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Coláiste na hOllscoile Corcaigh

# ***Al-based MOF derived self-assembled carbon nanosheets as innovative anodes for Li- and Na-ion batteries***

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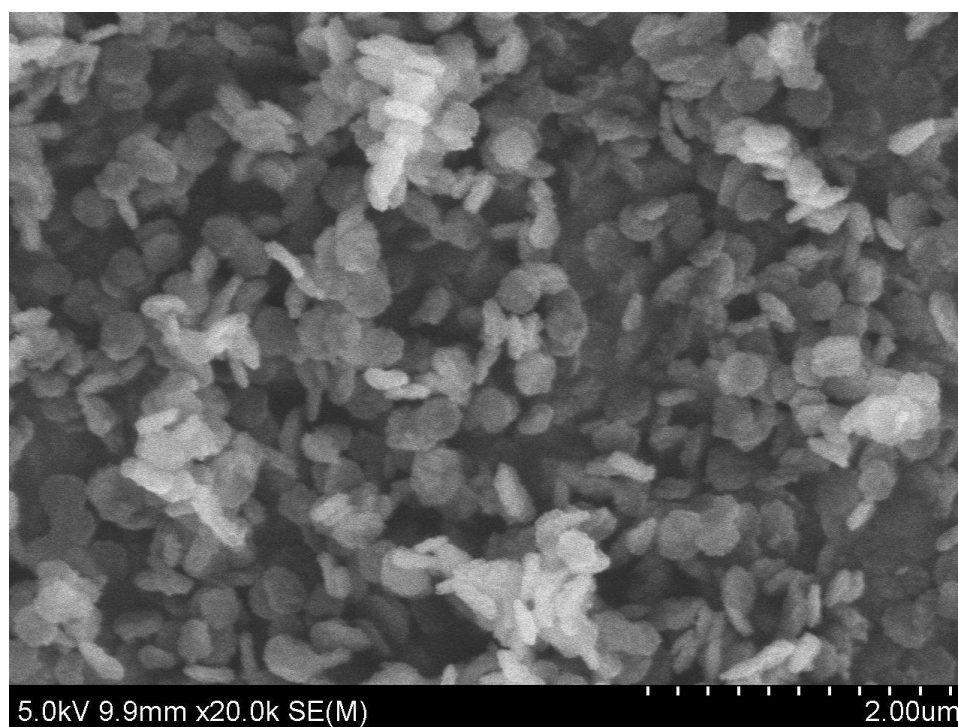
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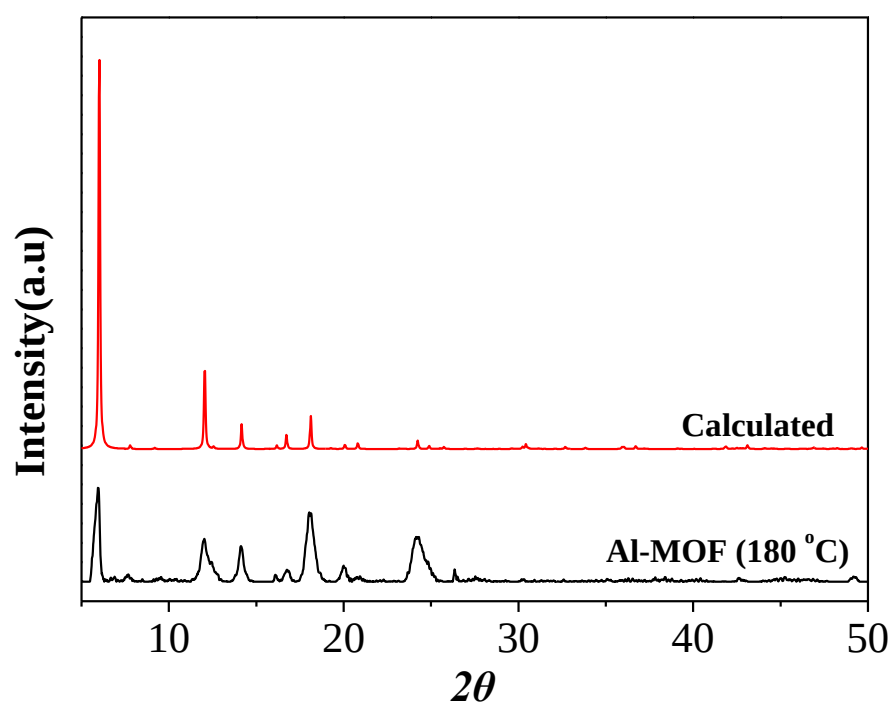
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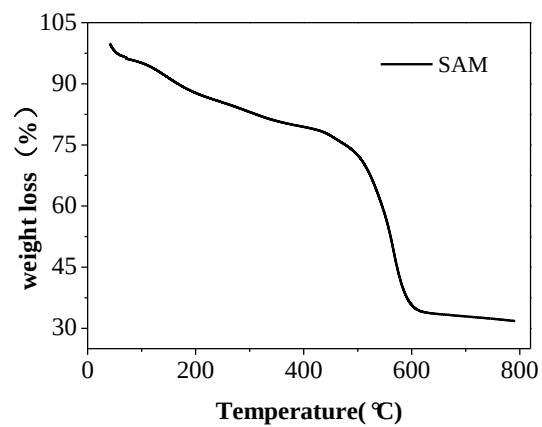
**Keywords:** Porous carbon nanosheets, nanostructure, 2D-MOF, Li-ion, Na-ion



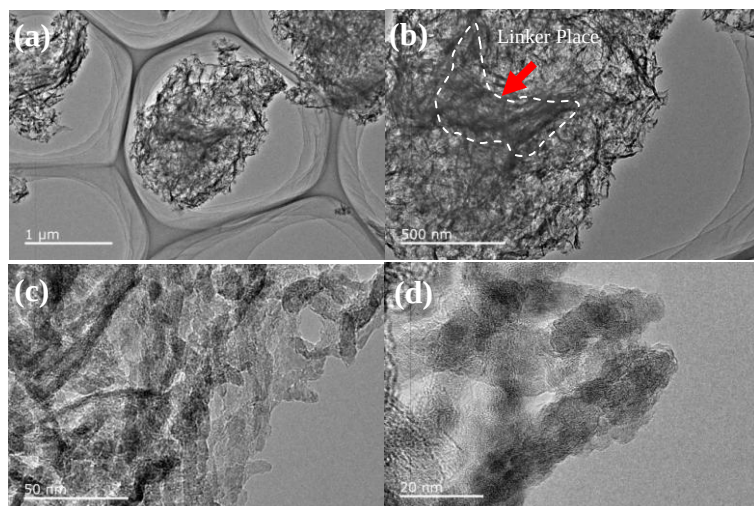
**Figure.S1. FESEM images of the SAM.**



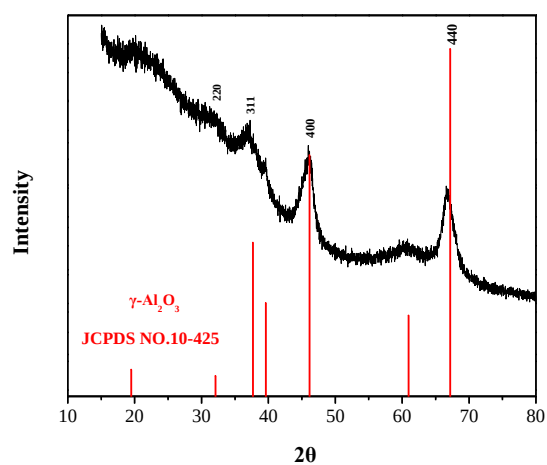
**Figure.S2. Powder XRD patterns of the Al-MOF (180 °C)**



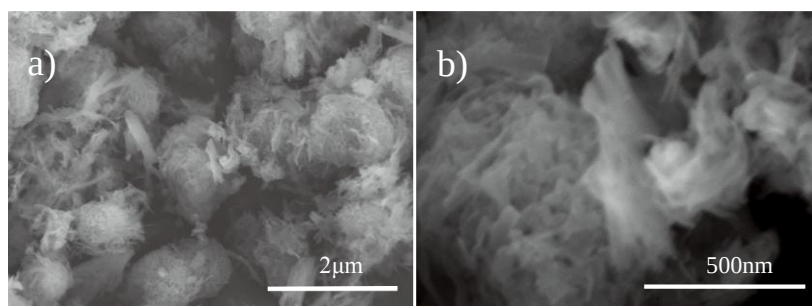
**Figure.S3. TGA curves of the SAM.**



**Figure.S4. (a,b) Low- and (c,d) high-magnification TEM images of the Al-MOF(180 °C) derived carbon.**



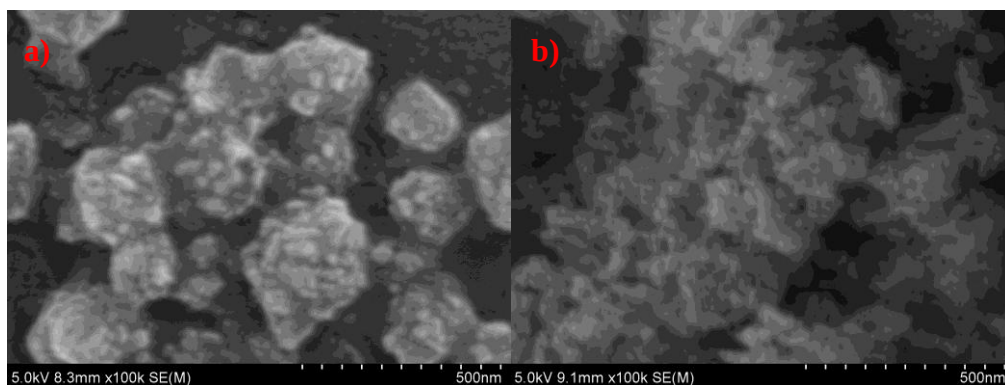
**Figure.S5.XRD patterns from the Carbonization product of the SAM without hydrofluoric acid.**



**Figure.S6. FESEM images of the Al-MOF (180 °C) derived Carbon (a,b).**

**Table.S1. Elemental Analysis Results for the carbonization product of the Al-MOF(180 °C)**

| Carbonization product | N [wt%] | C [wt%] | H [wt%] | S [wt%] |
|-----------------------|---------|---------|---------|---------|
| Al-MOF (180° C)       | 0.32    | 58.2    | 3.006   | 0.573   |



**Fig. S7 FESEM images of the PCNS-700 after 100 cycles at 0.1C for LIBs (a) and 0.5C for NIBs (b).**

**Table S2. A survey of electrochemical properties of the carbon materials for LIBs**

| Category                      | SSA*<br>(m <sup>2</sup> g <sup>-1</sup> ) | Template<br>type | activation | Cycling stability                                                         | C-Rate performance                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------|-------------------------------------------|------------------|------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PCNS-700<br>(This work)       | 1571.4<br>m <sup>2</sup> g <sup>-1</sup>  | —                | —          | 825 mAh g <sup>-1</sup> after<br>100 cycles at 0.1A g <sup>-1</sup>       | 1126 mA h g <sup>-1</sup> , (0.1 A g) <sup>-1</sup><br>748 mA h g <sup>-1</sup> , (0.2 A g) <sup>-1</sup><br>728 mA h g <sup>-1</sup> , (0.5 A g) <sup>-1</sup><br>702 mA h g <sup>-1</sup> , (1 A g) <sup>-1</sup><br>668 mA h g <sup>-1</sup> , (2 A g) <sup>-1</sup><br>489 mA h g <sup>-1</sup> , (5 A g) <sup>-1</sup><br>246 mA h g <sup>-1</sup> , (10 A g) <sup>-1</sup><br>244 mA h g <sup>-1</sup> , (20 A g) <sup>-1</sup>  |
| B-CN<br>(Ref. <sup>1</sup> )  | 480                                       | NaCl             | —          | 496 mA h g <sup>-1</sup><br>after 100 cycles at<br>0.1A g <sup>-1</sup>   | 697 mA h g <sup>-1</sup> , (0.1 A g) <sup>-1</sup><br>575 mA h g <sup>-1</sup> , (0.2 A g) <sup>-1</sup><br>472 mA h g <sup>-1</sup> , (0.3 A g) <sup>-1</sup><br>406 mA h g <sup>-1</sup> , (1 A g) <sup>-1</sup><br>345 mA h g <sup>-1</sup> , (2 A g) <sup>-1</sup><br>285 mA h g <sup>-1</sup> , (5 A g) <sup>-1</sup>                                                                                                             |
| NPCGS<br>(Ref. <sup>2</sup> ) | 781.3                                     | GO               | —          | 1040 mA h g <sup>-1</sup><br>after 200 cycles at<br>0.5 A g <sup>-1</sup> | 936 mA h g <sup>-1</sup> , (0.1 A g) <sup>-1</sup><br>854 mA h g <sup>-1</sup> , (0.2 A g) <sup>-1</sup><br>806 mA h g <sup>-1</sup> , (0.4 A g) <sup>-1</sup><br>728 mA h g <sup>-1</sup> , (0.6 A g) <sup>-1</sup><br>652 mA h g <sup>-1</sup> , (0.8 A g) <sup>-1</sup><br>606 mA h g <sup>-1</sup> , (1 A g) <sup>-1</sup><br>546 mA h g <sup>-1</sup> , (2 A g) <sup>-1</sup><br>459 mA h g <sup>-1</sup> , (4 A g) <sup>-1</sup> |

|                                                  |      |                   |     |                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------|------|-------------------|-----|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NOSDCA-3<br>(Ref. <sup>3</sup> )                 | 852  | —                 | KOH | 839 mAh g <sup>-1</sup> after<br>100 cycles at 0.1 A g <sup>-1</sup><br>390 mAh g <sup>-1</sup> after<br>500 cycles at 1 A g <sup>-1</sup> | 484 mAh g <sup>-1</sup> (1 A g <sup>-1</sup> )<br>228 mAh g <sup>-1</sup> (10 A g <sup>-1</sup> )                                                                                                                                                                                                                                                         |
| porous carbon<br>spheres(Ref. <sup>4</sup> )     | 559  | —                 | —   | 507 mAh g <sup>-1</sup> after<br>100 cycles at 0.1 A g <sup>-1</sup>                                                                       | 400 mAh g <sup>-1</sup> (0.2 A g <sup>-1</sup> )<br>340 mAh g <sup>-1</sup> (0.5 A g <sup>-1</sup> )<br>305 mAh g <sup>-1</sup> (1 A g <sup>-1</sup> )<br>280 mAh g <sup>-1</sup> (2A g <sup>-1</sup> )<br>245mAh g <sup>-1</sup> (5 A g <sup>-1</sup> )<br>190mAh g <sup>-1</sup> (10Ag <sup>-1</sup> )<br>150 mAh g <sup>-1</sup> (20Ag <sup>-1</sup> ) |
| mesoporous<br>nanosheets<br>(Ref. <sup>5</sup> ) | ~281 | AAO<br>substrates | —   | 833 mAh g <sup>-1</sup> after 60<br>cycles at 0.1 A g <sup>-1</sup>                                                                        | 770 mAh g <sup>-1</sup> (0.1 A g <sup>-1</sup> )<br>540 mAh g <sup>-1</sup> (0.2 A g <sup>-1</sup> )<br>430 mAh g <sup>-1</sup> (0.5 A g <sup>-1</sup> )<br>370 mAh g <sup>-1</sup> (1 A g <sup>-1</sup> )<br>255 mAh g <sup>-1</sup> (5 A g <sup>-1</sup> )                                                                                              |
| SRBCG<br>(Ref. <sup>6</sup> )                    | 1431 | MgO               | —   | 510 mAh g <sup>-1</sup> after<br>200cycles at 1 A g <sup>-1</sup>                                                                          | 855 mAh g <sup>-1</sup> (0.5 A g <sup>-1</sup> )<br>472 mAh g <sup>-1</sup> (1 A g <sup>-1</sup> )<br>257 mAh g <sup>-1</sup> (3.6 A g <sup>-1</sup> )                                                                                                                                                                                                    |
| VFPC<br>(Ref. <sup>7</sup> )                     | 2587 | —                 | —   | 2016 mAh g <sup>-1</sup> after<br>50cycles at 0.074A g <sup>-1</sup>                                                                       | 245 mAh g <sup>-1</sup> (5.55 A g <sup>-1</sup> )                                                                                                                                                                                                                                                                                                         |

\*SSA (Specific surface area of MOF-derived carbon materials)

**Table S3. A survey of electrochemical properties of the carbon materials for SIBs**

| Category                | SSA*<br>(m <sup>2</sup> g <sup>-1</sup> ) | Template<br>type | activation | Cycling stability                                                                                                                                 | C-Rate-performance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------------|-------------------------------------------|------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PCNS-700<br>(This work) | 1571.4                                    | —                | —          | 109.5 mAh g <sup>-1</sup><br>after 3500 cycles at<br>1A g <sup>-1</sup><br>193 mAh g <sup>-1</sup> after<br>100 cycles at 0.1A<br>g <sup>-1</sup> | 841.49mA h.g <sup>-1</sup> , (0.02 A g <sup>-1</sup> ) <sup>-1</sup><br>287.13mA h.g <sup>-1</sup> , (0.04 A g <sup>-1</sup> ) <sup>-1</sup><br>257.46mA h.g <sup>-1</sup> , (0.1 A g <sup>-1</sup> ) <sup>-1</sup><br>244.82 mA h.g <sup>-1</sup> , (0.2 A g <sup>-1</sup> ) <sup>-1</sup><br>233.62 mA h.g <sup>-1</sup> , (0.4 A g <sup>-1</sup> ) <sup>-1</sup><br>221.79 mA h.g <sup>-1</sup> , (1 A g <sup>-1</sup> ) <sup>-1</sup><br>212.92 mA h.g <sup>-1</sup> , (2 A g <sup>-1</sup> ) <sup>-1</sup><br>198.83 mA h.g <sup>-1</sup> , (4 A g <sup>-1</sup> ) <sup>-1</sup><br>179.77 mA h.g <sup>-1</sup> , (10 A g <sup>-1</sup> ) <sup>-1</sup><br>161.79 mA h.g <sup>-1</sup> , (20 A g <sup>-1</sup> ) <sup>-1</sup> |

|                                    |        |                         |     |                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------|--------|-------------------------|-----|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MOF5DC<br>(Ref. <sup>8</sup> )     | 1205   | —                       | —   | 89.04 mAh g <sup>-1</sup> after<br>66 cycles at 0.4A g <sup>-1</sup>                                | 152.00mAh h.g <sup>-1</sup> , (0.05 A g <sup>-1</sup> ) <sup>-1</sup><br>128.36mAh h.g <sup>-1</sup> , (0.1 A g <sup>-1</sup> ) <sup>-1</sup><br>106.59mAh h.g <sup>-1</sup> , (0.15 A g <sup>-1</sup> ) <sup>-1</sup><br>92.69mAh h.g <sup>-1</sup> , (0.2 A g <sup>-1</sup> ) <sup>-1</sup>                                                                                                                        |
| B-CN<br>(Ref. <sup>1</sup> )       | 480    | NaCl                    | —   | 195.1 mAh g <sup>-1</sup> after<br>100 cycles at 0.1A g <sup>-1</sup>                               | 276mAh g <sup>-1</sup> at 0.2 A g <sup>-1</sup><br>260mAh g <sup>-1</sup> at 0.5 A g <sup>-1</sup><br>228mAh g <sup>-1</sup> at 1 A g <sup>-1</sup><br>209 mAh g <sup>-1</sup> at 2 A g <sup>-1</sup><br>189 mAh g <sup>-1</sup> at 5 A g <sup>-1</sup>                                                                                                                                                              |
| BPC<br>(Ref. <sup>9</sup> )        | 763.3  | —                       | KOH | 229 mAh g <sup>-1</sup> at<br>200<br>cycles and 0.2A g <sup>-1</sup>                                | 224 mAh g <sup>-1</sup> at 0.05 A g <sup>-1</sup><br>242 mAh g <sup>-1</sup> at 0.1 A g <sup>-1</sup><br>238 mAh g <sup>-1</sup> at 0.2 A g <sup>-1</sup><br>207 mAh g <sup>-1</sup> at 0.5 A g <sup>-1</sup><br>158 mAh g <sup>-1</sup> at 1 A g <sup>-1</sup><br>102 mAh g <sup>-1</sup> at 2 A g <sup>-1</sup><br>68 mAh g <sup>-1</sup> at 5 A g <sup>-1</sup><br>43 mAh g <sup>-1</sup> at 10 A g <sup>-1</sup> |
| ACFs-5<br>(Ref. <sup>10</sup> )    | 1508.0 | —                       | KOH | 243 mAh g <sup>-1</sup> at 100<br>cycles<br>and 0.05 A g <sup>-1</sup>                              | 153 mAh g <sup>-1</sup> at 1 A g <sup>-1</sup><br>134 mAh g <sup>-1</sup> at 2 A g <sup>-1</sup><br>101 mAh g <sup>-1</sup> at 5 A g <sup>-1</sup><br>72 mAh g <sup>-1</sup> at 10 A g <sup>-1</sup>                                                                                                                                                                                                                 |
| G-NCs<br>(Ref. <sup>11</sup> )     | 133.8  | Graphene<br>oxide       | —   | 154 mAh g <sup>-1</sup> at<br>10000<br>cycles and 5A g <sup>-1</sup>                                | 250 mAh g <sup>-1</sup> at 100 mA g <sup>-1</sup><br>110 mAh g <sup>-1</sup> at 10000 mA g <sup>-1</sup>                                                                                                                                                                                                                                                                                                             |
| PGGs<br>(Ref. <sup>12</sup> )      | 1598   | Ag<br>nanoparticl<br>es | —   | 112 mAh g <sup>-1</sup> after<br>1000<br>cycles and 1A g <sup>-1</sup>                              | 210.2 mAh g <sup>-1</sup> at 0.028A g <sup>-1</sup><br>160.2 mAh g <sup>-1</sup> at 0.057 A g <sup>-1</sup><br>112.2 mAh g <sup>-1</sup> at 0.140A g <sup>-1</sup>                                                                                                                                                                                                                                                   |
| 3DHSC-4<br>(Ref. <sup>13</sup> )   | 119    | NaCl                    | —   | 200.7 mAh g <sup>-1</sup> at 120<br>cycles and 0.05 A g <sup>-1</sup>                               | 97mAh g <sup>-1</sup> at 5A g <sup>-1</sup>                                                                                                                                                                                                                                                                                                                                                                          |
| CNCs<br>(Ref. <sup>14</sup> )      | ~190   | ZnO<br>nanocrystal<br>s | —   | 212 mAh g <sup>-1</sup> after<br>1000cycles at 1.5 A g <sup>-1</sup>                                | 385 mAh g <sup>-1</sup> at 0.05 A g <sup>-1</sup><br>325 mAh g <sup>-1</sup> at 0.1 A g <sup>-1</sup><br>307 mAh g <sup>-1</sup> at 0.2 A g <sup>-1</sup><br>286 mAh g <sup>-1</sup> at 0.4 A g <sup>-1</sup><br>275 mAh g <sup>-1</sup> at 0.8A g <sup>-1</sup><br>262 mAh g <sup>-1</sup> at 1.6 A g <sup>-1</sup><br>252 mAh g <sup>-1</sup> at 3.2 A g <sup>-1</sup>                                             |
| NSCN<br>(Ref. <sup>15</sup> )      | 674    | Mg(OH) <sub>2</sub>     | —   | 248 mAh g <sup>-1</sup> after<br>500cycles at 0.1A g <sup>-1</sup>                                  | 176 mAh g <sup>-1</sup> (2 A g <sup>-1</sup> )                                                                                                                                                                                                                                                                                                                                                                       |
| NPC-CNT@G<br>(Ref. <sup>16</sup> ) | 529.6  | CNT                     | —   | 257 mAh g <sup>-1</sup> after<br>100cycles at 0.1A g <sup>-1</sup><br>163 mAh g <sup>-1</sup> after | 315 mAh g <sup>-1</sup> at 0.05A g <sup>-1</sup><br>284mAh g <sup>-1</sup> at 0.1 A g <sup>-1</sup><br>249 mAh g <sup>-1</sup> at 0.2 A g <sup>-1</sup>                                                                                                                                                                                                                                                              |

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300cycles at  $1\text{ A g}^{-1}$

208mAh  $\text{g}^{-1}$  at  $0.5\text{ A g}^{-1}$

174mAh  $\text{g}^{-1}$  at  $1\text{ A g}^{-1}$

146 mAh  $\text{g}^{-1}$  at  $2\text{ A g}^{-1}$

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**\*SSA (Specific surface area of MOF-derived carbon materials)**

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