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SSTP 2016 Partnership
Development of a Nano-Enabled Space Power System

NASA GRC

Team

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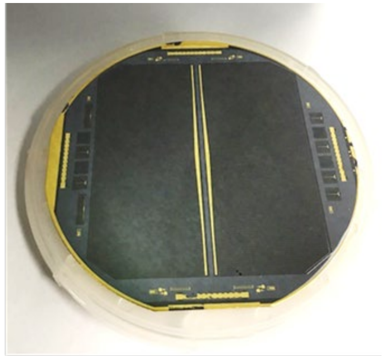
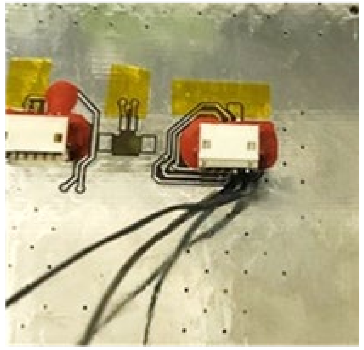
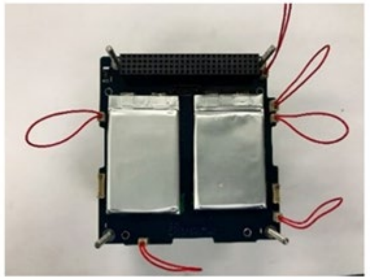
Technology



Quantum Dot Enhanced Multi-Junction III-V Solar Cells

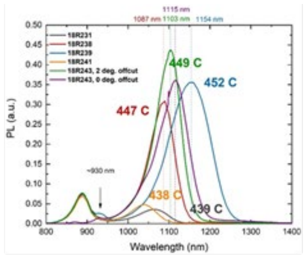


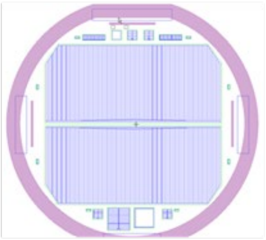
Carbon Nanotube Wiring Harnesses for CubeSats

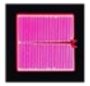


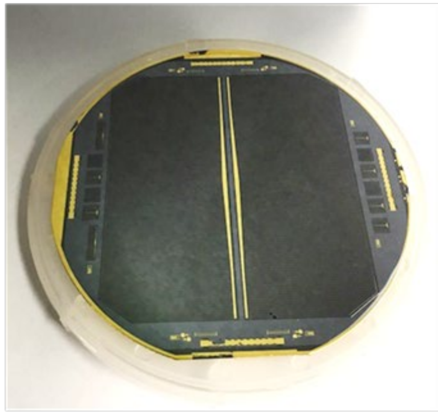
Carbon Nanotube Enhanced Lithium Ion Batteries

Quantum Dot Multijunction III-V Solar Cells

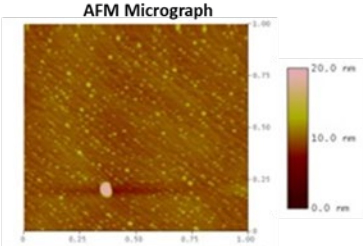




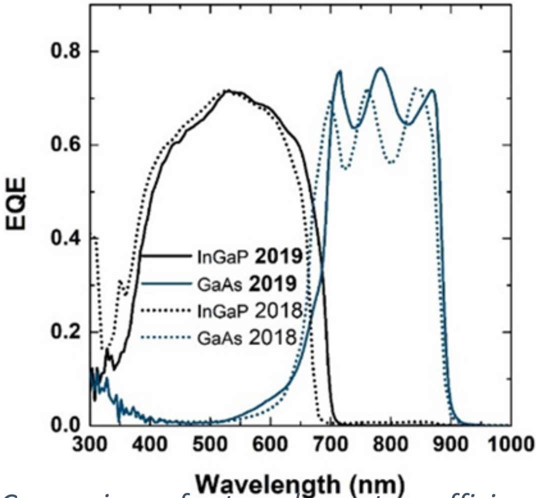


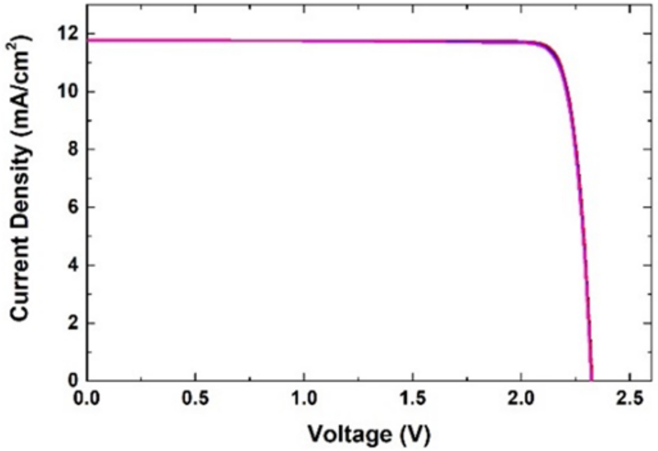


RIT Grown InAs Quantum Dot AFM Micrograph



RIT QD/QW enhanced photovoltaic cells were characterized and finished through electroplating gold contacts with a RIT designed mask.

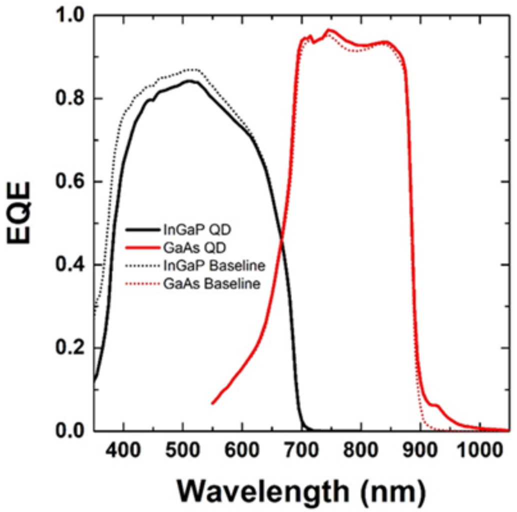


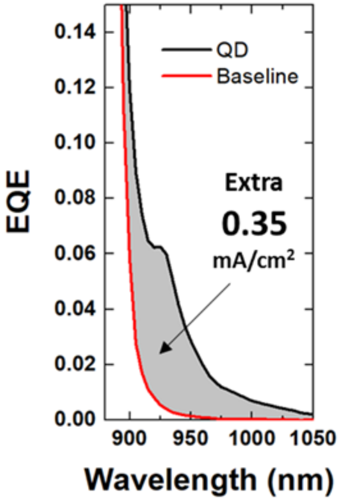


Comparison of external quantum efficiency from initial round and final round of 2J tandem without QDs (left). Light I-V for new 2J InGaP/GaAS tandem devices measured under simulated 1-sun AM0.

Large cells	I_{sc}, mA	J_{sc}, mA/cm^2	V_{oc}, V	FF, %	Eff., %	Power, mW
Baseline	432.69	16.15	2.346	63	17.55	642.3
QD	440.60	16.44	2.146	69	17.90	649.5

Small cells	I_{sc}, mA	J_{sc}, mA/cm^2	V_{oc}, V	FF, %	Eff., %
Baseline	3.29	15.11	2.345	80	20.84
QD	3.33	15.29	2.165	76	18.50

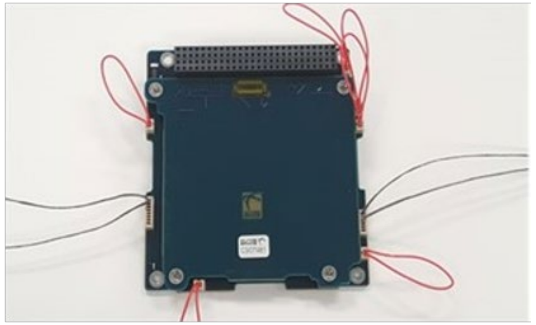




Area 26.8 cm^2

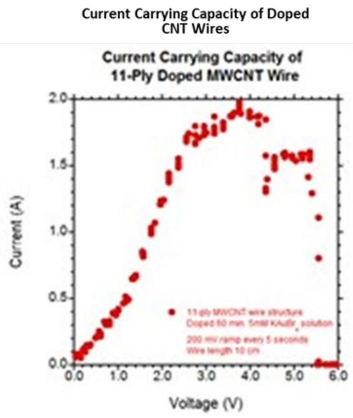
Performance and comparison of external quantum efficiency from final round of 2J tandem with and without QDs measured under simulated 1-sun AM0.

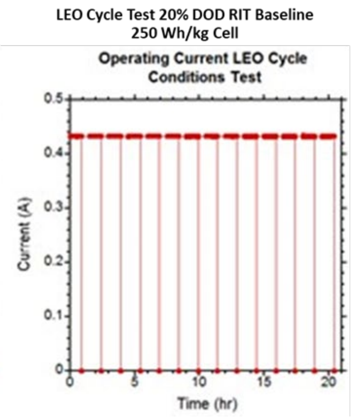
Carbon Nanotube Wiring

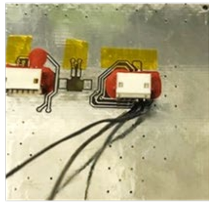


Parameter	Clyde Space Wire	Functional Replacement	Form Factor Replacement
Material	Copper with Insulation	5 mM $KAuBr_4$ Doped MWCNT Yarn with Insulation (22-ply)	Undoped MWCNT Yarn with Insulation (11-Ply)
Resistance/Length (Ohm/m)	3.25	3.26	13.89
Mass (g)	0.2004	0.1308	0.0384
AWG	20	16	20

A comparison of a commercial Clyde space wire with functional and form factor all CNT wire replacements. Images of the wires can be seen (top left) along with integration into a Clyde space board (top right).



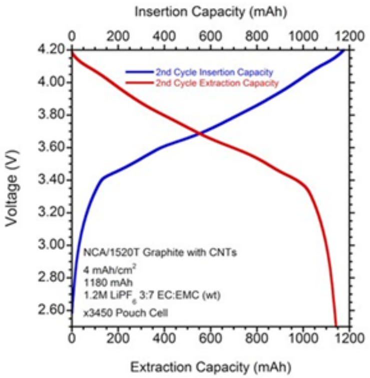




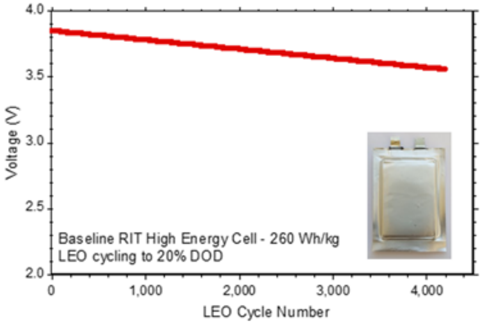
Metal-free carbon nanotube space wire harnesses were fabricated and tested for (left) current carrying capacity, (middle) LEO charge/discharge duty cycles, and (right) terminated with CubeSat interconnects.

Carbon Nanotube Enhanced Li Ion Batteries

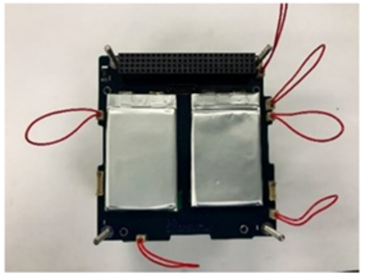
260 Wh/kg Formation Cycle



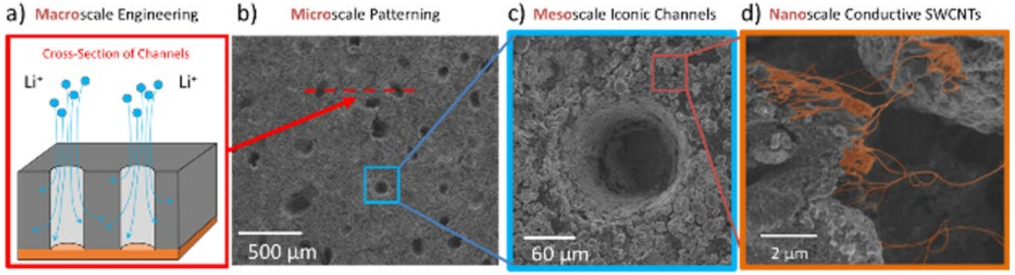
LEO Cycle Life Testing – 20% DOD

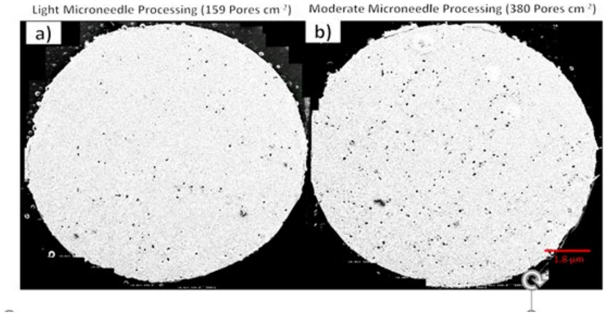


CNT Enhanced Cells on Power Board



Charge/discharge voltage curves for the CNT enabled lithium ion pouch cells, (middle) LEO cycling of the CNT-enabled pouch cells, and (right) the pouch cells integrated onto the Clyde space CubeSat EPS power board.





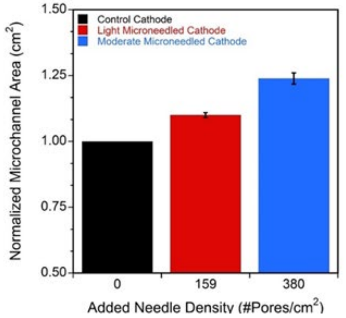
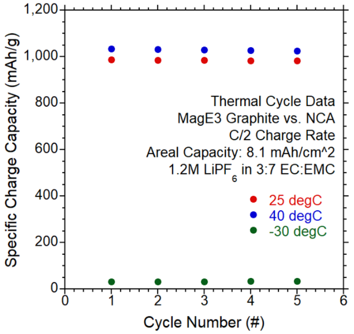
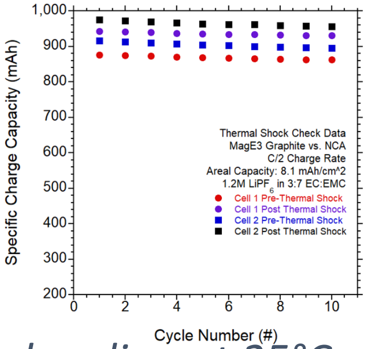


Diagram and SEM images of microscale patterning and CNT additive incorporation (top). Microscope images of micro needling (bottom left). Pore density of compared electrodes.

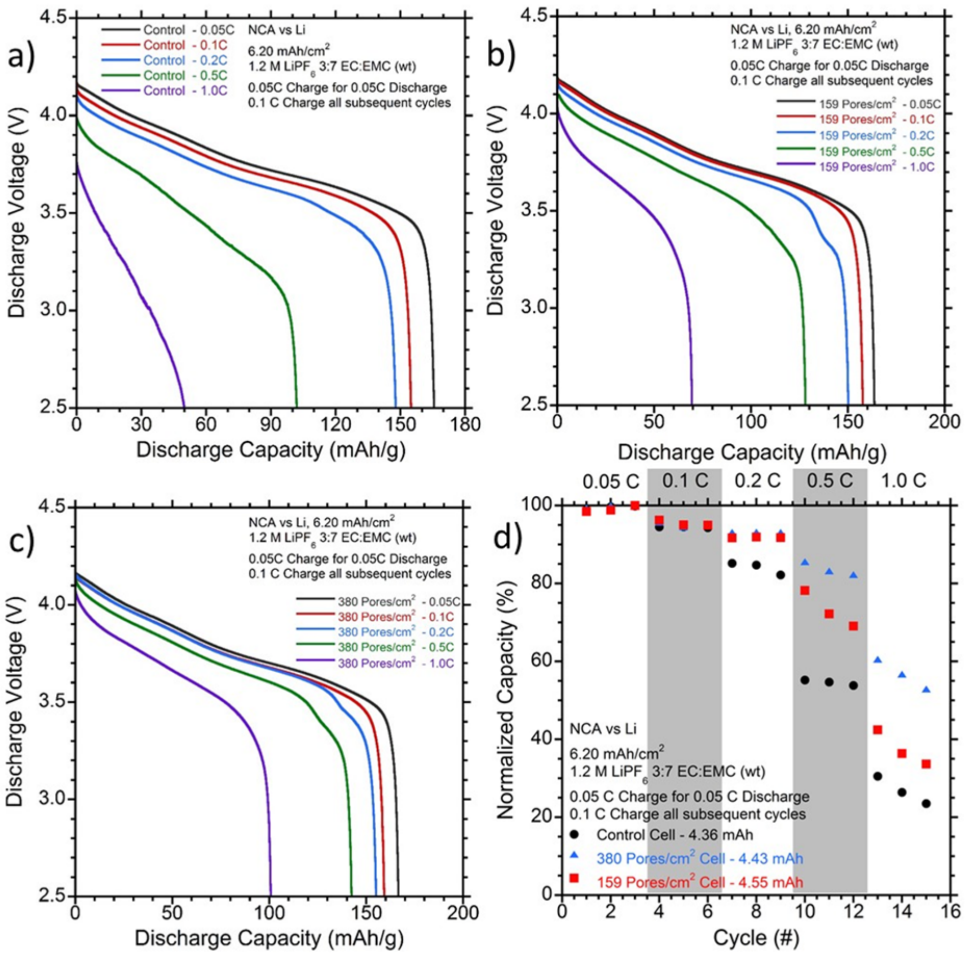
Thermal Shock Chamber

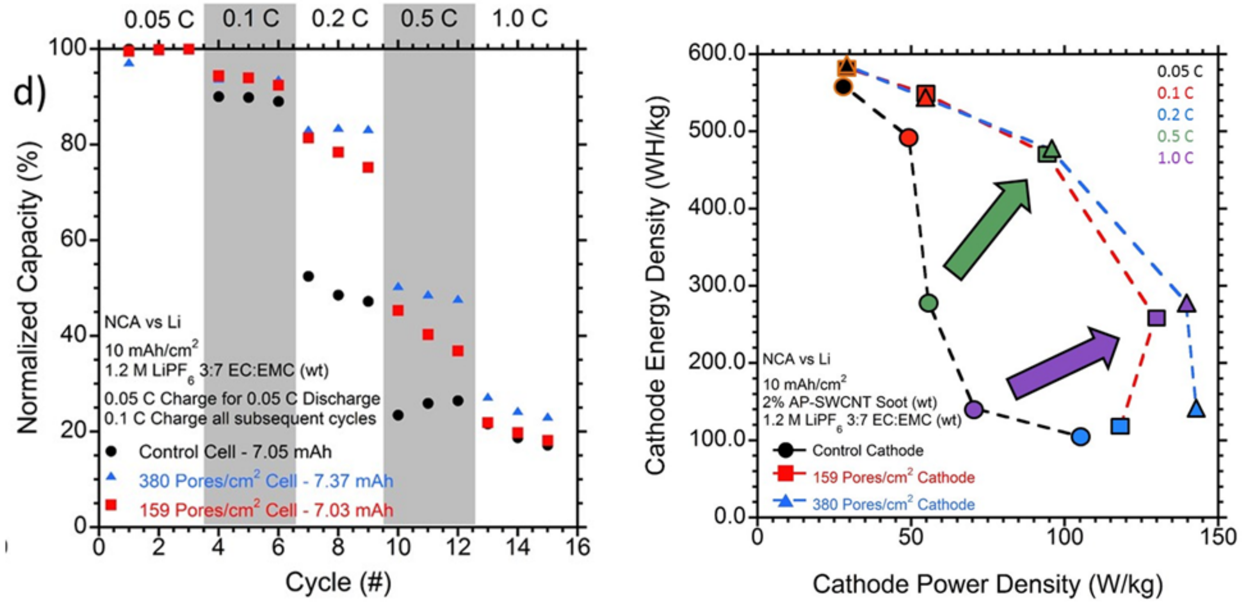




Thermal shock chamber (left). Electrochemical cycling at 25°C, 40°C, and -30°C (middle) and cycling post-thermal shock (right)

Carbon Nanotube Enhanced Li Ion Batteries

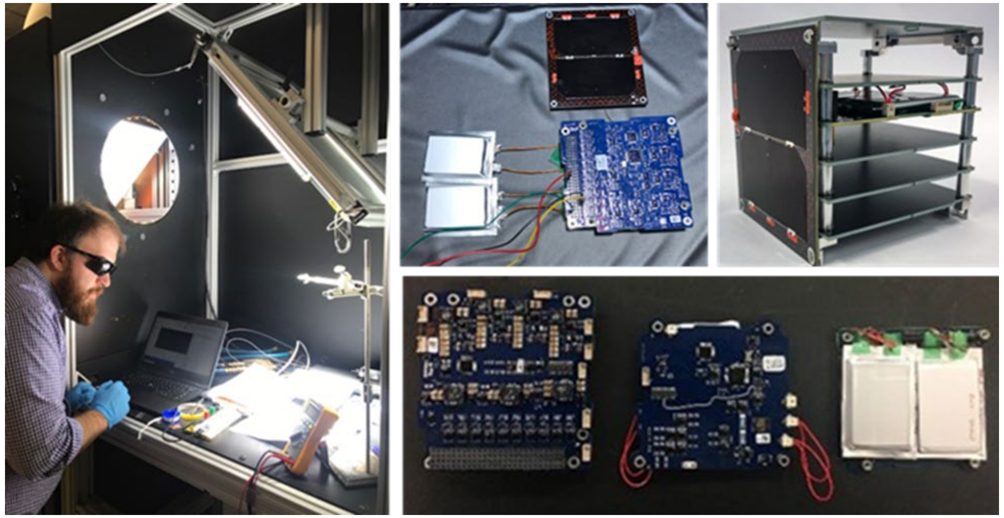




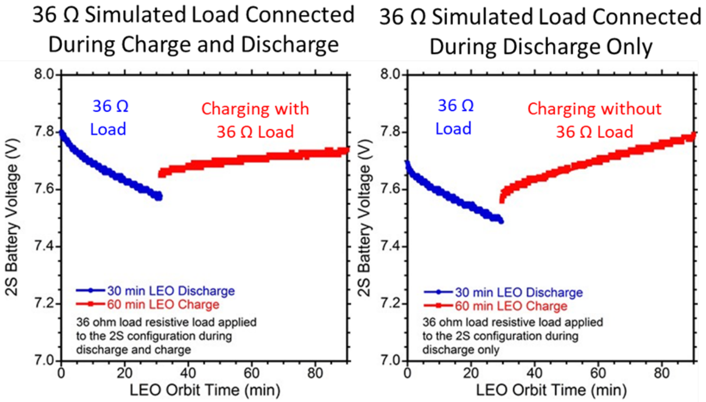
Rate and energy density comparison of varying pore densities at 10 mAh/cm².

Electrochemical testing of varying pore density at 6.2 mAh/cm².

Nanoenhance SmallSat Power System



Simulated LEO cycling under AM0 Illumination with and without an applied load.



NASA Glenn Research Center Summer Balloon Launch

NASA Glenn Research Center summer high-altitude balloon launch, Dayton, OH (Photo Credit: NASA GRC)

Questions?

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RIT

RIT Battery Prototyping Center

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Slurry Mixing and Roll-to-Roll Electrode Fabrication

Mixing and Coating from Small Volume to Multiple Liters

Pouch Cell Equipment

34 x 50 mm up to 250 x 250 mm Cell Sizes

Cylindrical Cell Equipment

18650, 21700, and 26650 Cell Sizes

» ***RIT BPC works with universities, start-up companies, material and cell manufacturers to prototype and test battery materials and custom electrode formulations in coin, pouch, and cylindrical cell formats.***

» ***All process steps are completed within dry room environment which is key to working with many new battery materials.***

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Slurry mixing and Roll-to-Roll Processing

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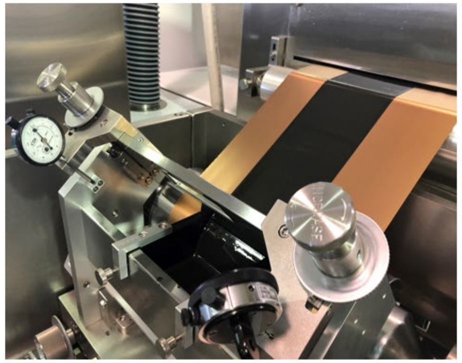
Mixing and Milling Equipment



- Small volume up to multiple liter slurry mixing
- Flacktek DAC100 – 100g planetary centrifugal bladeless mixer for small volume mixing
- Primix 1L planetary mixer has temperature control and vacuum to uniformly mix slurries
- Filmix high speed thin-film mixer can run in batch (50-90 mL) or continuous mode to homogenize slurry before coating
- Buhler laboratory bead mill can wet mill materials to the nano-scale

Roll-to-Roll Coating and Slitting

- Slot-die or knife over roll coating up to 330 mm web width
- 1L displacement tube slurry dispensing
- Edge alignment guide for accurate double sided-coating and rewind
- Forced-air floatation oven for drying
- Integrated slitting unit with two differential rewinds to slit cylindrical cell electrodes and custom widths

Roll-to-Roll Calendering

» ***Larger batch and continuous slurry mixing, coating, calendaring, and slitting now possible in the BPC. This enables more consistent and larger volume of cells to be produced. This equipment has enabled a wide variety of new projects.***

Cylindrical Cells and Pouch Cells

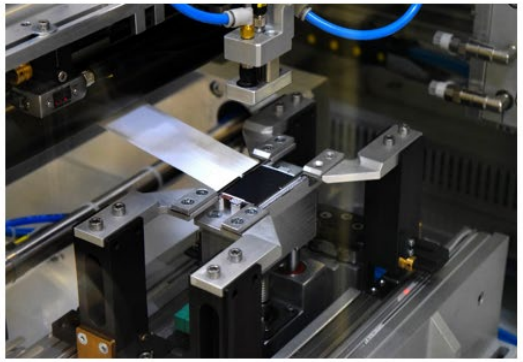
Cylindrical Cell Prototyping-Pilot Equipment

- Automated electrode winding
- Ultrasonic tab welding to strip
- Resistance welding of negative contact to can
- Ultrasonic welding of positive contact to cap
- Grooving machine
- Vacuum electrolyte filler
- Crimping machine

18650, 21700, and 26650 Cell Sizes

Pouch Cell Prototyping-Pilot Equipment

- Electrode Punching
- Z/Z Pick and Place Stacking
- Ultrasonic Welding
- Pouch Forming
- Top and Side Pouch Sealing
- Electrolyte Filling
- Degassing & Vacuum Sealing



34 x 50 mm up to 250 x 250 mm Cell Sizes

» ***Cylindrical cell line is operational and has led to a increased number of products to build cylindrical form factor. The BPC is in the process of adding a larger cell size capability (up to 16 Ah) with ~94 mm x 150 mm cell size tooling.***