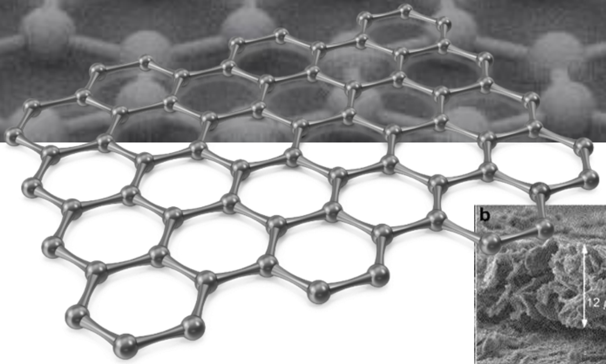
Commercialization of GN3 Graphene Material as the Active Electrode for High Energy Supercapacitors

CMSE 2025

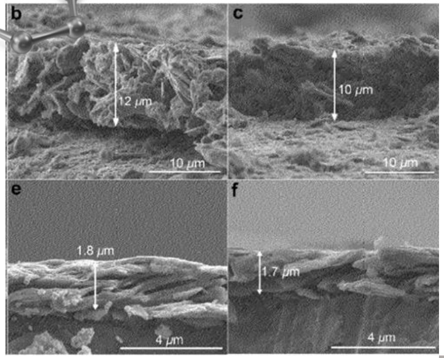
Tomáš Zedníček Ph.D.

EPCI European Passive Components Institute, Czech Republic



Content

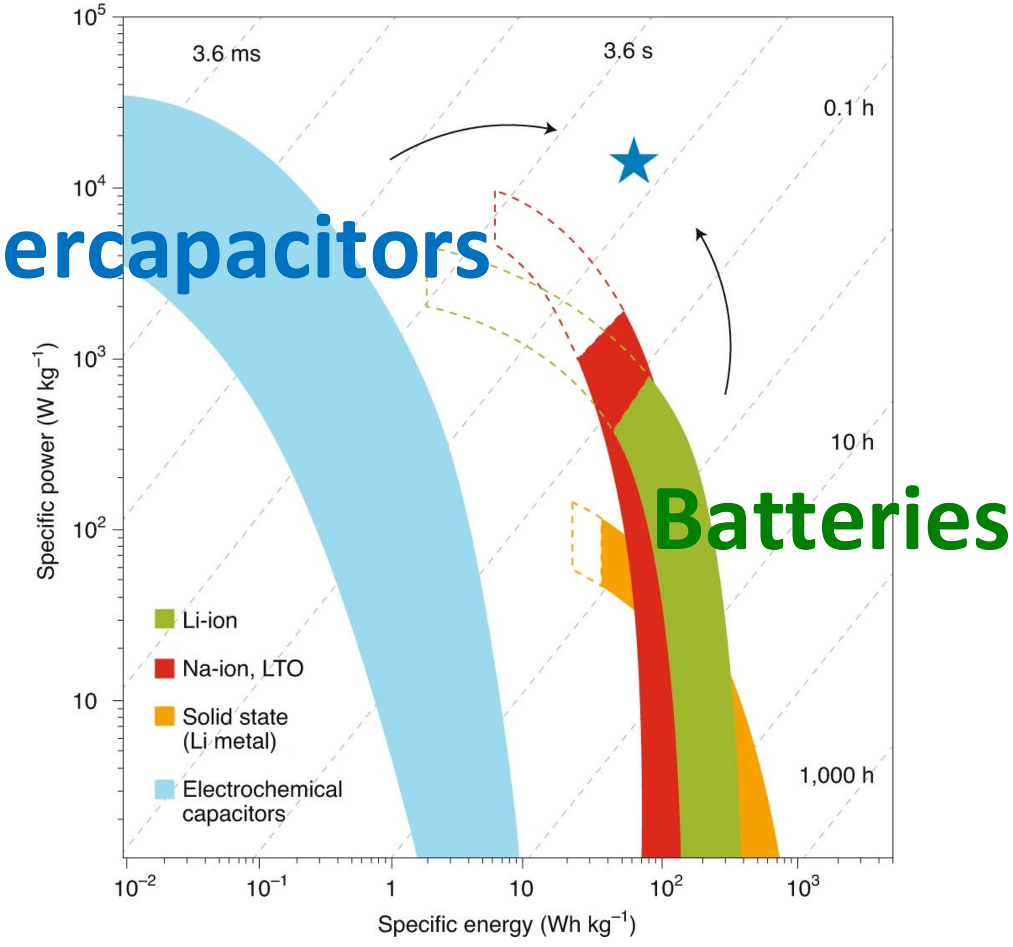
- Introduction – Why Graphene for SCs
- Novel SC-GN3 Graphene Introduction
- SC-GN3 Manufacturing and Scale-Up
- SC-GN3 Supercapacitor Assembly
- Supply Chain Considerations



Energy Storage Devices – Energy vs Power Density

Capacitors

Advanced in Energy and Power Storage Density

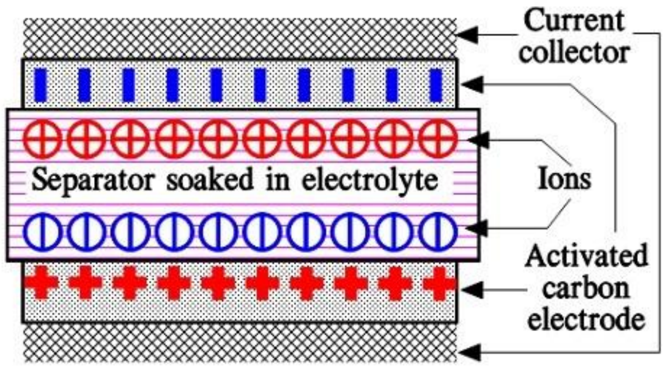


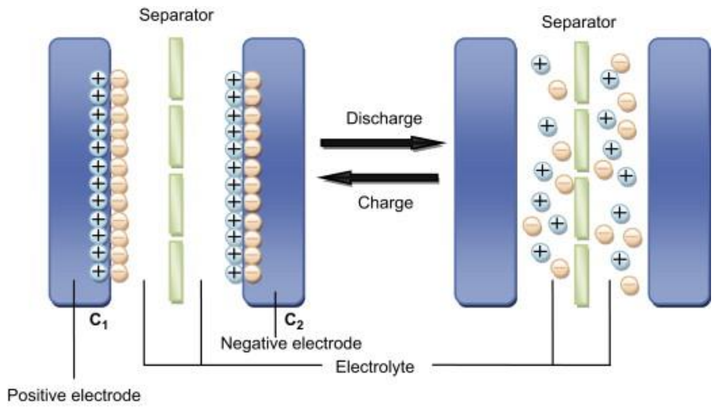
Parameters of supercapacitors compared with electrolytic capacitors and lithium-ion batteries

Parameter	Aluminum electrolytic capacitors	Supercapacitors			Lithium-ion batteries
		Double-layer capacitors for memory backup	Super-capacitors for power applications	Pseudo and Hybrid capacitors (Li-Ion capacitors)	
Temperature range (°C)	−40 to 125	−20 to +70	−20 to +70	−20 to +70	−20 to +60
Cell voltage (V)	4 to 550	1.2 to 3.3	2.2 to 3.3	2.2 to 3.8	2.5 to 4.2
Charge/discharge cycles	unlimited	10^5 to 10^6	10^5 to 10^6	$2 \cdot 10^4$ to 10^5	500 to 10^4
Capacitance range (F)	≤ 1	0.1 to 470	100 to 12000	300 to 3300	—
Energy density (Wh/kg)	0.01 to 0.3	1.5 to 3.9	4 to 9	10 to 15	100 to 265
Power density (kW/kg)	> 100	2 to 10	3 to 10	3 to 14	0.3 to 1.5
Self discharge time at room temperature	short (days)	middle (weeks)	middle (weeks)	long (month)	long (month)
Efficiency (%)	99	95	95	90	90
Life time at room temperature (years)	> 20	5 to 10	5 to 10	5 to 10	3 to 5

Simon, P., Gogotsi, Y. Perspectives for electrochemical capacitors and related devices. *Nat. Mater.* **19**, 1151–1163 (2020).

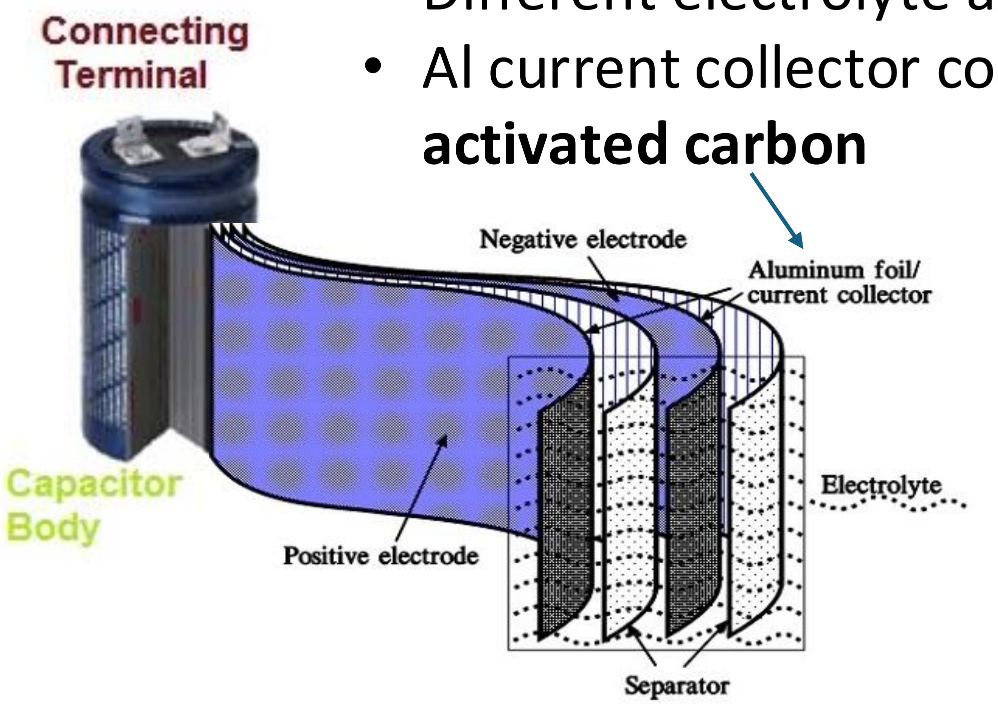
EDLC Wound Supercapacitor Construction





source: wikipedia

- Similar assembly technology to aluminum capacitors
- No etched foils (no dielectricum)
- Different electrolyte and its function
- Al current collector coated with **activated carbon**

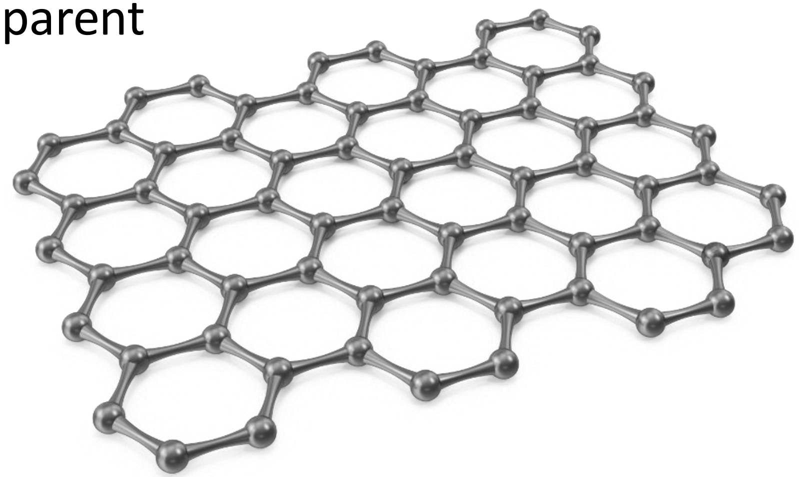


source: www.passive-components.eu

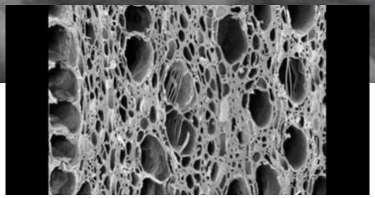
Graphene as Supercapacitor Active Material

Graphene Properties

- 2D one-atom thick
- **200x stronger than steel**
- 3x better electron mobility than silicon
- **Lightweight**
- Flexible
- Thin
- **Large surface area**
- **High electrical conductivity**
- **High thermal conductivity**
- Transparent



Graphene vs Activated Carbon



- Potentially more conductive / higher power density due to single layer vs two-dimensional lattice features:
  - high electron mobility
  - delocalized electrons with minimal scattering
- Theoretical max capacitance of 2D graphene is higher (>550F/g) than activated carbon
- Easy team up with various other nanomaterials, prominently carbon nanotubes (CNTs), to create lightweight and high-performance structures

Challenges:

- Lower TRL compared to activated carbon
- Supply chain not mature yet
- Electrolyte optimization required to maximize the material potential benefits

Supercapacitors are Enabling Technology of a Large Number of Industries

Communications
- Power supplies
- Back-up power

Aircraft
- Back-up power
- Battery alternative

Space
- Satellites
- Rockets / thrusters (ignition)

Ground vehicles
- High-performance power
- Energy recovery systems
- Trains, busses, etc.

Robotics / UAVs
- Primary / back-up power supply
- Hydraulics smoothing
- Frequent use robots (logistics, etc.)

Heavy Industry
- Lasers
- Construction vehicles
- Elevators
- Hydraulics smoothing

Medical devices
- Pacemakers, insulin pumps, hearing aids, etc.
- Primary / back-up power supply

Energy / Renewables
- Uninterruptible Power Supply (UPS)
- Wind turbines / wave system smoothing

Consumer
- Wearables
- Micro-mobility
- Laptops, Camera flashes …

Supercapacitors are ideal in environments that prioritize:
- High power
- High number of cycles
- Fast power cycles
- Safety

Graphene expands the capabilities of supercapacitors by adding high energy density, **opening entirely new applications and possibilities…**

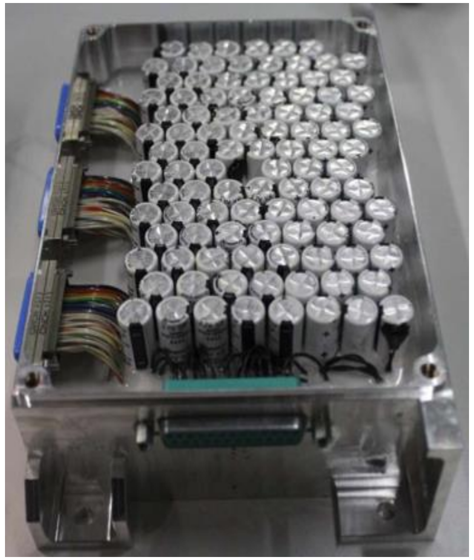
Supercapacitor Use and Evaluation in Space

“Supercapacitors powered various spacecraft applications, including high-power LIDAR, radars, and actuators. However, COTS supercapacitors face limitations and constraints for space applications.

Target developing **high-energy supercapacitors** (> 15 Wh/kg)

The proliferation of small satellites has made COTS supercapacitors developed for non-space applications relevant to the space community. In the future, graphene-based supercapacitors could enable improved and new services for small satellites, extending their life duration”

Summary of source: Supercapacitors for space applications: Trends and Opportunities ESA SPCD 2022, ESA ESTEC Geraldine Palissat, Leo Farhat, Joaquin Jimenez Carreira



BOSC based on commercial Maxwell 10F/2.7V small wound cell supercapacitor has been space qualified in 2015 Airbus Defence and Space for radars and pyrotechnics applications – currently still under use. R&T activities necessary to improve power density and high temperature lifetime.

Maxwell 10F/2.7V is also used by various nano-satelites. The main reason for SC use there is to reduce the discharge rate of battery during the peak load and extend the lifetime of battery as well as overall missions.

High Energy SC-GN3 Graphene Material

Principals of SC-GN3 High-Energy & High-Power Storage Capability

developed and patented by:

CATRIN Czech Advanced Technology and Research Institute

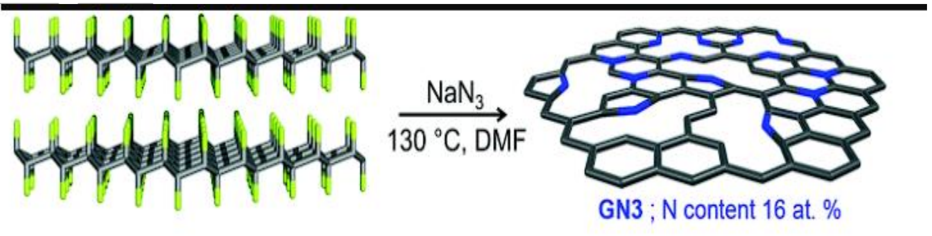
Palacký University Olomouc

- Graphene provides a higher volumetric energy density compared to active carbon
- Graphene doping can significantly alter its electronic structure
- Nitrogen doping imprints **active centers** on graphene supporting, which can contribute to a certain degree of pseudocapacitance

SC-GN3 Material Preparation

- Tunable synthesis of SC-GN3 highly nitrogen-doped graphene from fluorographene precursor has been developed

Fluorographene	Highly N-doped Graphene



Contents lists available at ScienceDirect
FlatChem
journal homepage: www.elsevier.com/locate/flatc

Covalently functionalized graphene as a supercapacitor electrode

Aristides Bakandritsos, Petr Jakubec, Martin Pykal, Michal Otyepka*
Regional Centre of Advanced Technologies and Materials, Department of Physical Chemistry, Palacký University Olomouc, 17. listopadu 12, 771 4 Republic

Issue 2, 2022

From the journal:
Energy & Environmental Science

(11) EP 3 907 184 A1
EUROPEAN PATENT APPLICATION

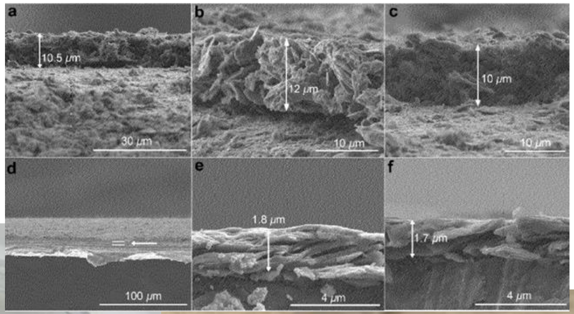
Nitrogen doped graphene with diamond-like bonds achieves unprecedented energy density at high power in a symmetric sustainable supercapacitor†

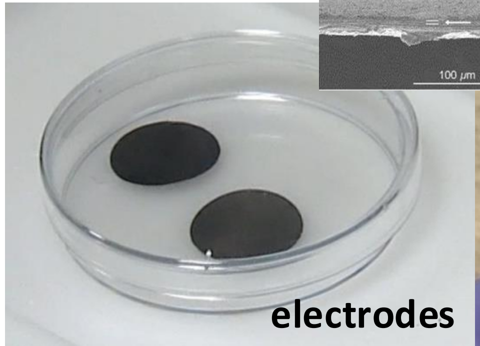
Veronika Šedajová,[ab] Aristides Bakandritsos,[*ac] Piotr Błoński,[a] Miroslav Medveď,[a] Rostislav Langer,[ab] Dagmar Zaoralová,[ab] Juri Ugolotti,[a] Jana Dzíbelová,[ad] Petr Jakubec,[a] Vojtěch Kupka[a] and Michal Otyepka[*ae]

SC-GN3 Development, Testing & Characterization

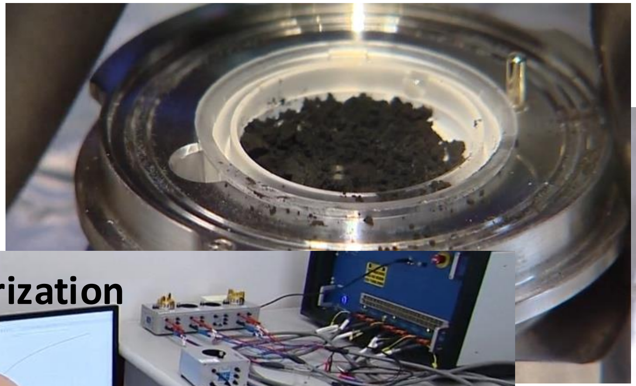
Features (achieved on material at electrochemical cell)

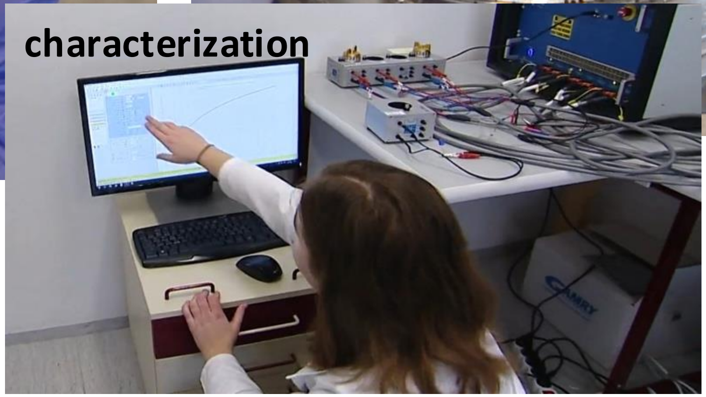
- energy density: **up to 200 Wh/L**
- power density: **up to 50 kW/L**
- sustains **15 000 C/D cycles** without significant capacitance loss

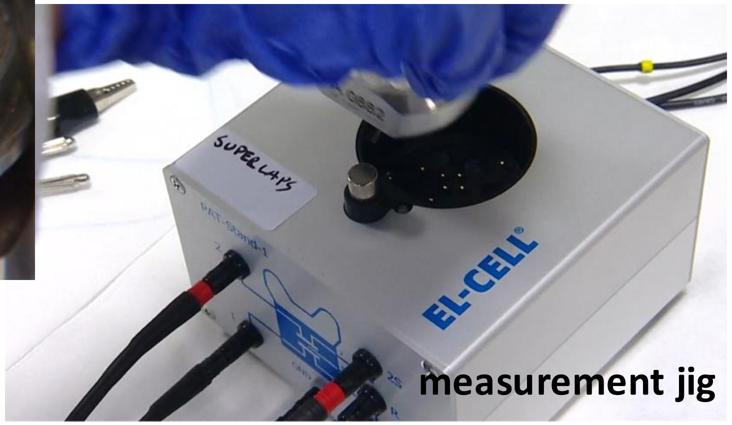



electrodes


capacitor contact holder



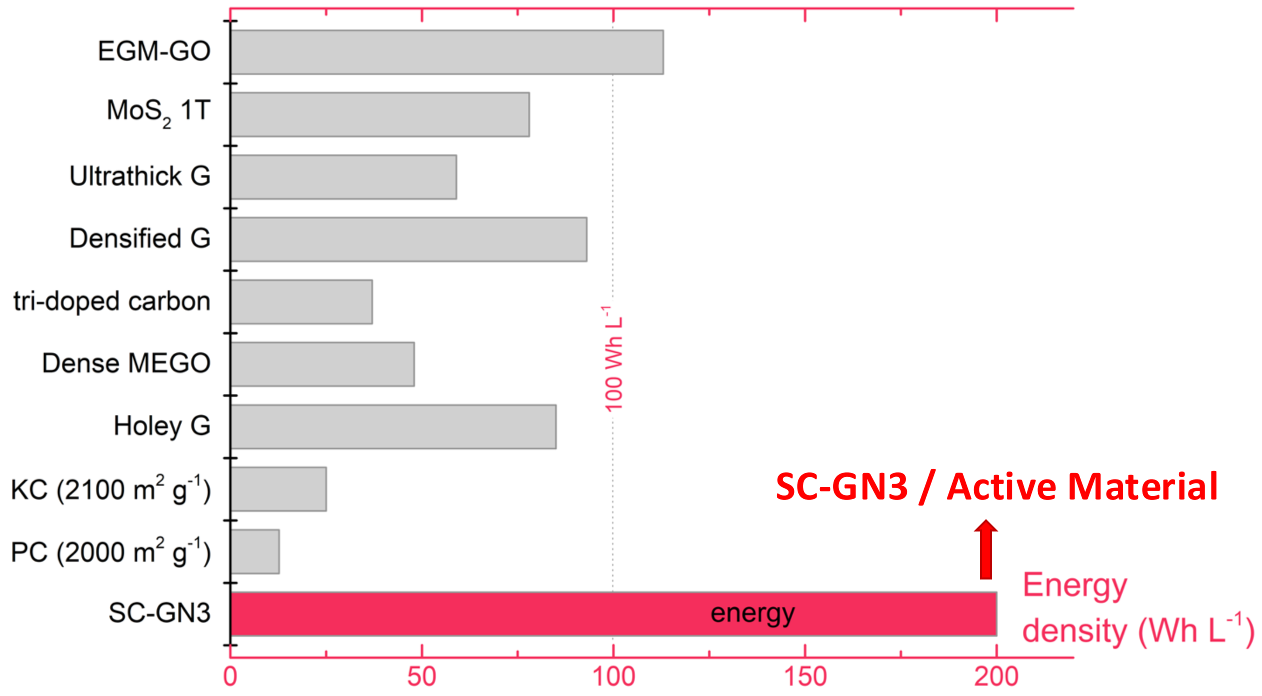

characterization



measurement jig

High Energy SC-GN3 Graphene Material

Published Materials



4 Wh/L
Pouch Cell

Target SC-GN3 Cell: 50 Wh/L

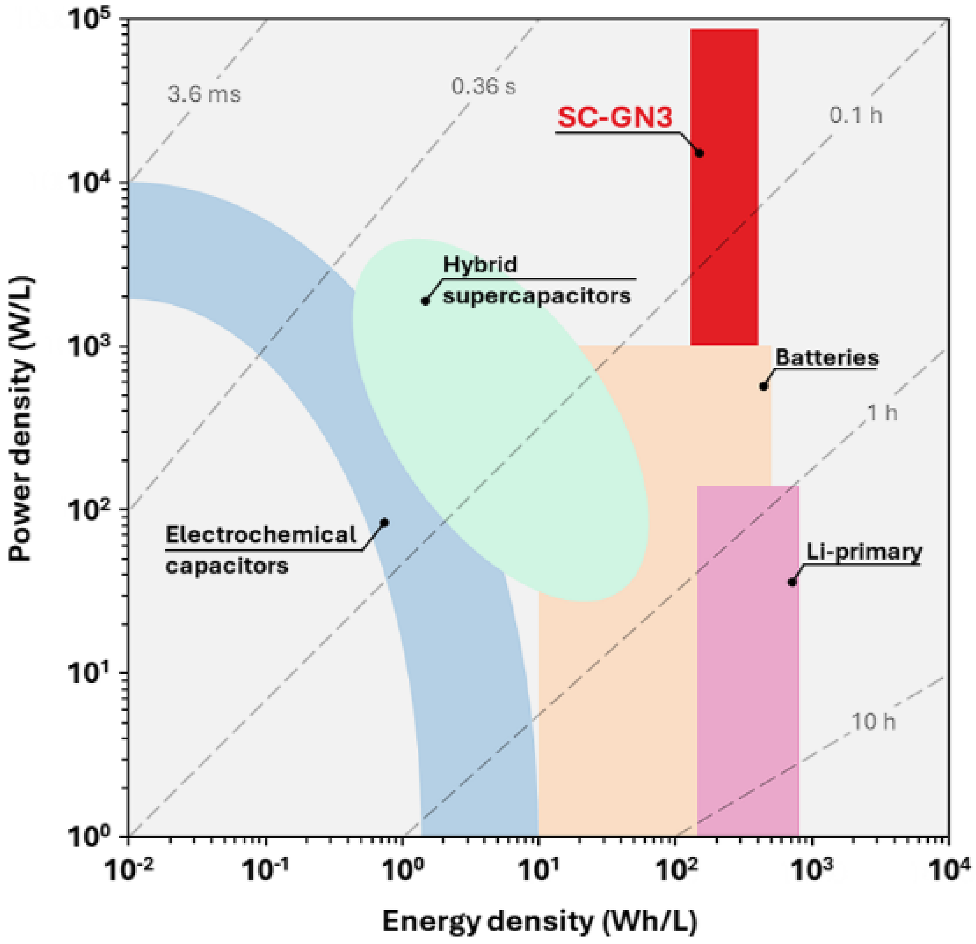
~55Wh/kg and 2-50kW/kg

Current Mass Market SCs

16 Wh/L Skeleton Curved Graphene

High Energy SC-GN3 Graphene Material

SC-GN3 Bridges the Gap Between Batteries and SCs



Batteries and SCs have always been suitable for specific and different applications - their use always requires some sort of compromise

Supercapacitors	Li-ion batteries
• **Safe**	• Relatively unsafe (thermal runaway risk)
• Relatively more expensive	• **Less expensive**
• **High power**	• Limited power (incl. shortened cycle life)
• Low energy density	• **High energy density**
• **Long cycle life** (~ million cycles)	• Short cycle life (< 10,000 cycles)
• Poor energy retention (hours to weeks)	• **Long energy retention (months)**

SC-GN3 address one of the key shortcomings of supercapacitors

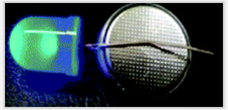
SC-GN3 Development & Commercialization (2019-2025)

2017-2020

ERC Consolidator
ERC PoC **UP2DCHEM**

Project goals:
- Synthesis
- Device concept
- Lab tested

Global patent applications submitted for SC-GN3



2021

ERC projects result in discovered performance:
- 200 Wh/L
- 50 kW/L
- C/D 100 000+

Scaled up synthesis

European Innovation Council

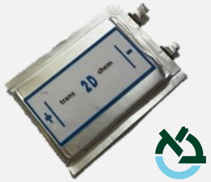
2022

EIC Transition project granted
Name: **TRANS2DCHEM**

2023

Established potential commercial performance of 55 Wh/L

Pouch cell prototypes



Bar-Ilan University

ATOMIVER GN3 ENERGY

H1 2024

ATOMIVER established as official spin-out

First wound-cell prototypes

Itelcond

H2 2024

ATOMIVER signed an exclusive license with UPOL

ATOMIVER obtained a € 200 ths. grant from CzechInvest

TECHNOLOGY INCUBATION BY CZECHINVEST

2025

Seed investment

Setup in-house commercial production facilities

First sales

and more…

ATOMIVER is accepted to the NATO DIANA accelerator program, incl. € 100 ths. grant

DIANA® Defence Innovation Accelerator for the North Atlantic

SC-GN3 Material Commercialization Plan

established in April 2024

SC-GN3 Material Supplier

ATOMIVER university spin-out start-up

GN3 ENERGY

www.atomiver.com

CATRIN
Czech Advanced Technology and Research Institute

Raw material SC-GN3

Technology Transfer

Support Service (recipe optimization / customization)

SC-GN3 *incentive activities*

Electrode foil with SC-GN3

wound

pouch

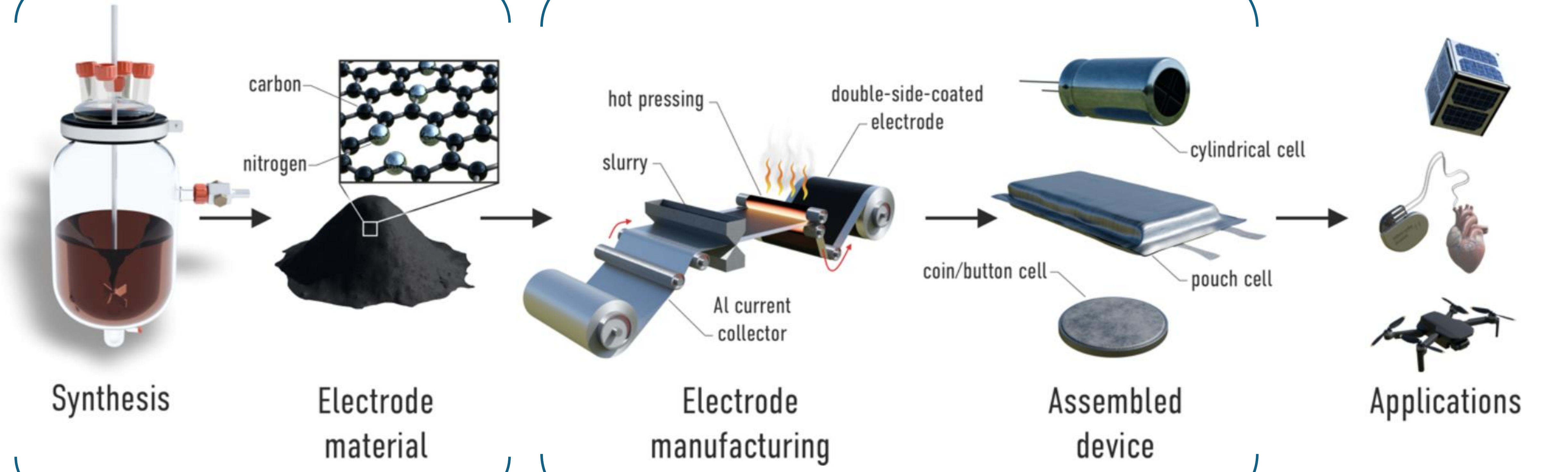
supercapacitor

SC-GN3 Material Supply Chain Mapping

ATOMIVER
GN3 ENERGY

SC Manufacturing

Applications



SC-GN3 Material Upscaling Plan

ATOMIVER
GN3 ENERGY

SC-GN3 Graphene Industrial Protocol

- exfoliation of the precursor GF
- synthesis of SC-GN3
- washing of synthesized SC-GN3 material
- desalination resulting in dispersion SC-GN3 in water
- freeze-drying of the SC-GN3 to final SC-GN3 powder

Exfoliation → Synthesis → Washing → Purification → Freeze drying

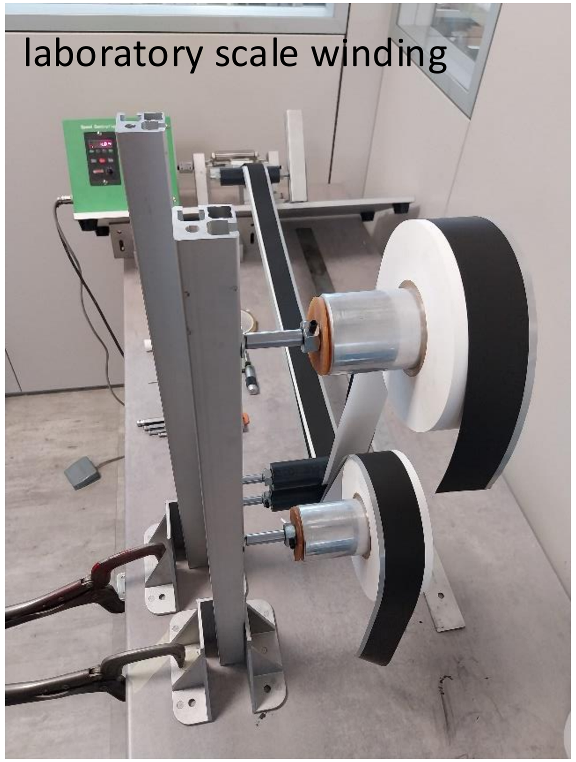
SC-GN3 Wound SC Cell Assembly

SC-GN3 Wound Cell Prototype Assembly

wound cell assembly scheme, with electrodes and tabs

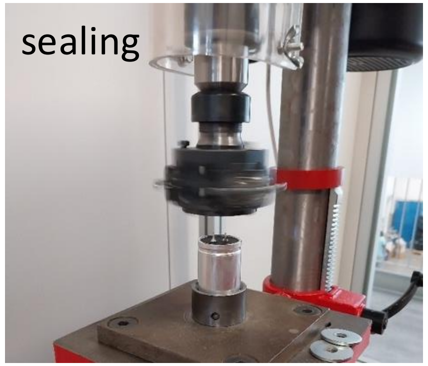
The layers are:

- Separator
- First electrode
- Separator
- Second electrode



laboratory scale winding

rolled sections



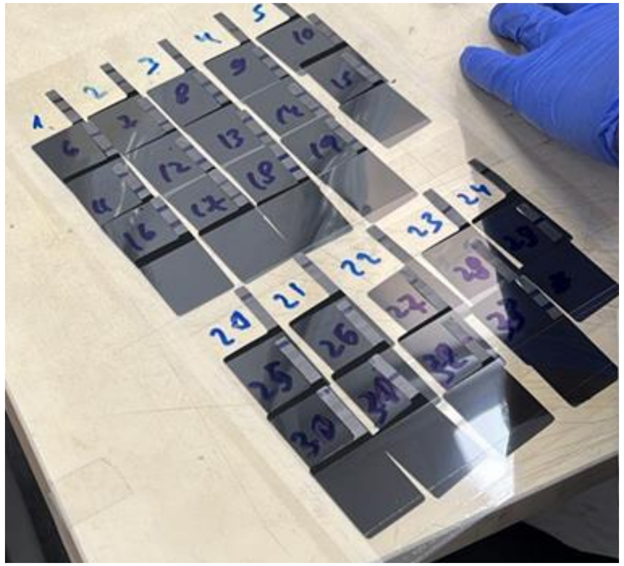
sealing

rolled section in a can

Itelcond

SC-GN3 Pouch Cell Prototype Assembly

SC-GN3 electrode stamping



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Stacked and assembled pouch prototype

500F test module

SC-GN3 Supply Chain Tasks 2025-2027

ATOMIVER
GN3 ENERGY

Commercialization status

- SC-GN3 technology transferred to *Atomiver* company spin-off
- *Atomiver* take over the SC-GN3 material supply chain and further commercialization
- Upscaling from *g* to *kg* material production – done
- Reproducibility verified by external manufacturing facility - done

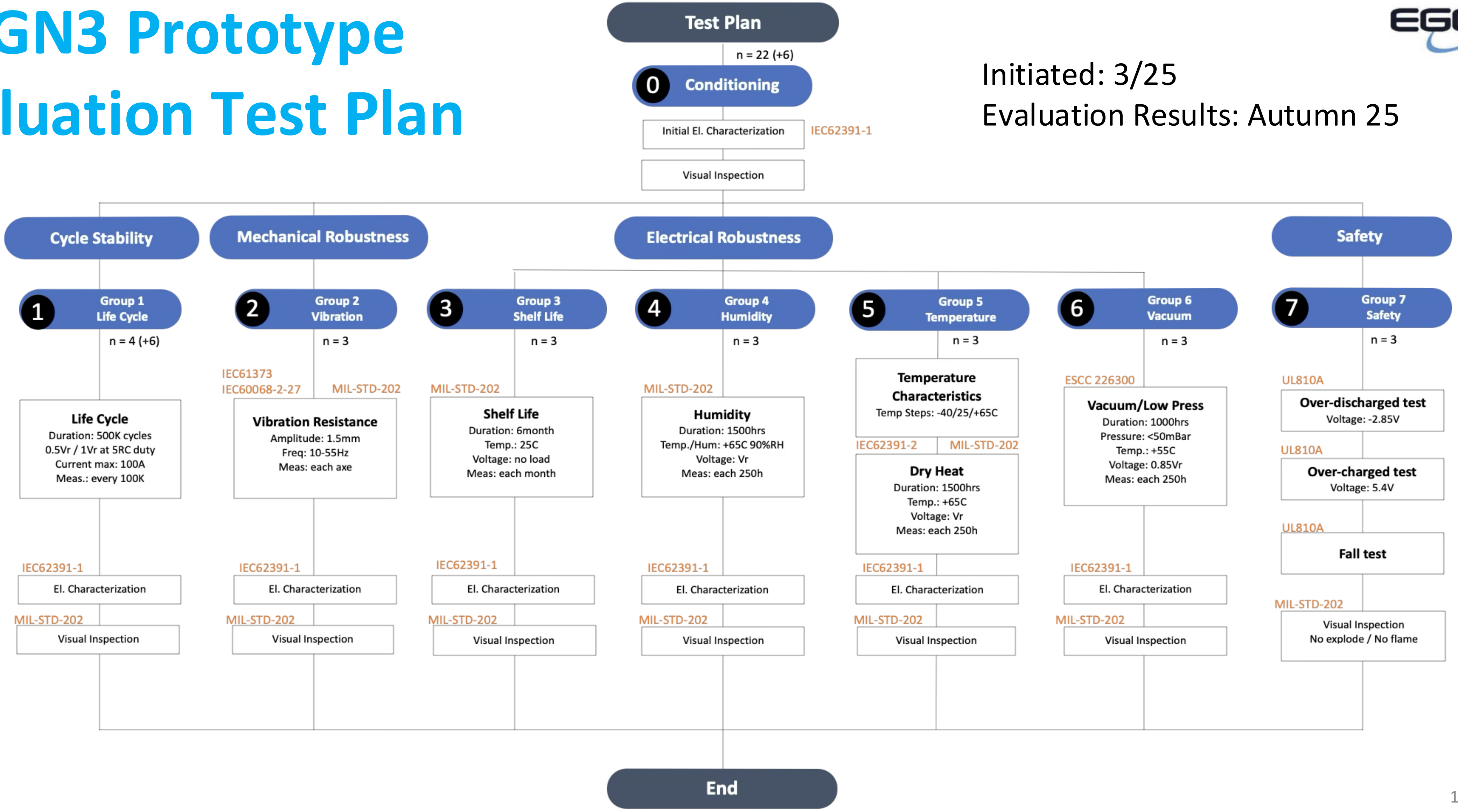
Major tasks for SC-GN3 material manufacturing readiness:

- Ongoing optimization and cost down
- GF raw material suppliers evaluation (USA, China, Czechia under evaluation)
- Expanding manufacturing capabilities up to 1 tonne / year
- Pilot manufacturing line under competitive offer stage for production in Czechia
- First prototype wound and pouch samples to be completed in 2025
- Evaluation and Qualification test began Q1/2025 = datapack ready Q3/2025

SC-GN3 Wound Cell Prototype Qualification Test Plan

SC-GN3 Prototype Evaluation Test Plan

Initiated: 3/25
Evaluation Results: Autumn 25



Summary and Conclusion

Start-up company Atomiver has been established as a spin-out from Palacký University Olomouc (CZ), for SC-GN3 graphene material scale-up, production and commercialization.

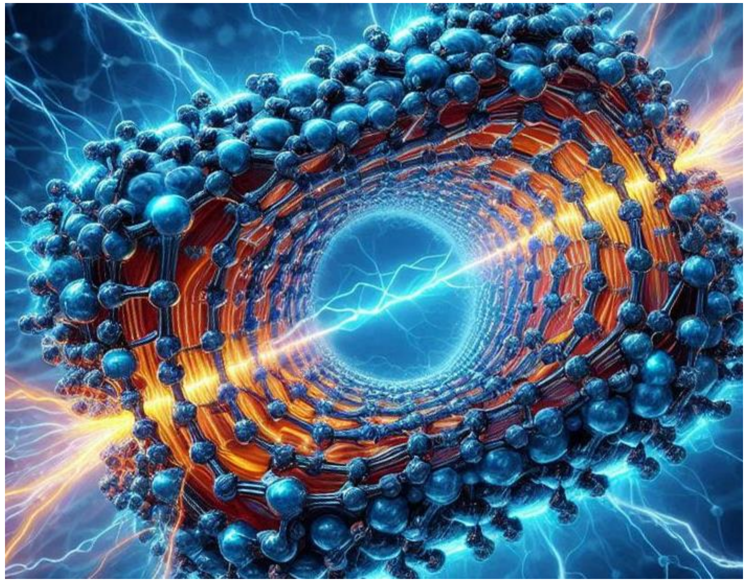
ATOMIVER
GN3 ENERGY

Aim:
Establish High Energy SC-GN3 Graphene Material Supply Based in Europe

- High energy density target: ~50Wh/L
- Sustainable, reproducible and reliable supply
- Multiple GF precursor suppliers to avoid single source, evaluation of domestic production capabilities ongoing
- Collaboration with SC manufacturers to establish SC manufacturing capabilities in Europe with benefits mainly for aerospace, defense or medical industry

European Innovation Council

THANK YOU



ACKNOWLEDGEMENT

This work has been supported and enabled by the EIC Transition project entitled “Transition of 2D chemistry-based supercapacitor electrode material from proof of concept to applications” (TRANS2DCHEM) No.101057616 funded by the European Union.

Further information can be found at the project website: https://trans2dchem.com/

contact: www.atomiver.com