White paper

Geyser battery:

Introduction to a power-dense battery for heavy-duty applications

www.geyserbatteries.com

GEYSER BATTERIES

Summary

Geyser Batteries has developed a new kind of rechargeable battery that can be described as a hybrid of a supercapacitor and a secondary (electrochemical) battery. With regard to power performance and cyclability, its behavior is comparable to a supercapacitor, but its energy density is substantially higher. Major difference to batteries is that the electrodes are not directly involved in chemical reactions responsible for storage of energy and their degradation is extremely slow, which ensures up to 100 times more charge-discharge cycles at remarkably high power.

This white paper serves as a snapshot of technology, applications and environmental considerations of Geyser Batteries.

Introduction

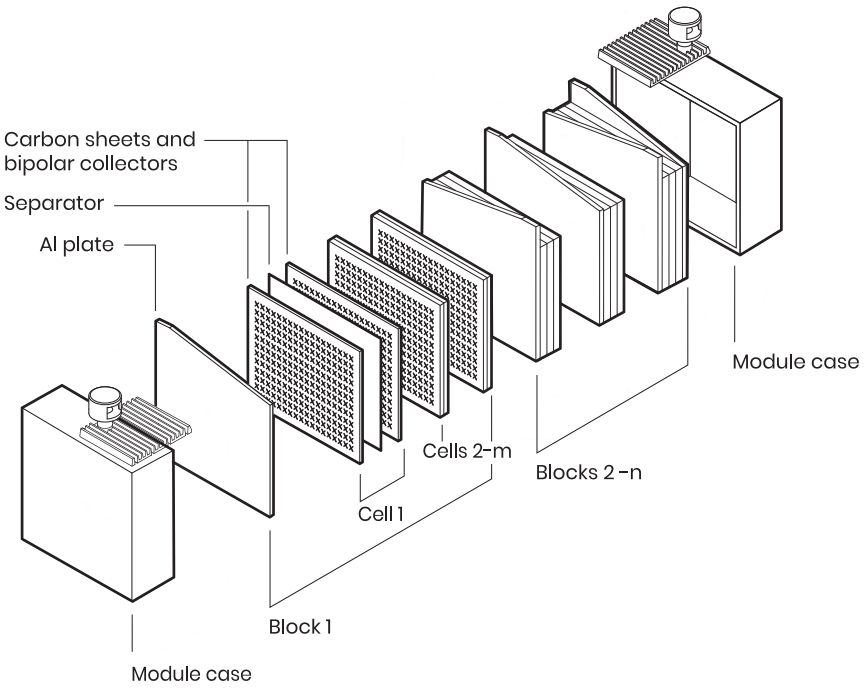
Geyser battery is a brainchild of a group of scientists that have decades of experience in developing and manufacturing electrochemical power sources and supercapacitors utilizing bipolar design. Geyser Batteries Oy has been set up to further develop and commercialize this new technology. It has gone through initial development stages, and currently we are supplying potential customers with sample products for in-house testing and, in parallel, developing automated manufacturing technology to enable high-volume production.

Technology

The electrochemistry is based on previous work with supercapacitors. Geyser team has managed to add a battery-type electrochemical reaction to the system without intercalation of ions into electrode structures. All chemical reactions are happening near the surfaces of the electrodes, which means no mechanical stress is present. This allows ultimately high cyclic performance. At this moment we cannot disclose exact details of the chemical reactions due to associated patents pending.

Electrodes are the heart of any battery. In our case both positive and negative electrodes are made of activated carbon and supported by anisotropic conductive substrate. To allow highest possible discharge performance the electrodes are so thin that each cell has a thickness of under 0,5 mm.

Cells are built in a bipolar design, which means that their current collectors serve simultaneously both as a conductive element of the negative electrode of one cell and that of the positive electrode of adjacent cell, i.e. they serve as intercell connections. In this case, each cell does not need external terminals (see drawing). The main benefit of the bipolar design is higher power density than in a traditional battery design. Furthermore, additional benefits include extremely efficient and flexible packaging and the relative ease of thermal management.



The electrolyte is a solution of inorganic chemicals that are dissolved in pure water. All electrolyte is absorbed in electrodes and separators. The separators keep positive and negative electrodes from short circuiting with each other. During normal operation the battery is hermetically sealed. To prevent damage in the case of misuse (for example serious overcharge) each battery is equipped with a safety mechanism that allows internal pressure to escape in a controlled manner.

Each group of cells (a block) consists of 7 to 150 individual cells. In a battery module, several blocks may be connected in parallel to create the energy storage needed. The validity of this design approach is based on decades of experience of Geyser Batteries' team in manufacturing supercapacitors utilizing bipolar architecture.

Each cell has a voltage of up to 1,6-2,0 V and an energy storage capacity of about 0,25-0,5 Wh so in a module we typically have a large number of cells, providing energy storage capacity of tens to hundreds of watt-hours (Wh).

The module housing is typically a casing made of aluminum which guarantees effective cooling of the unit in high-power applications. Other casing materials as well as further reduction of non-active material are possible. Module terminals are typically M6 to M10 female thread; custom terminals are also possible.

Applications

Geyser Batteries' products are capable of delivering extremely high rate and cyclic performance. Number of charge-discharge cycles can be up to millions and discharge power is comparable to a supercapacitor. In addition, high charge power can be used which means extremely short recharge time compared to traditional batteries. Typical performance characteristics are shown in the table below:

Parameters of module	Air active cooling	
Nominal voltage	**48V**	
Dimensions, LxWxH	**268x178x187 mm/ 8,9 l**	
Of which blocks of cells	*3,3 l*	
Weight	**10,1 kg**	
Of which blocks of cells	*5,4 kg*	
Specific power		
Operating	**2 kW/kg**	
Impulse (1 sec)	**5 kW/kg**	
Typical operating voltage window	**48 V-36.7V** *DOD 23,5%*	**48V-24V** *DOD 50%*
Delivered energy at 1kW after forced charge	**78 Wh**	**108 Wh**
Specific energy	**7,72 Wh/kg**	**10,69 Wh/kg**
Energy density	**8,7 Wh/l**	**12,1 Wh/l**
Delivered energy at 2kW after 2-min charge	**53 Wh**	**74 Wh**
Specific energy	**5,24 Wh/kg**	**7,32 Wh/kg**
Energy density	**5,96 Wh/l**	**8,31 Wh/l**
Discharge time		
at 2 kW	**95 sec**	**133 sec**
at 5 kW	**37 sec**	**51 sec**
at 7 kW	**26 sec**	**36 sec**
at 14 kW	**12 sec**	**17 sec**
Applications	+ **Mild hybrid powertrains, KERS** + **Opportunity-charged vehicles** *(on- and off-highway)*	
Life	*Projected cycle life at RT*	**>1.000 000 cycles**
Temperature	*Operating temperature range*	**-40°C to +60°C**

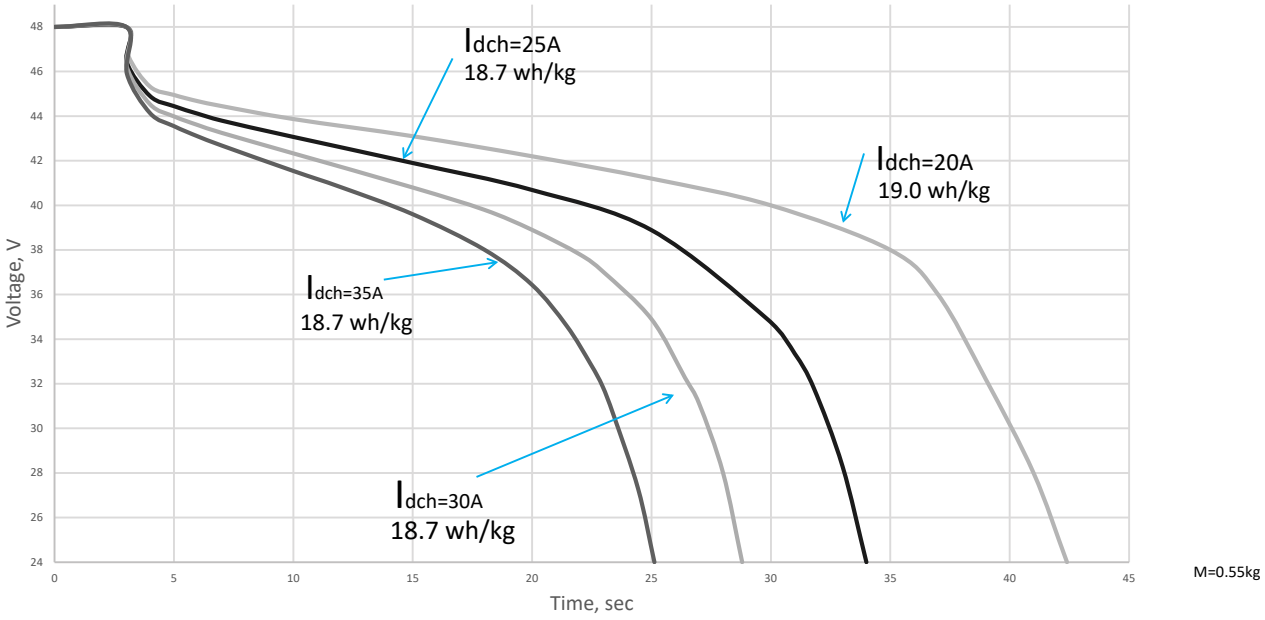
**Data may vary depending on a certain operation mode specified by the customer*

These performance characteristics make Geyser battery an excellent choice for a diversity of applications, for example:

- high-power energy storage in vehicles
- hybrid drive trains in heavy machinery
- grid stabilization in FFR (fast frequency reserve) markets
- any other applications where high power and/or ultimate cyclability is required (peak shaving)

Preferred charging method is according to IU-curve i.e. constant current phase followed by a constant voltage charge.

The discharge curve of a Geyser battery is rather flat, i.e. different from a supercapacitor's, where voltage decreases linearly during discharge. This makes integrating the product with power electronics less complex than in the case of supercapacitors. End of discharge voltage is typically 50% of the charge voltage, but discharging to a lower voltage, or even reversing the polarity of the battery, has no decremental effect on it. However, overcharge of the battery needs to be avoided. Partial state of charge operation is also possible.



Geyser battery can be safely operated in up to 60°C temperature. The electrochemical process itself allows operating temperatures up to 120°C. The current temperature limit is due to certain cell components and is expected to be raised to 85°C in the near future. Low-temperature operation down to -40°C temperature is also possible. Currently, long-term storage is allowed from -60°C to +45°C without facing the risk of damaging the product.

The internal construction of the battery is very robust which means that it can well stand vibration, shocks, etc. This is a major benefit in a variety of mobile / extreme applications.

Environmental considerations

One of the key benefits of Geyser Batteries' technology is sustainability. It all starts from the use of non-flammable electrolyte solvent, water, instead of the poisonous and highly flammable solvents used in supercapacitors and li-ion industries.

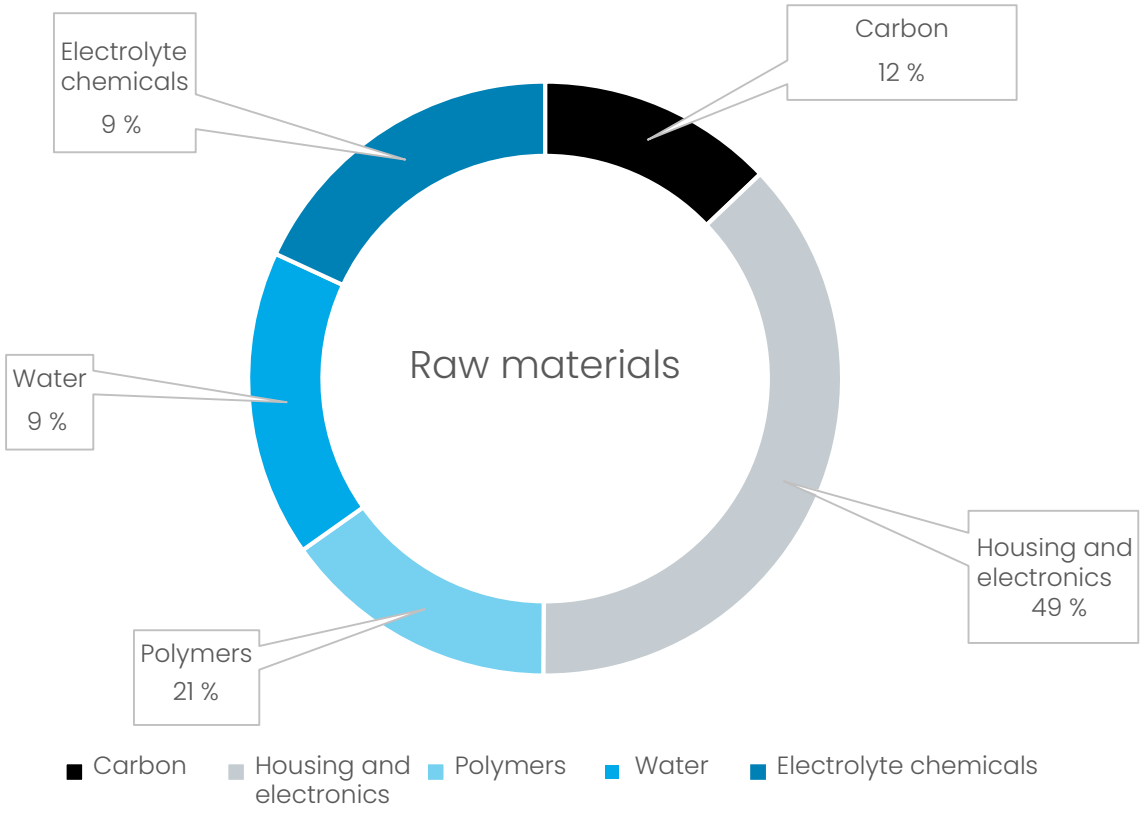
The sustainability of Geyser Batteries' products is further enhanced by the choice of other raw materials. Depending on the design, up to 42-47% of the materials can be of recycled or renewable origin. For example, both electrodes in a cell are made of wood-derived activated carbon, in opposite to metal-alloy cathodes used by li-ion batteries.

As Geyser Batteries does not rely on conflict or scarce materials, sourcing of the key materials is not deemed to cause environmental or societal constraints.

The manufacturing process also contributes to the environmental benefits; the nature of the technology eliminates the need for dry or clean rooms, making the production significantly less energy-intensive than manufacturing of li-ion batteries or supercapacitors. All these factors make the carbon footprint of cell manufacturing up to 74% lower than that of the competing technologies.

Water-based electrolyte and bipolar design contribute to the ease and safety of transportation and recycling. The components of the products can be either recycled or reused further contributing to the circularity of materials.

Typical content of a module by weight is:



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Geyser Batteries is an electrochemical technology company incorporated in 2018 to scale up production and expand adoption of disruptive high-power heavy-duty energy storage invented by our founding team, following its 25+ lifetime innovation and industrialization work in the energy storage space.

Geyser Batteries is being built with a vision that the future is electric, and that electrification shall be sustainable and accountable: it is the full life cycle of an electric solution that counts to make sure that the sum of all the changes it brings creates a positive impact on the planet.

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