Lithium-Ion Capacitors (LICs):
"Combining Energy With Power"

May, 2017
COMPANY PROFILE
JSR/JM Energy Corporate Structure

**JSR Corporation**
- Headquartered in Tokyo, Japan
- Founded in 1957, close to 6,000 employees worldwide.
- $4 billion leading supplier of advanced polymer materials.
- R&D driven company. Innovative material solutions in different markets.

**JSR Micro**
- European Headquarters of the JSR Group.
- Exclusive representative of JM Energy and its ULTIMO Lithium Ion Capacitor.
- Sales, Marketing and Technical support.

**JM Energy**
- Located in Yamanashi, Japan.
- Development and manufacturing of the ULTIMO Lithium Ion Capacitor.
- 100% owned JSR Subsidiary.
The original facility was launched on November 11th, 2008

- **New High Volume manufacturing plant**
  - Floor area: 8400 m²
  - Construction completed in January 2015
  - Commercial production started from June 2015
  - Total investment: ¥6 billions ($60 millions)
  - Production capacity: 3 million prismatic cells per year
JSR Micro NV, Leuven (Belgium)

- **Manufacturing**
  - Design Concept: Copy exact to JSR Corp. & US manufacturing process
  - Plant Completion: November 2002
  - Available space for new materials
  - Total Investment: 20 million EUR
  - Semiconductor Product Line
  - Protein A Ligand Manufacturing

- **Support our European Customers**
  - Technical & commercial support and Business Development in different fields (*Energy*, *Emerging Technologies*, *Life Science*)
  - Aqueous binder application lab
  - Multi-functional labs
  - Capital: €11 M (100% owned by JSR)
  - 130+ employees
THE ULTIMO LIC TECHNOLOGY
High power and high energy density capacitor

- **Fuel Cell**
- **Li Ion Battery**
  - Ni H Battery
  - Lead-Acid Battery
- **Lithium Ion Capacitor**
- **Supercapacitor**

**Legend**:
- **High power, longer life**
- **More energy per space and weight unit**
LITHIUM ION CAPACITOR

A hybrid technology

Lithium-ion Battery

- Output

Graphite Electrolyte LiMO$_x$

Electric Double Layer Capacitor

- Output

Activated Carbon Electrolyte Activated Carbon

Lithium Ion Capacitor (LIC)

- Output

Li-doped Carbon Electrolyte Activated Carbon

Energy

Power Life

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Characteristics of LIC

- High operation voltage (2.2 V to 3.8 V)
- High energy density combined with high power density
- Fast charge / discharge characteristics
- Wide operation temperature range (-30 °C to +70 °C)
- Excellent durability / reliability
- Small self discharge
- Safe in use
ULTIMO

PRISOMATIC CELLS
### Prismatic cells specifications

<table>
<thead>
<tr>
<th>Measurement Items</th>
<th>CPQ2300S Ultra Low Resistance</th>
<th>CPP3300S Low Resistance</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of operating temperatures</td>
<td>-30 °C~70 °C</td>
<td>-30 °C~70 °C</td>
<td></td>
</tr>
<tr>
<td>Rated Voltage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>3.8 V</td>
<td>3.8 V</td>
<td>10 A constant current discharge, 25 °C</td>
</tr>
<tr>
<td>Min.</td>
<td>2.2 V</td>
<td>2.2 V</td>
<td>9 kHz</td>
</tr>
<tr>
<td>Initial Characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacitance</td>
<td>2300 F</td>
<td>3300 F</td>
<td>1 kHz</td>
</tr>
<tr>
<td>ESR</td>
<td>0.6 mΩ</td>
<td>0.7 mΩ</td>
<td>10 A constant current discharge, 25 °C</td>
</tr>
<tr>
<td>DC-IR</td>
<td>0.7 mΩ</td>
<td>1.0 mΩ</td>
<td>1 kHz</td>
</tr>
<tr>
<td>Weight E density</td>
<td>8 Wh/kg</td>
<td>13 Wh/kg</td>
<td>10 A constant current discharge, 25 °C</td>
</tr>
<tr>
<td>Volume E density</td>
<td>14 Wh/L</td>
<td>20 Wh/L</td>
<td>1 kHz</td>
</tr>
<tr>
<td>Temp Dependence</td>
<td>-20 °C</td>
<td>+70 °C</td>
<td></td>
</tr>
<tr>
<td>Capacitance ratio (vs 25 °C)</td>
<td>85%</td>
<td>85%</td>
<td>10 A constant current discharge</td>
</tr>
<tr>
<td>Voltage reduction</td>
<td>100%</td>
<td>100%</td>
<td>3 months, 25 °C</td>
</tr>
<tr>
<td>Cell Size</td>
<td>150x93x15.5 mm</td>
<td>150x93x15.5 mm</td>
<td>Without terminals</td>
</tr>
<tr>
<td>Weight</td>
<td>0.365 kg</td>
<td>0.350 kg</td>
<td></td>
</tr>
</tbody>
</table>
Life performance

**Cycling life**

- Capacitance [%]
- DC-IR [%]
- 80% End-of-Life

**Floating test**

- Capacitance
- DC-IR
- 80% End-of-Life

**Test ongoing…**

<Test Conditions>
Charge: CC, 200A, 3.8 V
Discharge: CC, 200A, 2.2V
Rest time: zero
Ambient Temperature: 25°C

<Test Conditions>
Charge voltage: 3.8 V
Ambient Temperature: 70°C
Life performance

Cycling life

Floating test

<Test Conditions>
Charge: CC, 200A, 3.8 V
Discharge: CC, 200A, 2.2V
Rest time: zero
Ambient Temperature: 25°C

<Test Conditions>
Charge voltage: 3.8 V
Ambient Temperature: 70°C
Self discharge
Less than 5% after 3 months

<Test Conditions>
Ambient Temperature: 25°C
LITHIUM ION CAPACITOR

Safety

Overcharge

External short

20V, 1A

Over discharge

Nail penetration

0V, 1A

Detailed analysis published by NASA

ULTIMO Lithium Ion Capacitors are safe and are exempted from most transport restrictions imposed by regulation for dangerous goods under UN3508

Data and pictures courtesy of NASA
ULTIMO ADVANTAGES
Our unique value proposition

**ESS** (Energy Storage Systems)

- Safe, compact and flexible, a perfect fit for maintenance free critical power back-up at the lowest cost of ownership

**HD cycling** (Heavy Duty cycle applications)

- Safe, compact and flexible, a perfect fit at the lowest cost of ownership. It performs during the entire application life, and beyond
LITHIUM ION CAPACITOR

LIC key advantages (1)
Stationary Applications

- Long calendar life
  - Over 15 years

- Very high number of cycles:
  - LIC are very well suited for very dynamic applications

- Very low self discharge:
  - Achieves a higher overall efficiency compared to other technologies

- Maintenance free system
  - No need to visit remote location regularly for maintenance

- Highly scalable
  - Adding strings in parallel allows to increase energy and/or power based on customer requirements
LIC key advantages (2)
Stationary Applications

- **High temperature capabilities:**
  - LIC can float at high temperature (≈40°C) without drastic effect on life duration
  - Reduces the need for cooling equipment

- **Good floating voltage capabilities:**
  - Keeping the cells at the maximum rated voltage does not decrease their life time
  - Important in applications where cells spend most of their time in floating mode

- **High recharge rate capabilities**
  - The protection equipment can be restored to its full functionality very quickly after a discharge event
LIC key advantages (1)

Heavy Duty applications

- **Lighter and smaller than EDLC:**
  - Allows for a higher energy content on board or a lighter system, resulting in a higher overall efficiency

- **Less cells than EDLC:**
  - Reduces the system complexity and cost

- **High charging rate capabilities:**
  - Maximises the amount of energy stored in the LIC pack during deceleration and braking

- **Very high discharge rate capabilities:**
  - Allows quick acceleration
LIC key advantages (2)
Heavy Duty applications

- **Very long cycle life:**
  - Drastically reduces the number of ESS replacements over the life of the vehicle

- **Can be used over the full DOD range:**
  - All the on-board energy can be used without reducing the life of the LIC

- **Good high voltage capabilities:**
  - Keeping the LIC at the highest rated voltage does not impact its life duration
  - The LIC system can be kept fully charged during parking without reducing the life of the pack
ULTIMO LIC APPLICATIONS
Applications

LITHIUM ION CAPACITOR

High Voltage

- Large/ Medium UPS
- Large wind turbine
- Voltage Sag Compensator

Low Voltage

- Small UPS
- Small wind turbine
- Digital radiography

Static

Low Voltage / Stationary

High Voltage / Stationary

High Voltage / Movable

- Bus Truck
- Train Tram
- Construction Machine

Low Voltage / Movable

Dynamic

- AGV
- Forklift

Wide Spread ULTIMO Applications
Over 15 buses equipped in Transport for Greater Manchester (some as school bus)
Running since Summer 2014
25,000 - 30,000km/year on average
In total, over 1,000,000 km of operation
Advantages of Ultimo
  - Reduction of space
  - Reduction of weight
  - Long life

ULTIMO is commercially used in hybrid buses in Europe

<table>
<thead>
<tr>
<th></th>
<th>LIC System</th>
<th>EDLC System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage [V]</td>
<td>675</td>
<td>700</td>
</tr>
<tr>
<td>Energy [kWh]</td>
<td>0.55</td>
<td>0.51</td>
</tr>
<tr>
<td>Power [kW]</td>
<td>135</td>
<td>175</td>
</tr>
<tr>
<td>Weight [Kg]</td>
<td>135</td>
<td>340</td>
</tr>
<tr>
<td>Volume [dm³]</td>
<td>317</td>
<td>470</td>
</tr>
<tr>
<td>Dimensions [mm]</td>
<td>1588 x 915 x 218</td>
<td>1150 x 1940 x 211</td>
</tr>
</tbody>
</table>
LITHIUM ION CAPACITOR

Applications
Rolling stock

Will be certified against:
- EN45545: smoke and fire
- EN61000: Electromagnetic Interference
- EN61373: Shock and Vibration

Railway compliant module for catenary free and energy recovery applications

LIC provide a longer life time for the system

Acknowledgement to Centum Adetel Transportation Solution (CATS)

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LITHIUM ION CAPACITOR

600kW – 11 seconds - ~2000 cells

ULTIMO used for large scale power quality applications

Acknowledgement to Chubu Electric Power Co., Inc. and Meidensha Corporation

Applications
Power Quality

Voltage Sag at input from grid

Compensated at output to load!

Recovery in less than 2 ms

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Advantages of Ultimo

- High power capabilities
- Reliability for critical power
- Ultra fast recharge
- Small footprint
- Long life with low maintenance
- Maximum scalability for capacity and/or redundancy

ULTIMO provides a safe and reliable solution even at high temperature

Product being commercially offered by Socomec
Advantages of Ultimo
- Long calendar life (over 15 years)
- Very high number of cycles
- Very low self discharge
- Maintenance free system
- High recharge rate capabilities
- Maximum scalability for capacity and/or redundancy

ULTIMO provides a safe and reliable solution even at high temperature
LITHIUM ION CAPACITOR

Applications

Hybridization with fuel cells

- Lithium Ion Capacitor functions
  - Buffering of fuel cell power
  - Regenerative braking

By hybridization, ULTIMO can provide power to fuel cell vehicle in a small and light package

Pictures courtesy of Forze VI Racing team
Thank you!

Interested in learning more about our company? Please visit our website:

http://www.jsrmicro.be