




A PneumatiCoat Company

NDIA Military Power Sources Committee Meeting

Precision Nano-Coatings

Faster and More Affordable than Ever

www.ForgeNano.com

A full-page background image showing a soldier in camouflage gear aiming a shoulder-mounted weapon. In the background, there is an armored vehicle and other soldiers in a desert environment. A semi-transparent text box is overlaid on the right side of the image.

Forge Nano's proprietary technology and manufacturing processes make angstrom-thick coatings fast, affordable and commercially viable for a wide range of materials, applications and industries including Lithium Ion batteries.



ALD Enabled Lithium Ion batteries

100% Increase in Charge/Discharge Cycle Life

- Lower Cost of Ownership
- Reduced Maintenance

20% Energy Density Increase

- Weight Reduction
- Greater Electrification

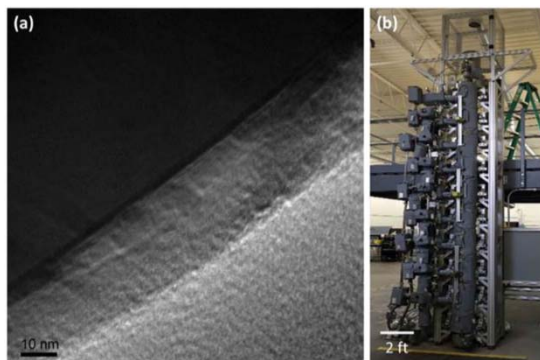
Increased Safety

- Reduced Internal Side Reactions
- Stable Operating Envelope



*Raw
Materials*

Nano Coatings

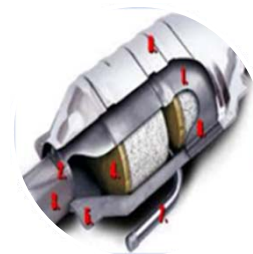


Scientific Reports | 6:26532 | DOI: 10.1038/srep26532

ALD



Innovative Products



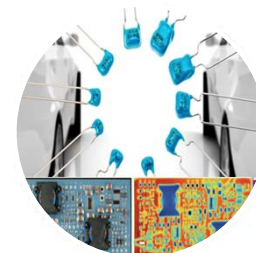
Catalysts



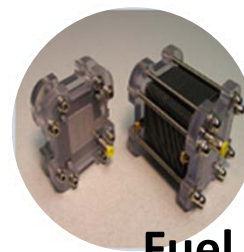
Conductive Inks



Li-ion Batteries



Capacitors

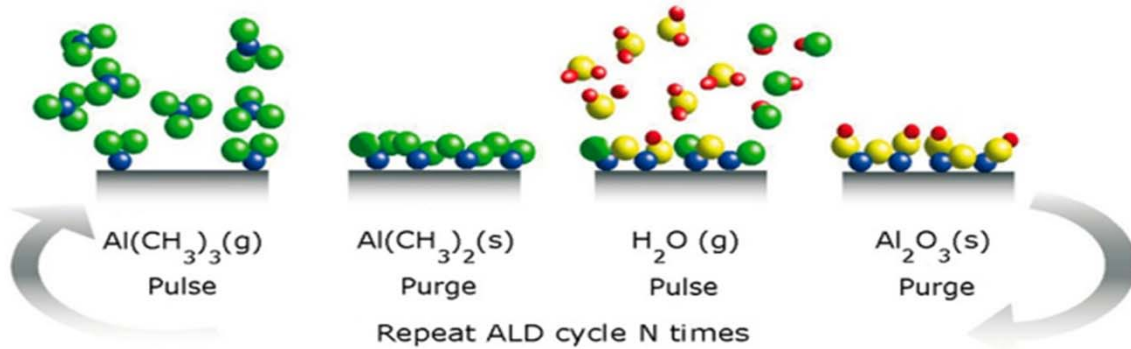


Fuel Cells

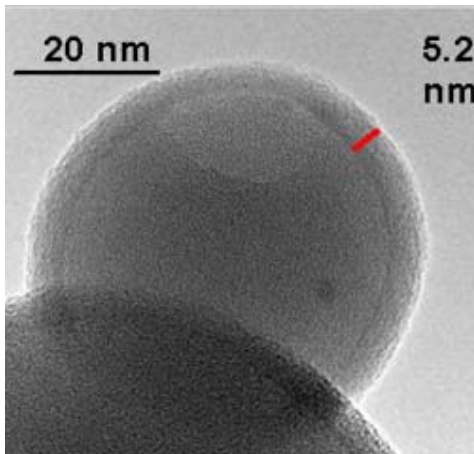


Advanced
Ceramics

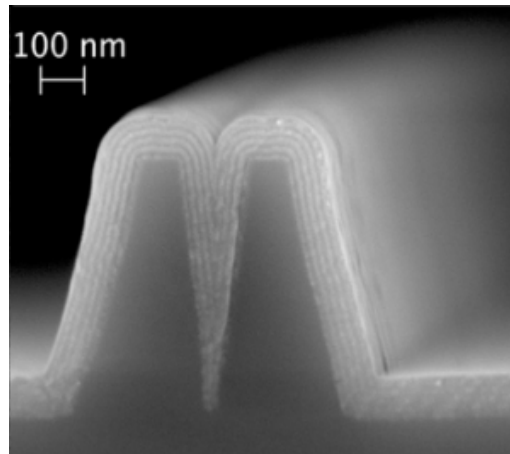
Atomic Layer Deposition



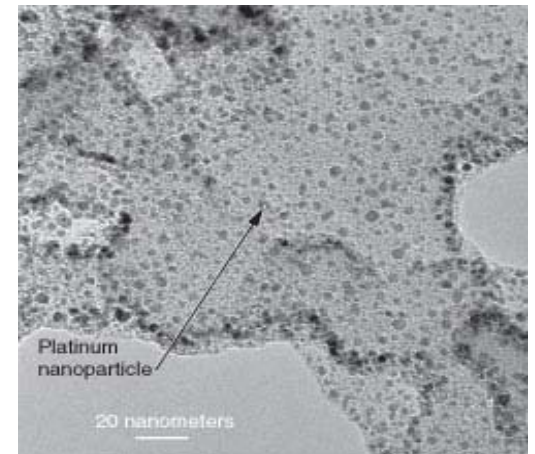
- Gas phase process
- Self limiting
- No line-of-sight restrictions
- Sub-nanometer control
- Pinhole free



Particle coatings



Multilayers



Nano-islands

Forge Nano's Technology Breakthrough



Conventional ALD has been Historically Slow and Expensive
Lack of Manufacturing Innovation Hindered Commercial Adoption

Forge Nano's
*Patented Continuous Particle ALD
Process is Fast and Economical*

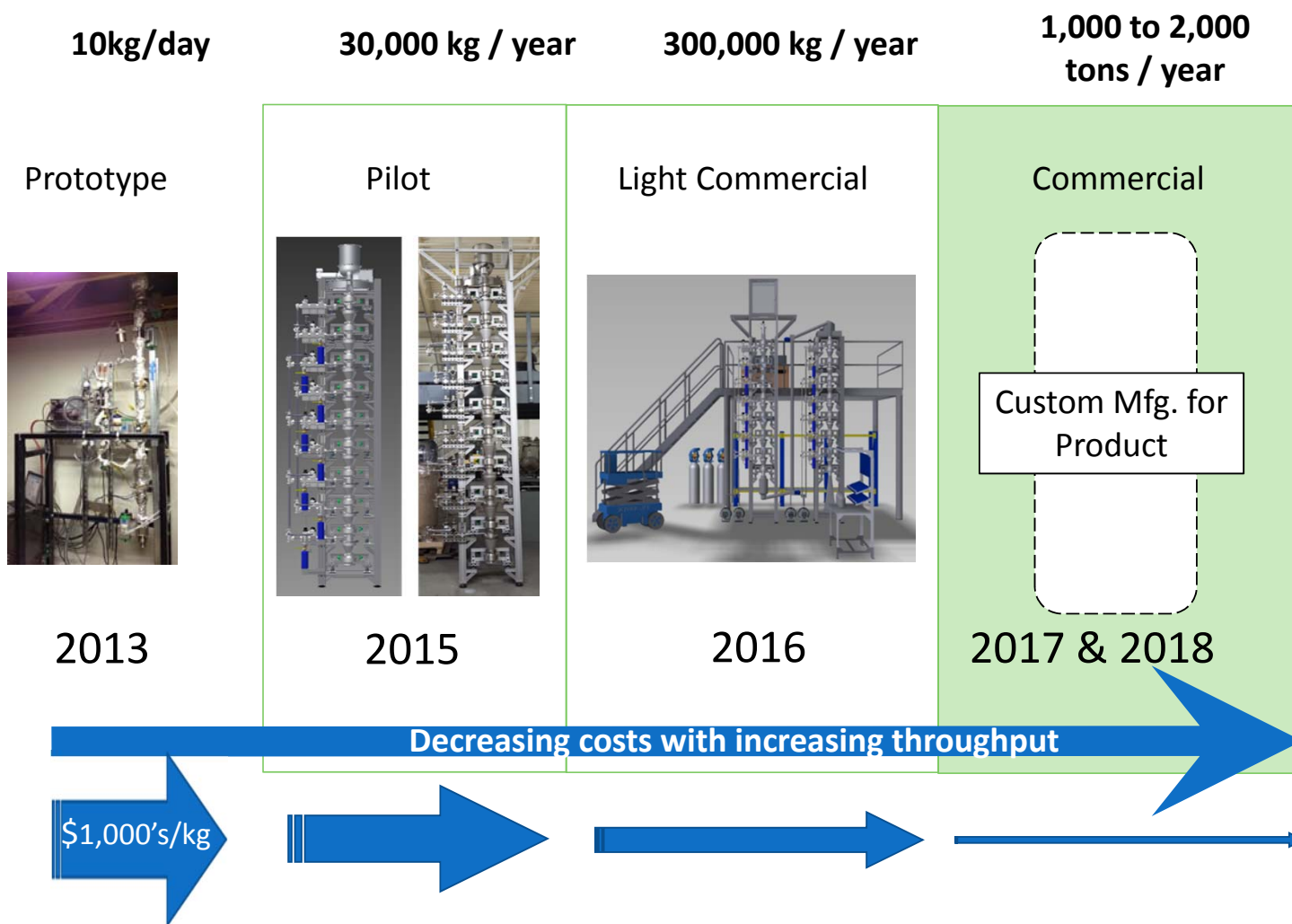


*The Only Proven High Throughput
ALD Production Tool*

**300 ton/year Light Commercial
Plant Under Construction**

Forge Nano ALD Processing

Scale-up Tool Roadmap



Our Patents

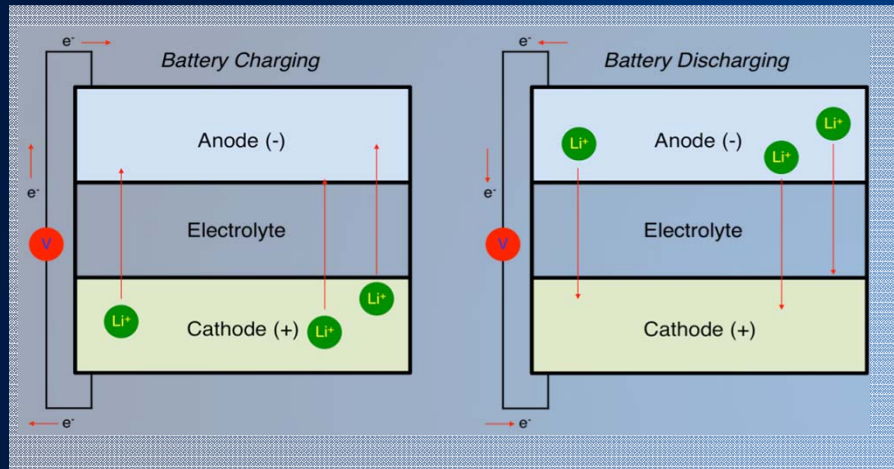
- **ALD Manufacturing Apparatus:** US 9,284,643
- **ALD Manufacturing Process:** US 9,546,424
- **Comprehensive ALD Battery IP:** Coated cathode, anode, solid electrolyte, and separators
 - Forge Nano Filed:** 3 additional pending patents
 - Licensed IP:** 13 issued and pending patents with exclusive licenses
- **Non-Battery IP:** 1 additional pending patent for coated metal uses
- **Ongoing Research & Licensing with National Labs / Universities:** Batteries, Fuel Cells, MLCCs, Supercapacitors, Conductive Inks, Catalysts



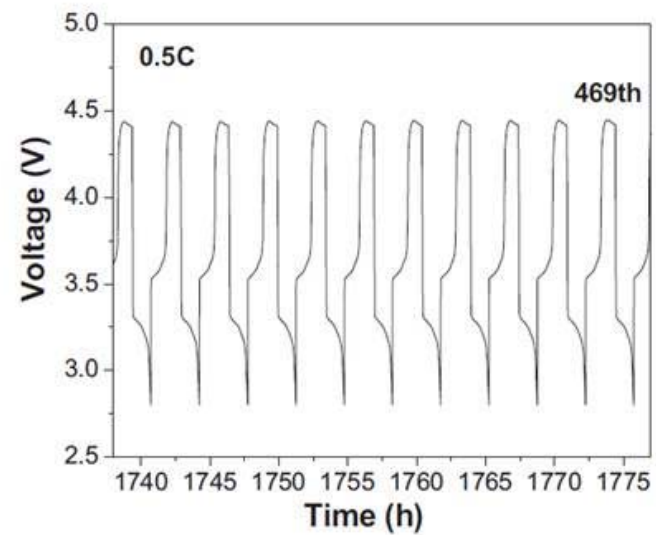
Li-Ion BATTERIES: Behind the Innovation Curve



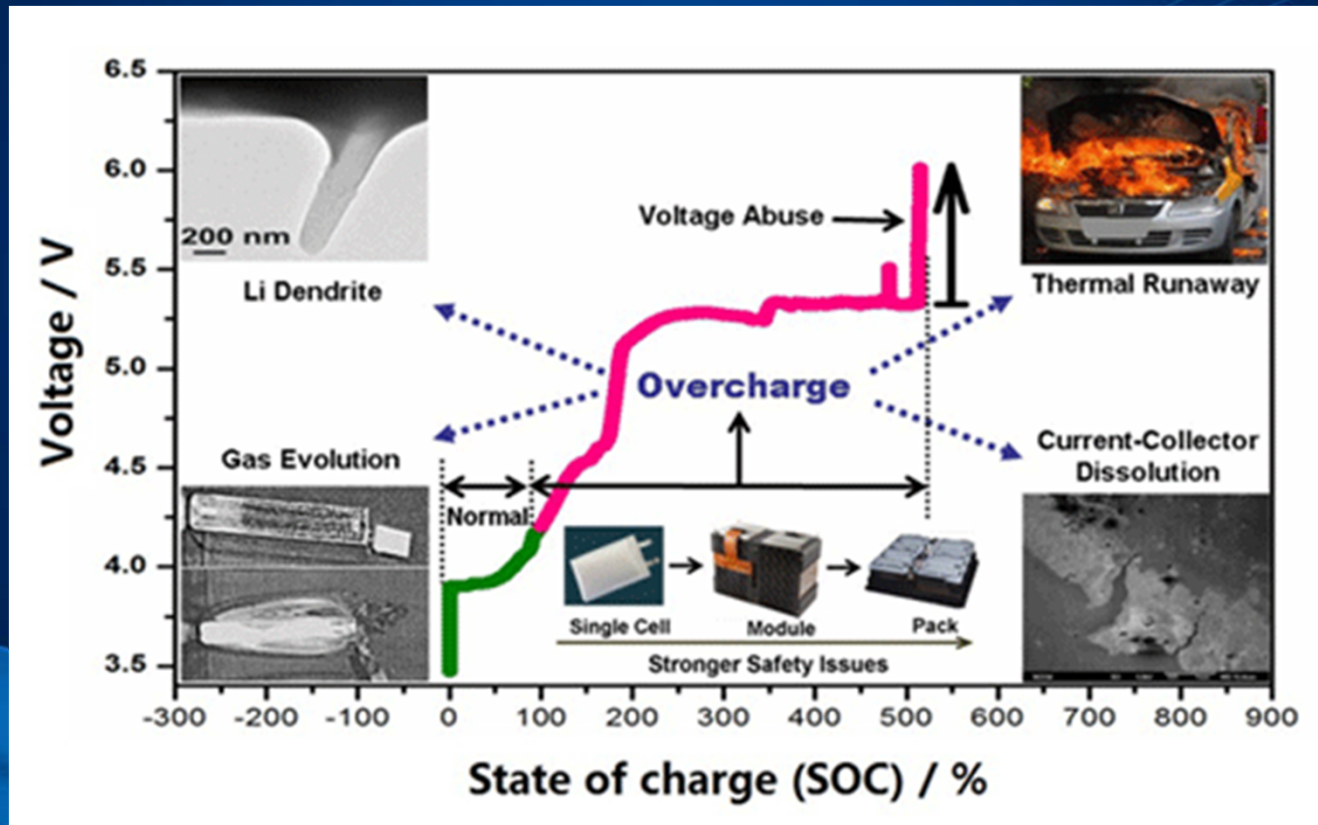
Battery Anode / Cathode



Battery Charge / Discharge Cycle



Performance Demands



Safety Pressures

How Lithium Ion Batteries GROUNDED THE DREAMLINER

Official report on Boeing 787 fires tells a cautionary tale about advanced batteries



At 10:21 a.m. on Jan. 7, 2013, about a minute after all 183 passengers and 11 crew members from Japan Airlines Flight 008 disembarked at Boston's Logan International Airport, a member of the cleaning crew spotted smoke in the aft cabin of the Boeing 787.

Cost to Boeing - \$600 Million

TESLA SAYS CAR FIRE STARTED IN BATTERY

.....

A Tesla Model S electric car caught fire on Tuesday morning in Washington State, and the company said that the fire began in the car's battery pack after the driver hit debris on a highway.

The Tesla's driver told the police that he had hit metal debris on the freeway and exited, and then, he said, the vehicle caught fire.



Titanium Shields- Adds Cost & Weight

Why is the Samsung Galaxy Note 7 Catching fire? THE LIHIUM-ION BATTERY EXPLAINED

Samsung has permanently stopped production of the Galaxy Note 7 less than two months after its release, as the phone caused hundreds of reported fires and explosions worldwide.

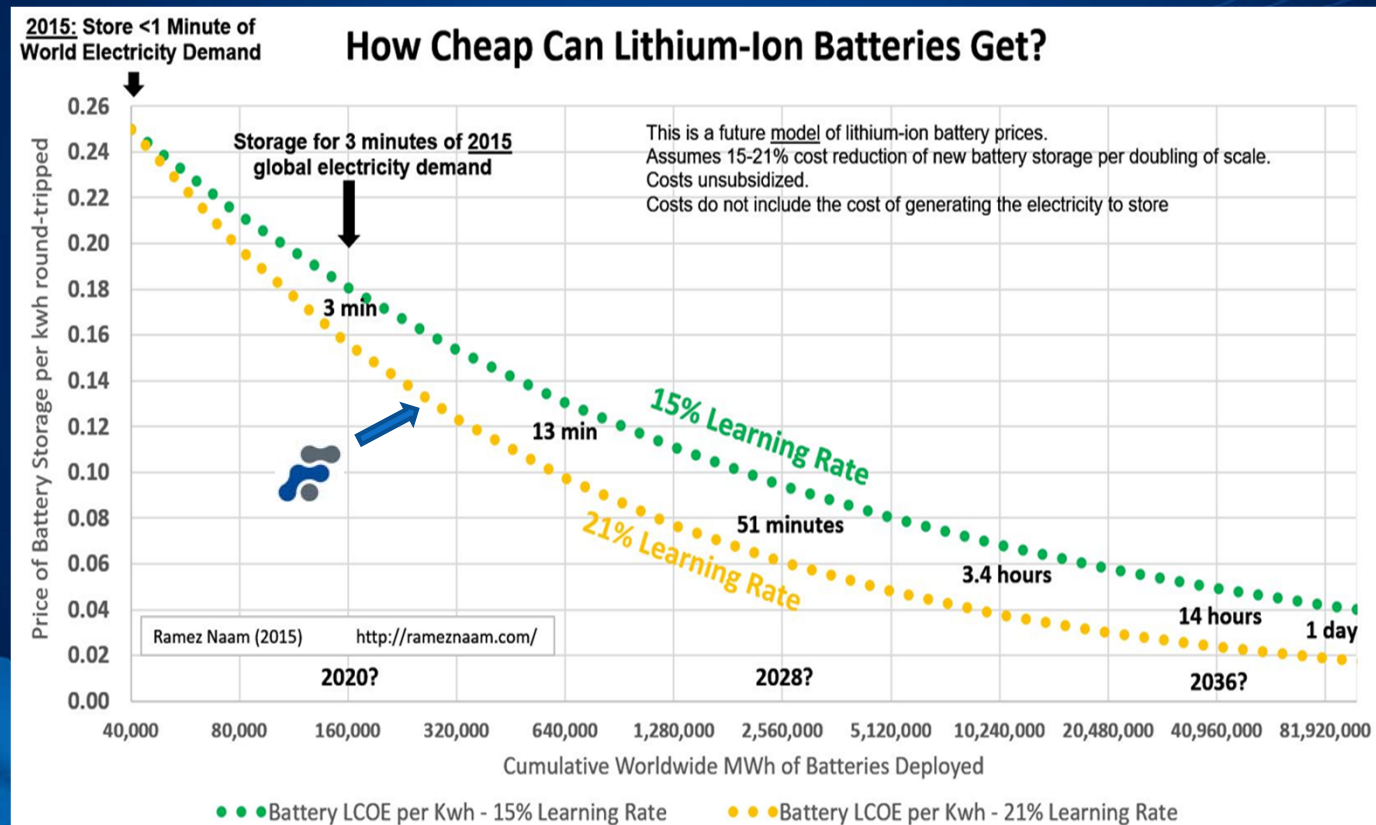


Its flagship smartphone - which retailed at £739 and was initially hailed as one of the best phones of 2016 - issued a global recall of the water-resistant phones, including "safe" replacement devices, amid overheating fears.

Samsung has not confirmed the number of incidents, but estimates suggests that fewer than 150 handsets have overheated and, in some cases, caught fire.

Cost to Samsung - \$5.3 Billion

Cost Pressures



(Ramez Naam)

Enabled
des

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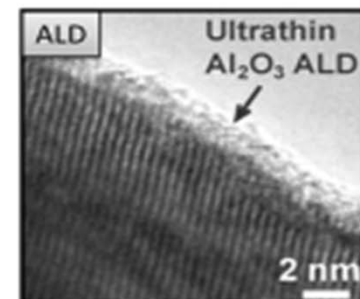
er Battery Capacities

er Cycle Rates

ger lifetimes

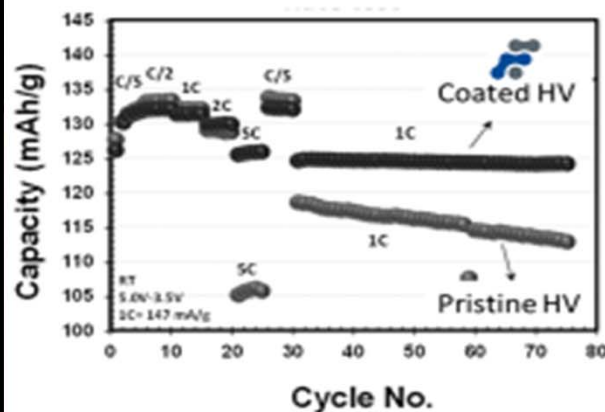
PERFORMANCE

FORGE NANO'S ALD PROCESSING PUSHES
CELL CAPABILITIES TO HIGHER
TEMPERATURES, FASTER C-RATES AND
LONGER LIFETIMES

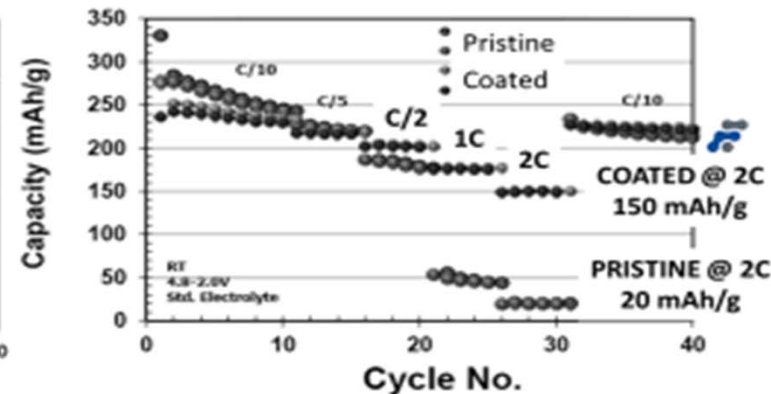


Scott, et al., Nano Letters 2011

HIGH VOLTAGE MATERIALS



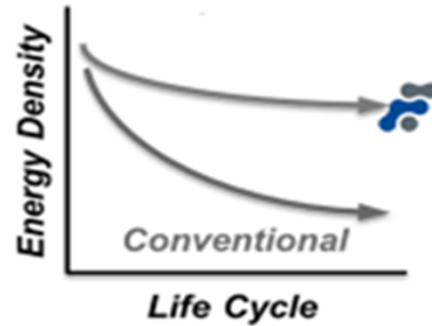
HIGH CAPACITY MATERIALS



ALD Enabled Cathodes

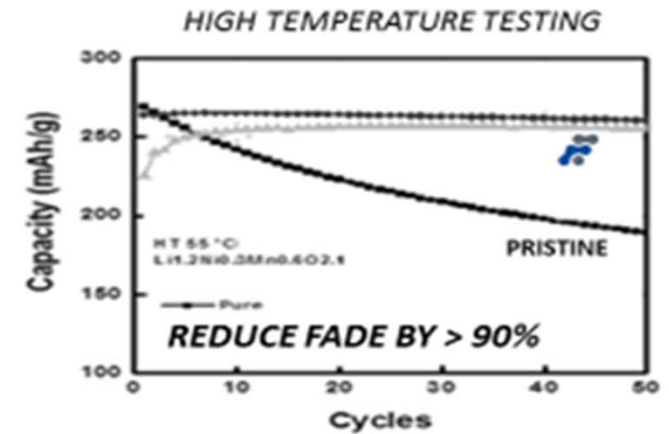
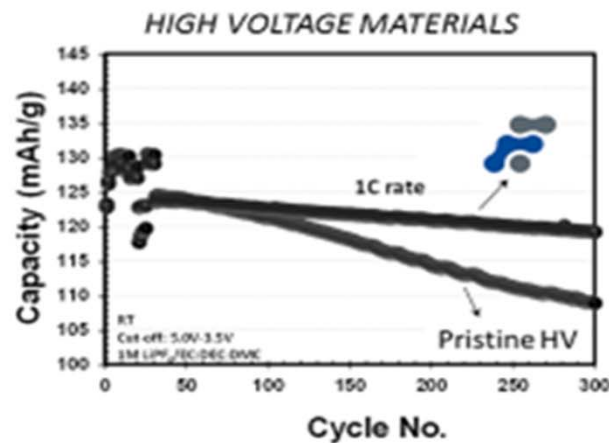
Longer Lifetimes

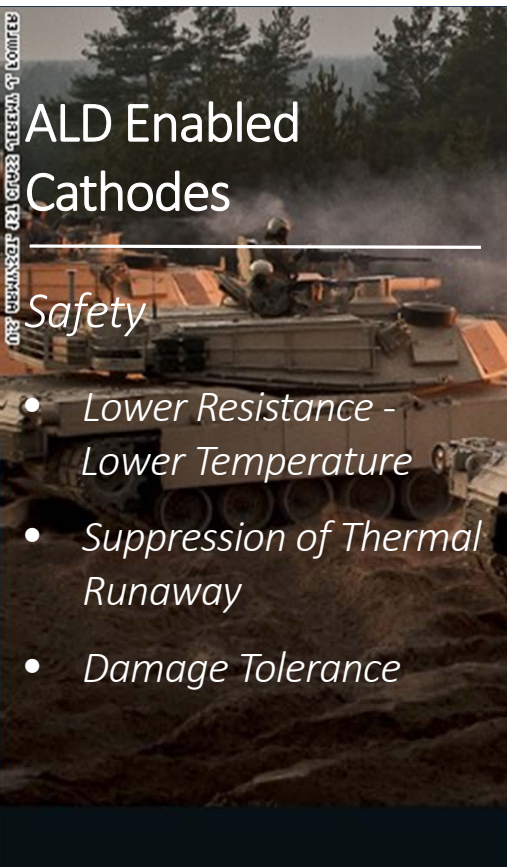
- Reduces Fade
- Longer Lifetimes
- Reduces Battery Overbuild



LONGEVITY

FORGE NANO'S PROPRIETARY MANUFACTURING SYSTEMS LOWER COST OF OWNERSHIP WHILE REDUCING OVERBUILDING NEEDS



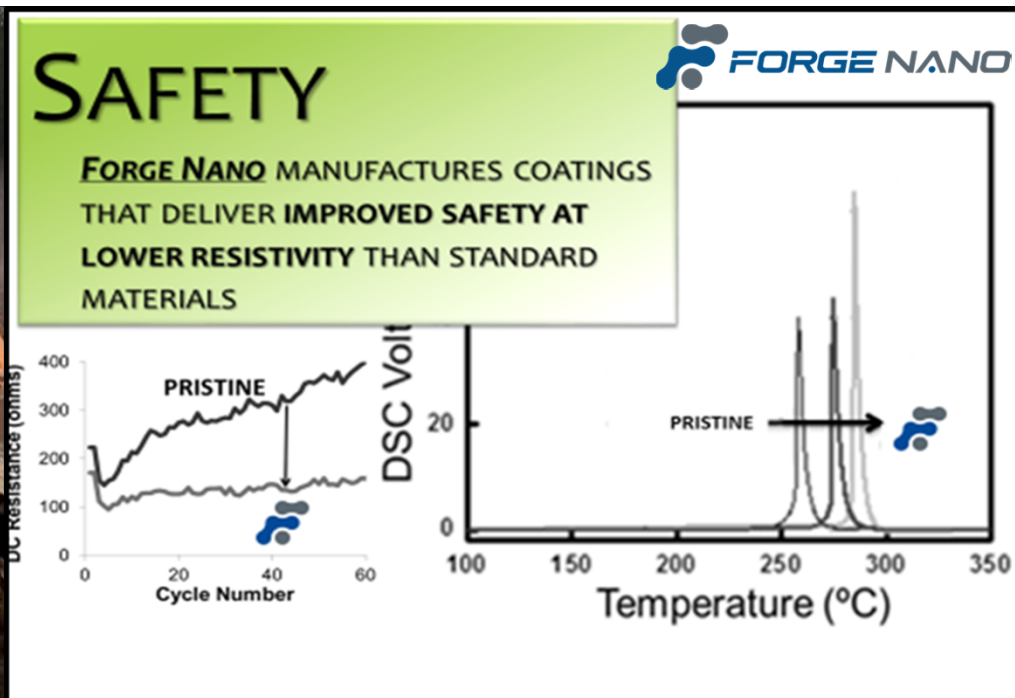


032 48434201 421 01233 47894 01 1001234

ALD Enabled Cathodes

Safety

- Lower Resistance - Lower Temperature
- Suppression of Thermal Runaway
- Damage Tolerance



Results:

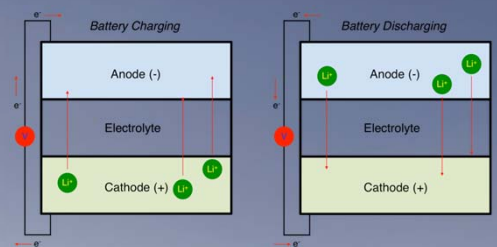
- Al_2O_3 and TiO_2 coatings improved NCA capacity retention during high rate (1 C/–1 C) cycling.
- Al_2O_3 coating improved NMC capacity retention during low rate (0.3 C/–0.3 C) and high rate (1 C/–1 C) cycling.





ALD Enabled Anodes

50% Lifetime Improvement
at 45°C with 1C Cycling



Results from 2 Ah pouch cells with ALD-Enabled Anode Materials

	Uncoated Graphite	Coating 1	Coating 2	Coating 3	Coating 4
Cycles to 10% Discharge Capacity Fade	87 ± 11	156 ± 13	129 ± 27	118 ± 10	121 ± 3
Relative Cycle Life Improvement	0	79%	48%	35%	39%
Cycles to 20% Discharge Capacity Fade	180 ± 6	*293 ± 28	*265 ± 41	*232 ± 24	*274 ± 18
Relative Cycle Life Improvement	0	62%	47%	29%	52%

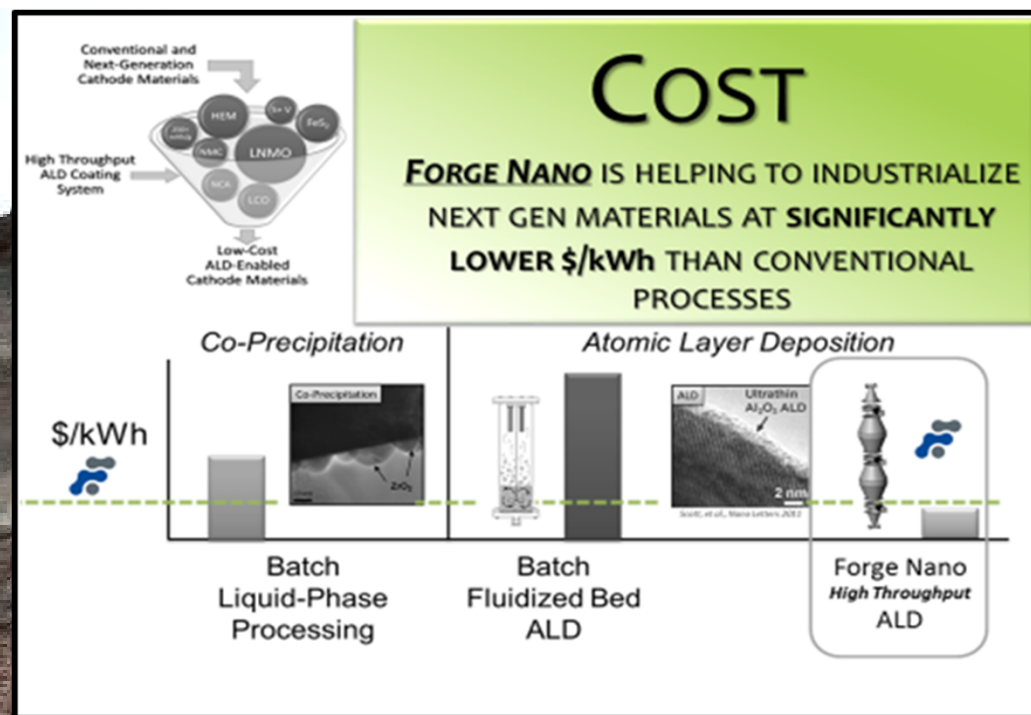
45°C, 1C-1C cycling; full NMC-532:Graphite coin cells using pristine NMC
*Projected by linear fit to last 25 cycles

FORGE NANO

ALD Enabled Li-ion Batteries

Forge Nano Coatings
Lower costs

- Scalability
- Improved Manufacturability
- Reduction in Battery Overbuild



Benefits of ALD Enabled Li-ion Batteries Summary

100% Increase in Cycle Life

- Longer Battery Life
- Fewer Battery Replacements
- Reduced Logistics Demand

20% Energy Density Increase

- Meet High Power Operational Requirements
- Reduced Transport Weight
- Enhanced Sustainment

Increased Safety

- Improving Operational Performance
- Improving Soldiers Lives

Savings



Military

\$1,000 / kW-hr

Tolerance, scale

Average
Consumer

\$200 / kW-hr

General Motors

\$150 / kW-hr

Savings @ Cell Level

- Double Battery Life = **\$200** / kW-hr Lifetime Savings
- 20% Energy Improvement = **\$ 40** / kW-hr Savings
- Eliminates Necessity for Battery Overbuild to compensate for Fade

Savings @ Pack Level Doubles

- Reduction of Thermal Management / Impact Shields
- Simplified BMS

Safety Savings

- Samsung \$5.3 Billion Earnings Loss
- **Lower Risk / Saving Lives**



FORGE NANO

A PneumatiCoat Company



Bill Flecky

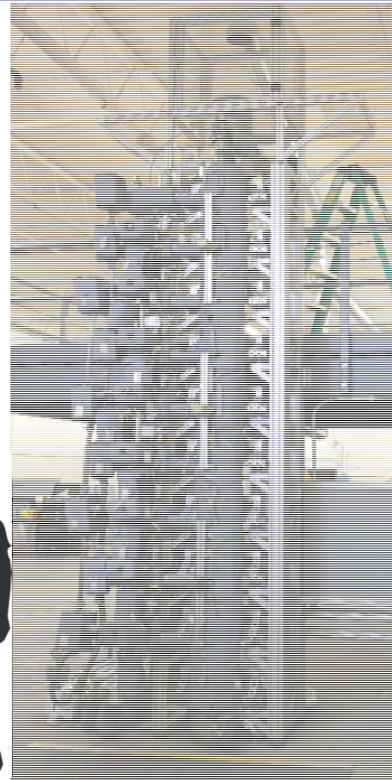
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Louisville, CO 80027

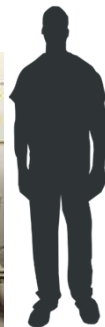
720-259-8579

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www.ForgeNano.com

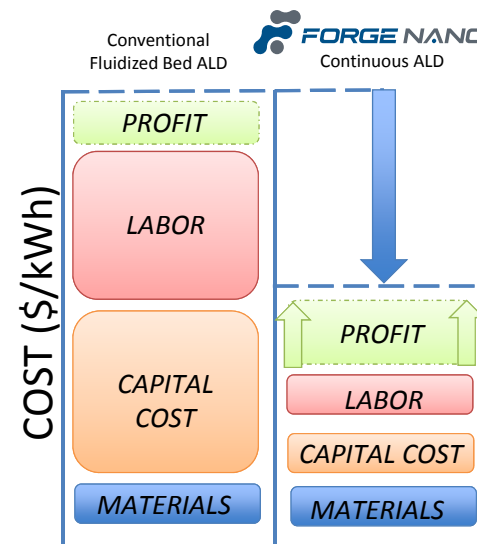


Conventional



Forge Nano's Lean Manufacturing Strategy

*Significantly Reduces Labor
and Capital Costs
Minimizes Waste*





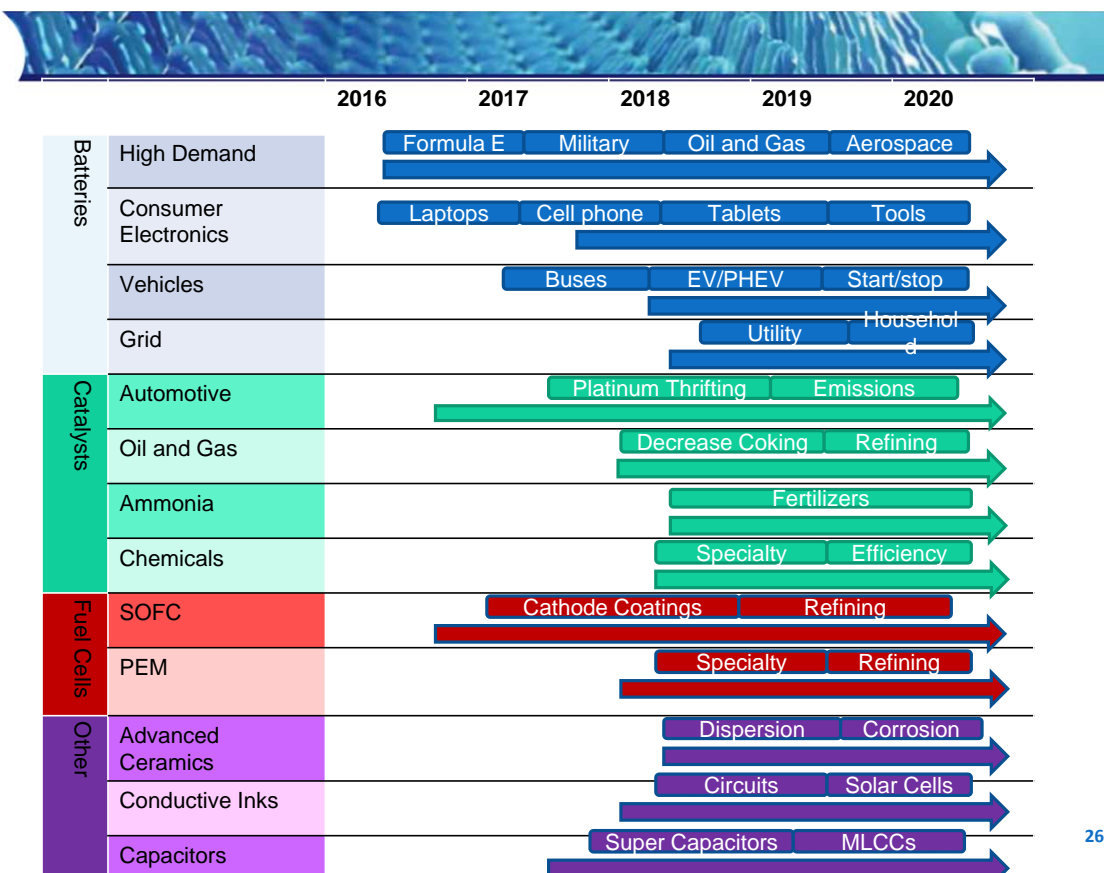
ALD Enabled Cathode Materials

*Performance
Improvements*

**Cycle Life Improvement with ALD Coated Cathode Materials
Half Cell Data**

Cathode	Top of Charge	Temp	Base Performance	ALD Performance
LCO	4.5 V *	25°C	40 Cycles	282 Cycles
LMO	4.5 V *	55°C *	100 Cycles	1,600 Cycles
NCA	4.3 V	25°C	390 Cycles	625 Cycles
NMC-111	4.5 V *	25°C	208 Cycles	733 Cycles
NMC-111	4.3 V	55°C *	22 Cycles	346 Cycles
NMC-111	4.5 V *	55°C *	16 Cycles	238 Cycles
NMC-721	4.35 V	25°C	775 Cycles	1,100 Cycles
LNMO	5.0 V	25°C	525 Cycles	1,000 Cycles
LNMO	5.0 V	50°C *	50 Cycles	750 Cycles







LEADERSHIP TEAM



CEO & Founder - Paul Lichty, Ph.D.

Founder of 5 companies that have raised over \$140 million. Developed Forge Nano technology and systems. Experience in leadership, process scale up, and project management.



CFO (part time) – Jack McFarland, MBA, CPA

Financial executive with experience in new business ventures and early stage companies. Skilled at corporate finance and securities in addition to holding several CFO positions with high tech companies such as Proterra.



VP of Business Development - Bill Flecky, MBA

Seasoned executive with 30 years of experience in high tech markets. Senior executive and has led market development for global companies Bruker, Cameca, Boston Scientific to name a few.



Senior Advisor (part time) – Ed Williams

Senior executive with track record of developing and growing new companies. Former CEO of Novinda, Firefly Energy. Former senior executive at Apple.



VP of Engineering - James Trevey, Ph.D.

Lithium-ion battery materials expert, solid state electrolytes, targeting automotive applications. Previous work with 2 other startups managing process scale-up.



Director of Technology & Founder - David King, Ph.D.

World expert in nano-coatings, experience in technology development. Over 15 years of ALD experience. Strong background in IP strategy.

