



Achieving a tactical advantage in energy storage using nano-coatings

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St. Louis, MO
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Company Highlights

Founded in 2011, Denver, CO

117 employees

Scaled nano-coating technology

Atomic Armor

Core business is
**commercializing
differentiated products
using Atomic Armor**

Materials and technology
development partner

Forge Nano supplies the world's largest, and largest selection of, particle ALD equipment – from R&D scale to equipment ready for the Gigafactory floor.



Battery Highlights



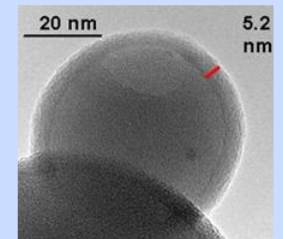
Product Benefits (any chemistry)

- Increase energy density
- Increase power density
- Increase cycle life
- Increase safety
- Decrease cost



Process Benefits

- Improved operational efficiency
- Improve corrosion tolerance
- Reduce batch variation
- Decrease cost
- Decrease pollution

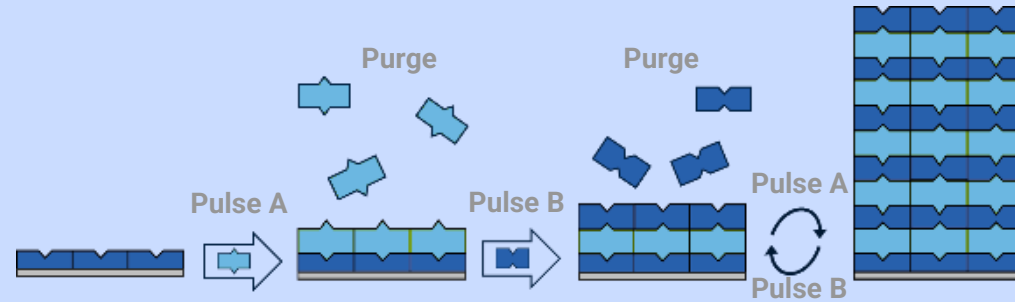


Precise thickness control

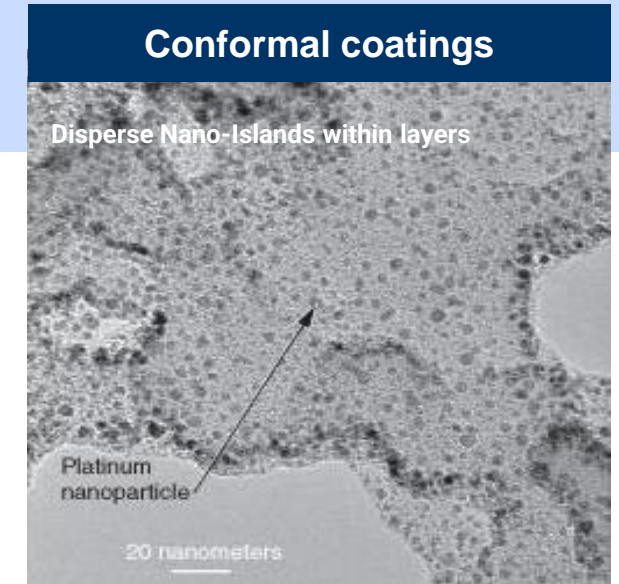
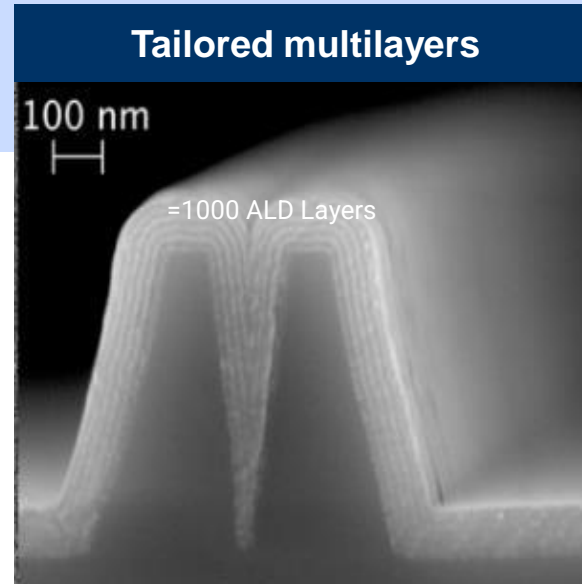
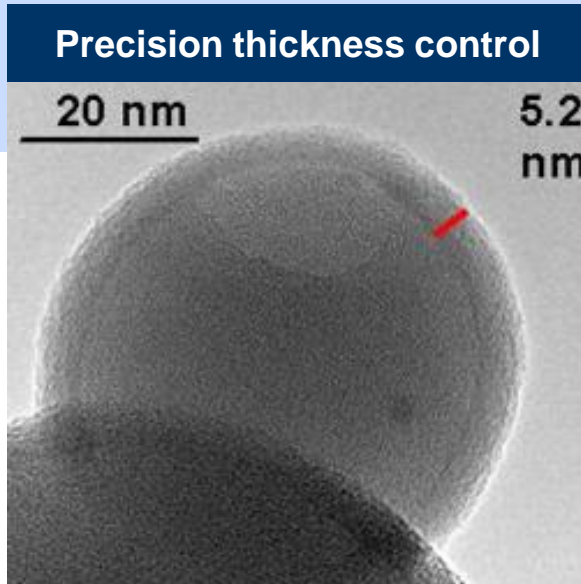
Forge Nano is an end-to-end (grams-to-tons) solution provider for advanced materials

ATOMIC LAYER DEPOSITION (ALD)

Gas phase process
Self-limiting
No line-of-sight limitations

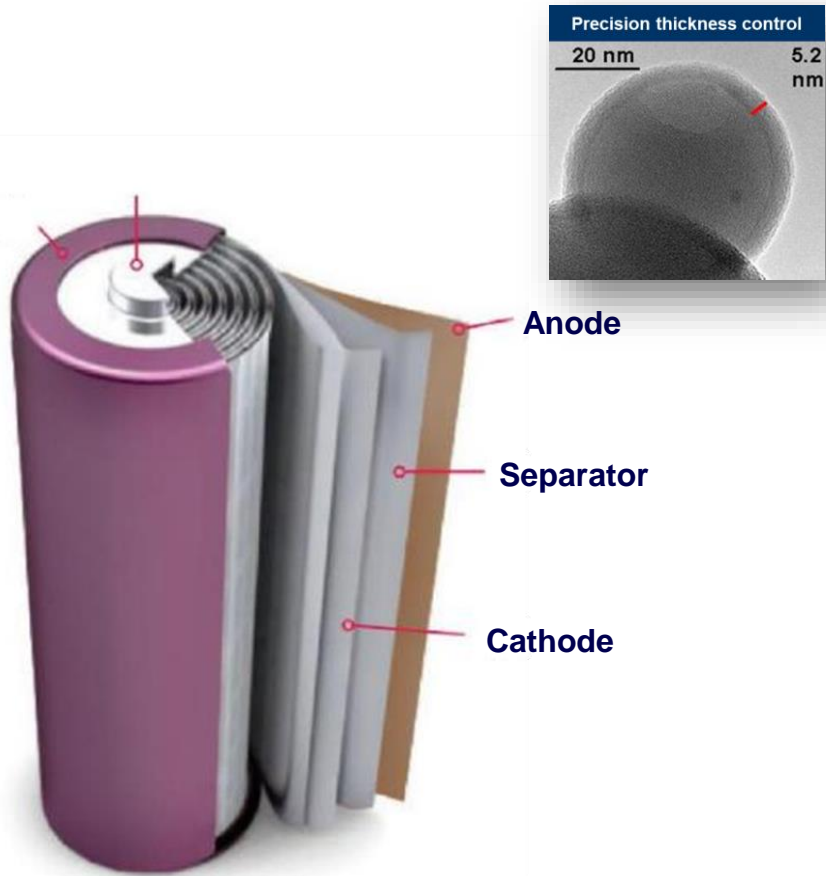


Atomic-scale control
Uniform, conformal
Customizable multi-layers



ALD is used to apply conformal coatings to materials to improve/control surface properties and reactions

Atomic Armor™ Can Improve Any Cell Component



Anode performance improvements

- Faster charging
- Reduced cost
- Higher energy density

Separator performance improvements

- Improved safety
- Higher energy density
- Reduced cost

Cathode performance improvements

- Higher energy density
- Longer life
- Reduced cost

Reduction of unwanted chemical and electrochemical reactions

Atomic Armor keeps resistance under control

Applicable to any chemistry or cell including next-gen

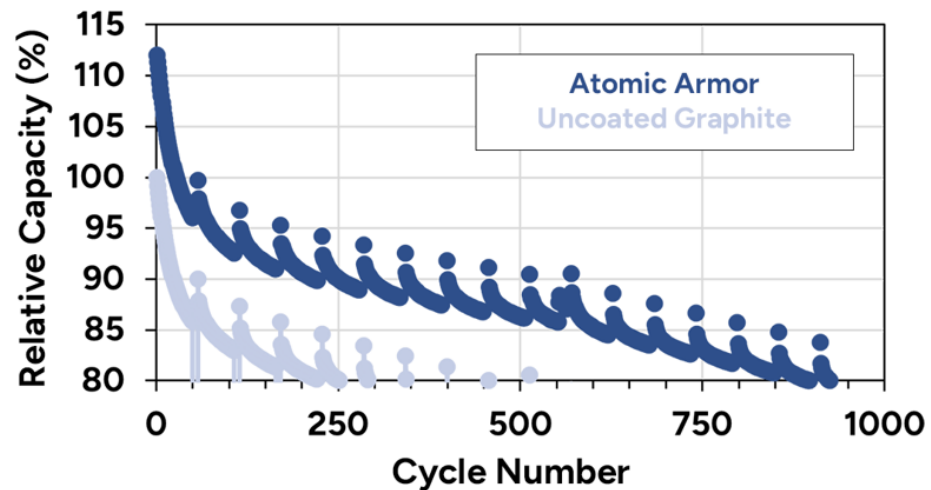
Forge Nano technology can improve any aspect of cell performance with 1-or-more coated materials

Atomic Armor™ Improves Crucial Cell Components

Atomic Armor™ coatings have shown durability and performance improvements on traditional and next-generation anode, cathode and separator materials.

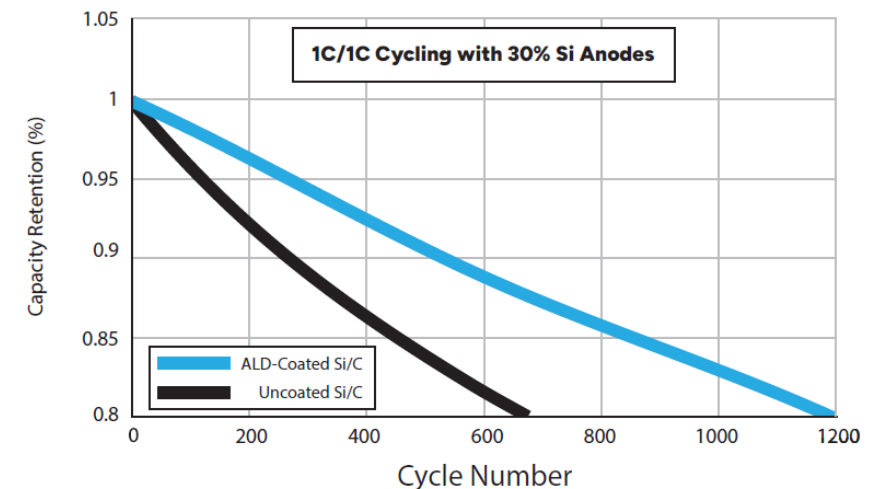
Graphite

Atomic Armor coating capacity impact (NMC811/graphite cells @30°C, 2C/1C)



Silicon

Atomic Armor coating impact on cycling stability (NMC811/Si-Graphite @ 4.4V)



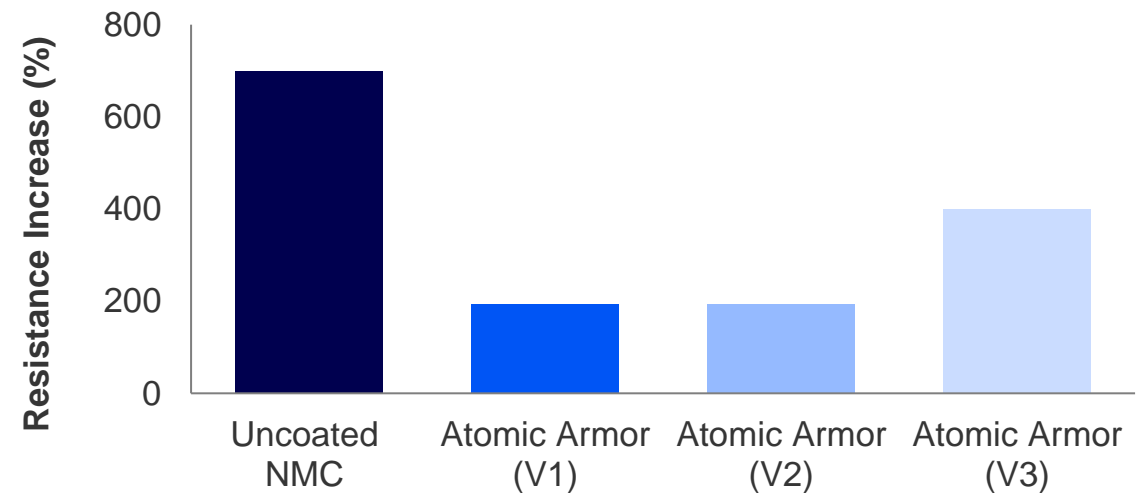
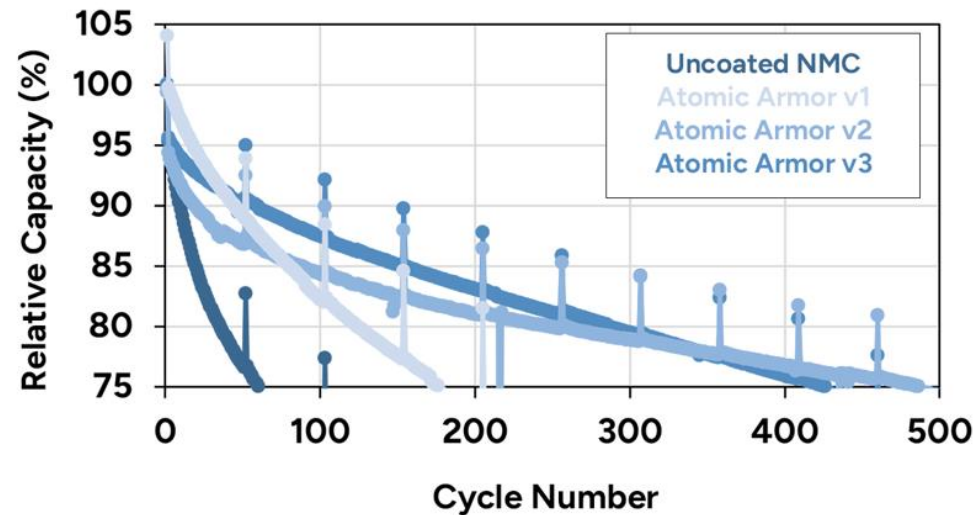
Atomic Armor enables increased anode performance w/ increased first cycle efficiency, fast charge, and longer life

Atomic Armor™ Improves Crucial Cell Components

Atomic Armor™ coatings have shown durability and performance improvements on traditional and next-generation anode, cathode and separator materials.

High-Nickel NMC

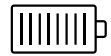
Atomic Armor coating impact on cycle life and resistance growth (NMC811/graphite cells)



Atomic Armor improves cathode energy density, cycle life and unlocks recycling benefits

Atomic Armor™ Improves Overall Cell Performance

Atomic Armor™ coatings can improve multiple aspects of cell performance with one or more coated materials.



Higher Energy Density

~20%
range increase

Higher voltage



Increased Lifetime

2x
cycle life⁽¹⁾

Reduced chemical
reactions



Safer

50%
decrease in
heat generation⁽²⁾

Lower fire risk



Faster Charge

10
minute fast charge
without sacrificing
battery life

Less heat made and
less sensitive to heat

Achieving Superior Performance and Lower Emissions

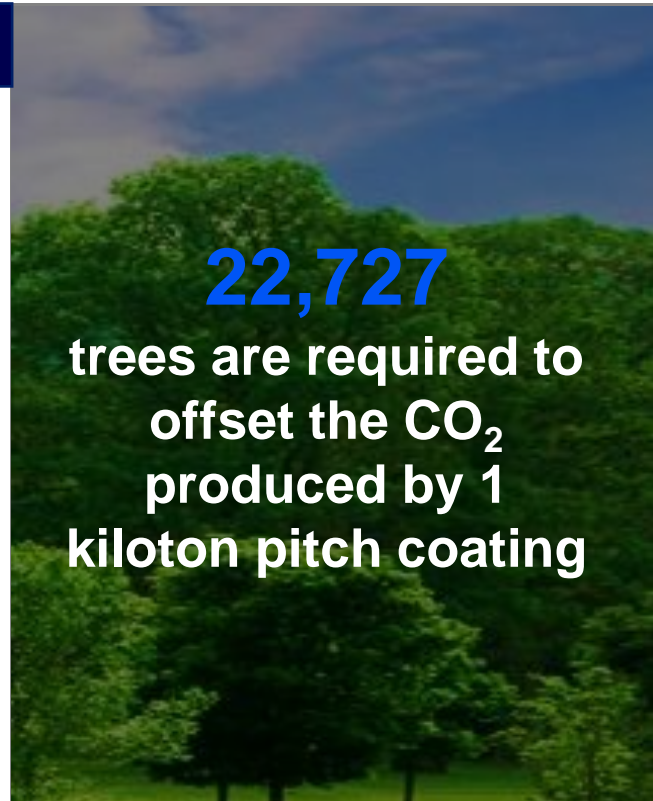
Per kiloton of graphite processed

Pitch Coating

Equivalent CO₂ emissions: **108 cars** over one year



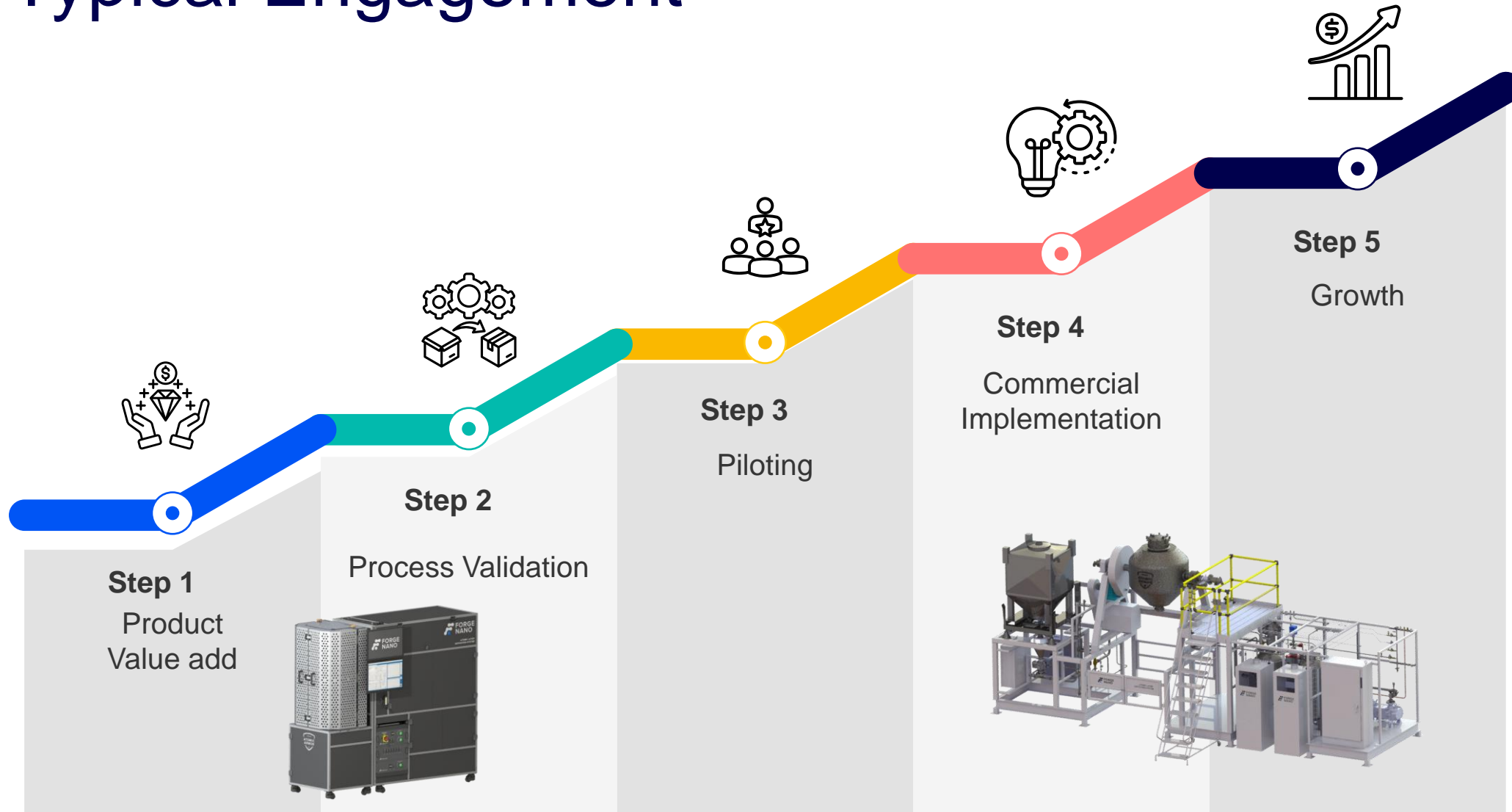
Equivalent CO₂ emissions
2 cars over one year



22,727
trees are required to
offset the CO₂
produced by 1
kiloton pitch coating

Forge Nano technology paves the path for more sustainable material production

Typical Engagement



Forge Nano supports any commercial implementation model (sales, tolling, partnerships, JVs, etc...)

Forge Nano is a proud US government partner

More than 50 government contracts awarded since 2013 leading to..
More than \$50M in commercial activity leading to..
More than 100 hires to support US leadership in..
Sustainability, Chemical Processing, and Energy Security



Example | Forge Nano ALD can improve technology critical to the warfighter

Chemical resistance

Thin films coatings can provide an extra layer of protection for the warfighter by making uniform materials more chemical resistant.



Reduced battery weight

Thin films can isolate battery materials from unwanted chemical reactions, allowing for lighter-weight Li-ion cells that store more energy without the safety risk.



Optical enhancement

Thin films can be applied to lenses, mirrors, and windows to reduce glare, prevent fogging, increase light transmission and improve scratch resistance.

Better microelectronics

Thin film deposition technology is critical to building high quality and increasingly complex and small electronic sensors to keep US warfighters at an advantage.

More reliable power

Thin films improve batteries used in the next generation of electric military vehicles by enabling longer lifetime, faster charging, and more power.

Pigment robustness

Thin films applied to pigments result in more tactical and longer lasting vehicle coatings for improved mission effectiveness and upkeep.

Vehicle lifetime enhancement

Coatings can be applied to materials that make up vehicle components and tires to make them stronger and more oxidation resistant so that they can be used for more missions.

Example | Forge Nano ALD can improve technology critical in Aerospace

Fuel energetics

Longer range and higher impact munitions



Abrasion resistance

Thin films can enhance durability of military equipment by providing a protective layer that reduces friction, resists scratching, abrasion and wear.

Corrosion protection

Thin films can protect against corrosion, extending the lifespan of military equipment, energy storage technology, and infrastructure exposed to harsh environments such as at high altitudes and high heat.

Temperature regulation

Thin films can regulate temperature within military vehicles and electronic devices. By reflecting, absorbing and transmitting heat more effectively, systems become more reliable.

Example | Forge Nano ALD can improve technology critical to underwater applications

Safer batteries

ALD coatings can prevent thermal runaway reactions in Li-ion batteries and replace aging PbA technology safely.

Cleaner air and water

Filters treated with thin film coatings can yield better removal of impurities in breathing oxygen and drinking water for underwater crews.

Radar absorption

Thin films can absorb radar waves, making vehicles and equipment less detectable to enemy radar systems

Safer nuclear power

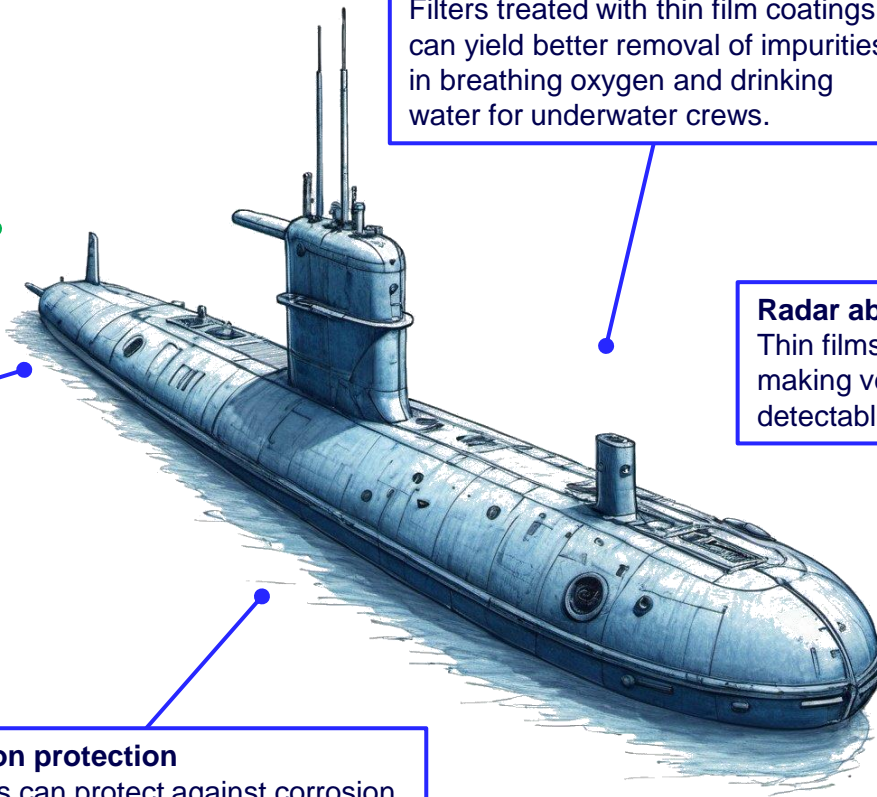
Coated nuclear materials can provide greater stability and safety for nuclear-powered submarines.

Corrosion protection

Thin films can protect against corrosion and reduce friction, extending the lifespan of military equipment and infrastructure exposed to harsh environments such as deep underwater.

Improved sensor technology

Thin film deposition to improve the most advanced sensor technologies will be key for enabling very sensitive and precise data communications.

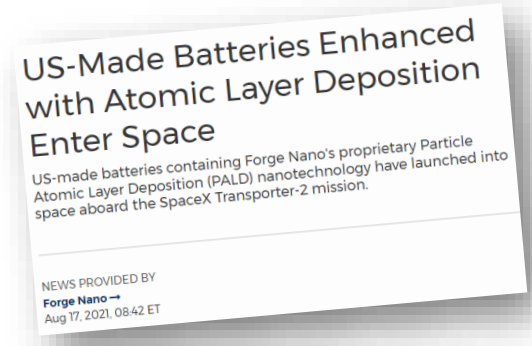


Example | Forge Nano ALD can improve technology critical to Space exploration

Better solar energy capture
Coatings can improve solar energy capture technology to better power US intelligence.

Better microelectronics
Thin film deposition to manufacture microelectronic technologies will be key for enabling precise data collection for defense purposes.

Improved robusticity
Thin film coatings can make US satellites more resistance to the extreme conditions encountered in outer space through temperature and corrosion resistance that lasts.



Reliable and efficient power
Coating battery materials leads to increased lifetime, higher energy density, faster charging, and lower cost all without compromising on safety. These advantages can keep US Space efforts ahead of foreign entities.

Successful Engagements in Batteries



6K Energy to Implement Forge Nano Equipment for Commercial Production of NMC 811

NEWS PROVIDED BY
6K →
29 Aug, 2023, 08:00 ET

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Anovion and Forge Nano Sign Strategic Partnership to Strengthen the U.S. Domestic Graphite Anode Battery Materials Supply Chain

NEWS PROVIDED BY
Anovion →
27 Jun, 2022, 09:43 ET

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Forge Nano to open battery cell plant in North Carolina

The US start-up Forge Nano, specialising in defense, aviation and special electric vehicles, supported by Volkswagen, plans to build a gigawatt-hour-scale battery factory in Morrisville North Carolina. The factory will manufacture battery cells coated with its Atomic Armor surface technology, for which the company is establishing a spin-off called Forge Battery.

Forge Nano has demonstrated significant success in batteries

US Innovation Success

Forge Nano Prototype Line

10MWh/yr (rated)

\$\$, Project

Cylindrical, Prismatic, Pouch

Innovation (any)



Forge Battery Production Line

1GWh/yr +

\$, Product

Cylindrical

Production (US Supply Chain)

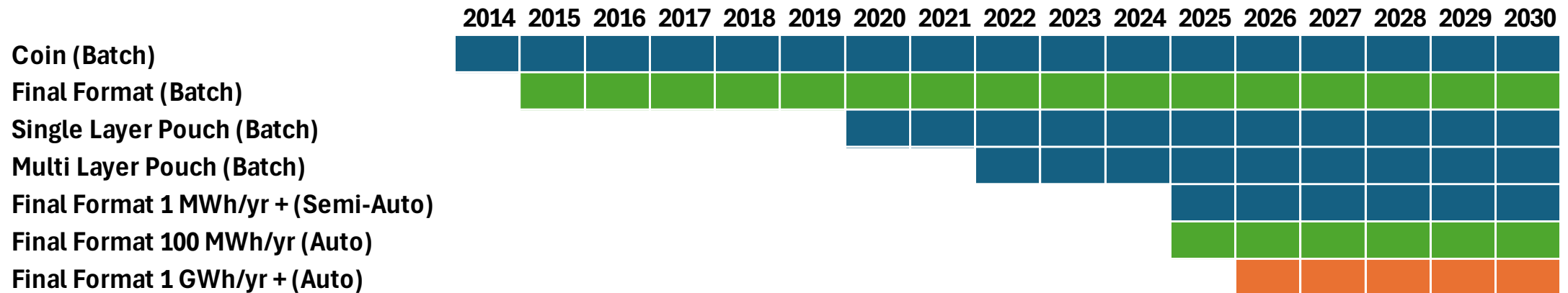


3.9Ah 18650
5.6Ah 21700
>90% US content

Forge Nano/Battery will be an innovation-to-commercialization conduit

Satisfying Demand

- Forge Nano has over 10-years of battery design expertise and is expanding capability to serve DOD needs
- Forge Nano will be poised to rapidly commercialize new technology and deploy advanced cells at low, medium, and high volume



Forge Nano will be poised to commercialize new, highly promising and scalable technology faster than anyone

Summary

- Differentiated product improvements
- Cell prototyping, any format
- Low volume cell production



- High-performance cylindrical cells
- High volume cell production
- US Sourcing



Particle coatings in the field of battery technology is an enabler to excel in the marketplace, which Forge Nano is the global leader in ALD methods to achieve the essential coating characteristics. The US battery supply chain depends on this kind of innovation to compete on the world stage

Bob Galyen,
Li-ion Industry Leader

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