

Electrochemical double-layer capacitance and pseudo-capacitance in negative electrode of the UltraBattery

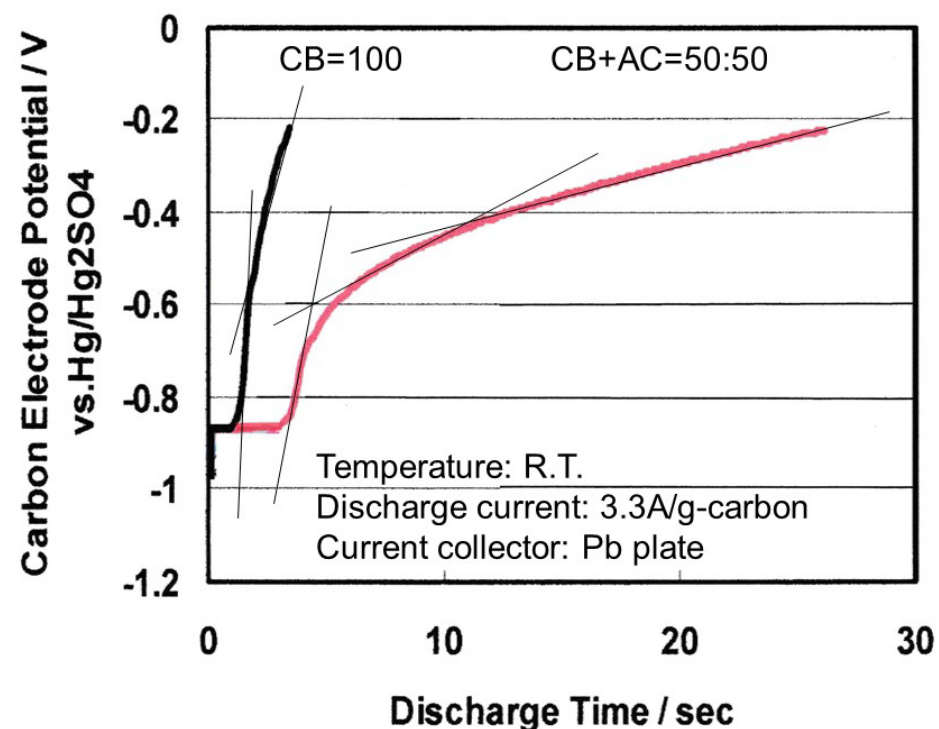
ALBA 2026, May 19th - 20th 2026, Mainz

Dr. Jun Furukawa, Consultant

Electrochemical double-layer capacitance and pseudo-capacitance in negative electrode of the UltraBattery

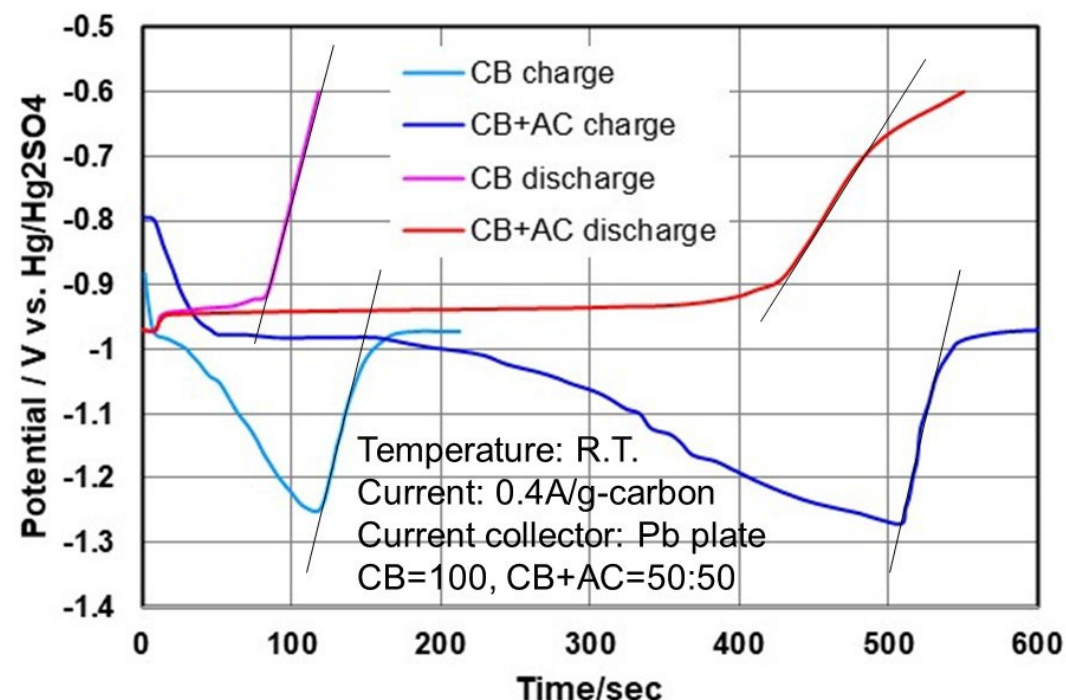
ALBA 2026 May 19th – 20th 2026, Mainz, Dr. Jun Furukawa, Consultant

1. The negative electrode of the UltraBattery consists of a lead electrode and an activated carbon electrode. It comprises electrochemical double-layer capacitance, pseudo-capacitance, and lead charge/discharge capacity.



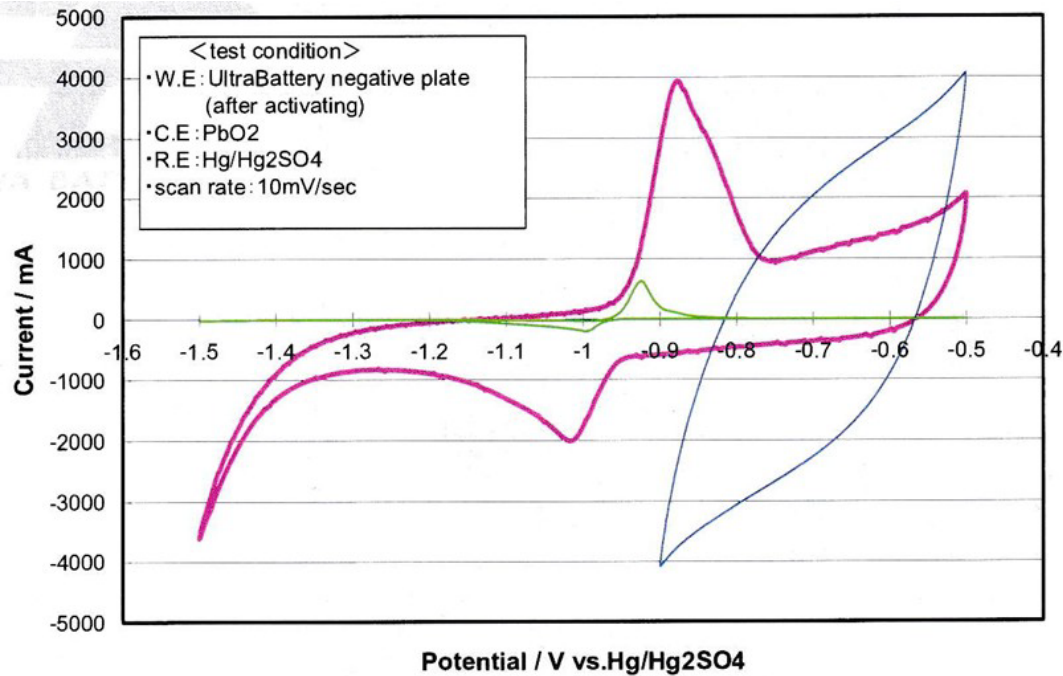
High rate discharge I-V characteristics of carbon electrode

2. Within the charge/discharge potential range of the lead electrode, the contributions of electrochemical double-layer capacitance is not very large. The pseudo-capacitance can be ignored.



Charge and discharge behavior of carbon electrode

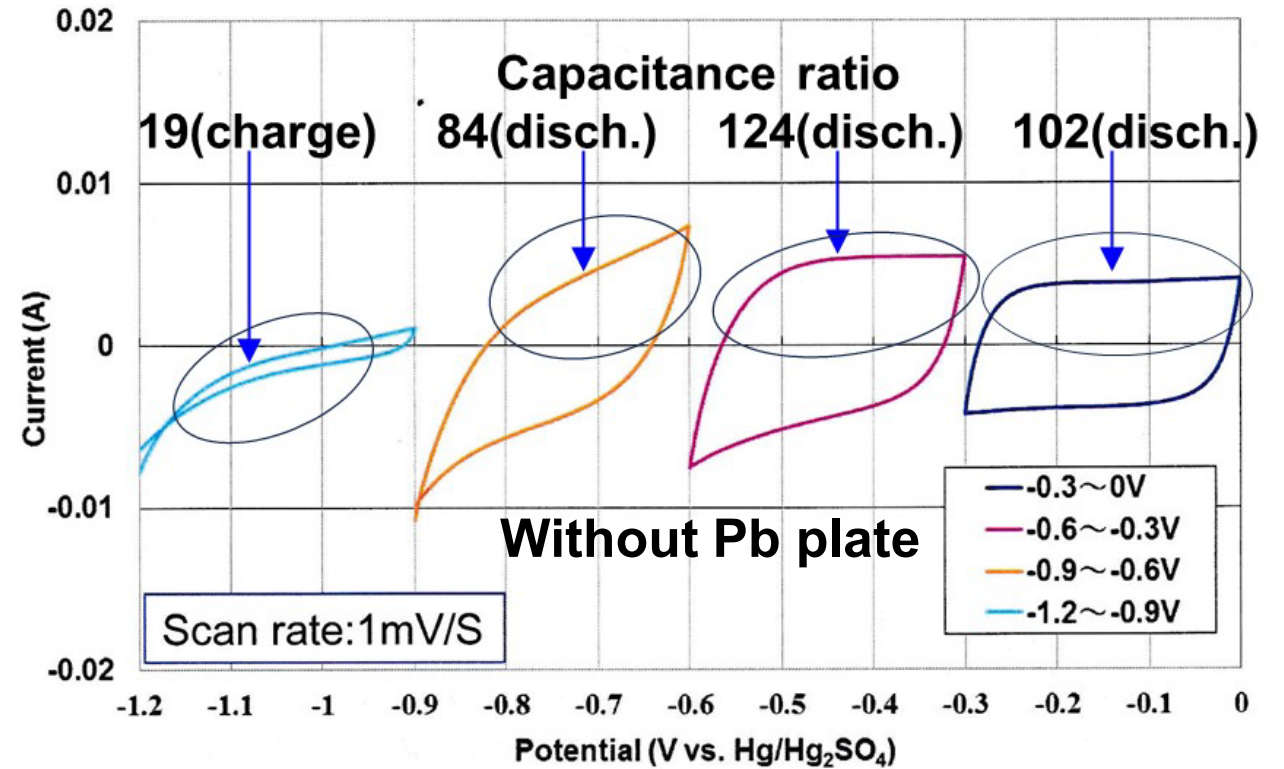
3. At potentials where the lead electrode over-discharges, the electrochemical double-layer capacitance and pseudo-capacitance of the activated carbon electrode come into play, preventing over-discharge of the lead electrode.



Carbon electrode after activating
(Carbon electrode: activated carbon,
carbon black and Pb plate)

Comparison of cyclic voltammogram

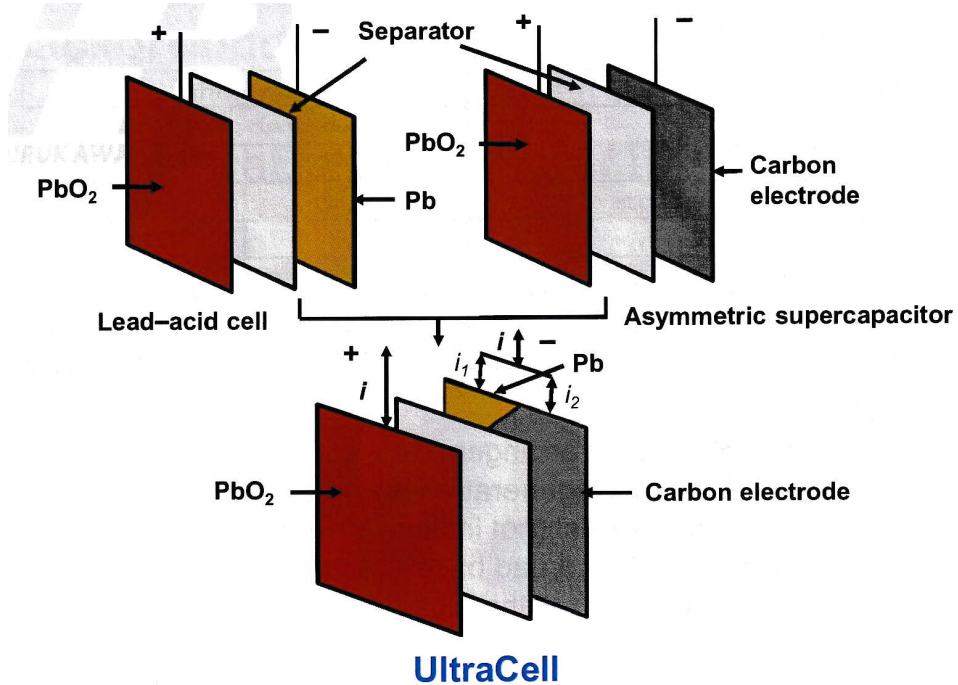
Thank you for your attention



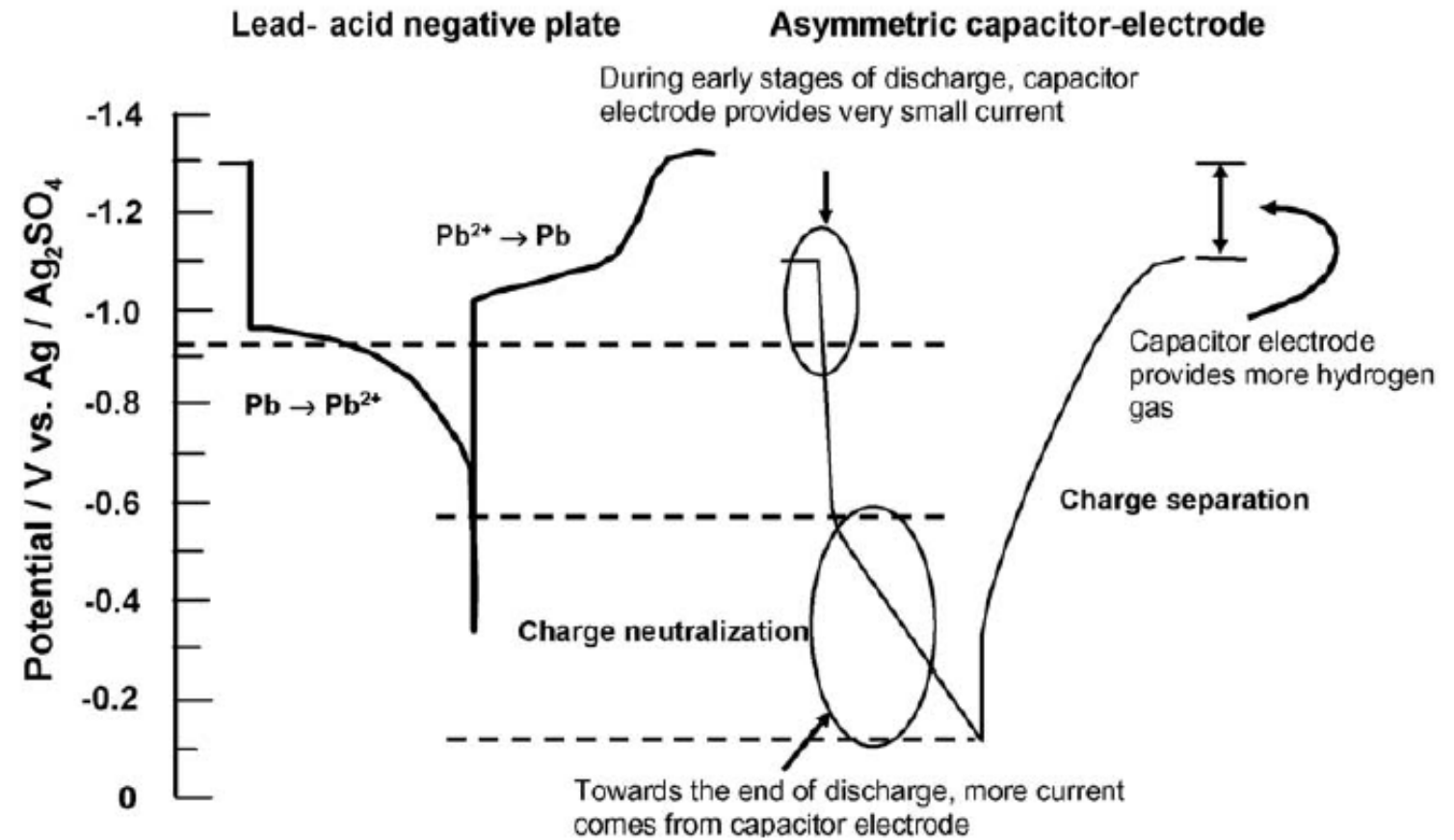
- 1.2V to -0.9V: Hydrogen evolution.
- 0.9V to -0.6V: Hydrogen evolution & Double-Layer Capacitance.
- 0.6V to -0.3V: Double-Layer Capacitance.
- 0.3V to 0.0V: Double-Layer Capacitance & Pseudo-capacitance from redox reaction of quinone group.

Cyclic voltammogram of carbon electrode without Pb

Configuration of UltraCell

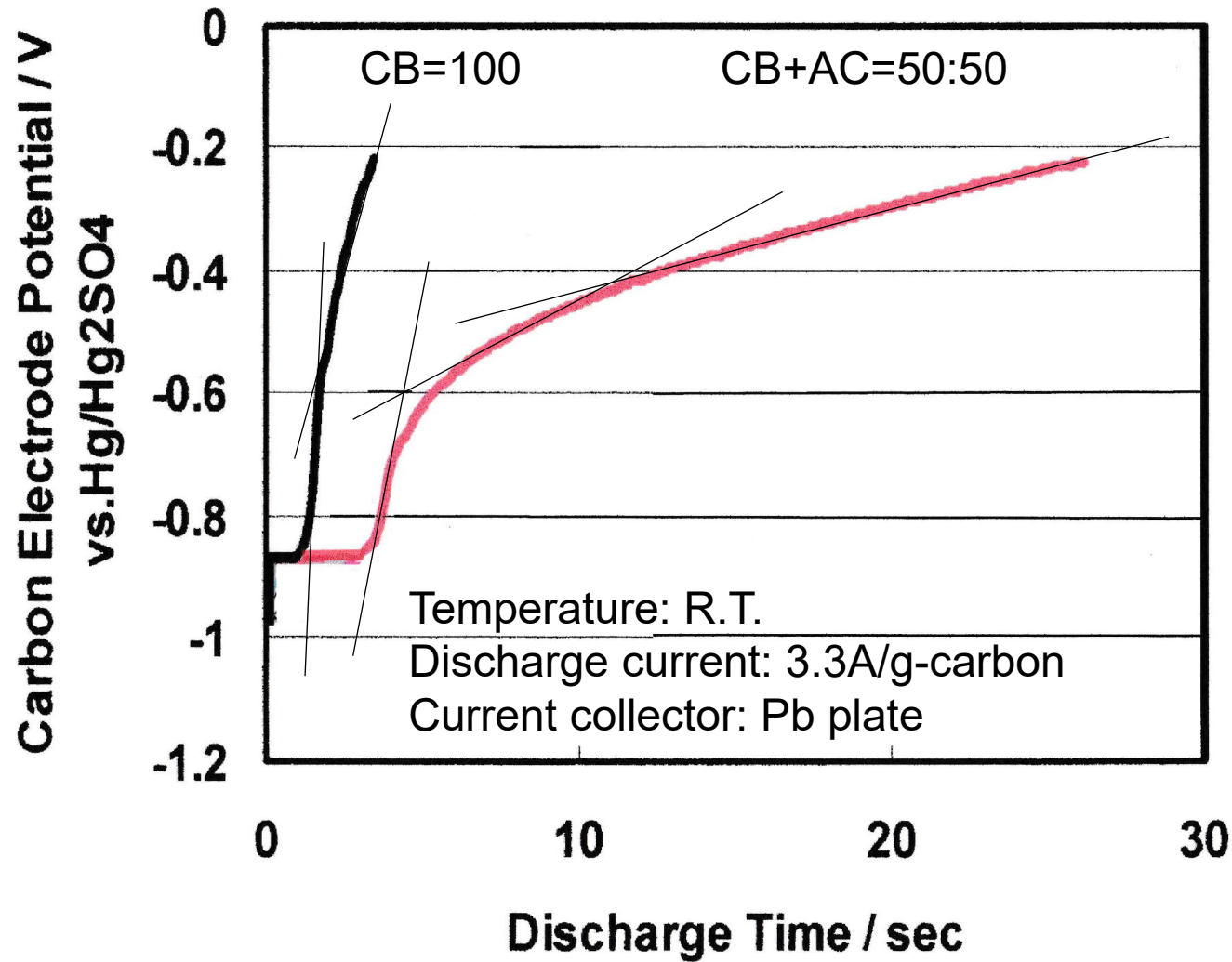


Operational potentials of lead-acid negative plate and carbon-based capacitor electrode during discharge and charge.



Source: L. T. Lam and R. Louey (2006)

High rate discharge I-V characteristics of carbon electrode

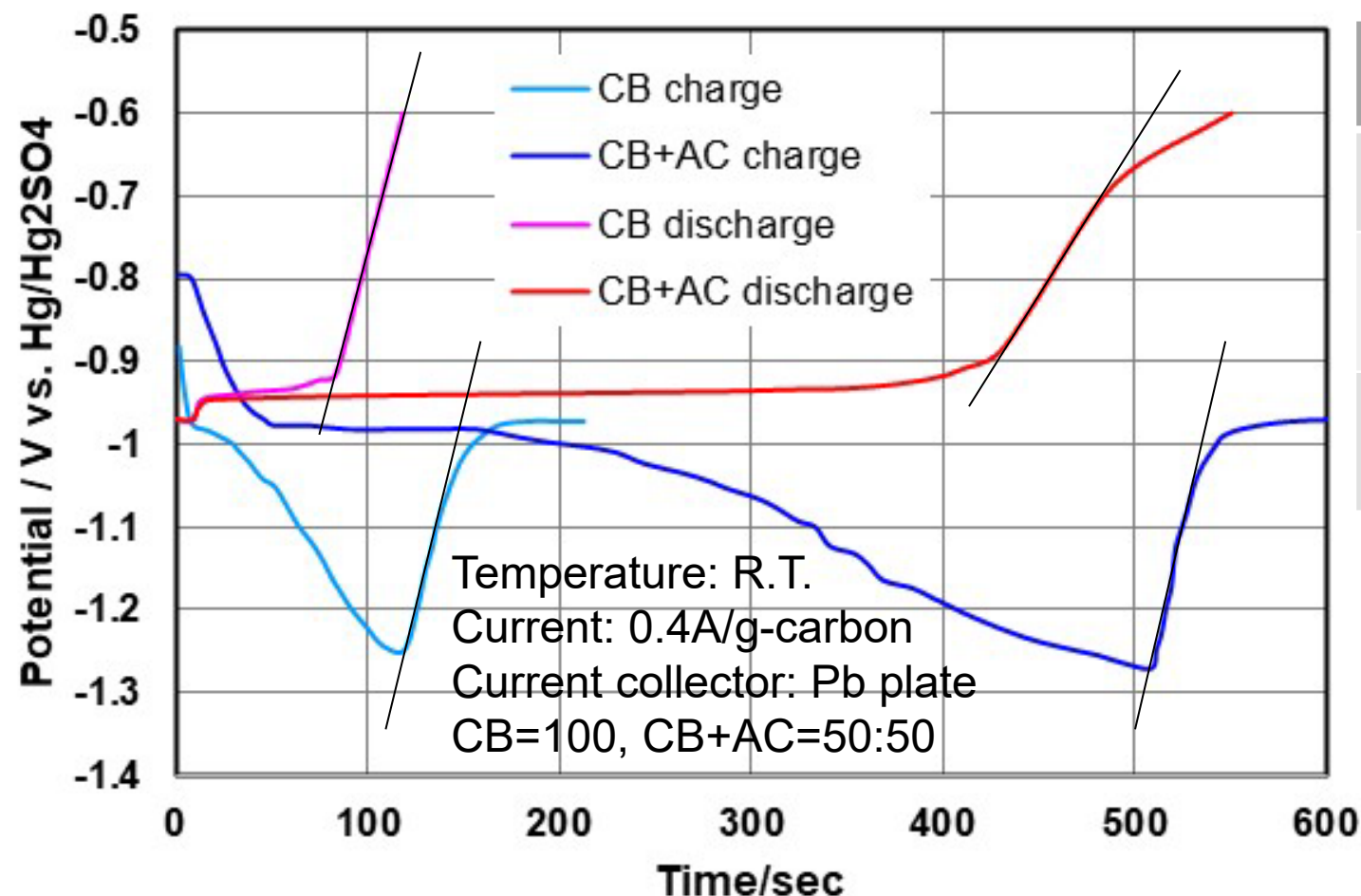


Item	CB	CB+AC
OCV	-0.97 V	-0.97 V
-1.0V to -0.6V Pb discharge	5.2 As/g	14.9 As/g
-0.6V to -0.2V DLC/Pseudo- Capacitance discharge	14.8 F/g	194 F/g

CB: Carbon Black, AC: Activated Carbon

Source: J. Furukawa and L. T. Lam (2005)

Charge and discharge behavior of carbon electrode



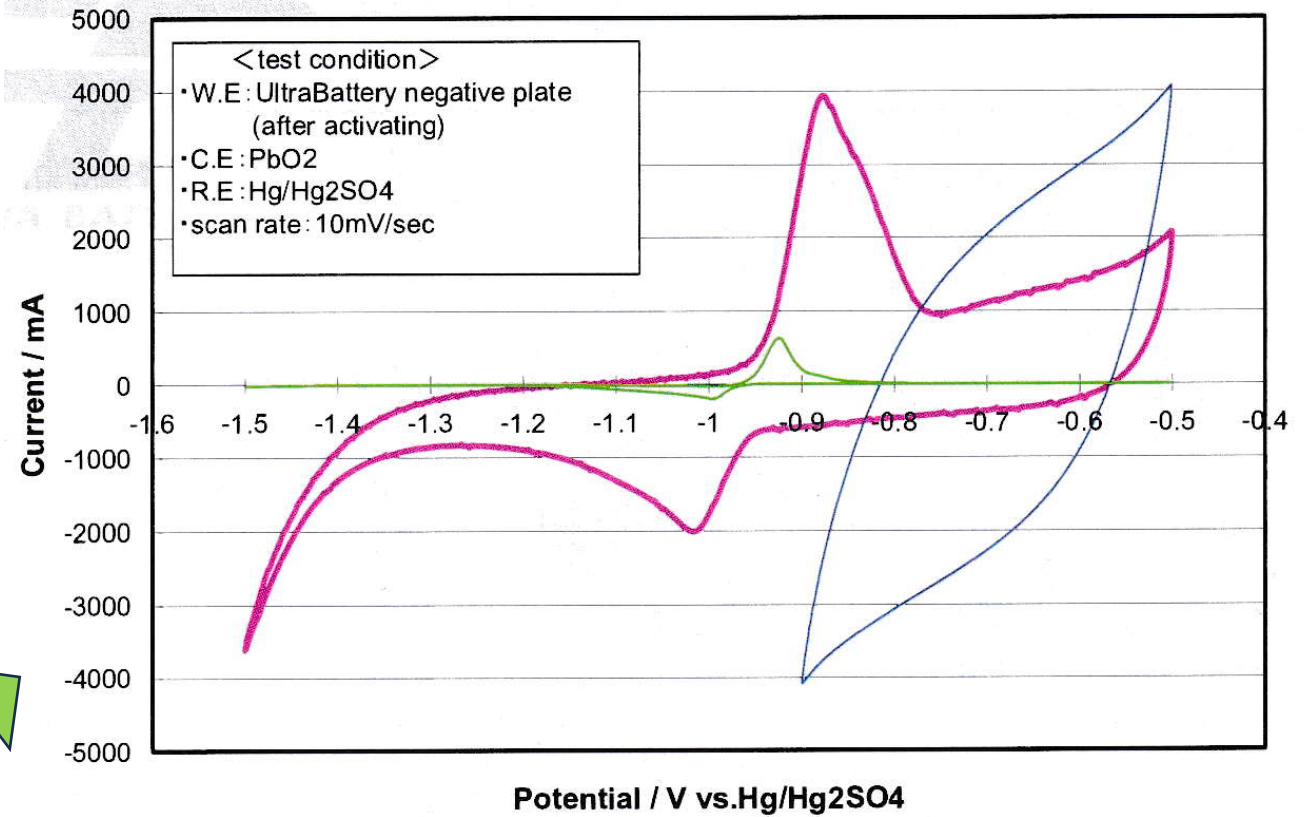
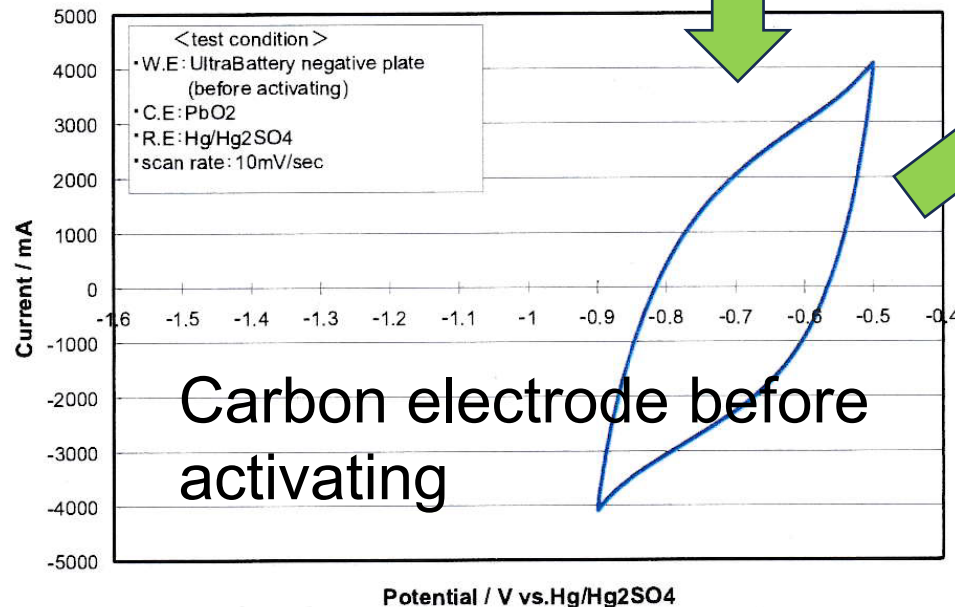
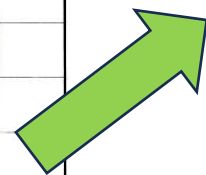
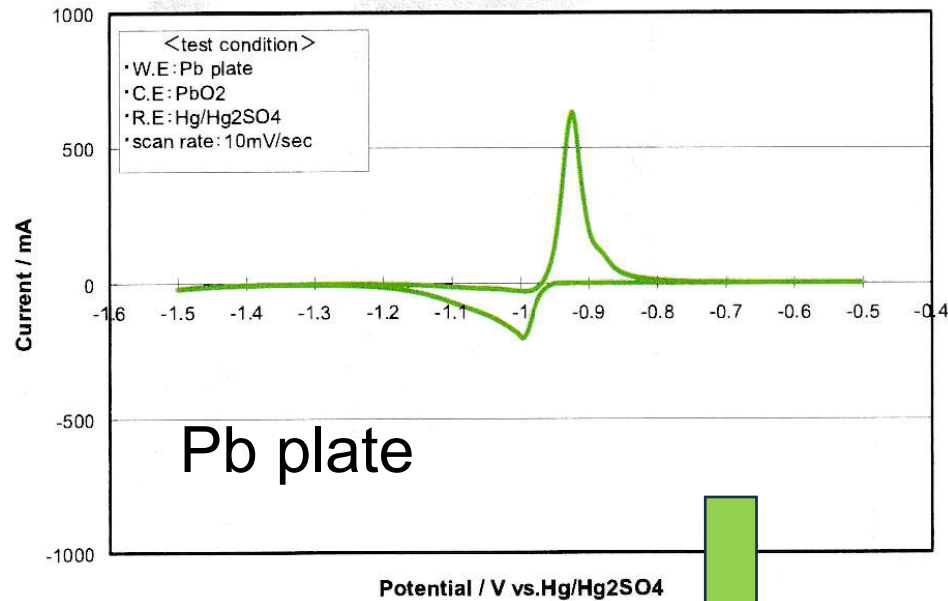
Item	CB	CB+AC
OCV	-0.97 V	-0.97 V
-1.0V to -0.6V Pb discharge	47.2 As/g	203 As/g
-1.2V to -1.0V Time constant	0.008 V/s	0.01 V/s

CB: Carbon Black, AC: Activated Carbon

- ✓ AC contributes to dissolving the lead substrate.
- ✓ Lead deposition causes the TOCV to fall below -1.2V.
- ✓ In the range of -1.3V to -0.6V, the DLC's contribution is small.

Source: J. Furukawa and L. T. Lam (2005)

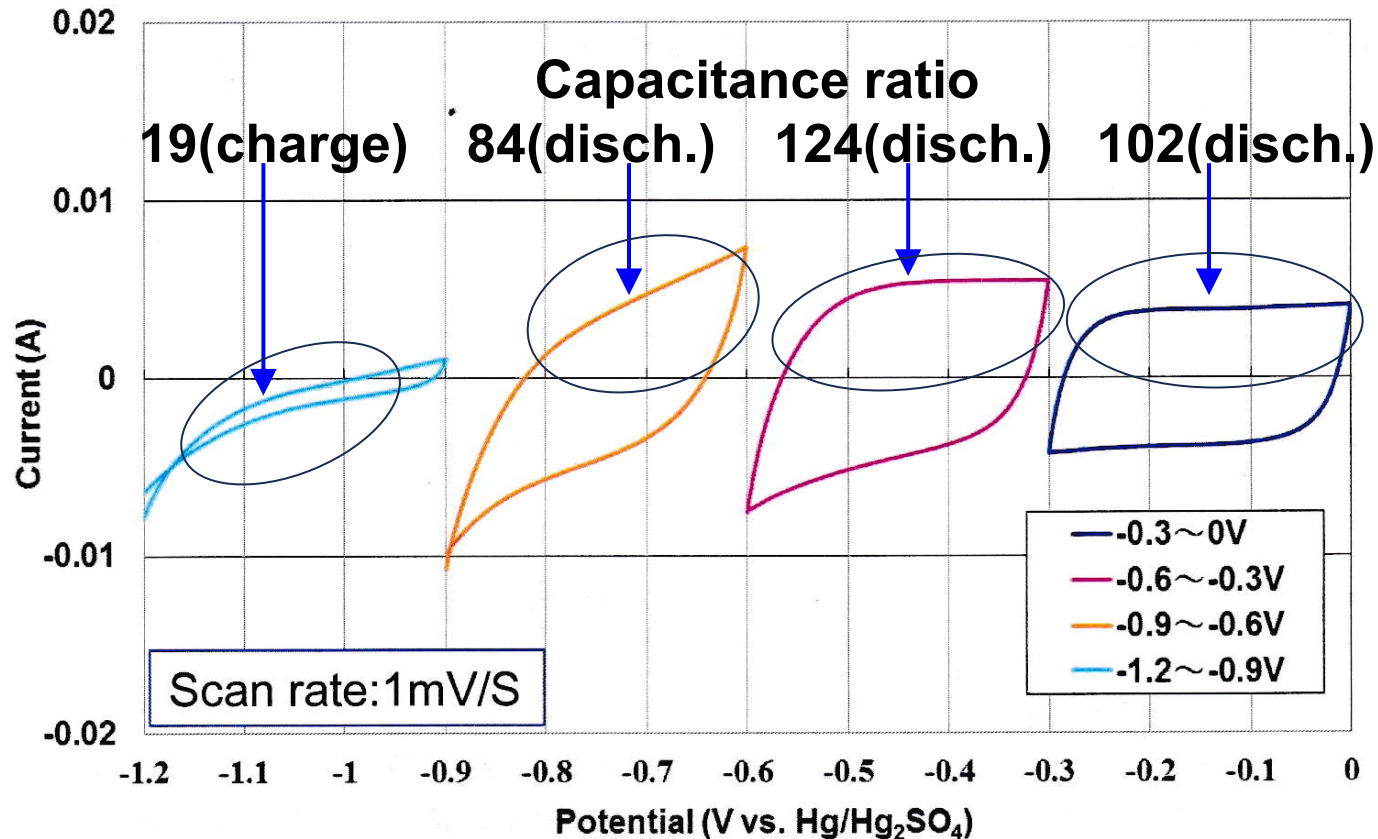
Comparison of cyclic voltammogram



Carbon electrode after activating
 (Carbon electrode: activated carbon,
 carbon black and Pb plate)

Source: J. Furukawa (2014)

Cyclic voltammogram of carbon electrode without Pb



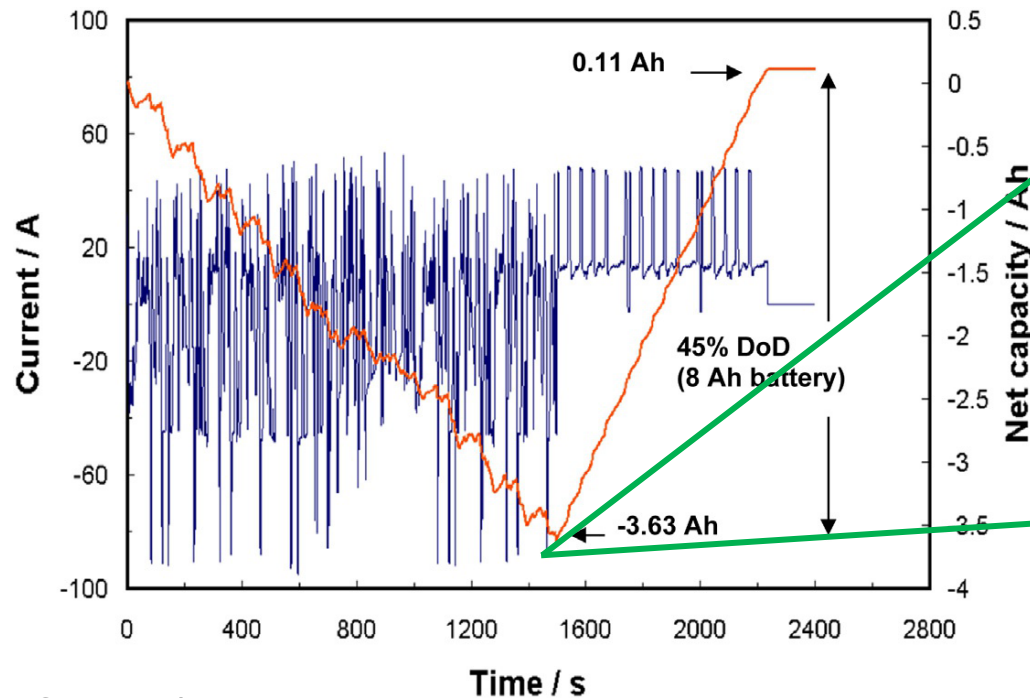
✓ Carbon Black + Activated Carbon electrode with glass like carbon current collector (Without Pb)
✓ Scan rate: 1mV/s

-1.2V to -0.9V: Hydrogen evolution.
-0.9V to -0.6V: Hydrogen evolution and Double-Layer Capacitance.
-0.6V to -0.3V: Double-Layer Capacitance.
-0.3V to 0.0V: Double-Layer Capacitance and Pseudo-capacitance from redox reaction of quinone group.

Test result of 12V VR-UltraBattery for Honda moderate-HEV pack (144V)

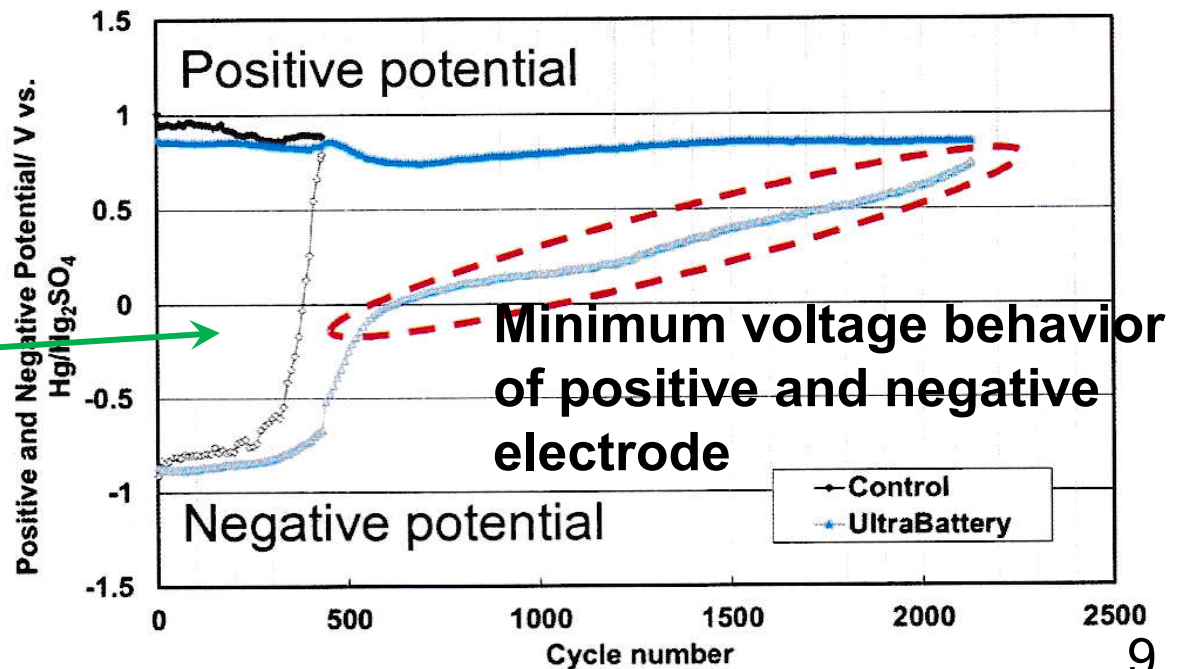
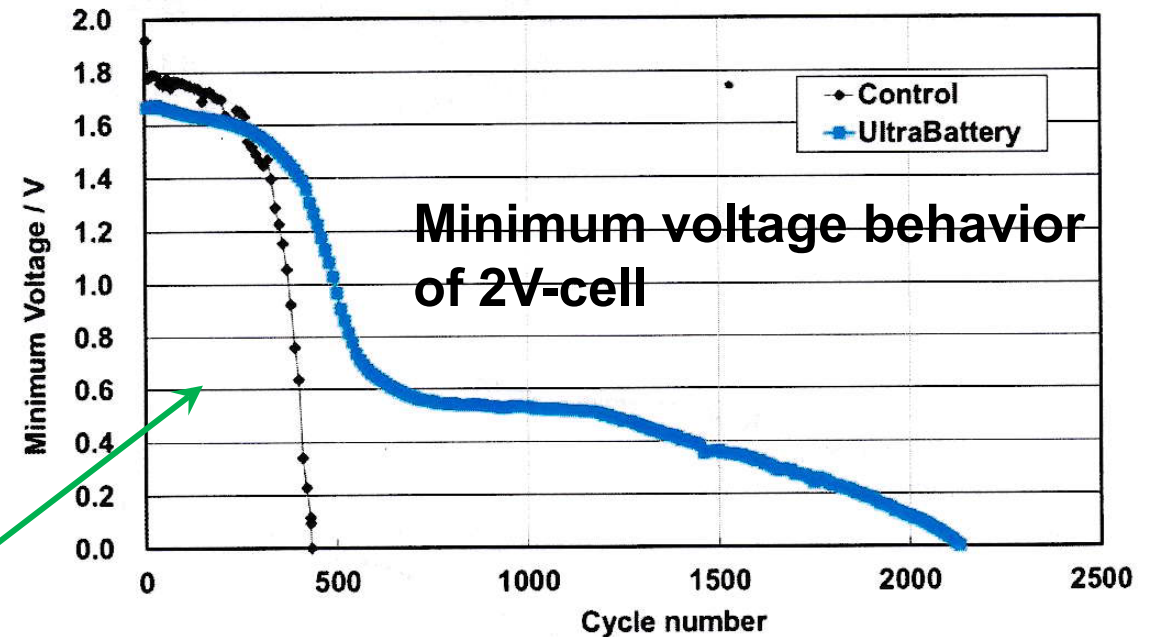


110Hx87Wx150L
6.7Ah@1HR, 8.5Ah@5HR
Achieved 160,000 km driving in proven ground test



RHOLAB (reliable, highly optimized, lead-acid battery) profile

Source: L. T. Lam and J. Furukawa (2009)



Conclusions

1. The negative electrode of the UltraBattery consists of a lead electrode and an activated carbon electrode. It comprises electrochemical double-layer capacitance, pseudo-capacitance, and lead charge/discharge capacity.
2. Within the charge/discharge potential range of the lead electrode, the contributions of electrochemical double-layer capacitance is not very large. The pseudo-capacitance can be ignored.
3. At potentials where the lead electrode over-discharges, the electrochemical double-layer capacitance and pseudo-capacitance of the activated carbon electrode come into play, preventing over-discharge of the lead electrode.
4. Therefore, the UltraBattery is suitable for high-voltage battery packs with a large number of 2V cells, such as those used in ESSs and hybrid vehicles.
5. When charging battery packs with a large number of 2V cells, the self-equalization effect of the UltraBattery's negative electrode allows the SOC of all cells to be equalized to 100% during charging.

Thank you for your attention