JSR Micro
MATERIALS INNOVATION

Advances in ULTIMO™ Lithium Ion Capacitor (LIC) Technology

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NCCAVS "Technology for Clean Energy", February 22, 2012

Agenda

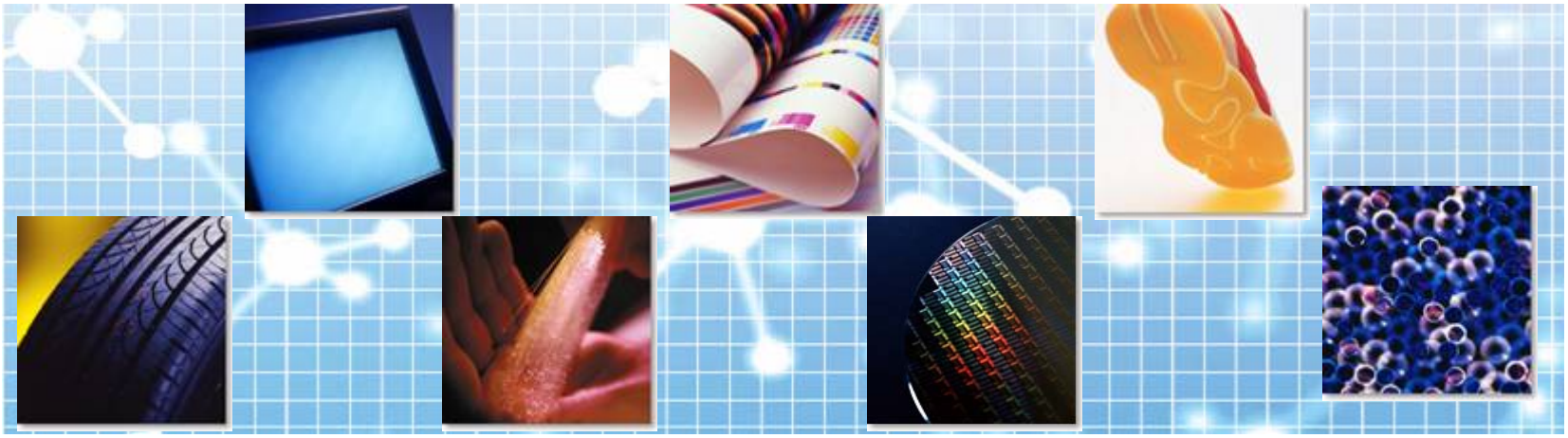
- Introduction to JSR, JM Energy
- Fuel Cell vs Battery vs EDLC vs LIC
- Introduction to Lithium Ion Capacitor Technology
- Technical performance
- Applications
- Summary

It all started in 1957 …

Japan **S**ynthetic **R**ubber was created by the Japanese government to produce synthetic rubber for making car tires ….

Groundbreaking Chiba Plant	Opening Ceremony Yokkaichi Plant
	

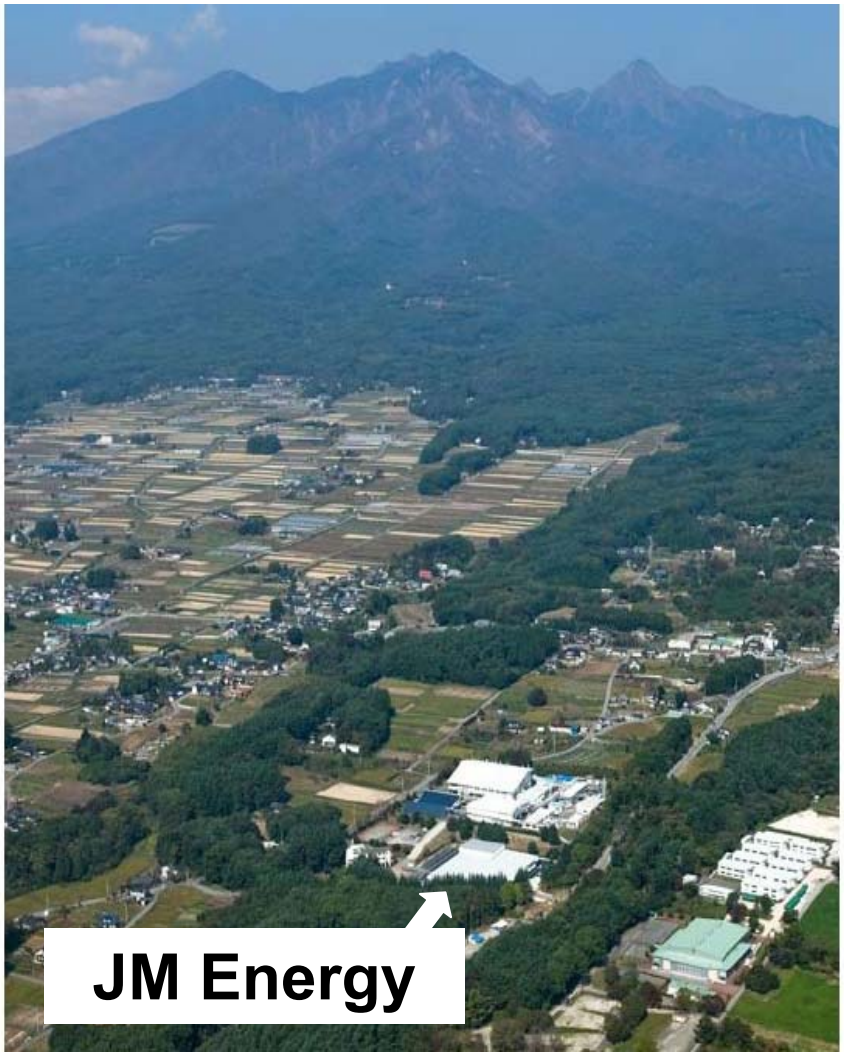
JSR Corporation - Today



Since 1957 JSR has developed a unique expertise in the field of polymer chemistry
We are a $4 billion leading supplier of advanced polymer materials with more than 5000 employees

JSR is the parent company of JM Energy Corp and JSR Micro Inc

JM Energy Corporation (Yamanashi Plant)



JM Energy:
Established August 1st, 2007
HQ and Production Plant:
Launched November 11th, 2008

ISO 9001: 2008
ISO 14001: 2004
certified

“ULTIMO” – JM Energy’s Lithium Ion Capacitor

LAMINATE CELL
1100F, 2200F

ON SALE

MODULE FOR LAMINATE CELL

1100F Module

2200F Module

ON SALE

PRISMATIC CELL
2300F, 3300F

ON SALE

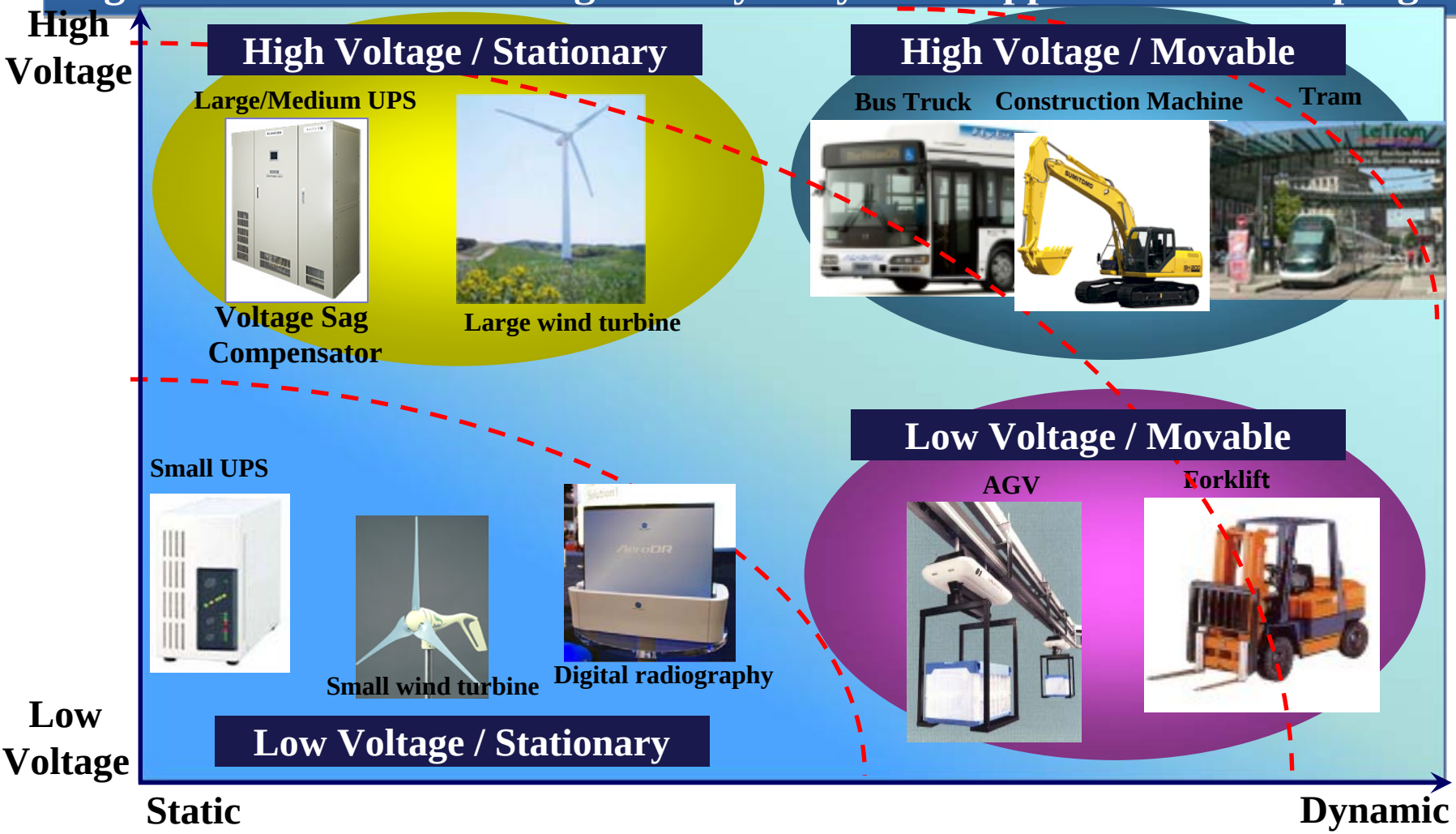
MODULE FOR PRISMATIC CELL

ON SALE

Application Trends of LIC

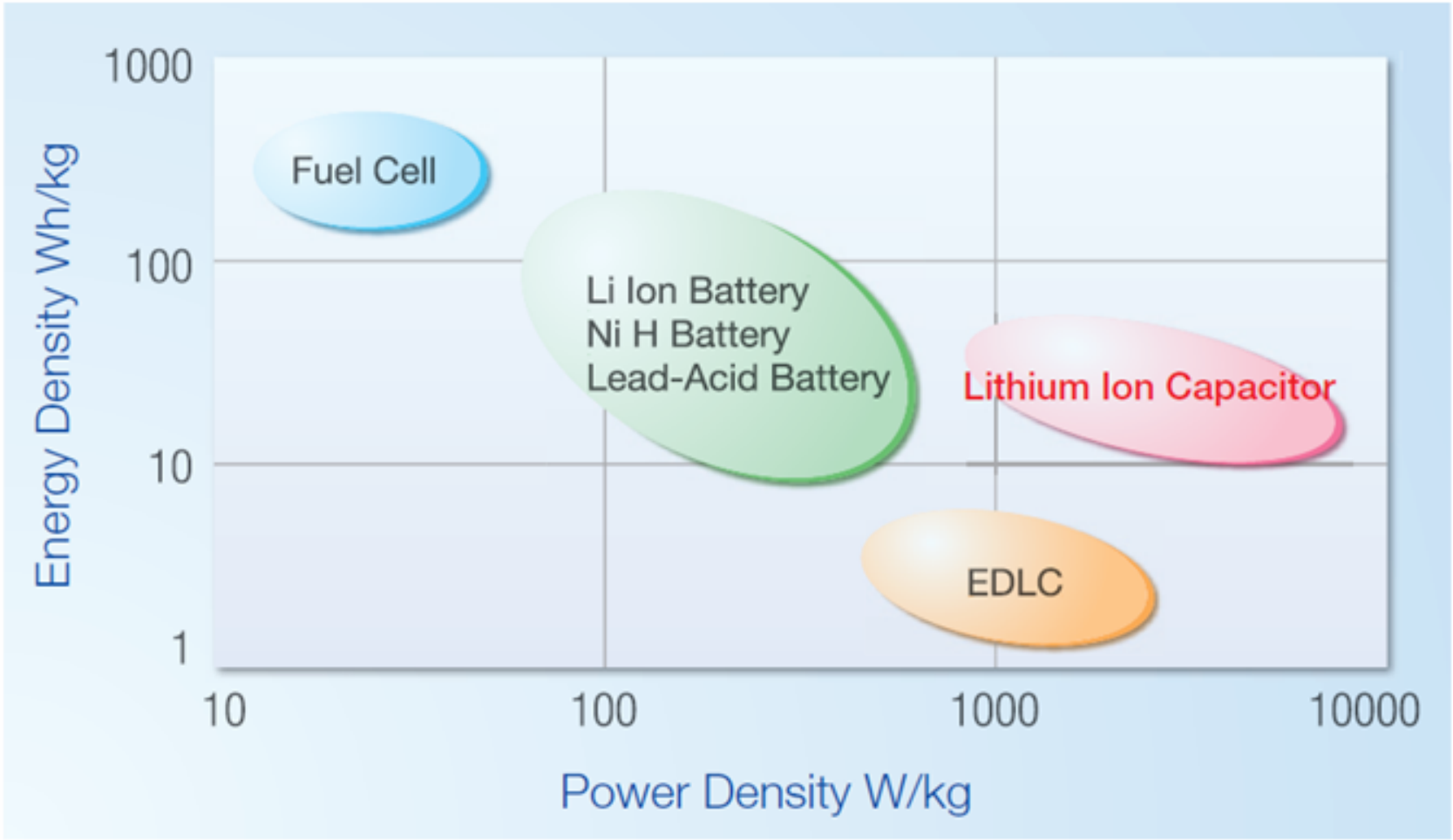
Static applications are in commercial phase with ULTIMO.

Vigorous evaluation in a large variety of dynamic applications are in progress.



Position of Lithium Ion Capacitor

High power, and high energy density capacitor



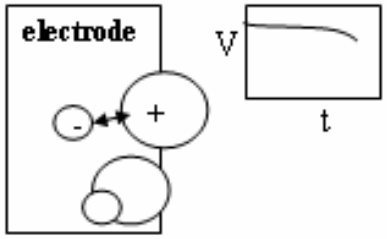
Why ULTIMO, Instead of Lithium-ion Battery?

Comparison with LIB

In case of LIB	In case of ULTIMO
Only a few thousand cycles available → HARD to apply for Peak Assist, Regenerative Energy	More than 100,000 cycles possible
Safety issue: Potential thermal runaway	No thermal runaway → Described in the following slide.
Low rate charge / discharge (~10C)	High rate charge / discharge (~200C)

Battery

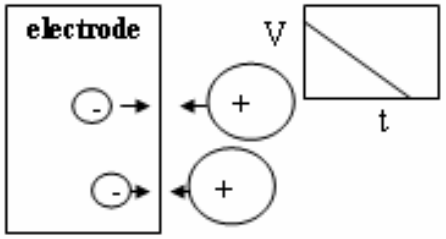
Based on electrochemical reactions.
→ Slow charge/discharge rate.



Redox reaction
(constant voltage)

Capacitor

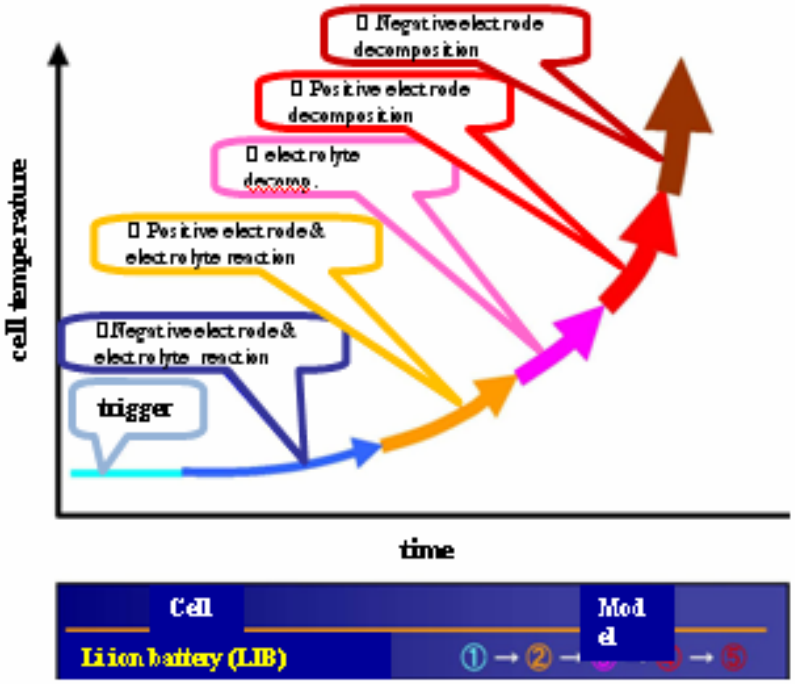
Based on electrostatic induction.
→ Rapid charge/discharge rate.



Electrostatic reaction
(voltage is proportional to quantity of electricity)

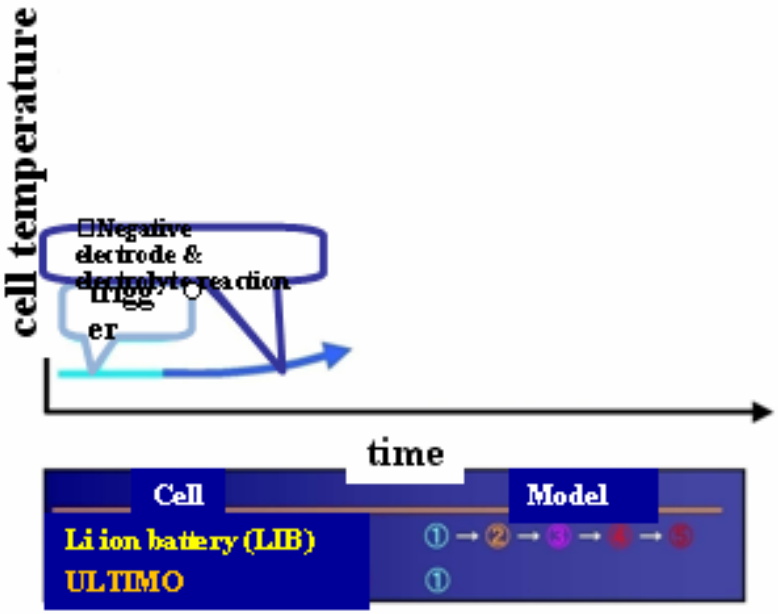
Thermal stability of ULTIMO

Thermal Runaway Model of LIB (Li-ion Battery)



Commercial LIBs don't showthermal runaway in ordinary conditions
since several preventive measures are taken.

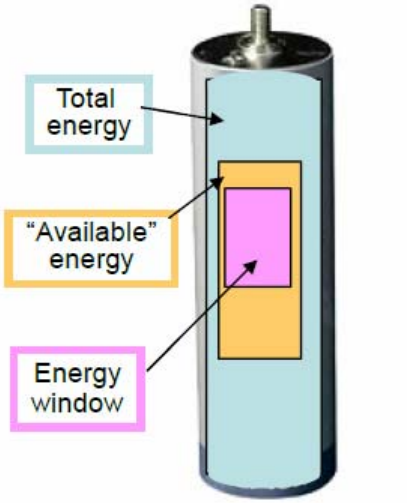
Thermal Stability Model of ULTIMO



Unlike LIB, ULTIMO DOES NOT use lithium metal oxide which potentially causes thermal runaway.

Why Ultimo Instead of Battery?

Energy vs Efficiency



Battery Energy Distribution

Ultimo Energy Distribution

- Although a battery has a high energy density
  - Due to cycle life concerns, only a portion of the energy is available
  - Due to its high internal resistance, only a portion of the available energy is in the useable energy window
- Ultimo is capable of deep charge/discharge cycles; it contains less energy but uses it more efficiently
  - A small UC module, can replace a large battery pack
  - In a mild hybrid vehicle comparison, NREL demonstrated that a 500Wh Battery Pack could be replaced by a 35Wh UC module
  - The UC module provided equal performance
  - *Hybrid Vehicle Comparison Testing Using Ultracapacitor vs. Battery Energy Storage; NREL/PR-540-47355*

Why ULTIMO Instead of EDLC Supercap?

Characteristics of ULTIMO compared to EDLC

Energy density: ULTIMO is 4 times higher.
ULTIMO enable to make products smaller and lighter.

$U = \frac{1}{2} CV^2$

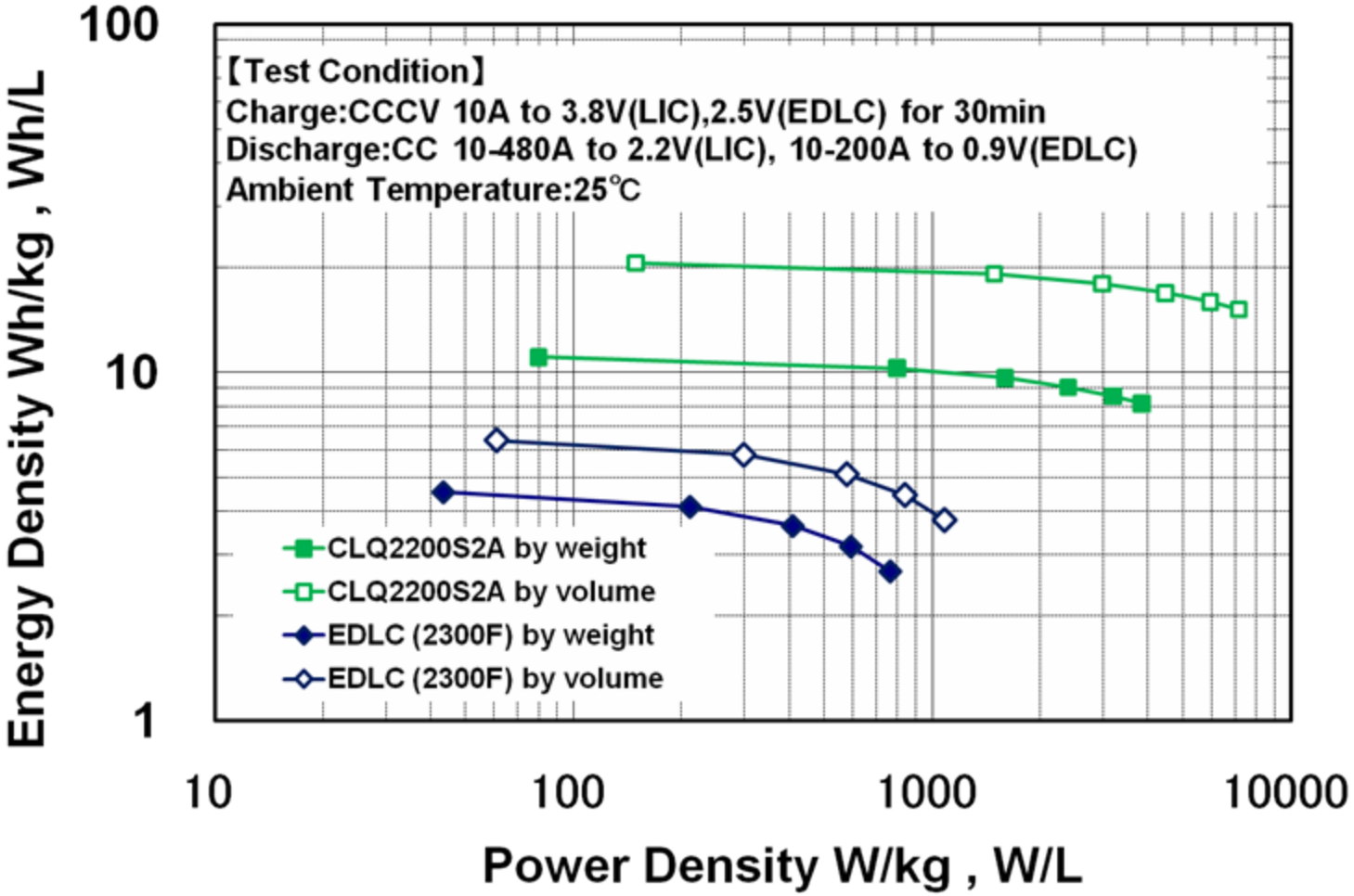
C is 2 times higher
(with same amount of activated carbon)
V is 1.5 times higher

Rated voltage: ULTIMO is 1.5 times higher. ULTIMO requires about 2/3 cells than EDLC for same voltage module.

2.5V / 3.8V = 0.65
About 1/3 of cells can be saved with ULTIMO.

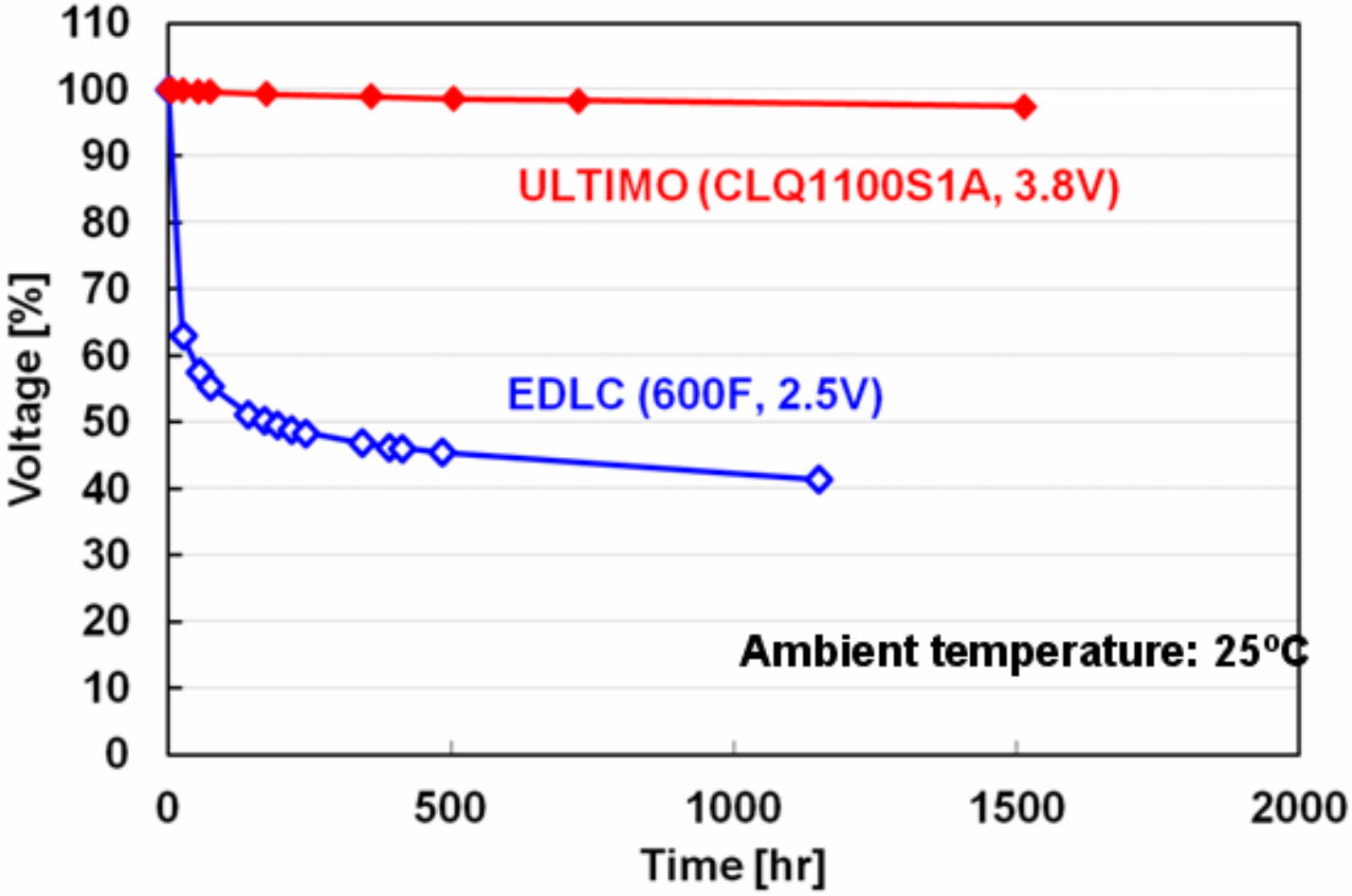
Self discharge: ULTIMO shows significantly lower self discharge rate.
ULTIMO is more suitable for energy storage device and easier to utilize to local grid, for example.

Ragone Plot (ULTIMO vs EDLC)



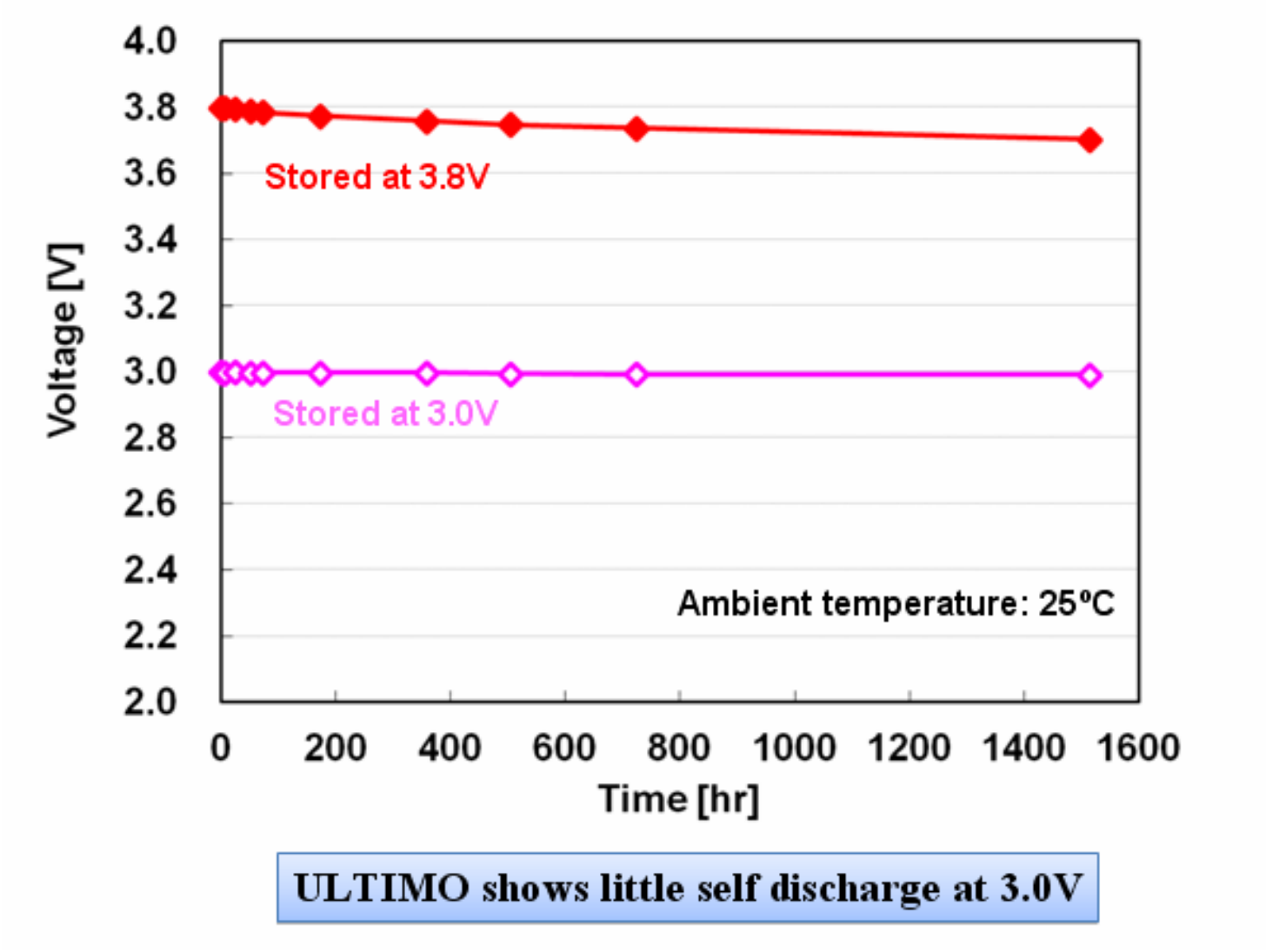
ULTIMO shows 4 times higher energy density

Self discharge properties (ULTIMO vs EDLC)



ULTIMO shows significantly lower self discharge rate

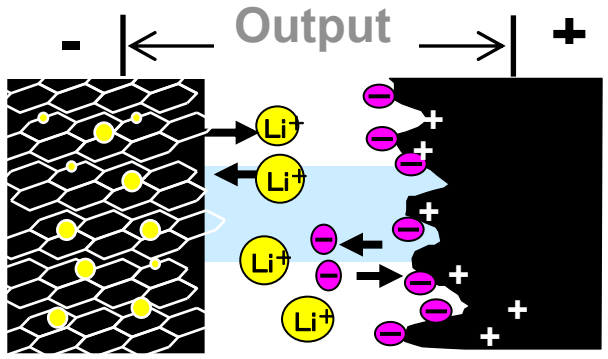
Self discharge properties (ULTIMO: CLQ1100S1A)



ULTIMO shows little self discharge at 3.0V

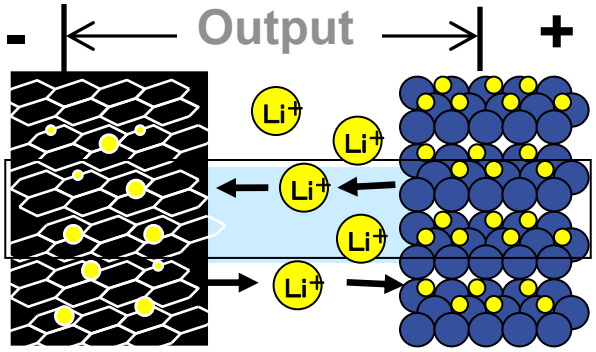
LIC Design Concept

Lithium Ion Capacitor



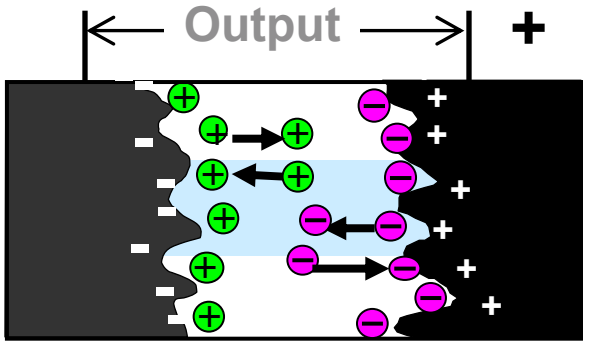
Li-doped Carbon **Electrolyte** Activated Carbon

Lithium Ion Battery



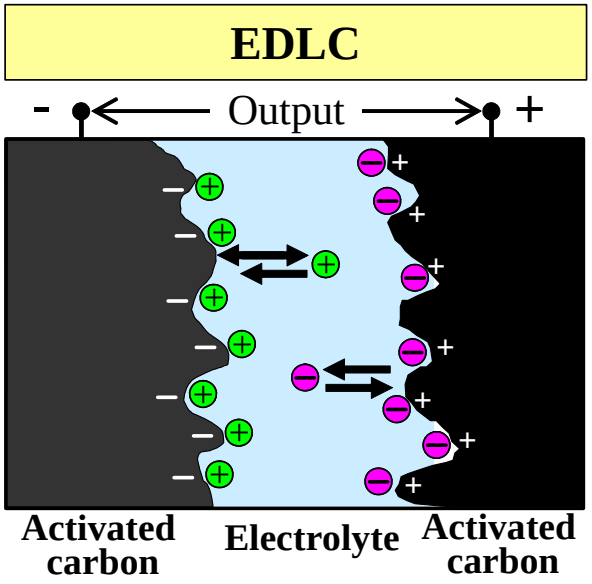
Graphite **Electrolyte** $LiCoO_2$

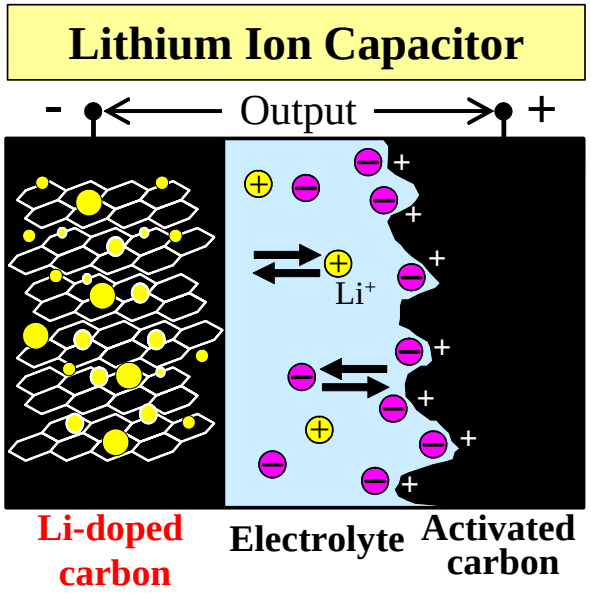
EDLC



Activated Carbon **Electrolyte** Activated Carbon

Capacitance of EDLC vs LIC





$$\frac{1}{C_{cell}} = \frac{1}{C-} + \frac{1}{C+}$$

$C- = C+ = C$

$C_{cell} = 1/2C$

LIC's Capacitance is twice as high

$C- >> C+$

$C_{cell} = C+$

Why ULTIMO (Lithium Ion Capacitor)? (Summary)

Advantage of ULTIMO

- ✓ **High Working Voltage (3.8V - 2.2V)**
- ✓ **High Energy Density**
- ✓ **Wide Operation Temperature (-20C / 70ºC)**
- ✓ **Long Cycle Charge Discharge Durability (>100K cycles*)**
- ✓ **Low Rate Self Discharge (< 5% voltage loss in 3 months)**

(*the number of possible cycles depends upon applied condition.)

Suitable Applications

Peak Assist
Energy Storage
Energy Back Up
Energy Leveling
Battery Life Extension
Hybrid
Energy Regeneration

First Generation ULTIMO™ LIC

- Introduced in 2008
- Customers liked
  - Form Factor
  - High Energy Density and High Max Voltage, 3.8v
  - Low Leakage
- Customers asked for
  - Higher capacitance
  - Lower internal resistance
  - Increased robustness
  - Modules

The New Gen 2 Laminate ULR ULTIMO™

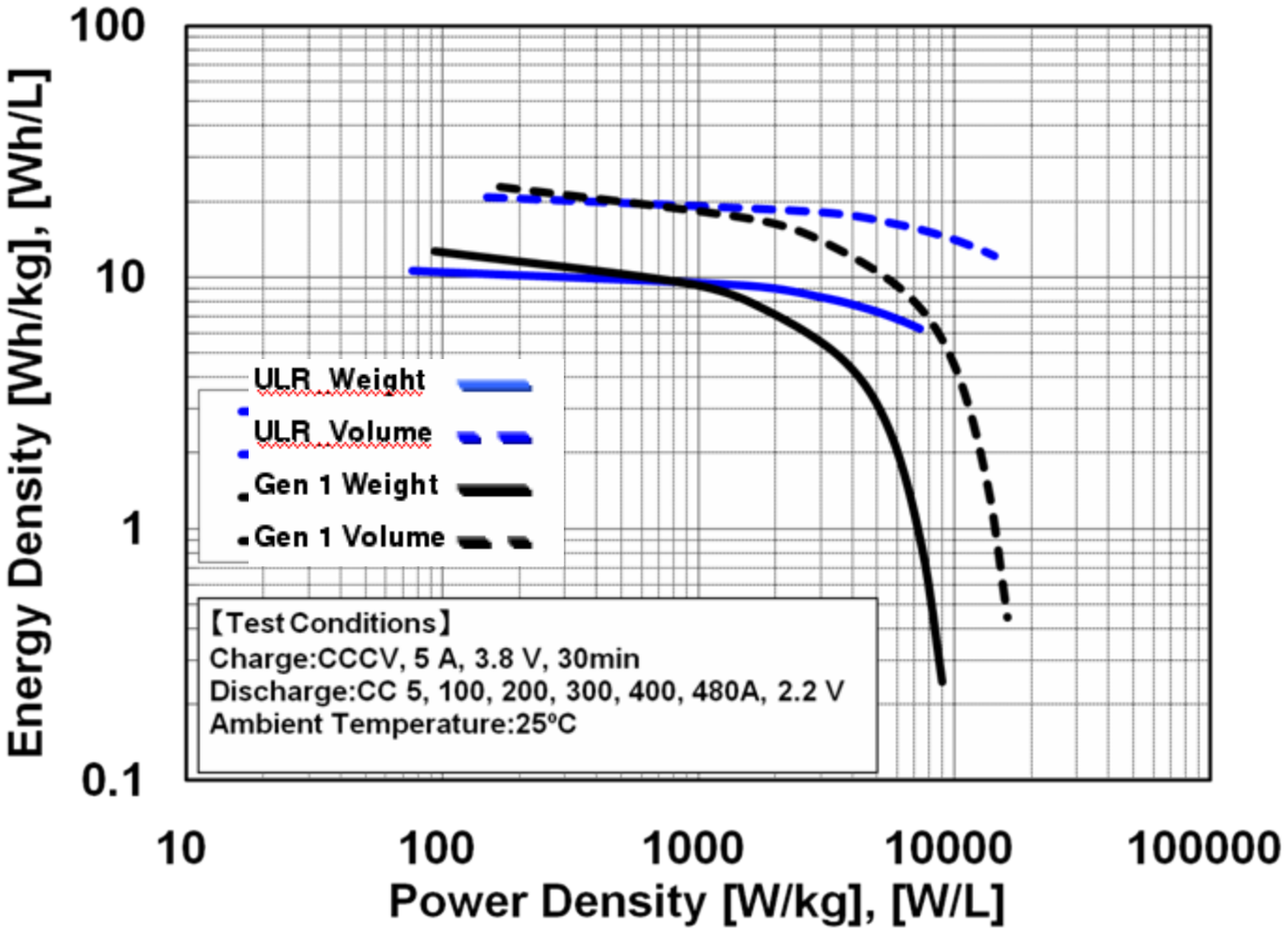
ULR = Ultra Low Resistance

Items	1100F type		2200F type		Remarks
	Gen 1	Gen 2*	Gen 1	Gen 2*	
Rated voltage [V]	2.2 ~ 3.8	2.2 ~ 3.8	2.2 ~ 3.8	2.2 ~ 3.8	
Capacitance [F]	1100	1100	2200	2200	
DC-IR [mΩ]	4.5	1.2	2.3	0.7	70% REDUCTION
Weight energy density [Wh/kg]	12	10	14	10	
Volume energy density [Wh/L]	21	19	25	19	
Dimension (L x W) [mm]	180 x 126	180 x 126	180 x 126	180 x 126	without terminals
Thickness [mm]	4.5	5.5	8.5	10.9	

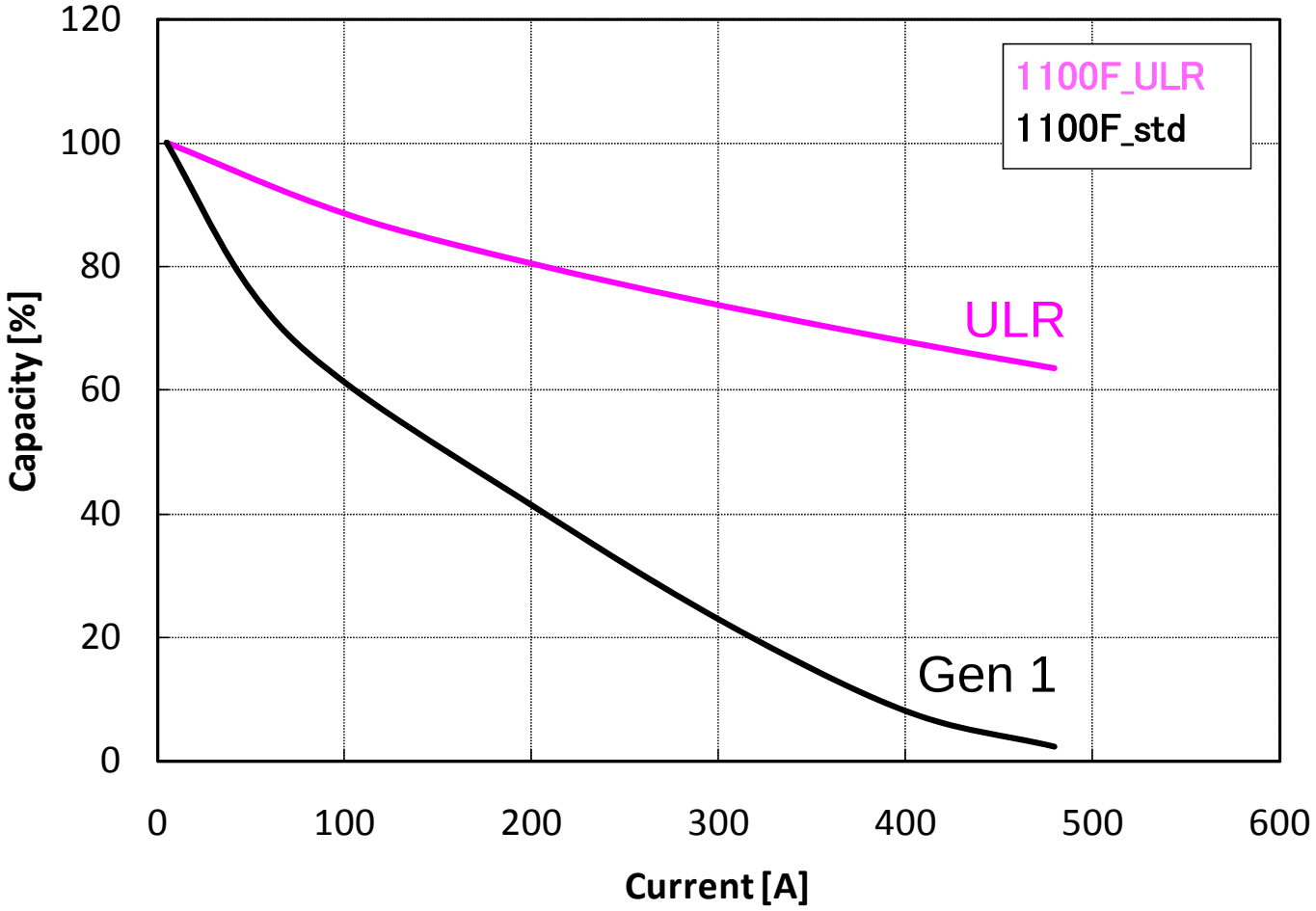
* Tentative values

Ragone Plot

1100F ULR vs Gen1



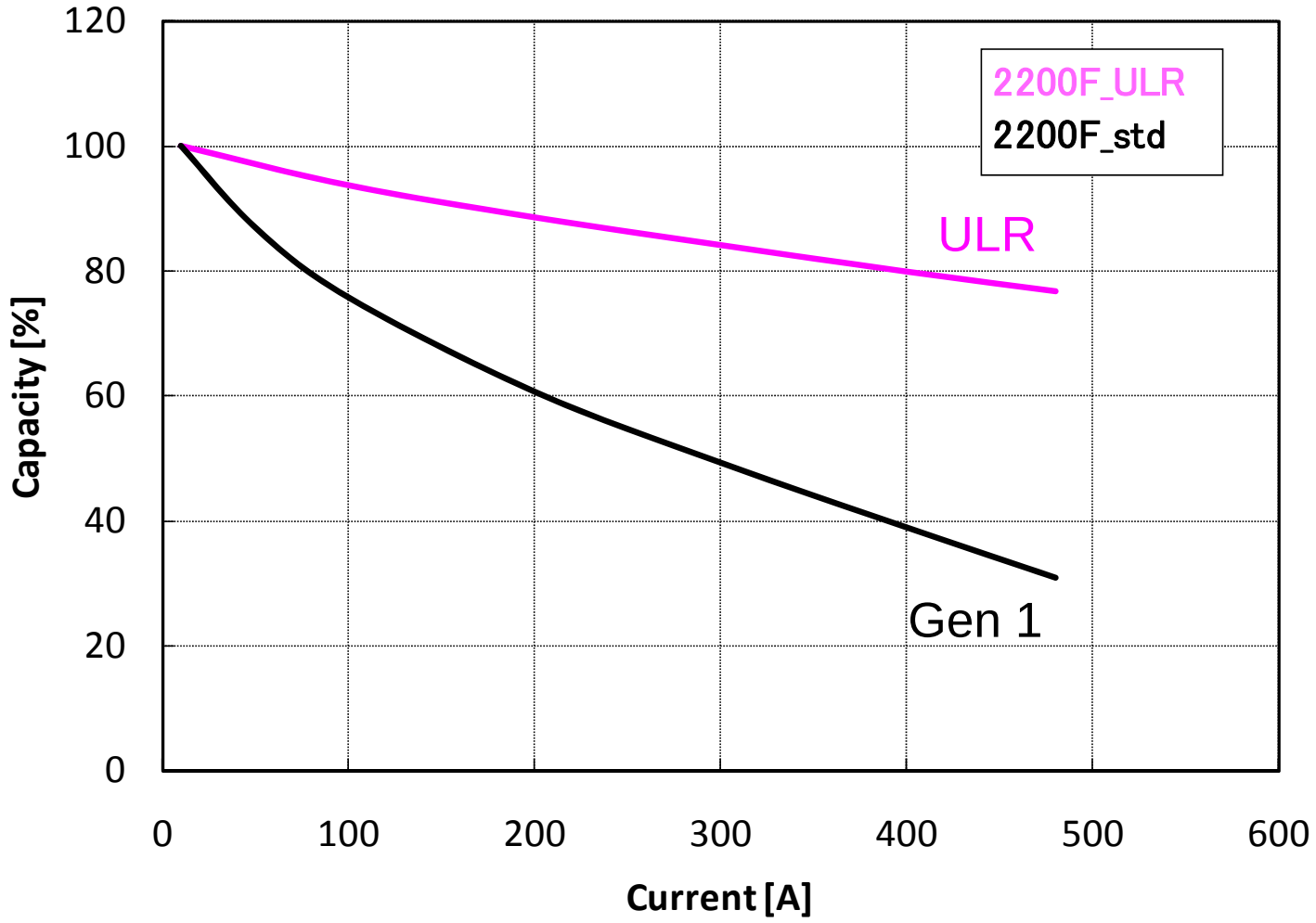
Rate properties, 1100F



ULR retained significantly higher capacity especially at higher discharge rates

- **2X at 200A(400C rate); over 3x at 300A(600C rate)**

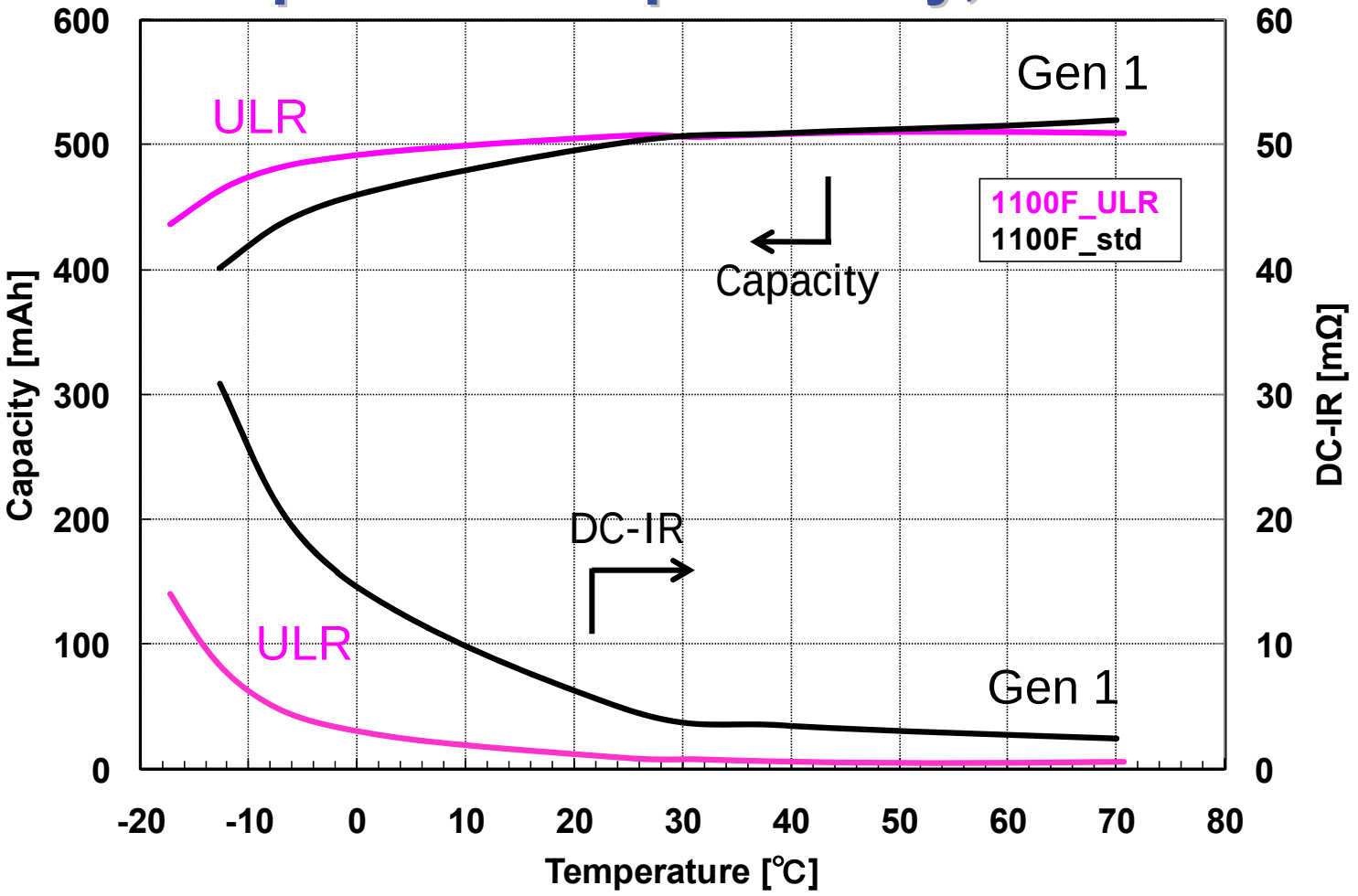
Rate properties, 2200F



ULR retained significantly higher capacity especially at higher discharge rates

- **1.5X at 200A(200C rate); over 2x at 400A(400C rate)**

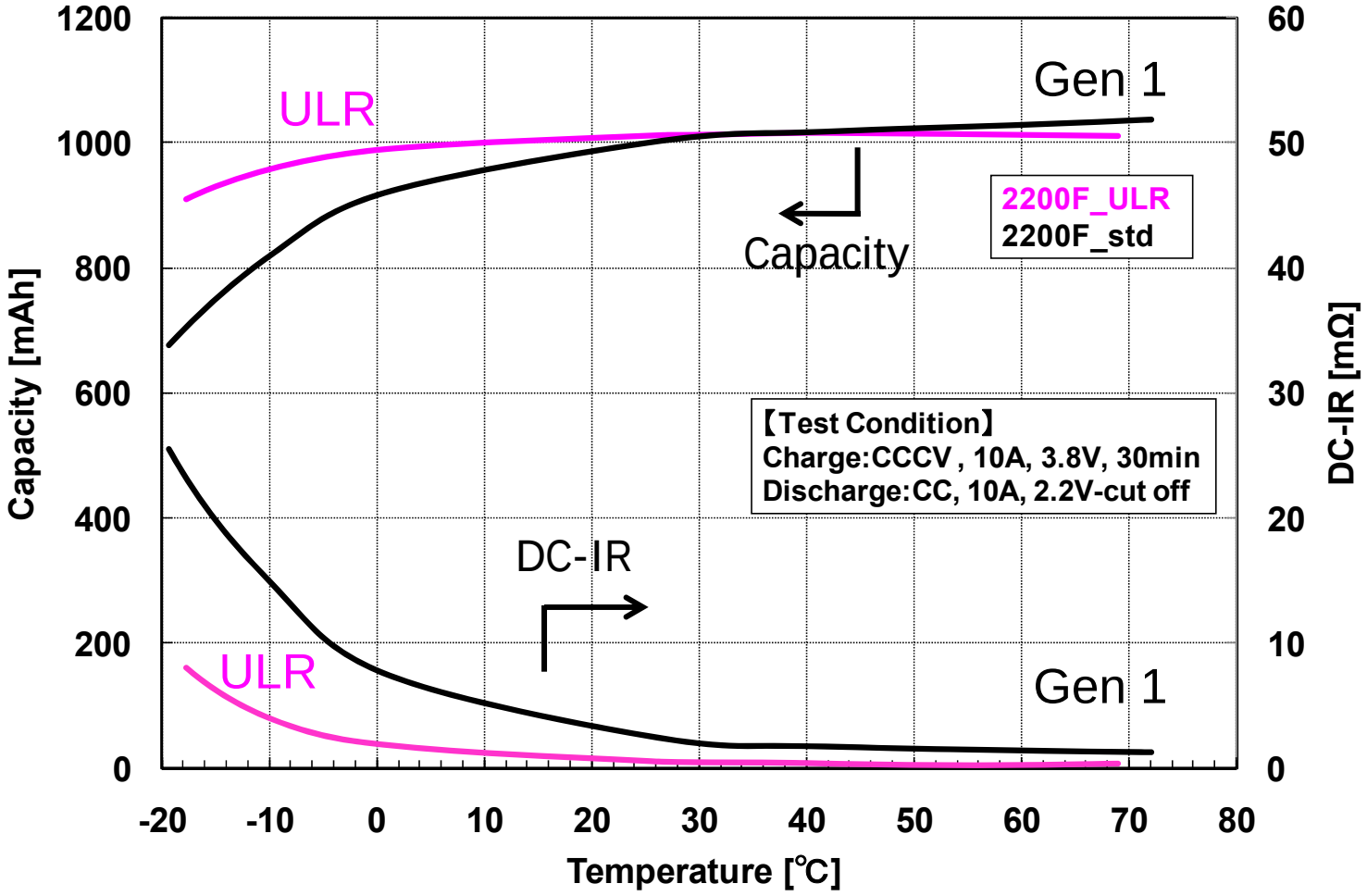
Temperature dependency, 1100F



ULR shows higher capacity and lower DC-IR at low temperature

- **DC-IR is ca 70% lower in the 70° C to -20° C range**

Temperature dependency, 2200F



ULR shows higher capacity and lower DC-IR at low temperature

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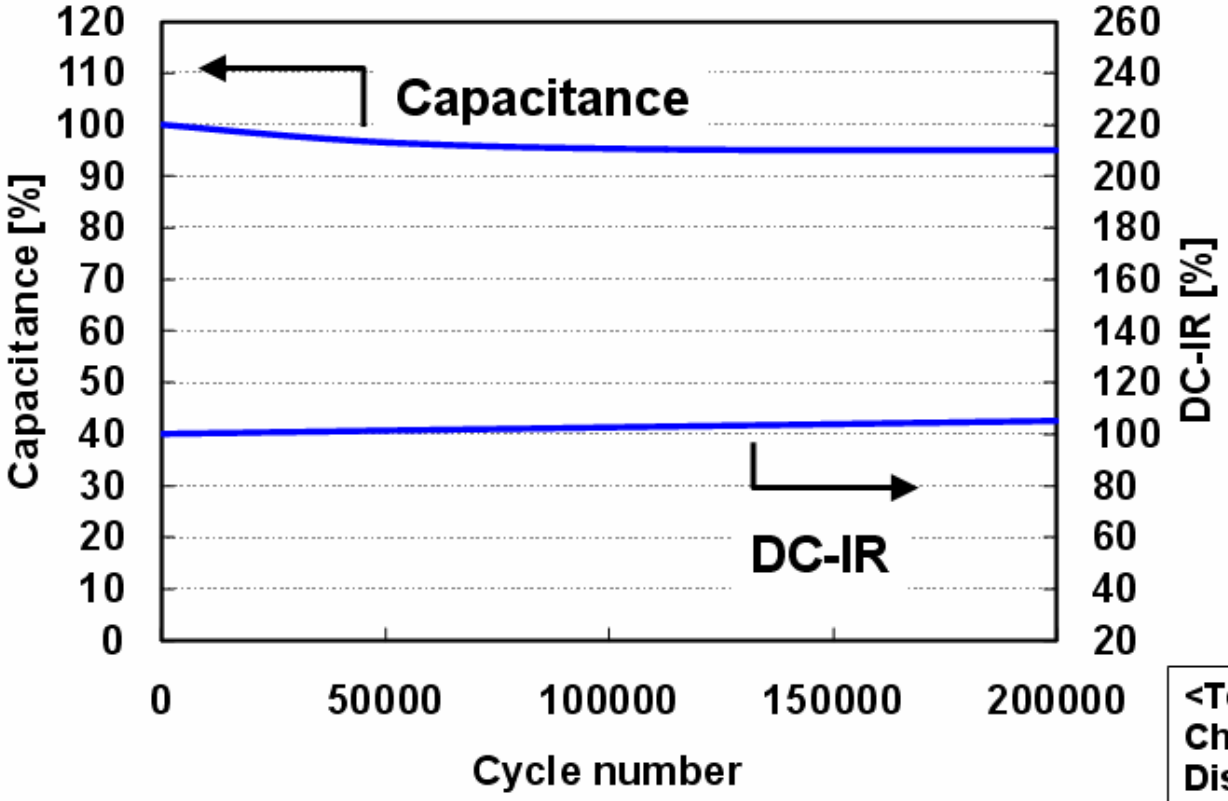
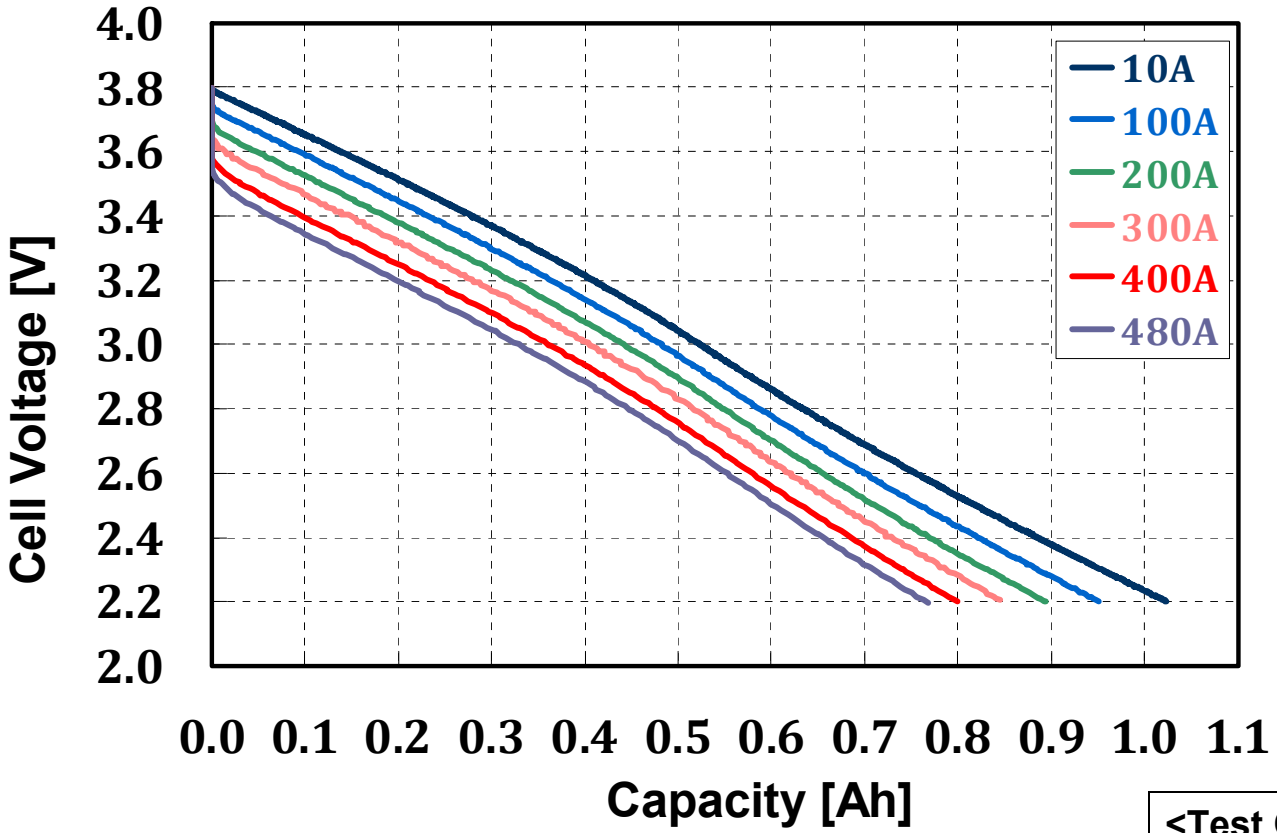
Cycle-life performance, 1100F ULR



<Test Conditions>
Charge: CC, 100A, 3.8 V
Discharge: CC, 100A, 2.2V
Rest time: zero
Ambient Temperature:25°C

ULR cell retained high capacity at high discharge rate, 200C, continuous cycling

Discharge Curve, 2200F ULR



<Test Conditions>
Ambient Temperature: 25ºC

ULR cell retains linear discharge

Prismatic type ULTIMO suitable for mobile applications

The first Prismatic Type LIC In The World

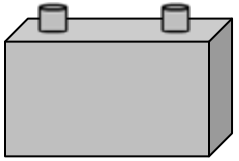
Typical properties of Prismatic type ULTIMO

R&D prototype cell Characteristics	2300F type	3300F type	Remarks
Rated voltage [V]	2.2 ~ 3.8	2.2 ~ 3.8	
Capacitance [F]	2300	3300	
DC-IR [mΩ]	0.7	1.0	
Weight energy density [Wh/kg]	8	12	Charge: CCCV, 3.8V for 30min Discharge: CC, 10A, 2.2V Ambient temperature: 25°C
Volume energy density [Wh/L]	15	20	
Weight power density [kW/kg]	8	7	Average discharge power at maximum discharge current at 25°C
Volume power density [kW/L]	15	13	
Maximum discharge current [A]	1200	1100	Maximum Peak Current, for a 1 second discharge @25°C, estimated by rate data up to 480A.
Dimension (L x W x t) [mm]	150 x 91.5 x 15.5	150 x 91.5 x 15.5	Without terminals
Weight [g]	375	360	

* Tentative values

Winding type cell development

Comparison between Cylindrical Cells and Prismatic Cells

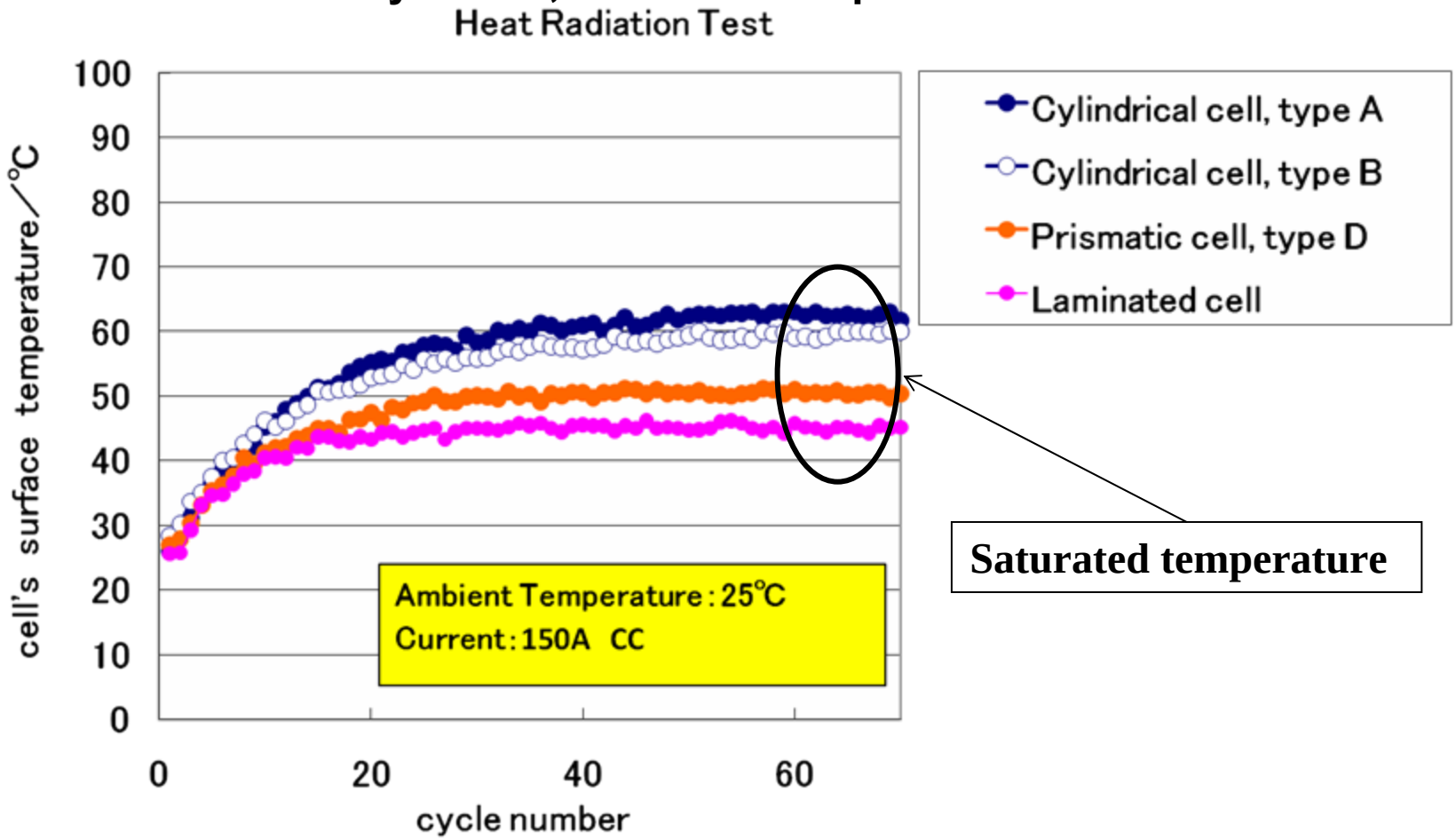


	Cylindrical Type	Prismatic Type
As a cell	Flexible terminal position	Efficient heat release Easy handling
As a module	- Cylindrical EDLC module design compatibility	Easy assembly Compact module High energy density

Winding type cell development: Heat Radiation Test

Experimental

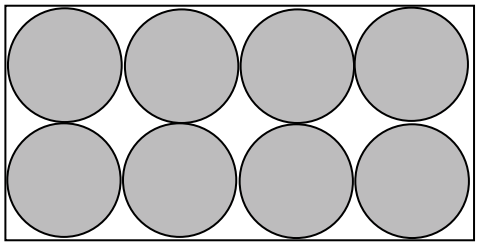
For heat radiation test, high rate charge-discharge cycle was applied to generate heat internally. Then, saturated temperature was recorded.



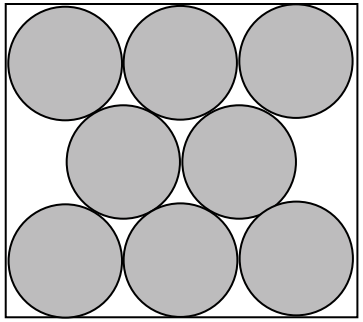
Winding type cell development: Why Prismatic?

Spatial efficiency

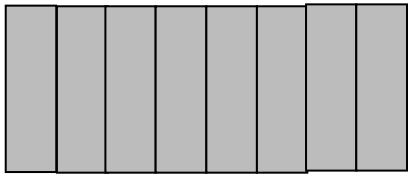
Eight cell package example



Extra space: 27%



Extra space: 30%



Extra space: 0%

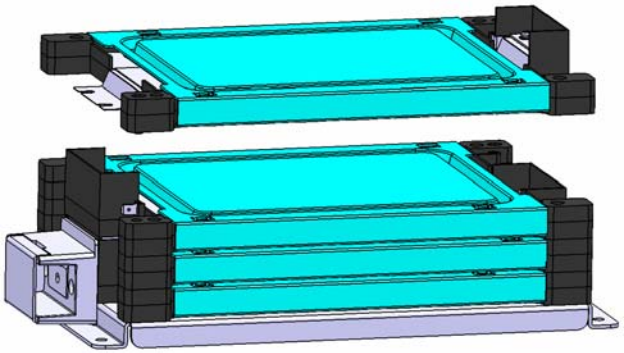
Prismatic type cell makes module more compact.

Heat radiation efficiency

Prismatic type cell showed better heat radiation.

96% (24/25) of customer chose Prismatic type cell as a preferable form. (JM Energy's marketing research)

Laminate Module

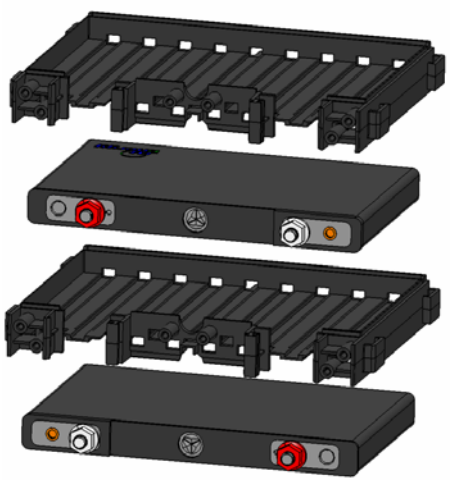


8 x 2200F

8 x 1100F

- Each cell is in an individual stacking tray
- Module framework provides easy connectivity and custom sizes

Prismatic Module



- Stacking units will provide easy connectivity and custom module sizing

ULTIMO in commercial use

<30kW－60sec－200V>

Thanks to Meidensha

<Product introduction>

①20kVA～10,000kVA compensation

②New Voltage sag compensator by fusion of new storage device and high efficient converter system

（feature）

1)System efficiency >99%

2)Long compensation time enable establish the combination system with emergency generator.

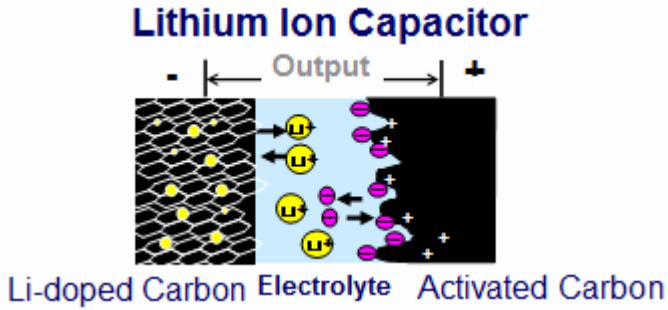
<Function of ULTIMO>

①Long compensation time compared to EDLC

②Small system by reducing cell numbers (high cell voltage: 3.8volt).

③Long life and environmental friendly compared to lead acid battery.

Summary



- ULTIMO™ LIC Advances
  - Ultra Low Resistance Cell
    - ✓ 70% reduction in internal resistance
  - New Prismatic Cells & Modules
    - ✓ World's first
    - ✓ Improved thermal and stacking efficiency

  - Expanding commercial & future enabling applications
    - ✓ Remote/portable medical imaging
    - ✓ Instantaneous backup power; sag compensation; peak-leveling
    - ✓ Transportation … hybrid electric vehicles …aerospace