# Development and evaluation of a composite supercapacitor-based 12 V transient start-stop (TSS) power system for vehicles: modelling, design and fabrication scaling up

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SUPPLEMENTARY INFORMATION

## Experimental methods

**Figure SI-1.** Pilot scale coater for the fabrication of AC coatings at University of Surrey

**Figure SI-2.** Photographs of large supercapacitor cells

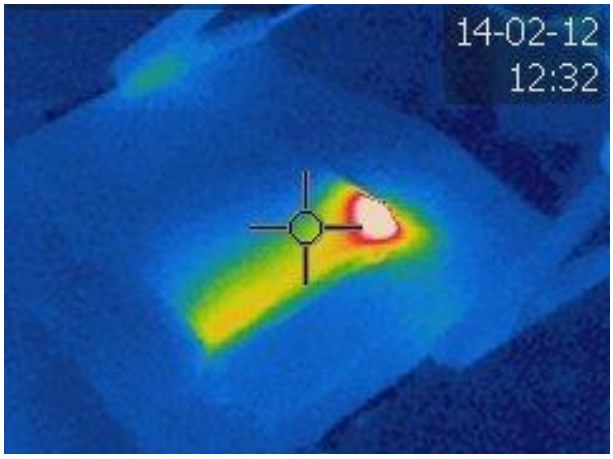


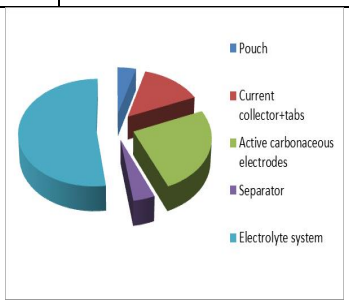

**Figure SI-3.** Thermal IR image of an EDLC cell with a hot spot during low current operation, indicating a fabrication defect.

**Figure SI-4.** Voltage balancing testing of four large composite EDLC cells in series in the range of 0-8 V using the Hocherl & Hackl NL1V8C320 source-sink instrument.

**Figure SI-5.** Start test of a two-cylinder diesel engine via a 12 V, 0.9 kW starter motor, using a supercapacitor bank of 5 large, composite EDLC pouch cells in series.

## Results

**Table SI-1.** Data and performance parameters of large size cells

| | **555.58g-Cell** | **554.8g-Cell** | **560.4g-Cell** | **560.85g-Cell** |
|---|---|---|---|---|
| Targeted operating current (A) | 300 A | 300 A | 300 A | 300 A |
| % Mass composition of cell |  | | | |
| Electrode/ Cell g/g | 24.9% | 24.9% | 24.7% | 24.6% |
| $R_{ESR}$ (milli-ohm) | 0.8 | 0.37 | 0.45 | 0.41 |
| Capacitance of cell (F) | 3305F @ 300A<br>3363F @ 200A<br>3490F @75A<br>3526F @30A | 3099F @ 300A<br>3502F @ 200A<br>3660F @75A<br>3777F @30A | 3488F @ 300A<br>3579F @ 200A<br>3740F @75A<br>3810F @30A | 3483F @ 300A<br>3757F @ 200A<br>3975F @75A<br>3782F @30A |
| $C_{spec,elec}$ (F/g) | 101.9 | 108.4 | 109.3 | 108.5 |
| E: 3-0V (Wh/kg ele) | 31.8 | 33.9 | 34.2 | 33.9 |
| E: 2.7-0V (Wh/kg ele) | 25.8 | 27.4 | 27.7 | 27.5 |
| E: 2.7-0V (Wh/kg-cell) | 6.4 | 6.8 | 6.8 | 6.76 |

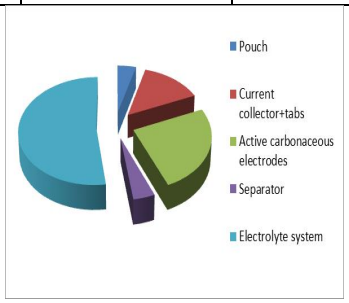
| | **566.8g-Cell** | **568.4g-Cell** | **573.4g-Cell** |
|---|---|---|---|
| Targeted operating current (A) | 300 A | 300 A | 300 A |
| % Mass composition of cell |  | | |
| Electrode/ Cell g/g | 24.4% | 24.3% | 24.1% |
| $R_{ESR}$ (milli-ohm) | 0.31 | 0.5 | 0.41 |
| Capacitance of cell (F) | 3294F @ 300A<br>3412F @ 200A<br>3557F @75A<br>3600F @30A | 3488F @ 300A<br>3603F @ 200A<br>3699F @75A<br>3739F @30A | 3564F @ 300A<br>3640F @ 200A<br>3701F @75A<br>3848F @30A |
| $C_{spec,elec}$ (F/g) | 103.3 | 107.3 | 110.4 |
| E: 3-0V (Wh/kg ele) | 32.3 | 33.5 | 34.5 |
| E: 2.7-0V (Wh/kg ele) | 26.1 | 27.2 | 27.9 |
| E: 2.7-0V (Wh/kg-cell) | 6.4 | 6.6 | 6.7 |

**Table SI-2.** Experimental data of cell voltage balancing in system of four large, composite EDLC cells in series

| **System voltage (V)** | **Cell1 voltage (V)** | **Cell2 voltage (V)** | **Cell3 voltage (V)** | **Cell4 voltage (V)** |
|---|---|---|---|---|
| 0.293 | 0.026 | 0.077 | 0.107 | 0.085 |
| 2 | 0.470 | 0.497 | 0.529 | 0.502 |
| 4 | 0.987 | 0.993 | 1.024 | 0.996 |
| 6 | 1.494 | 1.494 | 1.520 | 1.496 |
| 8 | 1.993 | 1.994 | 2.017 | 2.000 |