Return to Menu

# Solid State Ultracapacitor

## Project Manager(s)/Lead(s)

Dr. Terry D. Rolin/ES43
(256) 544–5579

## Sponsoring Program(s)

Space Technology Mission Directorate
Center Innovation Fund, SLS Advanced Development,
Oak Ridge National Laboratory

## Project Description

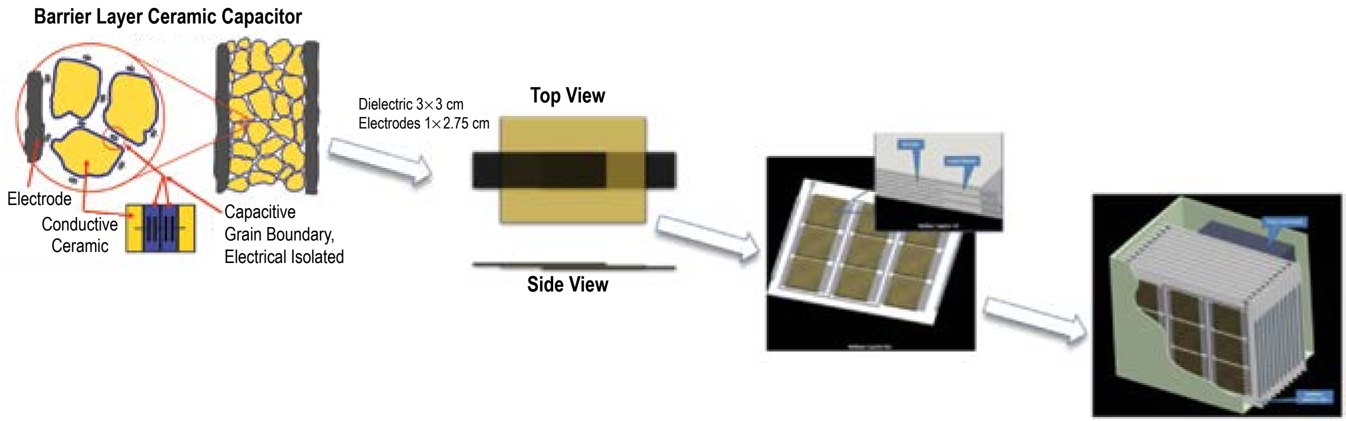
NASA analyzes, tests, packages, and fabricates electrical, electronic, and electromechanical (EEE) parts used in space vehicles. One area that NASA wishes to advance is energy storage and delivery. Currently, space vehicles use rechargeable batteries that utilize silver zinc or lithium ion electrochemical processes. These current state-of-the-art rechargeable batteries cannot be rapidly charged, contain harmful chemicals, and suffer from early wear-out mechanisms. A solid state ultracapacitor is an EEE part that offers significant advantages over current electrochemical and electrolytic devices.

The objective of this research is to develop an internal barrier layer ultracapacitor (IBLC) using novel dielectric materials as a battery replacement with a focus on these advantages: longer life, lower mass-to-weight ratio, rapid charging, on-demand pulse power, improved on-pad standby time without maintenance, and environmental friendliness.

The approach is unique in two areas. A deposition technique is used that has been shown to produce a more uniformly coated nanoparticle than sol-gel, which has resulted in colossal permittivities. These particles are then distributed in an ink formulation developed at NASA Marshall Space Flight Center (MSFC) and deposited utilizing a 3D aerosol jet technique. This additive manufacturing technique controls layer thickness, resulting in extremely large capacitance and energy density.

**First ultracapacitor single cell built at MSFC (electrodes are dark blue and active material is pale blue). This device weighs <10 gm but has an equal capacitance and voltage of a bank of capacitors weighing over 490 gm.**


**Ultracapacitor single cells printed using 3D aerosol jet printing—the first board printed using multiple single cells to test scalability.**






**The ultimate goal of this project is to advance the state of the art from a concept of nanoparticles and nanoparticle manipulation to a single cell to a board with multiple cells to a module with multiple boards. This research project is currently building multiple cells on a board to test scalabilty.**

**Current state-of-art energy densities of various energy storage solutions compared to the MSFC developed solution.**

| Device | Energy Density (J/cc) |
|---|---|
| Aerospace Battery (Li-ion/28 V) | 172 (calculated from spec) |
| Aerospace Range Safety Battery (Ag Zn/28 V) | 57 (calculated from spec) |
| Commercial Electrolytic Ultracap (59 V) | 15 (provided by manufacturer) |
| ES43 HESSCap Module/Multilayer Device | 200 (calculated from model) |
| ES43 Single Layer/Single Cell Device (50 V) | 1 (measured) |

### *Anticipated Benefits*

Once scalability has been achieved, energy densities of tens of J/cc are predicted in a small robust package. This will pave the way for smaller and more robust power sources in CubeSats and nanosats. Additionally, the large breakdown voltages and fast discharge rates that have been demonstrated will greatly benefit applications that require pulse power such as electric propulsion systems. If sufficient energy density is achieved in the final module, it could replace lithium ion batteries with a more reliable, longer lasting, and safer alternative.

### *Potential Applications*

The Propulsion Research Center at MSFC is already considering this technology for their electric propulsion systems in order to replace wet tantalum capacitors. The CubeSat community is also looking at this technology to provide emergency supplemental power as primary power systems drain below required operating levels.

## Notable Accomplishments

Ultracapacitors with energy densities exceeding 1 J/cc have been produced. Devices have shown charging times in milliseconds, breakdown voltages as high as 900 V in a 30 micron layer, and demonstrated ability to activate light-emitting diodes. This work has resulted in the submission of three patent applications and discovery of two spinoff technologies. The spinoffs include creation of a low-temperature conductor ink that was not commercially available and the construction of an ultrasensitive ceramic humidity sensor element that is only 30 microns thick.