National Aeronautics and Space Administration

Nanostructured High Energy/High Power Electrodes for Swarm Spacecraft Energy Storage

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Program: Innovative Spontaneous Concept

Background and Project Objective:

- There is growing interest in the application of very small spacecraft, particularly for swarm-based architectures smaller than the traditional 1U form factor (1000 cm3 and 1 kg)
- Providing adequate energy and power (particularly for functions requiring burst power such as communications) are very difficult to achieve in such small units, where traditional lithium-ion cells *can be larger than the spacecraft themselves*
- An ideal technology offers a blend of high energy and high power capability over wide temperatures, to provide sufficient energy (for eclipse periods) as well as support burst power needs.
- **The objective of this proposal was to develop a electrode system with a high specific capacity and high operating voltage supporting high rate and low temperature operations.**

Technical Approach and Results:

- Using nanostructured active materials combined with careful electrode design and processing can support both high energy and high power capabilities
- Cells were built with both JPL-fabricated and commercial electrode.
- NCA for JPL-fabricated cathodes was procured from MTI corp. and Sigma-Aldrich
- Graphite used in JPL-coated electrodes was from Mitsubishi MPG70
- NCA and graphite electrodes were from Saft
- Electrodes were coated onto very thin aluminum (20µm) and copper (10µm) foil substrates for the cathodes and anodes
- A layer of colloidal carbon ink was applied to the foil to provide a better conductive path and adhesion surface
- The active material was sprayed onto the dried carbon ink layer as a slurry of NCA or graphite, Super P carbon, and polyvinylidenedifluoride (PVDF) (85:10:5 wt%).
- Total electrode loadings tested ranged from 5 – 20 mg cm^{-2} coated on a single side of the foil substrate.
- For multilayer cells, this process was repeated on the backside of some electrodes

Table 1. Summary of cell and electrode build data

Cell Name	Cathode	Anode	Cat. loading (mg/cm^2)	Anode loading (mg/cm^2)
SWA-01	NCA (JPL)	Graphite (JPL)	10.01	5.43
SWA-02	NCA (JPL)	Graphite (JPL)	10.93	6.28
SWA-03	NCA (JPL)	Graphite (JPL)	7.14	4.50
SWA-04	NCA (Saft)	Graphite (Saft)	18.66	7.62
SWA-05	NCA (JPL)	Graphite (JPL)	9.14	7.03
SWA-06	NCA (JPL)	Graphite (JPL)	9.17	7.38
SWA-07	NCA (JPL), blade coated	Graphite (JPL), blade coated	18.29	10.54
SWA-08	NCA (JPL), blade coated	Graphite (JPL), blade coated	18.25	11.31
SWA-09	NCA (Saft)	Graphite (Saft)	16.86	5.25
SWA-10	NCA (Saft)	Graphite (Saft)	17.08	5.48
SWA-11	NCA (Saft), 2 layers	Graphite (Saft), 2 layers	10.2	9.76
SWA-12	NCA (Saft), 2 layers	Graphite (Saft), 2 layers	10.15	9.75
SWA-13	NCA (Saft), 2 layers	Graphite (Saft), 2 layers	10.26	9.76
SWA-14	NCA (JPL), 2 layers	Graphite (JPL), 2 layers	12.85	5.01
SWA-15	NCA (JPL), 2 layers	Graphite (JPL), 2 layers	16.79	5.78
SWA-16	NCA (JPL), 2 layers	Graphite (JPL), 2 layers	13.72	5.31

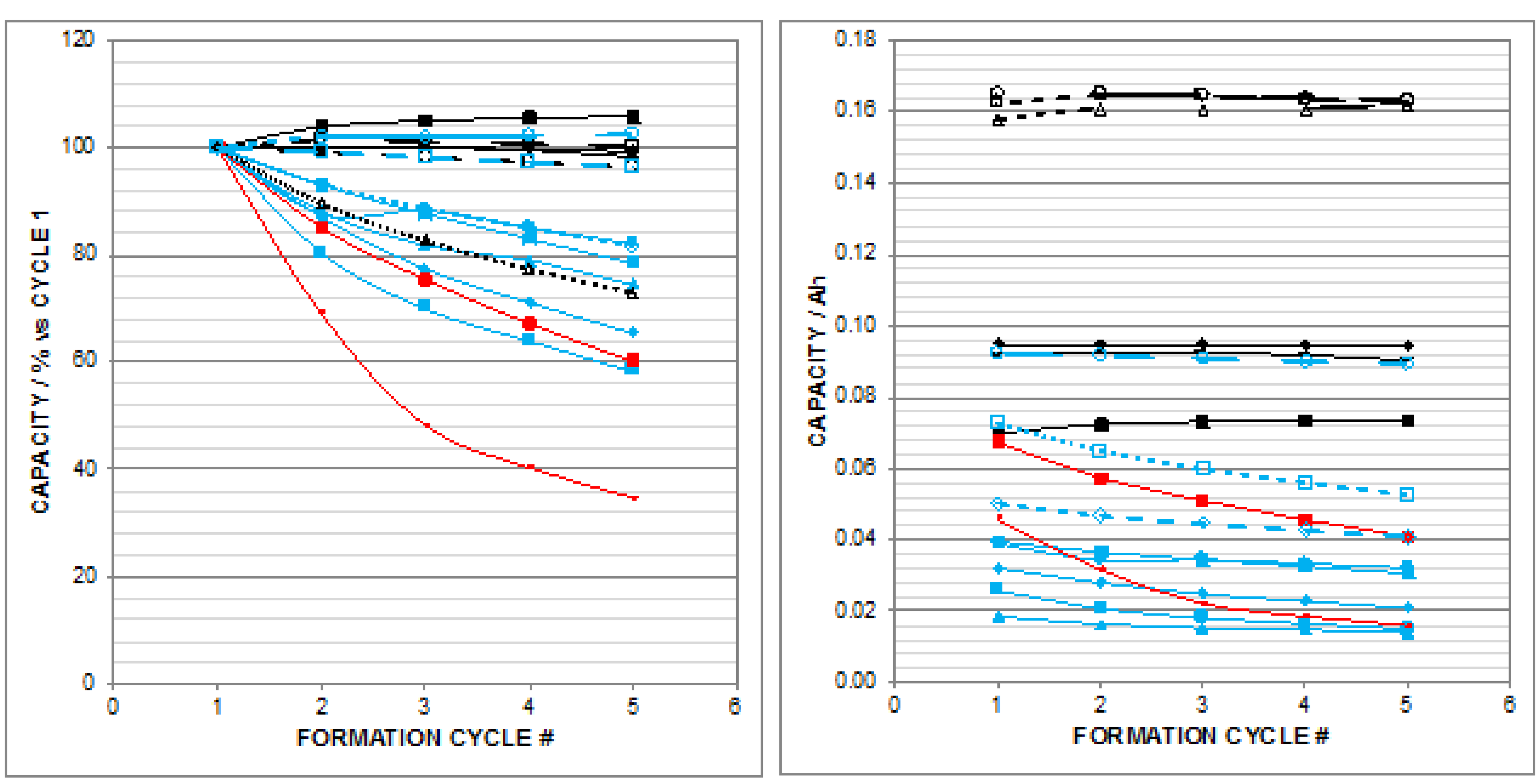


Figure 1. Formation capacities of pouch cells in Ah (left) and as a percentage of cycle 1 (right). Blue: JPL spray-coated NCA vs. graphite. Red: JPL blade-coated NCA vs. graphite. Black: Saft NCA vs. graphite. Solid: single anode/cathode. Hollow: double-layered anode/cathode stack.

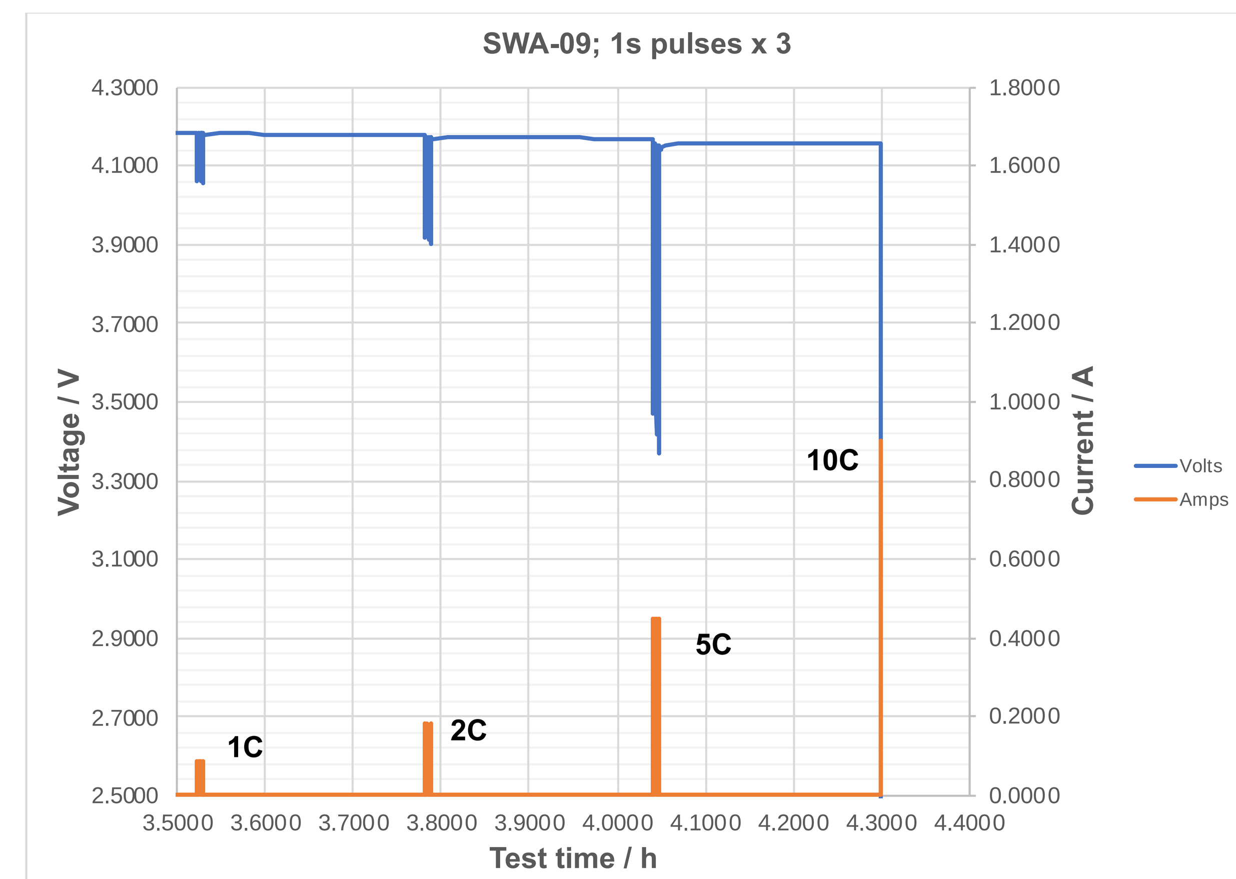


Figure 2. Pulse response at 1C rate in 90mAh capacity pouch cell.

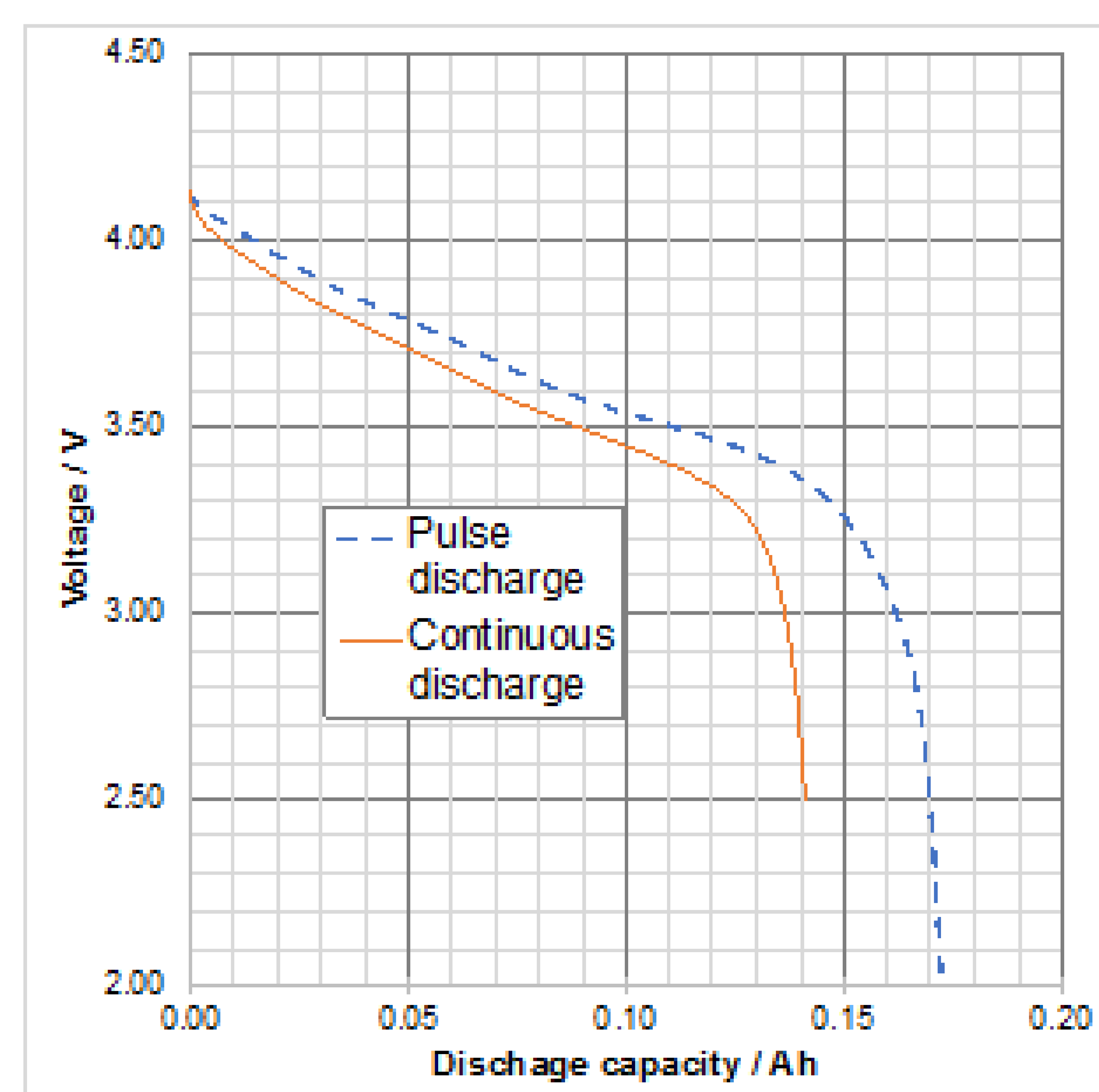
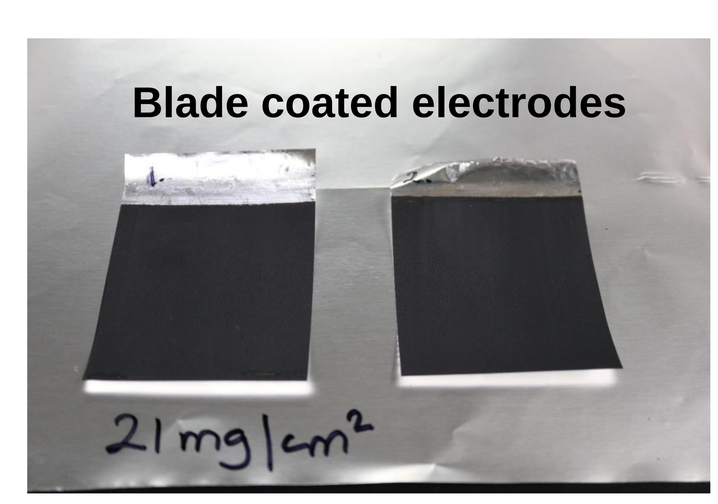
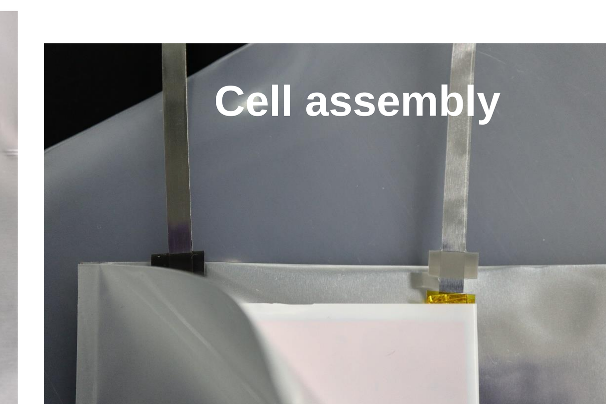
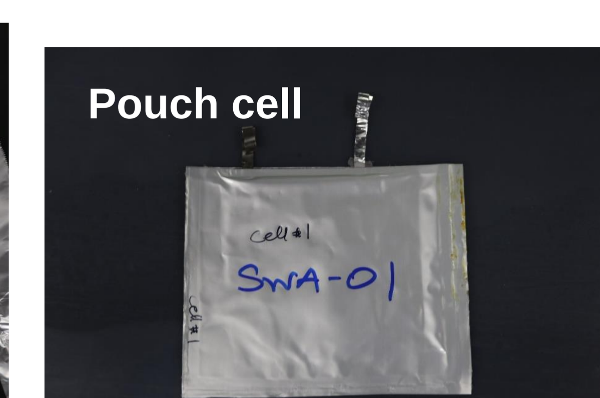


Figure 3. Discharge curves of cell SWA-13 in continuous mode and pulsed mode.







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Significance of results:

- Developed new electrode process for fabricating electrodes with high power capability in a pouch cell format
- Excellent high pulse power capability of electrodes, with good voltage response under pulse and continuous discharge conditions
- Will continue to pursue electrodes designs in FY20 collaboration with Deutsches Zentrum für Luft- und Raumfahrt (DLR, Germany), for potential scale-up and future infusion

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