

AR.Ion™

An Introduction to the hybrid capacitor



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Hybrid Capacitor Performance

AR.Ion is an advanced energy storage system combining both high rate battery materials and ultracapacitor technology. The breakthrough performance is based on Allotrope's patented nanostructured carbon composite materials and combines;

- ❖ Ultra-high charge and discharge powers up to 10kW/kg.
- ❖ Class leading energy density up to 60Wh/kg.
- ❖ Extraordinary cycle-life of over $10^5 - 10^6$ cycles ^{*1}.
- ❖ Capacitor-level charge/discharge energy efficiency up to 97%.

AR.Ion at a glance...

Energy Density Range	25-60	Wh/kg
Max Power Density	10,000+	W/kg
Volumetric Energy Density	80	Wh/l
Volumetric Power Density	15,000	W/l
Cycle life ^{*1}	$10^5 - 10^6$	cycles
Recommended Charge Routine	$C_{rate} < 40$	CC
Pulse charge (<5s)	$C_{rate} = 200$	
Pulse discharge (<5s)	$C_{rate} = 200$	
Max voltage	3.1	V
Recommended Discharge Voltage	1.6	V
Min transport voltage ^{*2}	0	V
Low operating temperature	-40 to +70	°C
High operating temperature	-10 to +110	°C



* all data is based on preliminary performance, specific cell performance may vary

^{*1} In lab tests

^{*2} Depending on selected cell

AR.Ion blurs the lines between fast-charging battery, powerful battery and high energy density capacitor and opens the door to incredible opportunities.

APPLICATION: Performance Hybrid Vehicle

An application was defined requiring a high-power ES (energy storage) unit in a performance hybrid system. The guidelines outlined the following boundary conditions;

Application Requirements			
Accessible Energy	4MJ (1.1kWh)	Max Weight	20-25kg
Peak Charge Power (<5s)	200kW	Peak Discharge Power (<5s)	250kW
Average Charge Power	100kW	Average Discharge Power	100kW
Max operating temperature	100 °C	Operating Voltage	V_{max} to $\frac{1}{2}V_{max}$

Based on the high efficiency pouch format, the ALLOTROPE **ALL/F1-A** architecture is tailored for the rigours of performance hybrid systems, like those often found in motorsport or high power sportscars.

With 200kW of charge power, 1.1kWh of accessible energy and 250kW of short-term boost, all in a compact and light-weight 20-25kg unit, the cell represents a next generation approach for the serious motorsport team.

Unlike 'high power' battery systems, **AR.Ion** is comfortable undergoing many thousands of aggressive charge/discharge procedures, even at extreme temperatures, (see below), without effecting capacity or life-time.



Figure 1: ALL/F1-A exceptionally high C-rate hybrid focused battery

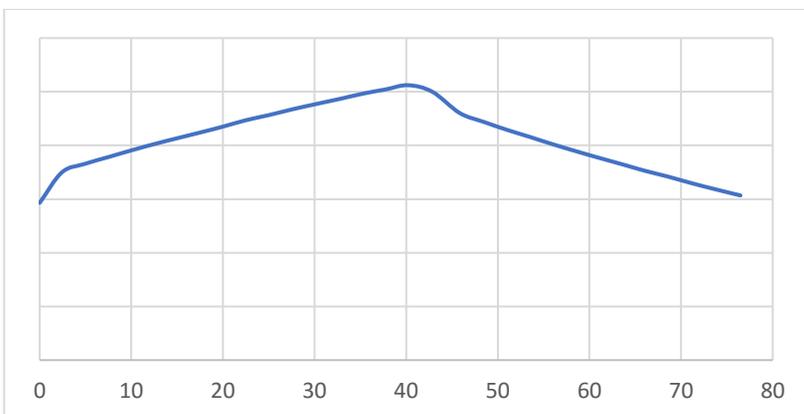


Figure 2: ALL/F1-A 100% charging/discharging in 42 seconds (symmetric $C_{rate}=90$) at low temperatures (5°C).

Suitable for;

- High performance hybrid
- 'Partial' full electric hybrid
- Motorsport
- Heavy industry
- UPS & micro/grid stabilisation

APPLICATION: Next Generation Hybrid

Adopting a hydrogen fuel cell power unit, the Riversimple Rasa is a ground-breaking development in personal transport. Based entirely on the motivation, “*To pursue, systematically, the elimination of the environmental impact of personal transport*”, the move to hybridisation was an obvious choice.

Riversimple Rasa: Application Requirements

Accessible Energy	> 0.6kWh	Max Weight	~15kg
Peak Charge Power (<5s)	~80kW	Peak Discharge Power (<5s)	~60kW
Requested lifetime	> 15 years	Average Discharge Power	40kW
Max operating temperature	80 °C	Operating Voltage	V_{\max} to $\frac{1}{2}V_{\max}$

Adopting a similar cell to the **ALL/F1-A**, the program altered the requirements to emphasize the importance of low life-time costs and low integration costs, whilst also favouring regenerative braking energy and high energy efficiency.

With cell costs < £1500/kWh the unit would generate a dramatic weight, cost and volume saving over the traditionally adopted technology - all whilst improving the charge/discharge performance.



Figure 3: Riversimple Rasa, cutting edge hydrogen powered hybrid.

APPLICATION: Rapid Charge Mobility

Battery – Motor – Wheel. Mobility spans a greater breadth than almost any other sector; from fork lift trucks and wheelchairs to golf trolleys and e-scooters, with everything in between.

With battery-level energy-density, **AR.Ion** can replace the conventional battery options to provide a rapid-charge alternative.

Rapid Charge Mobility: Requirements

Battery Description	12V 22Ah	Charge Time	3-7 minutes
Cell Weight	5.5kg	Operating Voltage (max - min)	~15V – 9V
Size	~170 x 180 x 80 mm	Max Discharge Current	1000A
Max operating temperature	-15 - +100 °C	Operating life	10 ⁴ cycles

With form and function resembling that of the ubiquitous lead acid cell, ALLOTROPE's **ALL/RC-B** battery meets all the targets of mobility systems with the added benefit of a 3+ minutes charge ^{*1}.

With simple charging methods and extended life-times, the **AR.Ion** cell brings both long-term cost savings and new opportunities alike.



Figure 4: Rapid charge mobility

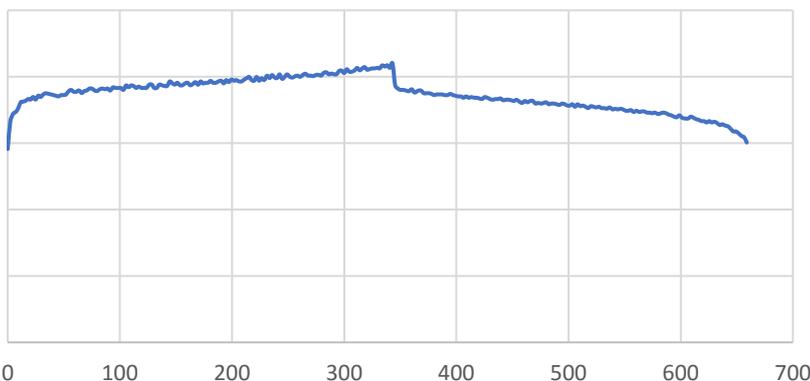


Figure 5: **ALL/RC-B** charging in 350 seconds (5 minutes 50 seconds) from flat.

Suitable for;

- Wheel chairs / scooters
- 2-wheel scooters
- Hoverboards
- Fork lifts
- Pallet Trolleys / warehouse equipment
- Golf carts / trolleys

* 1 – rapid charging requires a plug capable of supplying the required power.

APPLICATION: Rapid Charge Appliance

The capabilities of **AR.Ion** allow us to consider innovative approaches to common systems. Convenience is a powerful motivator and the ability to recharge a domestic appliance, e.g. a hand-held power tool, is a new direction to consider.

Cordless Screwdriver Application Requirements

Accessible Energy	18V 1.5Ah	Total Weight	~0.5kg
Charge Time	4-5 minutes	Cranking Discharge Power	2kW
Size	~(13 x 7 x 6) cm	Average Discharge Power	500W
Shipping voltage	0V	Operating Voltage	V_{\max} to $\frac{1}{2}V_{\max}$

The **ALL/RC-D** is specifically designed to offer the most versatile route for application and business. Designed to rest at 0V the cell can be shipped via airfreight, and can remain uncharged almost indefinitely.

With the convenience of a 4 minutes charge, coupled with exceptional discharge capabilities the cell is perfectly aligned for small, hand-held, cordless tools.



Figure 6: Fast charging hand held tool

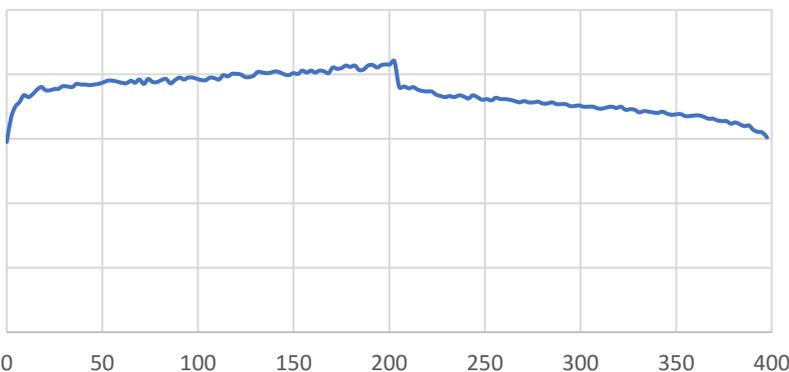


Figure 7: **AI/RC-D** charging in 205 seconds (3 minutes 25 seconds) from flat.

Suitable for;

- Power tools
- Cordless equipment
- Toys
- Garden Equipment

Available from 3V 0.1Ah to over 36V 10Ah, never again will we have to wait for our cordless equipment to charge!