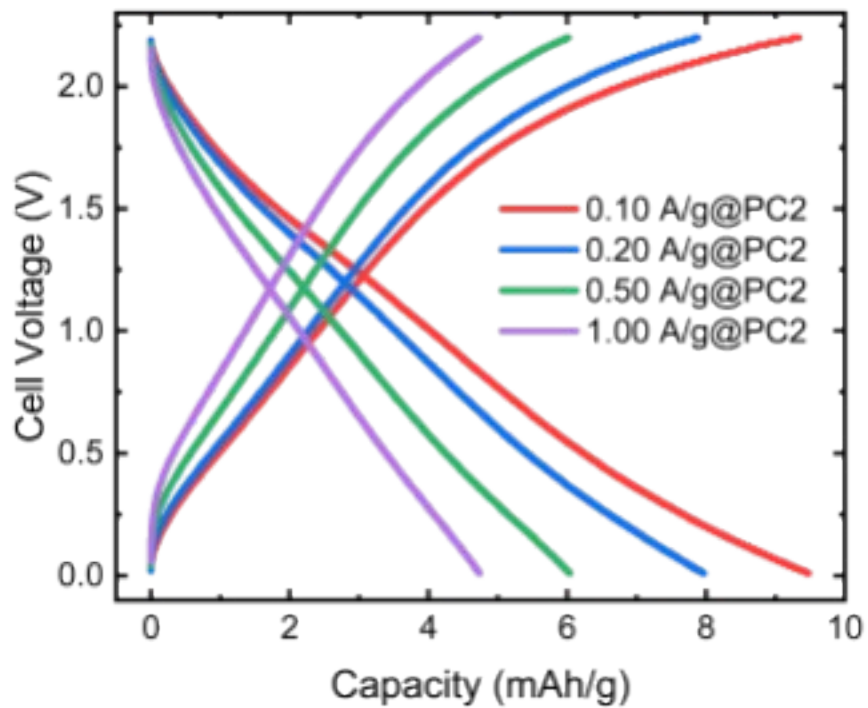
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192 **Fig. S20** Galvanostatic charge and discharge curves of an aluminum-ion battery with the cathode
193 material of PC2 at a series of current densities

194 PC2 (MSP-20) was commercially purchased and directly used as a cathode material

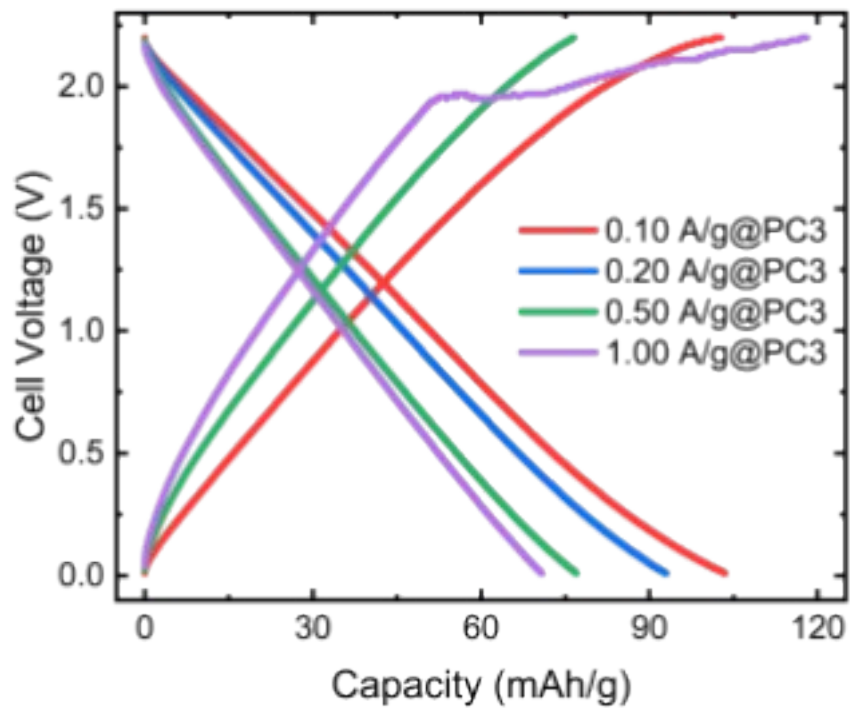
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201 **Fig. S21** Galvanostatic charge and discharge curves of an aluminum-ion battery with the cathode
 202 material of PC3 at a series of current densities

203 PC3 (MSA-20) was commercially purchased and directly used as a cathode material

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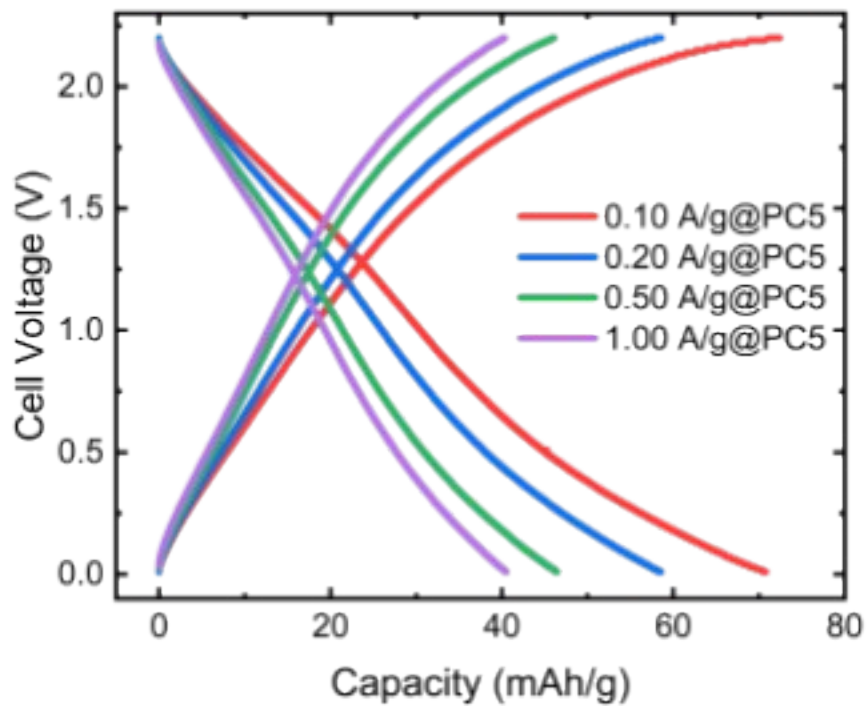
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211 **Fig. S22** Galvanostatic charge and discharge curves of an aluminum-ion battery with the cathode
212 material of PC5 at a series of current densities

213 PC5 (CNovel 20 nm) was commercially purchased and directly used as a cathode material

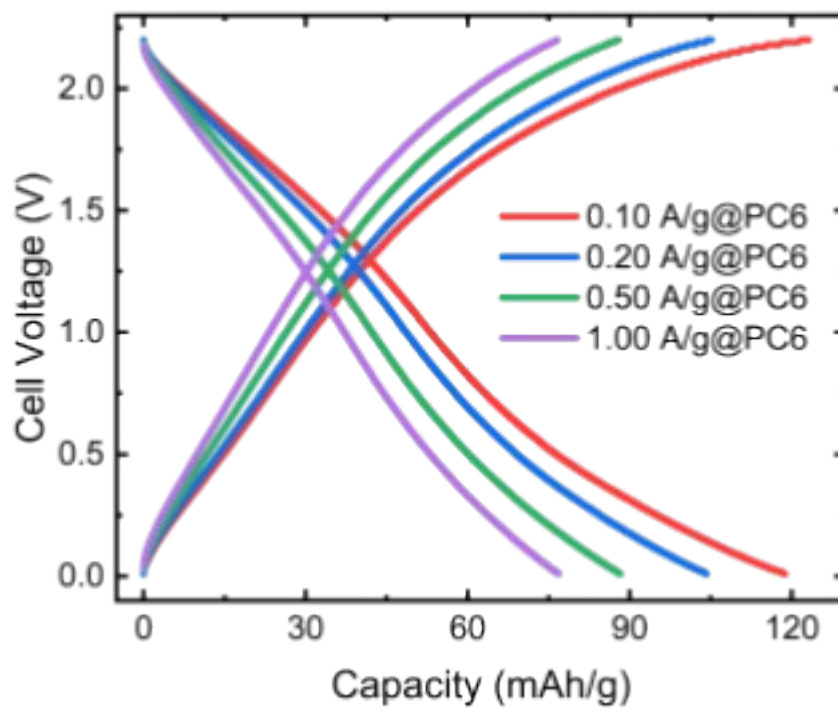
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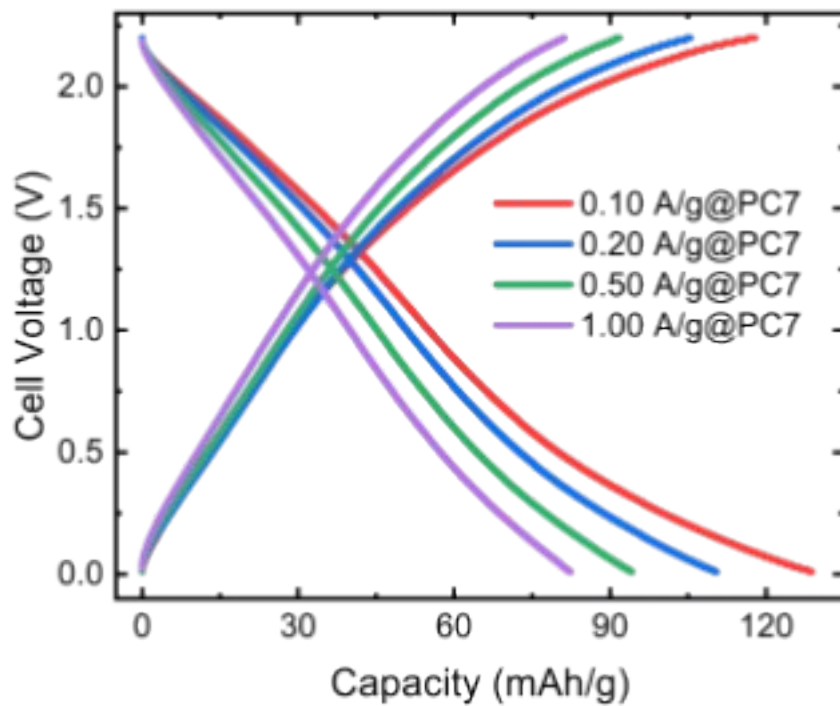
220 **Fig. S23** Galvanostatic charge and discharge curves of an aluminum-ion battery with the cathode
221 material of PC6 at a series of current densities

222 PC6 (CNovel MJ4 010-00) was commercially purchased and directly used as a cathode material

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227 **Fig. S24** Galvanostatic charge and discharge curves of an aluminum-ion battery with the cathode
228 material of PC7 at a series of current densities

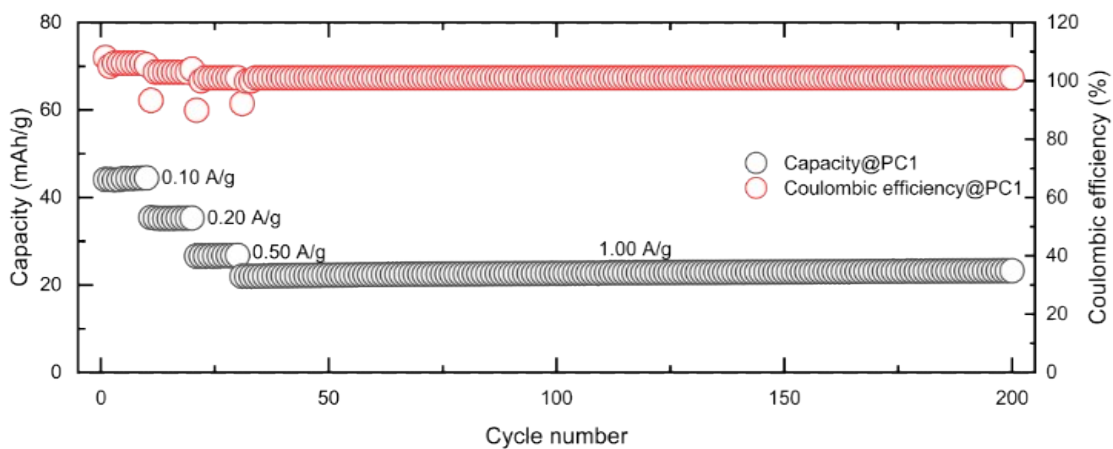
229 PC7 (CNovel MH-00) was commercially purchased and directly used as a cathode material

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235 **Fig. S25** Discharge capability and coulombic efficiency of an aluminum-ion battery with the

236 cathode material of PC1 at a series of current densities

237 PC1 (YP50F) was commercially purchased and directly used as a cathode material

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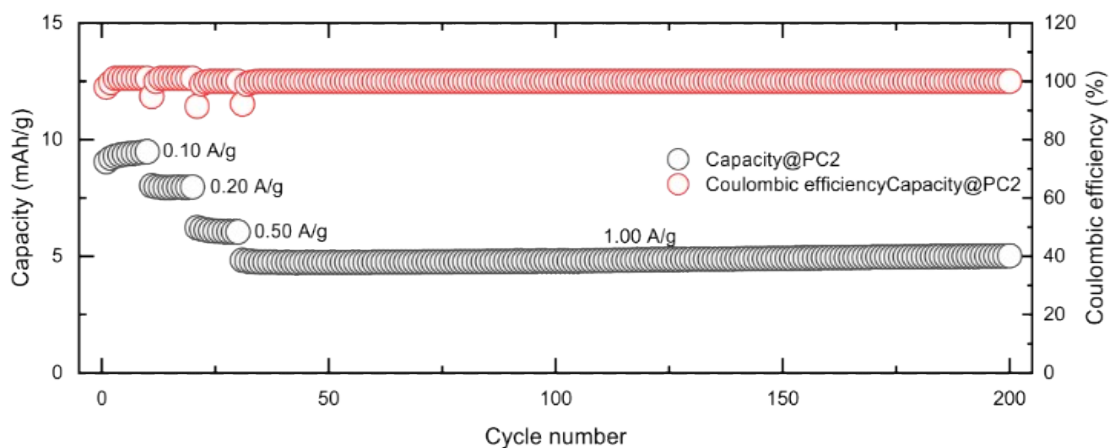
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248 **Fig. S26** Discharge capability and coulombic efficiency of an aluminum-ion battery with the

249 cathode material of PC2 at a series of current densities

250 PC2 (MSP-20) was commercially purchased and directly used as a cathode material

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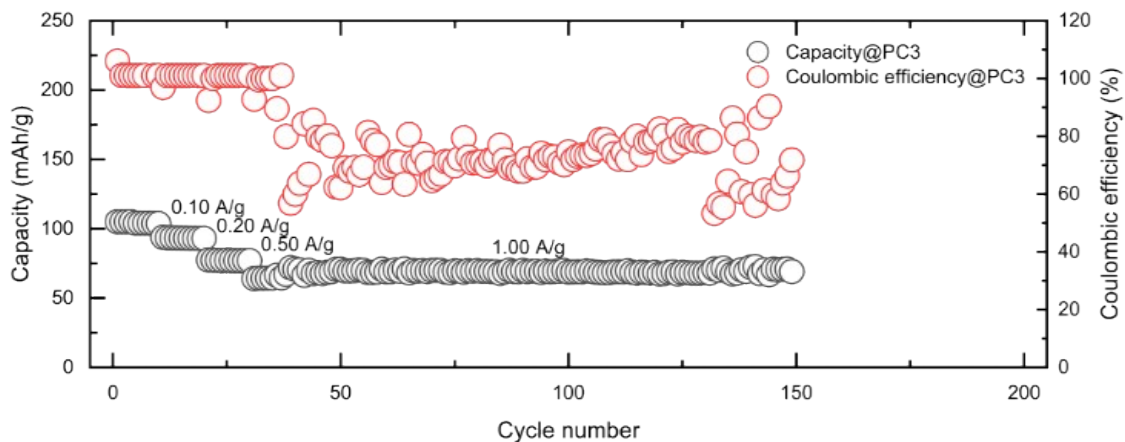
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261 **Fig. S27** Discharge capability and coulombic efficiency of an aluminum-ion battery with the
 262 cathode material of PC3 at a series of current densities

263 PC3 (MSA-20) was commercially purchased and directly used as a cathode material

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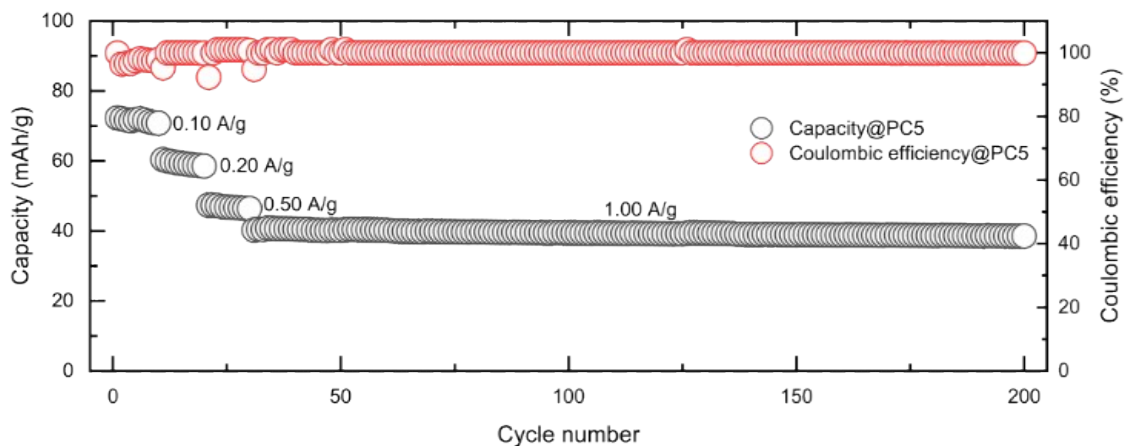
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275 **Fig. S28** Discharge capability and coulombic efficiency of an aluminum-ion battery with the

276 cathode material of PC5 at a series of current densities

277 PC5 (CNovel 20 nm) was commercially purchased and directly used as a cathode material

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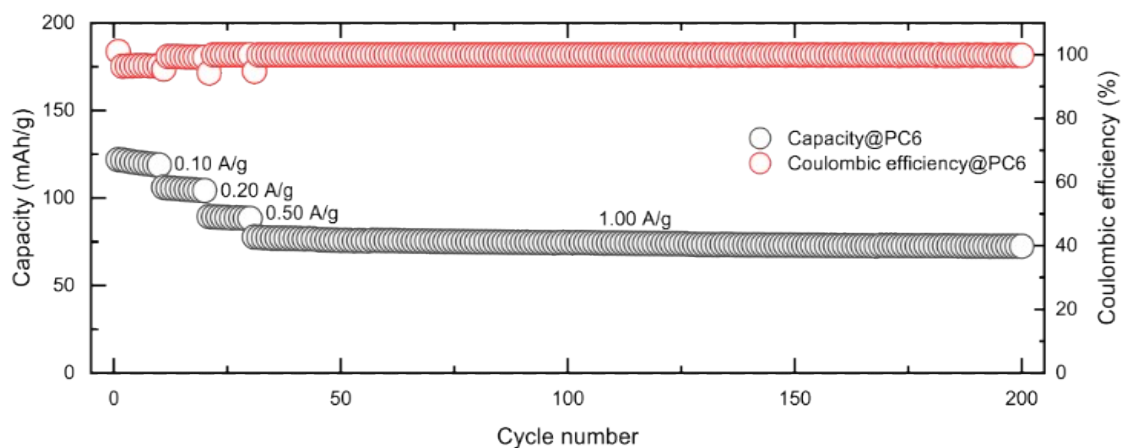
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288 **Fig. S29** Discharge capability and coulombic efficiency of an aluminum-ion battery with the

289 cathode material of PC6 at a series of current densities

290 PC6 (CNovel MJ4 010-00) was commercially purchased and directly used as a cathode material

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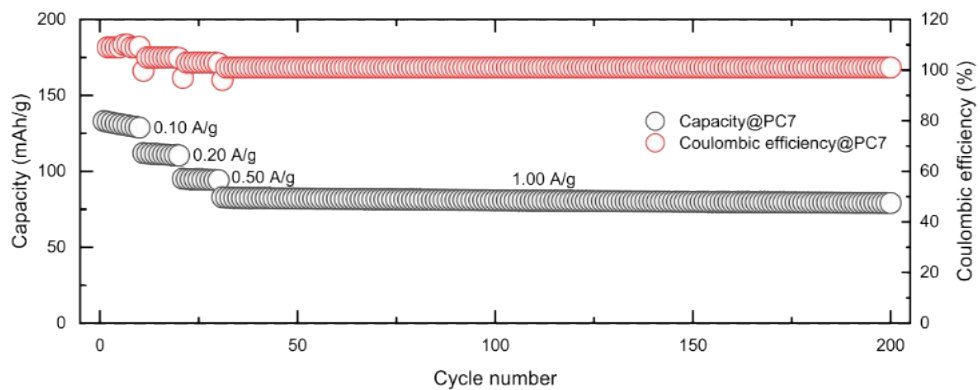
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298 **Fig. S30** Discharge capability and coulombic efficiency of an aluminum-ion battery with the

299 cathode material of PC7 at a series of current densities

300 PC7 (CNovel MH-00) was commercially purchased and directly used as a cathode material

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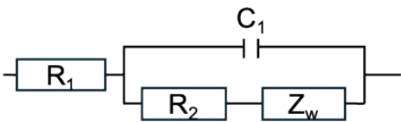
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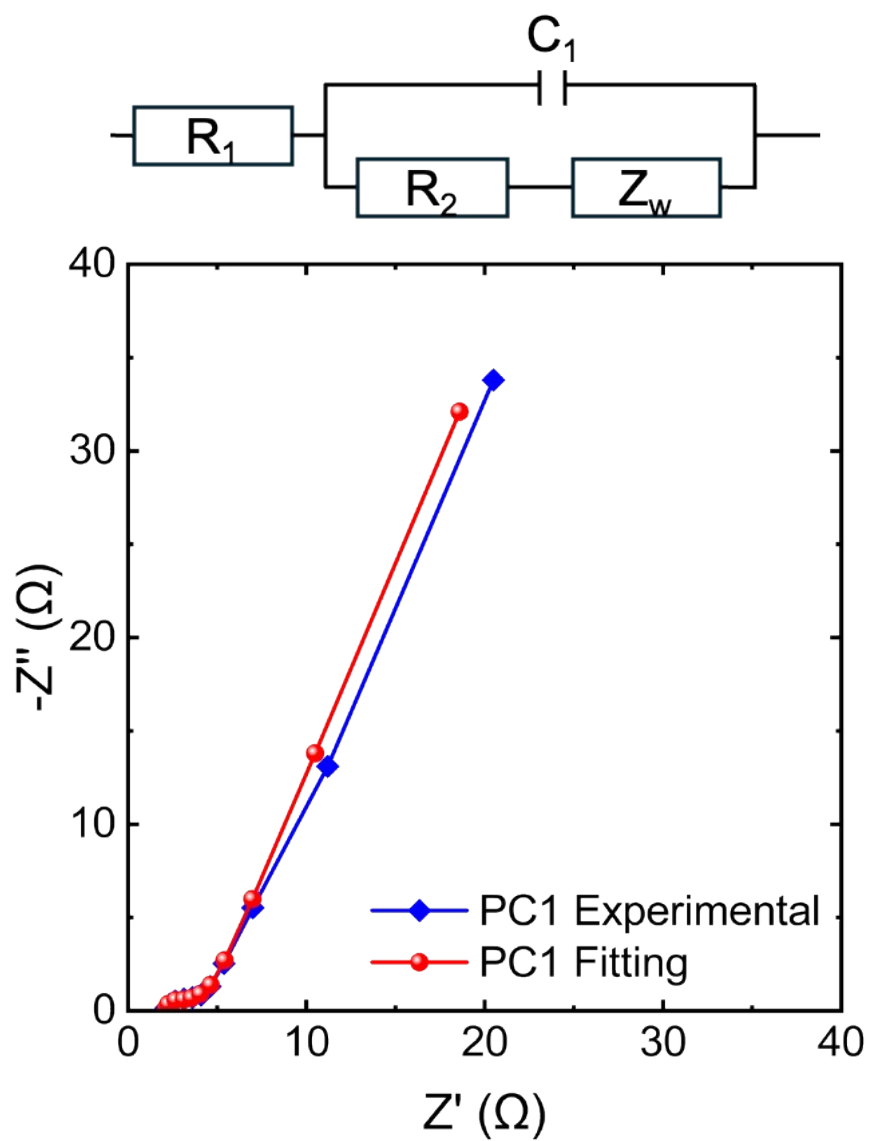
312 **Table S2** The fitting values of R_1 , R_2 , Z_w -R, Z_w -T, Z_w -P and C_1 for PC1, PC2, PC3, PC4, PC5,

313 PC6 and PC7, along with the real part of impedance at 0.1 Hz that roughly corresponds to the

314 $Z_w+R_1+R_2$.

Sample	The fitting values of R_1 (Ω)	The fitting values of R_2 (Ω)	The fitting values of Z_w -R (Ω)	The fitting values of Z_w -T	The fitting values of Z_w -P	The fitting values of C_1	The real part of impedance at 0.1 Hz (Ω)
PC1	2.113	0.7356	4.688	0.10196	0.36671	0.00011151	20.5
PC2	2.194	0.61106	5.578	0.14214	0.36463	0.00011891	18.2
PC3	2.446	0.48036	4.909	1.246	0.39047	0.00030301	6.52
PC4	1.812	0.22684	4.99	1.289	0.29148	0.00019475	7.21
PC5	2.547	1.151	75.47	25.55	0.55218	0.00049315	13.6
PC6	2.325	0.91136	28.64	6.194	0.48155	0.00034412	12.8
PC7	2.289	0.29664	3.911	0.34656	0.32775	0.00019481	10.5
 <p style="text-align: center;">Equivalent circuit</p>				$Z = R \cdot \frac{\coth[(j \cdot T \cdot \omega)^P]}{(j \cdot T \cdot \omega)^P}$			

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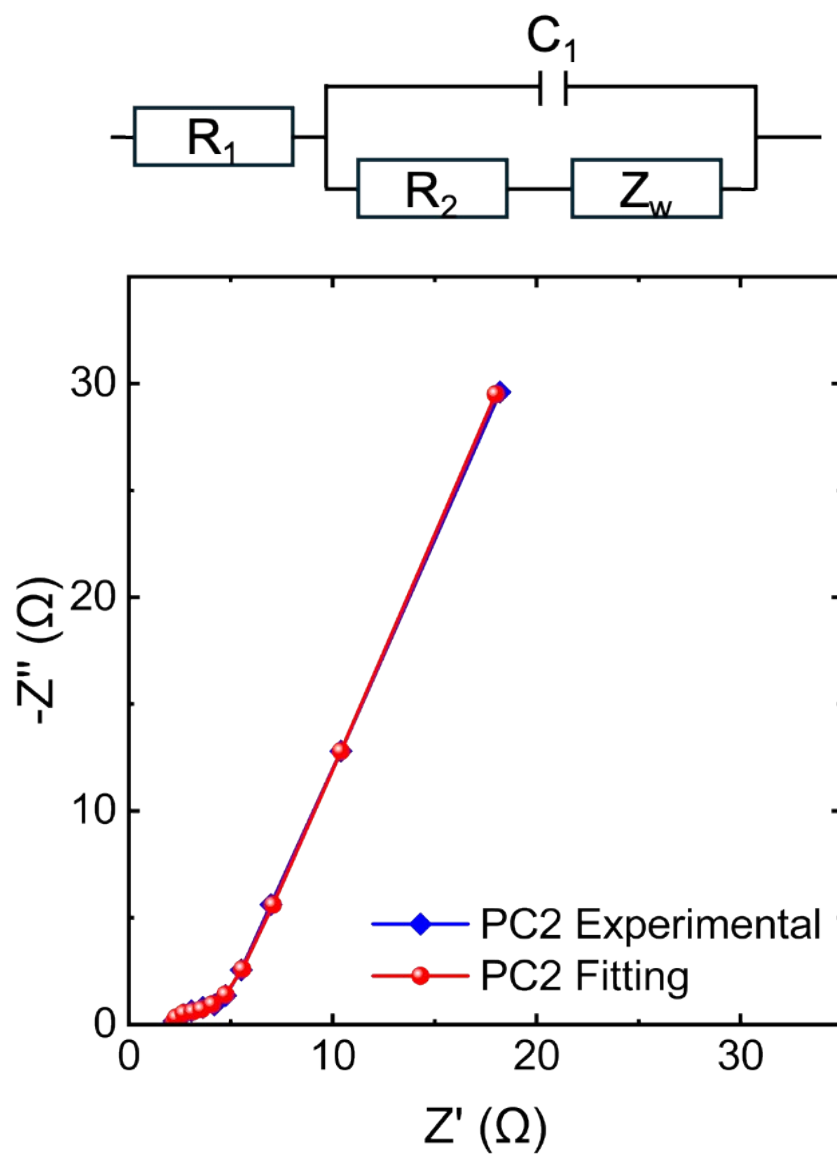
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317 **Fig. S31** Nyquist plot of PC1 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

318 from 1.0 MHz to 0.1 Hz and the fitted curve of PC1

319 PC1 (YP50F) was commercially purchased and directly used as a cathode material

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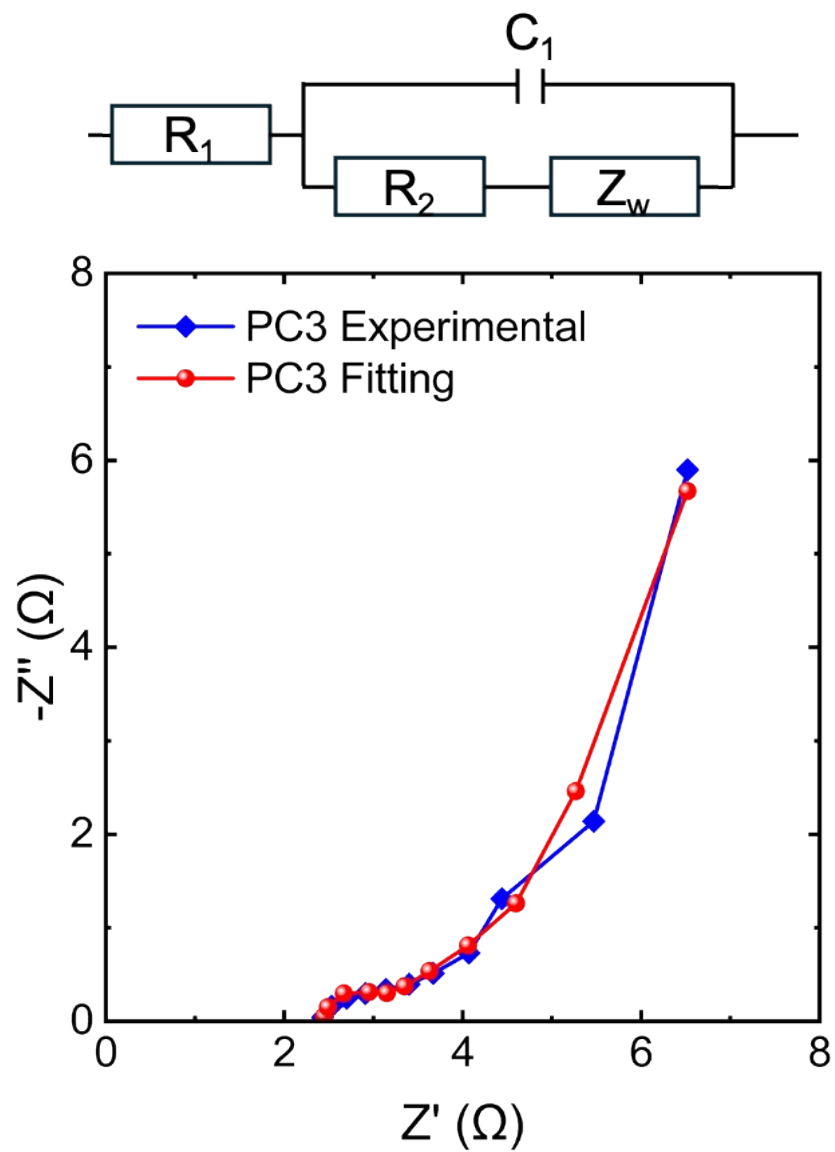
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322 **Fig. S32** Nyquist plot of PC2 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

323 from 1.0 MHz to 0.1 Hz and the fitted curve of PC2

324 PC2 (MSP-20) was commercially purchased and directly used as a cathode material

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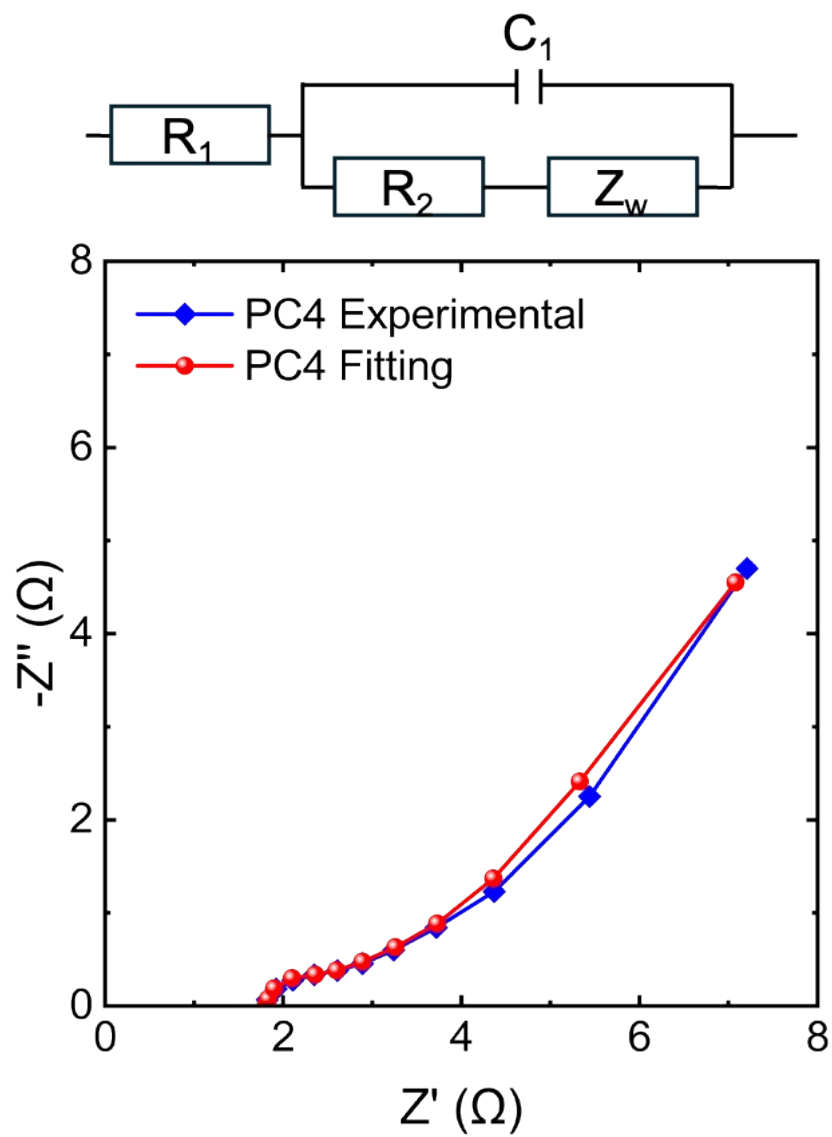
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327 **Fig. S33** Nyquist plot of PC3 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

328 from 1.0 MHz to 0.1 Hz and the fitted curve of PC3

329 PC3 was commercially purchased and directly used as a cathode material

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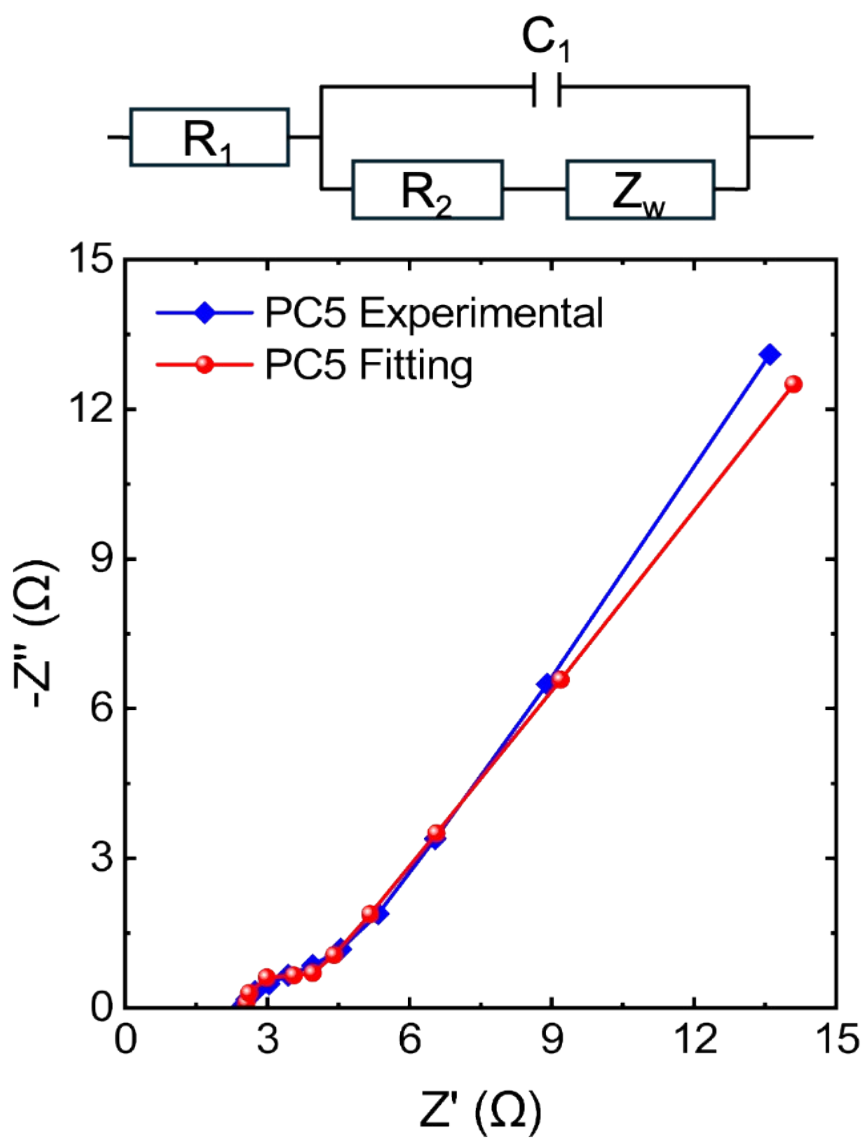
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332 **Fig. S34** Nyquist plot of PC4 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

333 from 1.0 MHz to 0.1 Hz and the fitted curve of PC4

334 PC4 (MSC-30) was commercially purchased and directly used as a cathode material

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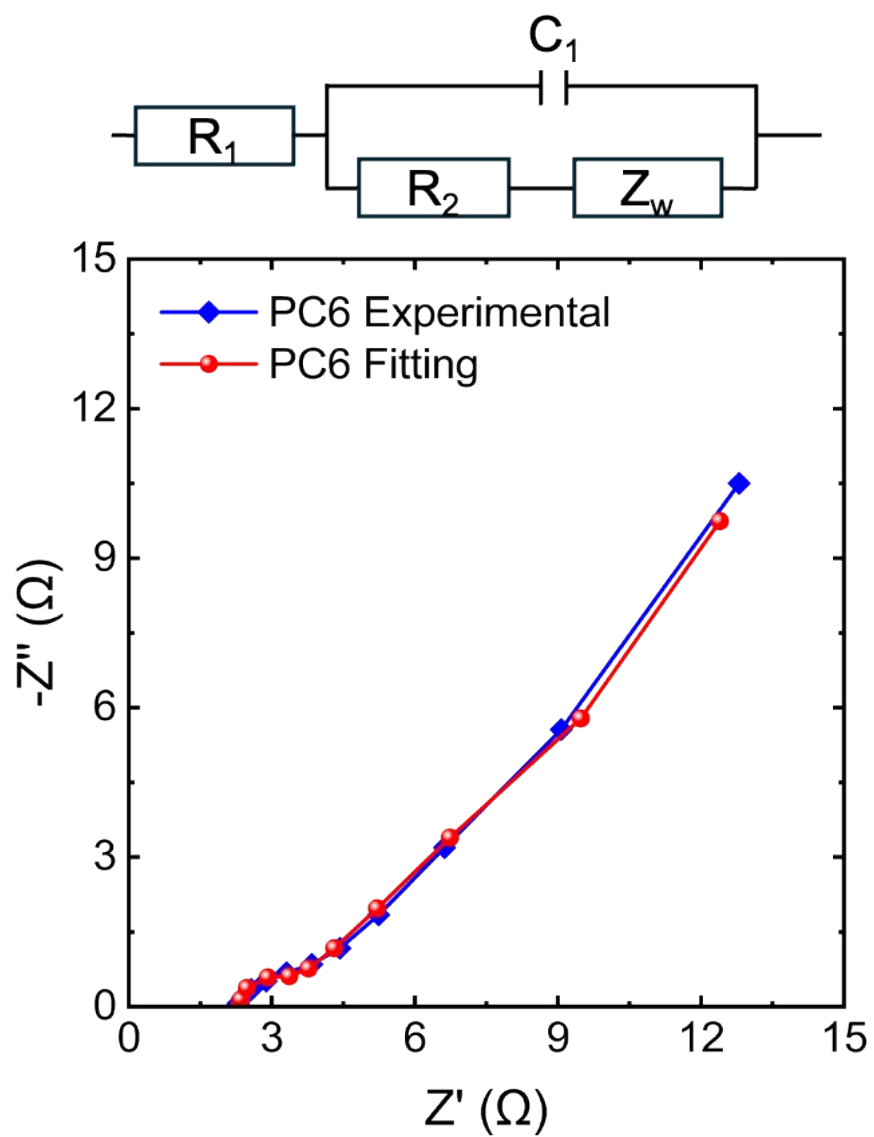
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337 **Fig. S35** Nyquist plot of PC5 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

338 from 1.0 MHz to 0.1 Hz and the fitted curve of PC5

339 PC5 (CNovel 20 nm) was commercially purchased and directly used as a cathode material

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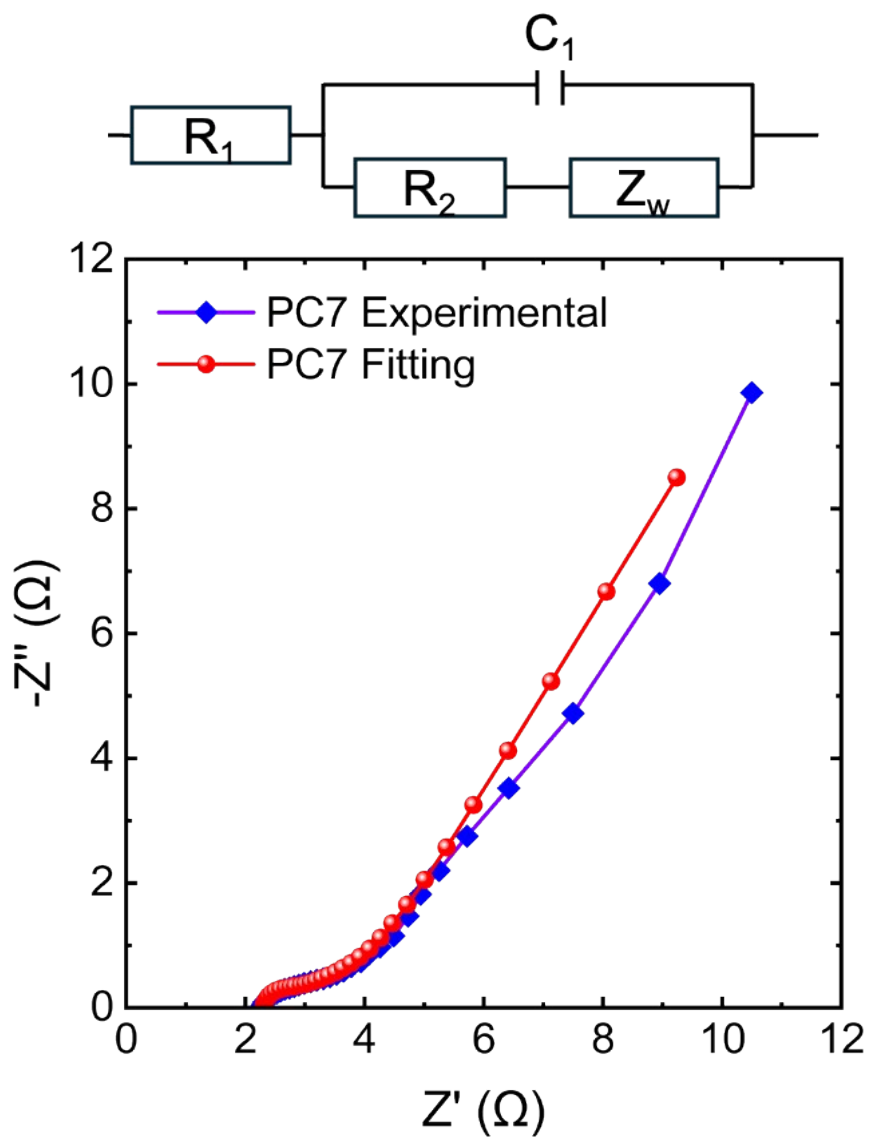
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342 **Fig. S36** Nyquist plot of PC6 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

343 from 1.0 MHz to 0.1 Hz and the fitted curve of PC6

344 PC6 (CNovel MJ4 010-00) was commercially purchased and directly used as a cathode material

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347 **Fig. S37** Nyquist plot of PC7 at 2.2 V and at an amplitude of 10.0 mV and frequencies ranging

348 from 1.0 MHz to 0.1 Hz and the fitted curve of PC7

349 PC7 (CNovel MH-00) was commercially purchased and directly used as a cathode material

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