ULTRACAPACITORS

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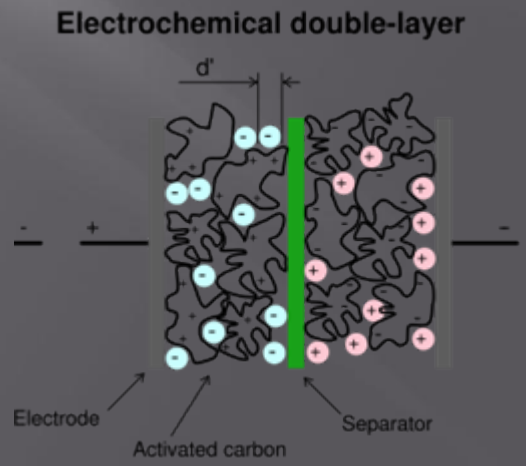
Ultracapacitors
The basics

- Similar to normal capacitor, but stores charge in porous carbon that has a very high surface area.

Maxwell PowerCache ultracapacitor 2.7 kF, 2.5 V

- Each layer attracts ions, + or -, and the layers are spaced nanometers apart.



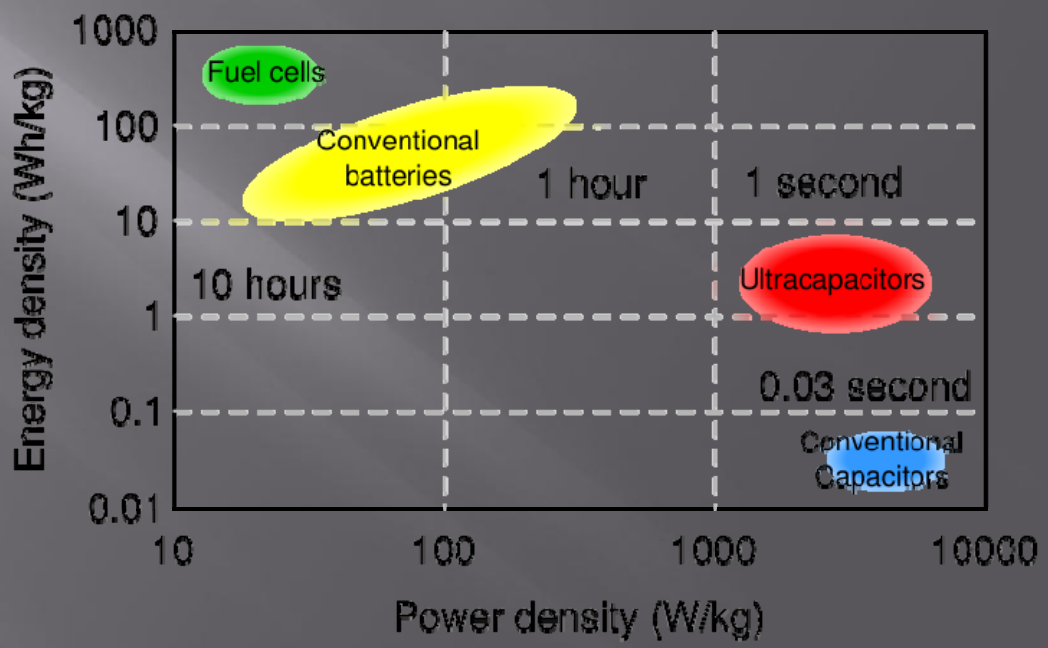
Ultracapacitors
A brief history

- Effect of porous carbon holding large amounts of charge first discovered in 1957 by GE. They didn't follow up on the discovery.
- Standard Oil re-discovered this when working with fuel cell technology in 1966. They also did not strongly follow up their discovery.
- Nippon (Japan) Electric Company eventually bought the license and commercialized it for use in computer memory.
- It has been a materials problem ever since.
- Also known as Supercapacitor or Double-layer capacitor

Energy Storage Advantages

- Can charge and discharge thousands (millions?) of times before wearing out
- Can charge and discharge quickly
- Highly efficient
- Less heating
- Stackability
- Wide temperature range

$$E_{\text{stored}} = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}VQ$$



Comparison to Current Technologies

Parameters	Electrostatic Capacitor	Ultra-capacitor	Battery
Discharge Time	10^{-6}~10^{-3}sec	1~30 sec	0.3~3 hrs
Charge Time	10^{-6}~10^{-3}sec	1~30 sec	1~5 hrs
Energy Density (Wh/kg)	< 0.1	1~10	20~100
Power Density (W/kg)	< 10,000	10,000	50~200
Charge / Discharge Efficiency	~ 1.0	~10	0.7~0.85
Cycle Life	Infinite	> 500,000	500~2,000

Advantages

1. Power (20 times better)
2.
3. All-weather, Tough environment
4. Semi-permanent life
5. Energy efficiency
6. No maintenance
7. Quick charging

Disadvantages

1.
2. Energy (10 times less)
3.
4.
5.
6.
7.

Energy Storage
The Problem-Low Voltage Ratings

- Low Voltage, Low Energy Storage
- Ultracapacitors need to be stacked in order to meet voltage requirement.
- Like normal capacitors, overvoltage causes ultracaps to fail

Surge Phenomena
Can ultracaps survive a surge?

- Most ultracaps have a surge voltage of 1.05-1.2 times larger than rated average voltage.
- According to Maxwell, their capacitors "will accept as much charge as they are given."

Energy Storage
The Problem

Set of 160 in Series, 16.875 F, 400 V from 2700 F and 2.5 V Ultracapacitors

Surges on Ultracapacitors

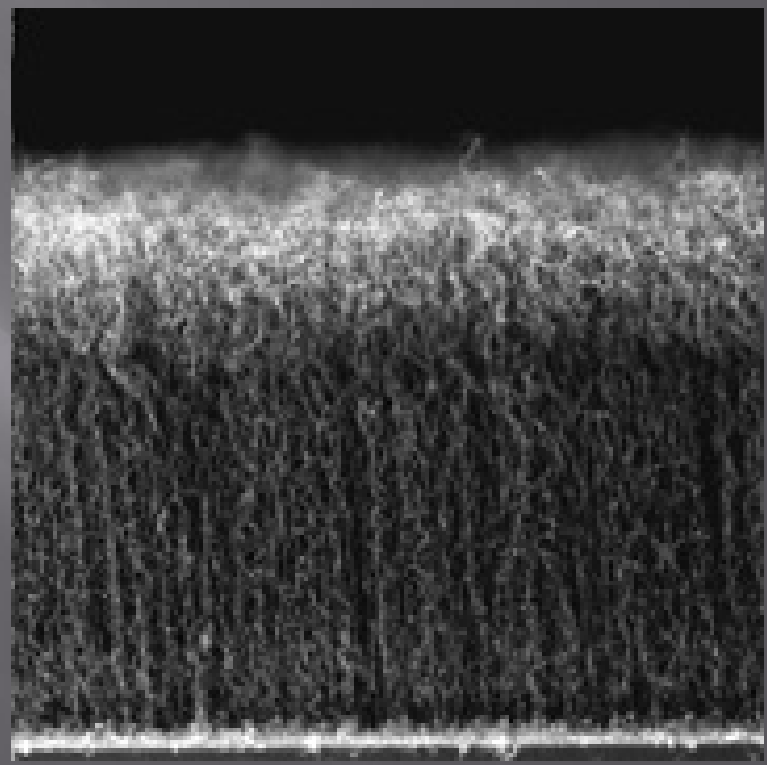
- What happens if one of the stacked ultracaps shorts?
- Fuses could be used between capacitors to limit damage.
- Excessive overvoltage will damage an ultracap as it would a normal capacitor

Applications

- In conjunction with batteries in Hybrid/Electric Vehicles (connected with power electronics)
- Storage for wind, solar, fuel cell and other renewable energies
- Use in cell phones, iPods, laptops, any personal device that may need short bursts of power
- Much talk given to ultracapacitors eventually replacing batteries altogether…

Ultracapacitors Future Developments

- Carbon nanotubes: further increasing surface area of ultracapacitors
- Researchers at MIT have claimed their simulations allow for a carbon nanotube ultracap stores the same amount of energy as a battery of the same size



Carbon Nanotubes like what was produced at RPI

Ultracapacitors
Future Developments

EEStor: a company in Texas claiming serious advances in ultracapacitor technology, but it is staying very quiet about it, leaving many skeptical and many hopeful.

It claims 31 F at 3500 V in 336 pounds (yielding 350 Wh/kg)

Manufacturers

- Maxwell Technologies, Inc
- NessCap Co. Ltd.
- Epcos AG.
- And many more outside of the U.S.

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Questions?