KURANODE™

BIOHARDCARBON

Anode Material for Secondary Batteries

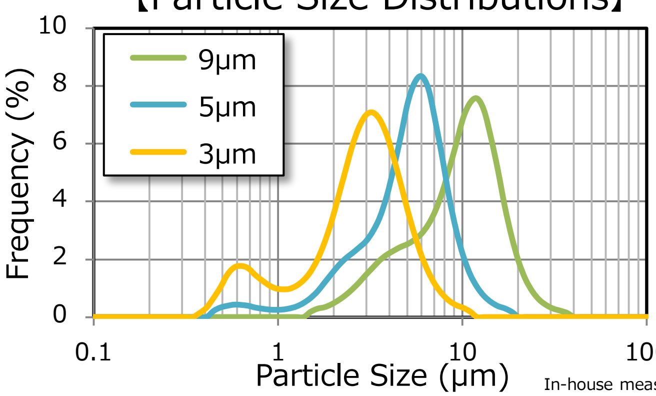
05/2019

Calgon Carbon was acquired by Kuraray in March 2018. With complementary products and services, the combined organization will continue to focus on providing the highest quality and most innovative activated carbon products to meet customer needs anywhere in the world. KURANODE™ hard carbon is made from a renewable raw material (plant based) and is commonly used as anode material in secondary batteries. It demonstrates high performance at low temperatures, high cycle ability, increased power performance, and cost competitiveness compared to other anode materials in the market.

Basic Properties

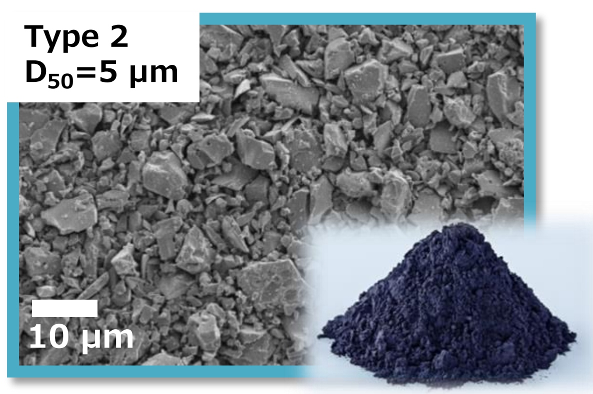
Measurement	Units	Type 1	Type 2			Type 3
Average particle size, D_{v50}	μm	9	3	5	9	5
Specific surface area	m^2/g	4	12	6	4	6
Interlayer spacing, d_{002}	nm	>0.380				
Crystallite size, $L_{c(002)}$	nm	1.1				
True density*	g/cm^3	1.48				

【Particle Size Distributions】

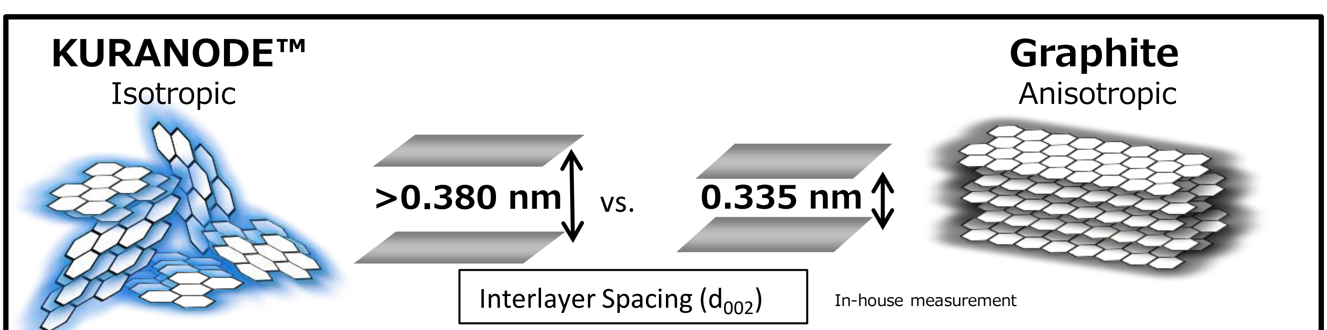


In-house measurement

【SEM image】



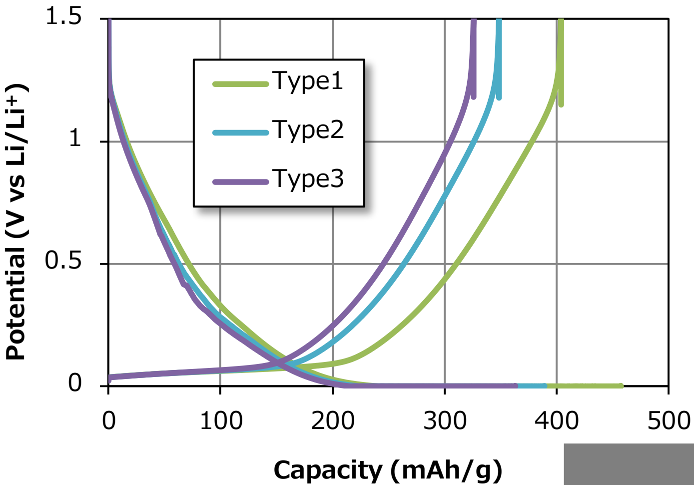
- **Wider interlayer spacing (d_{002})** is a feature of KURANODE™ compared to graphite and other hard carbon. It contributes high current charge / discharge and less expansion during intercalation, which results in longer cycle ability. The wider interlayer spacing also makes KURANODE ™ suitable for larger ions, such as Sodium, not just for Lithium ions.



All the data on this brochure are representative value, not guaranteed.

Capacity

- Below table shows capacity (mAh/g) at CCCV charging conditions.



■ Measurement condition

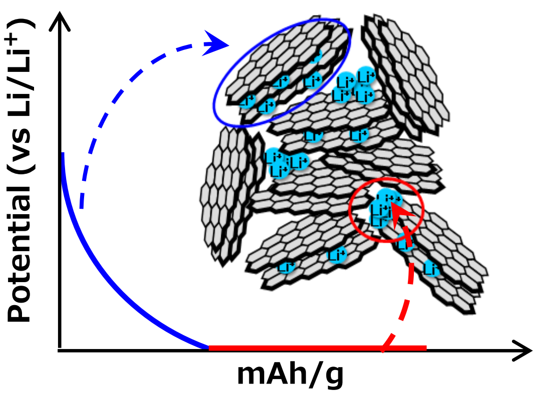
- KURANODE™/PVDF = 94/6 (6mg/cm²)
- Counter electrode: Li metal (half cell)
- Electrolyte: 1.0 M $LiClO_4$ in PC/DME = 1/1(vol)

■ Charge/Discharge condition

- Charging (lithiation) (CCCV)
  - ✓ **CC**: 0.77 mA (ca. 0.2C) to 0 V
  - ✓ **CV**: 0 V to 0.02 mA
- Discharging (delithiation) (CC)
  - ✓ **CC**: 0.77 mA (ca. 0.2C) to 1.5 V

In-house measurement

	Capacity			Efficiency
	Charge	Discharge	Irreversible	
	mAh/g	mAh/g	mAh/g	%
Type 1	460	405	55	88
Type 2	391	350	41	89
Type 3	358	320	38	90



Li⁺ is stored in cavities as Li-cluster

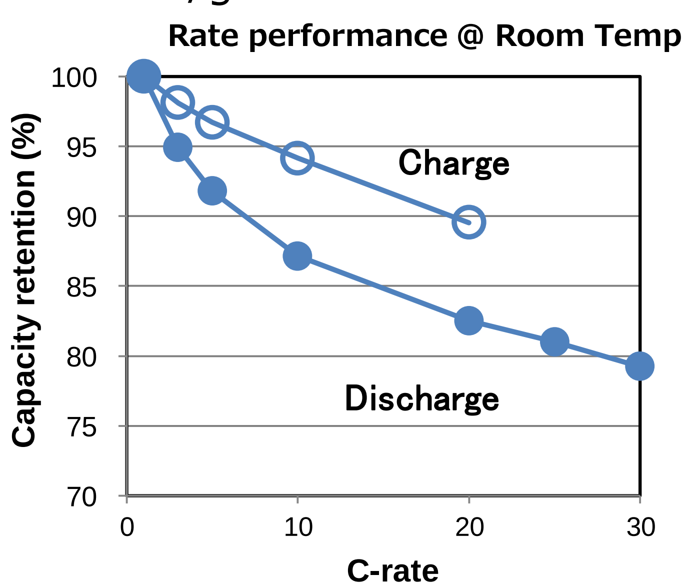
Thanks to its isotropic morphology, Hard Carbon can store Lithium ions into both the interlayer spaces of graphene and cavities, resulting in a higher theoretical capacity than Graphite. **Depending on the design and conditions, Hard Carbon can discharge more than 500 mAh/g without Li plating.** Please contact us further detail.

■ Example of higher designed charge capacity (Type 2 (5um))

Measured by third party

391 mAh/g ⇒ 500 mAh/g

	Cathode	Anode
Active Material	LFP	KURANODE™ Type 2
Design Capacity (mAh/g)	150	**500**
A/C Ratio	1.1	
Loading (g/m²)	100	29
Thickness (um)	53	31

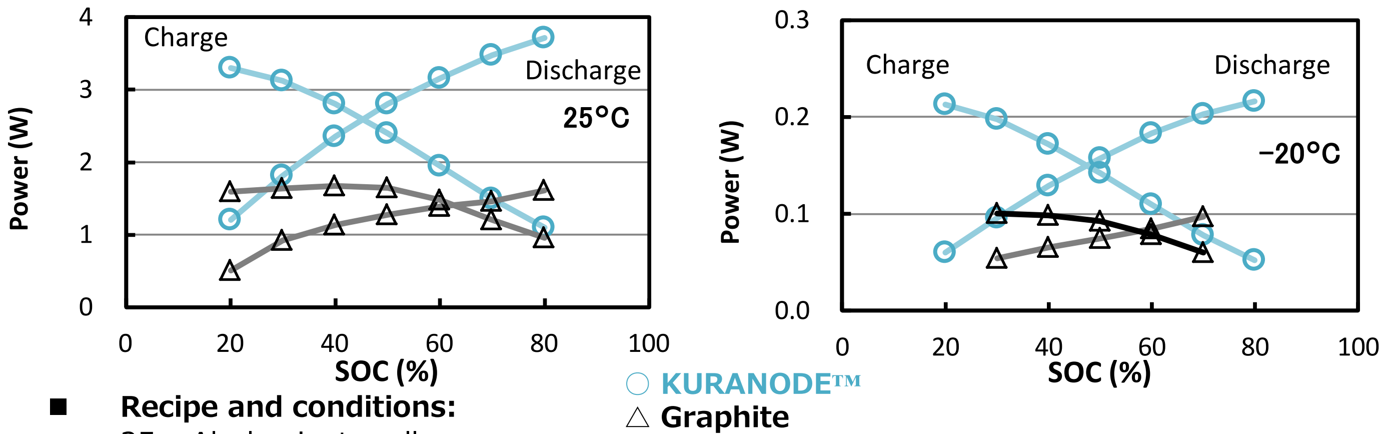


Higher designed cell using CV capacity shows high rate performance. This cell also shows better cold cranking performance even after 2,000 cycles.

HPPC (Hybrid Pulse Power Characterization) Performance

HPPC test below shows the power of charge and discharge at the different SOC. In comparison with Graphite, KURANODE™ shows better pulse power performance of charge at low SOC and discharge at higher SOC. Performance advantages are more significant at lower temperatures.

In-house measurement

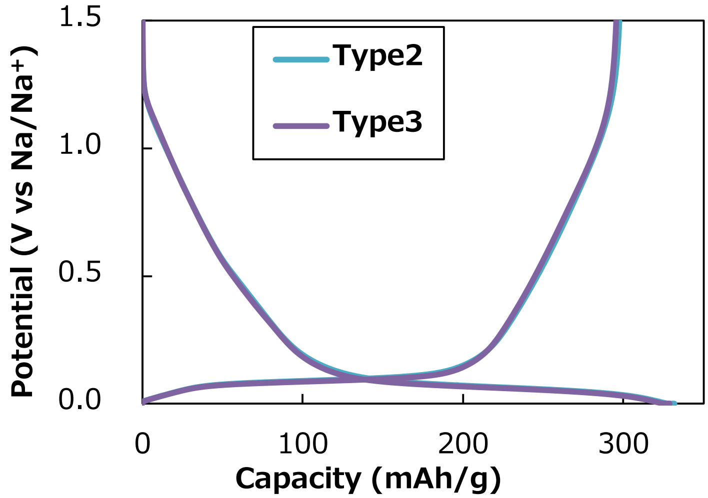


■ **Recipe and conditions:**

- 25 mAh, laminate cell
- Anode : Active material*/Additives/SBR/CMC = 95/2/2/1, ca. 8.1 mg/cm²
  (*KURANODE™ Type 2, Graphite)
- Cathode : NCM523/Additives/PVDF = 92/5/3, ca. 9.5 mg/cm²
- A/C Ratio = 1.1
- Electrolyte : 1.0 M $LiPF_6$ in EC/EMC/DMC=1/1/1

Anode Material for Sodium ion Battery

KURANODE™ can work as an anode material for Sodium ion Battery because of its wider interlayer spacing.



■ **Measurement condition**

- KURANODE™/PVDF = 94/6
- Counter electrode: **Na metal** (half cell)
- Electrolyte: 1.5 M **$NaPF_6$** in EC/DMC/EMC = 1/2/2(vol)

■ **Charge/Discharge condition**

- Charging (lithiation) (CCCV)
  - ✓ CC: 0.1 mA/cm² to 0 V
  - ✓ CV: 0 V to 0.02 mA
- Discharging (delithiation) (CC)
  - ✓ CC: 0.1 mA/cm² to 1.5 V

Measured by third party

	Capacity			Efficiency
	Charge	Discharge	Irreversible	
	mAh/g	mAh/g	mAh/g	%
Type2	332	298	34	90
Type3	329	295	33	90

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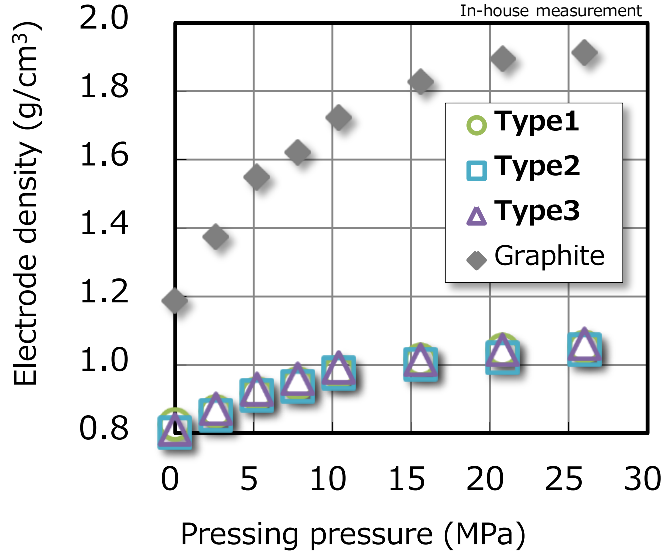
Electrode Density

If KURANODE™ is 100% used for anode active material, recommendable electrode density is around 0.95～1.0 g/cm^3.

- ■ Electrode information
- KURANODE™/PVDF = 96/4,
- Graphite/Conductive additive/SBR/CMC = 95/2/2/1

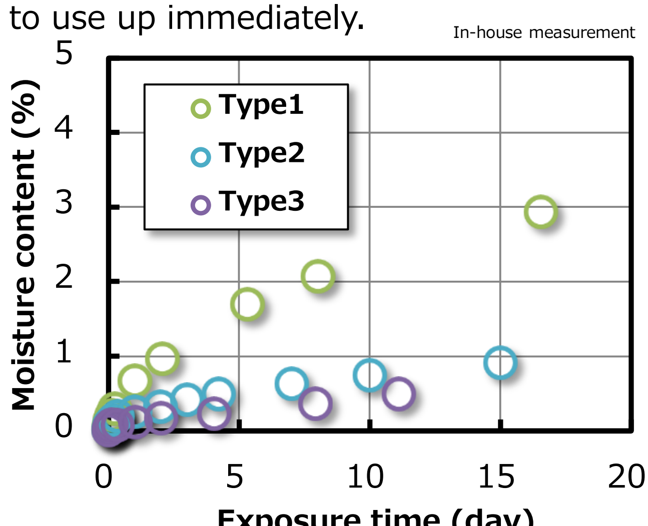


Handling Instructions

KURANODE™ has electrically conductive material and dustproof measures preventing the short circuit of electric equipment is desirable. It is also recommended that the proper PPE measures be taken when handing this material. Always wear a mask and gloves during treating **KURANODE™**.

KURANODE™ readily adsorbs moisture and oxygen and processing in a dry room is desirable. After package is opened, it is better to use up immediately.

It is recommended coated electrode is stored under inert atmosphere (e.g. Nitrogen or Argon).



Conditions

Not only PVDF binders but also aqueous binders (e.g. SBR/CMC) can be applied. Standard drying condition of coated electrodes is vacuum-dry at ca. 120℃. The optimum drying condition depends on other conditions, e.g. grade of KURANODE™, type of binders, or immersion time in slurry.

- ■ Exposure condition: 25°C, 50%RH, in air
- ■ Measured by Karl Fisher Method

Disposal & Others

When disposing of KURANODE™, dispose it as industrial waste and follow to local laws and regional regulations. Landfill is standard and adequate way. Additional notes are available in SDS or please contact either one below.

Contact Information

Contact in the U.S.
Calgon Carbon Corporation
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EnergyStorage@calgoncarbon.com

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