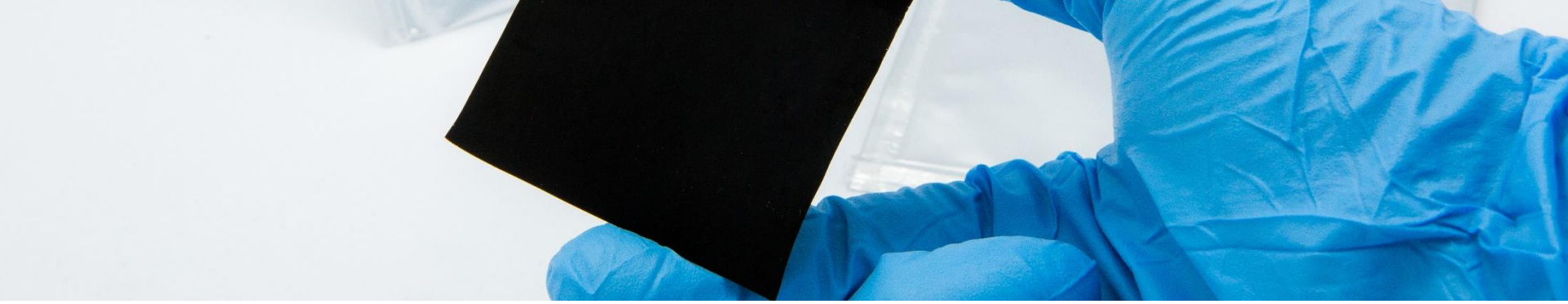


NAWA TECHNOLOGIES

ULTRA-FAST CARBON ELECTRODES FOR CAPACITORS-ULTRACAPACITORS AND LITHIUM BATTERIES

Dr. Pascal BOULANGER – CTO/COO/COB

BOLOGNA – 28th June 2019

What We Do Not Want To See Anymore

1

WE ARE NAWA

1

HISTORY AND STATUS

2001 — cea

2008 — Proof of concept

2013 — Spin off & NAWA created

2014 — Fund raising 5,6 M€

Today

15	Years of R&D
24	Employees
20	Letters of interest and Business cases
2	Common lab, Publicly funded R&D labs
14	Patent Application families (US, EU,JP)

- **R&D Done**
- **Cells tested by third parties**
- **Proprietary pilot production line (foils 0,3 m x 200 m)**
- **First customers booked**
- **Industrialization phase started**

1

TEAM

COLLABORATIVE MANAGEMENT

MOTIVATION

CREATIVITY

1

MANIFESTO

- We believe Ultracapacitor is the most virtuous way to store electricity
  - High efficiency, safety, reliability, robustness
  - Lifetime: all along its lifetime a Ucap store 50-100 times more energy than a LIB
  - Less rare materials, easier to recycle, less waste

- Why Ultracapacitor is not widely used ?
  - All in $\mathbf{€ / (1/2\ C\ V^2)}$
  - How to design a new technology that is
    - Not expensive (use existing and industry proven equipment)
    - Higher C: specific accessible surface and higher capacitance
    - Higher V: new electrolytes (bigger ions, viscosity)

2

ELECTRODE TECHNOLOGY

2

NAWA = STRUCTURE + FUNCTION

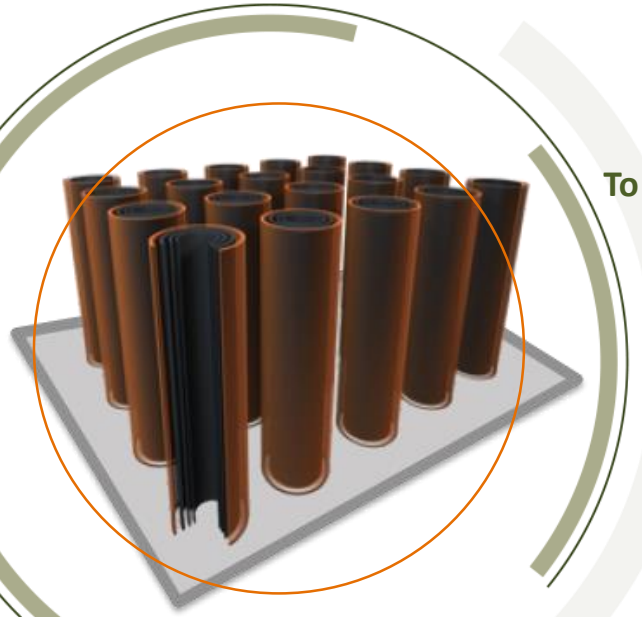
VACNT: VERTICALLY ALIGNED CARBON NANOTUBES

TOPOLOGY

Combining nano-objects and nano-confinement

COATING

Functionalisation
To increase intrisic capacitance (higher than only carbon)

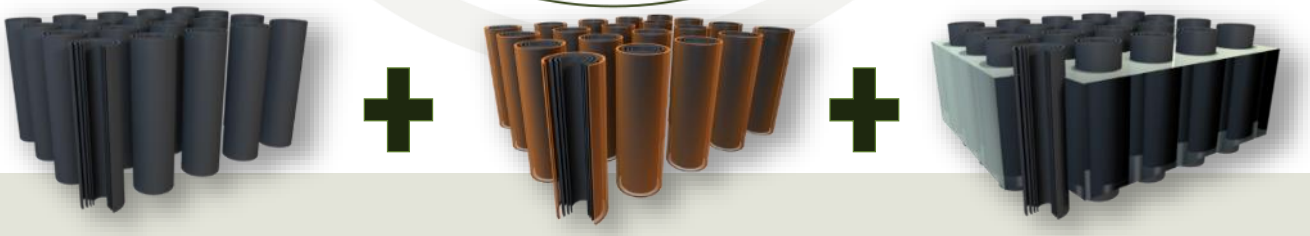


PHYSICAL PROPERTIES

Continuous Carbon nanotubes and graphene intrinsic electrical, thermal, mechanical properties

SUBSTRATE

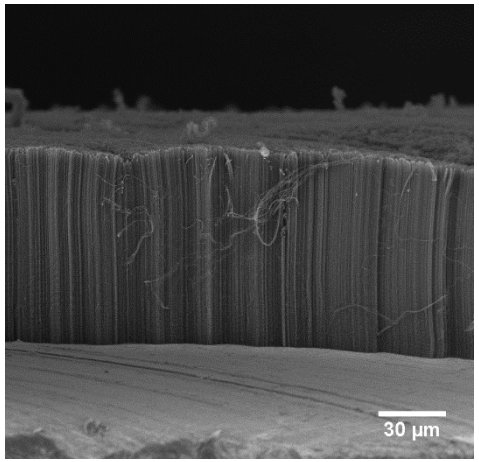
Better contact
on various substrates
Intrinsic anchoring

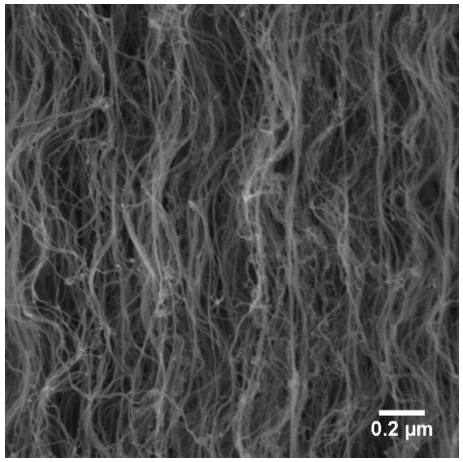


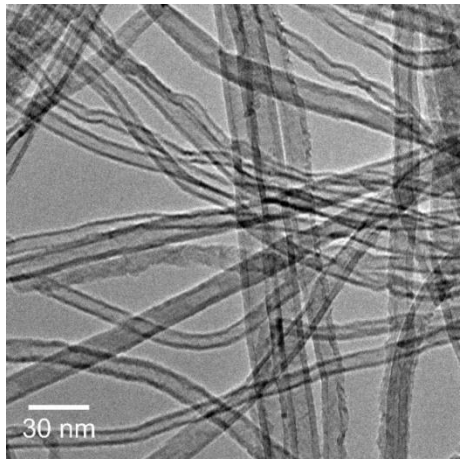
Bare VACNT + Coating + Embedded

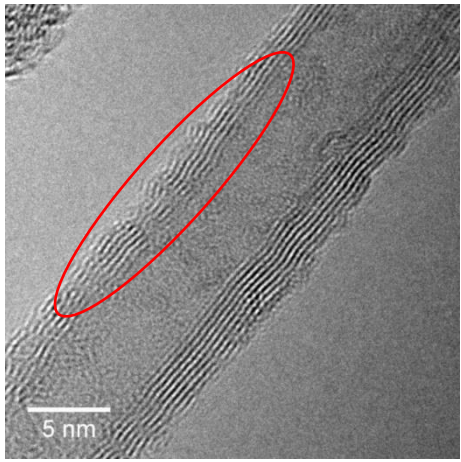
2

CNT FEATURES @ <600°C









99,6

PURE

Clean CNT surface
ID/IG (0,75-1,25)

Fe

PURE

Very low Catalyst Content

1000

LONG

Up to meters
Infinite growth
No bundle

10^{11}

DENSE

Ext diameter 4-8 nm
Int diameter 2-5 nm
Spacing for coating

10

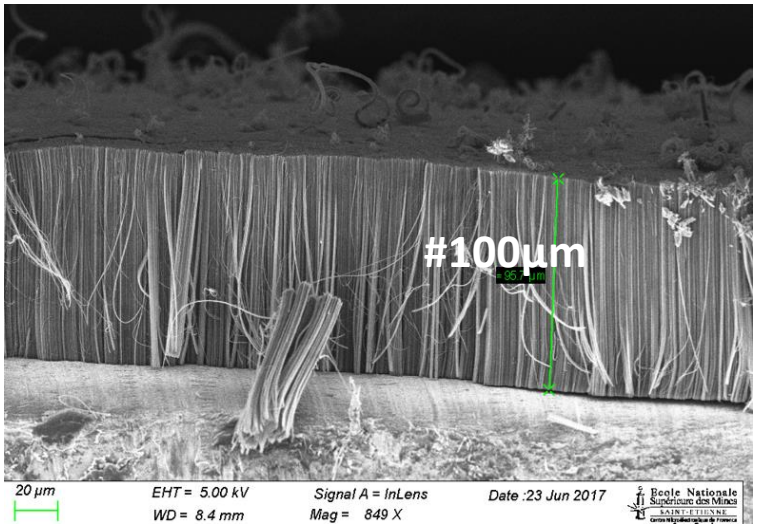
FAST

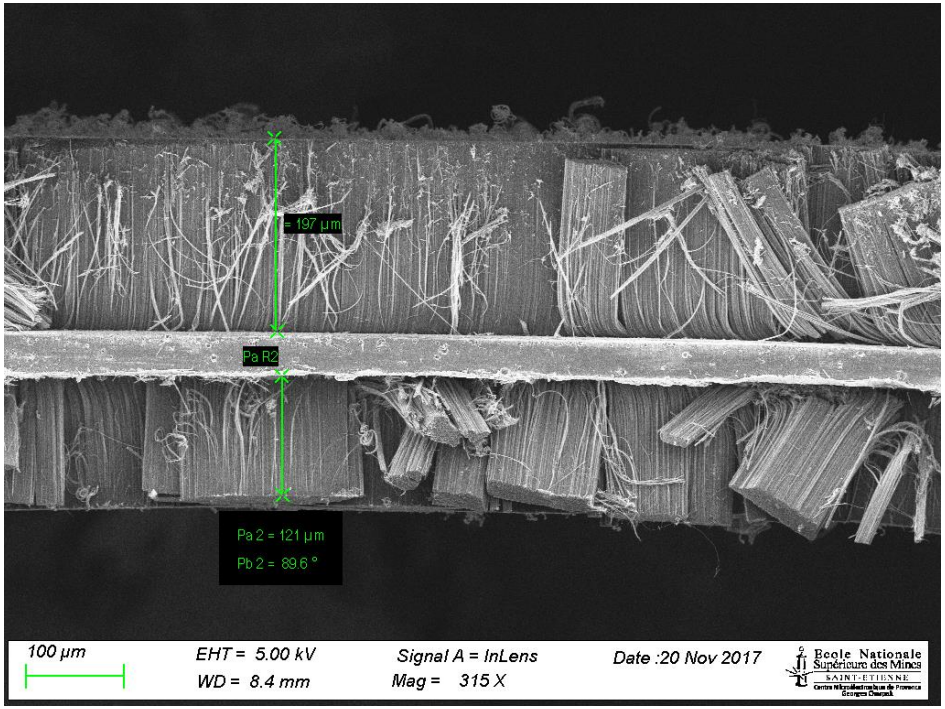
Growth rate
200 µm/min

Mechanical, thermal properties : see P. Olivier's presentation

2 PROCESSABILITY ON TWO SIDED AL FOIL & SELECTIVE GROWTH

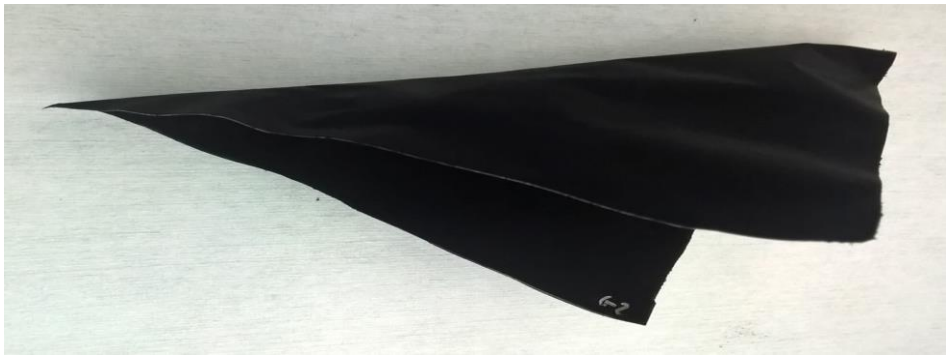
UNIQUE IN THE WORLD





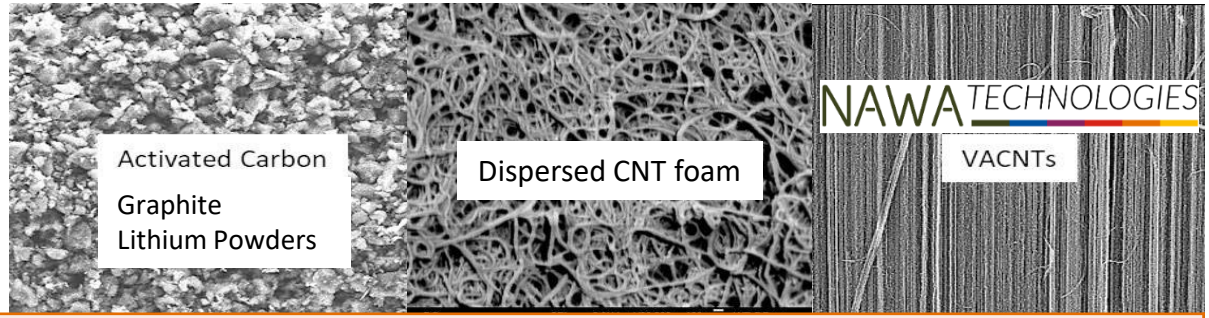
Selective Growth

NAWATECHNOLOGIES



2

NAWA'S ULTRA-FAST CARBON ELECTRODE
IS THE FASTEST ELECTRODE IN THE WORLD

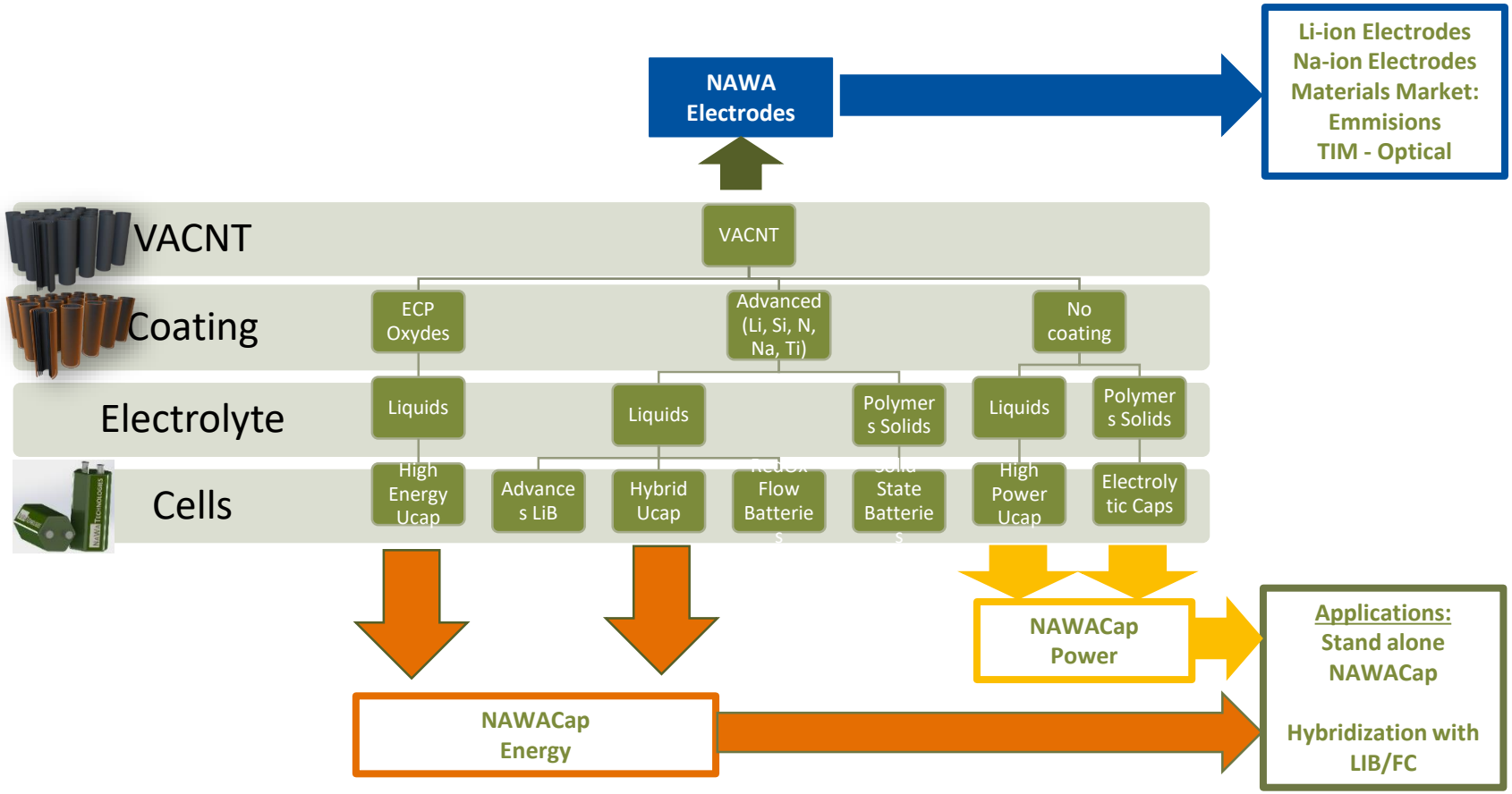


Electrical conductivity	If 1	10-50	100-1000
Ionic conductivity	If 1	2	5-10
Thermal conductivity	If 1	2	10-100
Mechanical cohesion	If 1	100	100 000 Intrinsic anchoring
NAWA versus competitive technologies	Binder (?) Tortuosity Bad percolation Blocking holes	Binder Tortuosity Good percolation No blocking holes	No Binder Straight Channels Very Good percolation No blocking holes Bigger ions More viscuous electrolyte

2

NAWA TECHNOLOGY PLATFORM

IS COMPATIBLE WITH ALL KINDS OF ELECTRICITY STORAGE



3

VACNT FOR ULTRACAPACITORS

3

TWO TYPES OF ELECTRODES
TO UNLOCK THE LIMITATIONS OF CAP/UCAP/BATTERIES

Versus

Raw VACNT

Coated VACNT

Pure EDLC
Higher Power Density due to VACNT electrical conductivity
Higher Energy density (C)
Symetrical

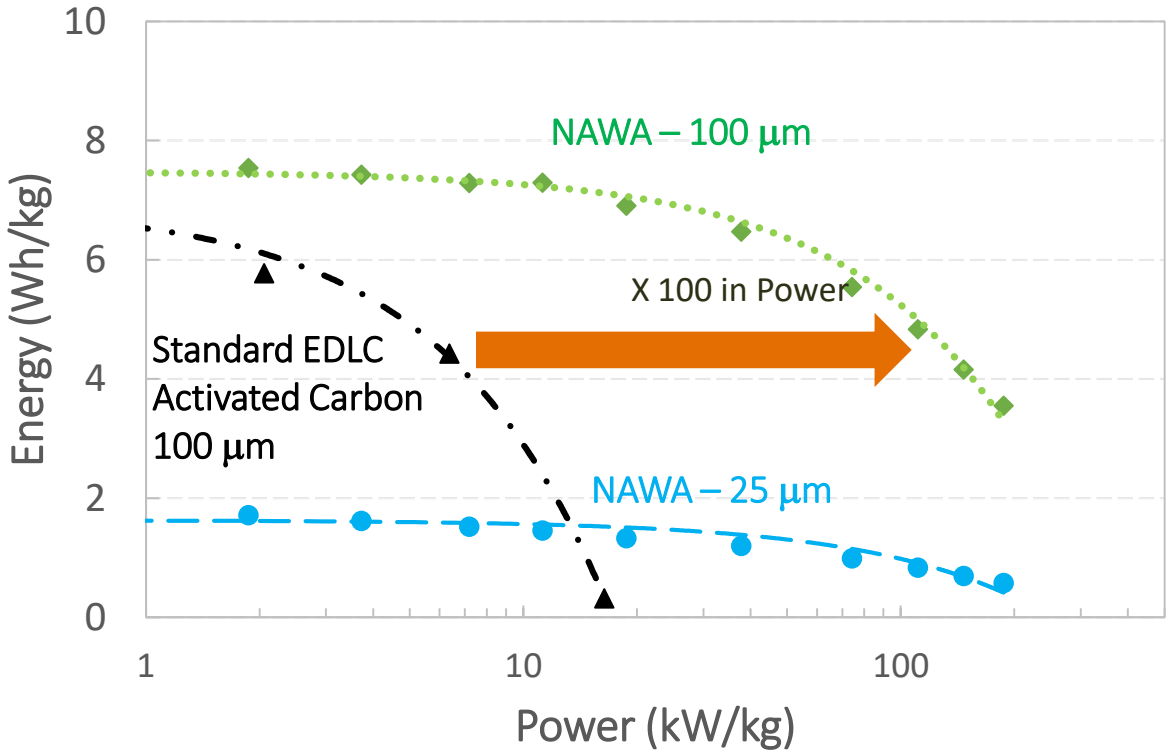
Pseudo EDLC
Higher Energy Density due to VACNT coating
Higher Power Density (structure)
Asymetrical

3

NAWACAP POWER
READY FOR PRODUCTION

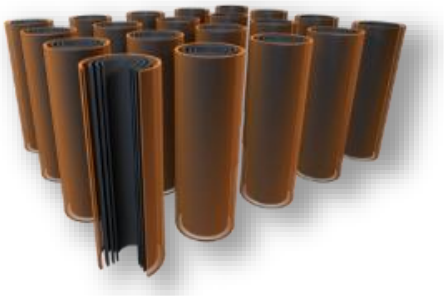
Raw VACNT

Pure EDLC
Higher Power Density due to VACNT electrical conductivity
AC-like Energy density
Symetrical



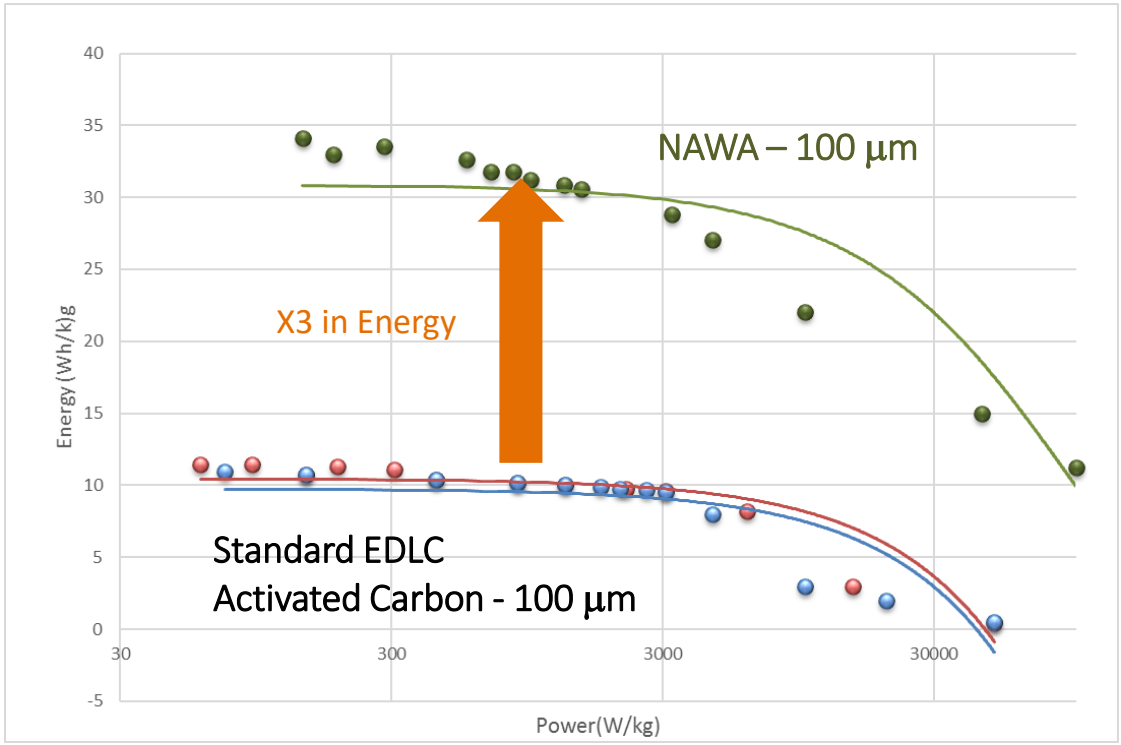
3

NAWACAP ENERGY
UNDER DEVELOPMENT



Coated VACNT

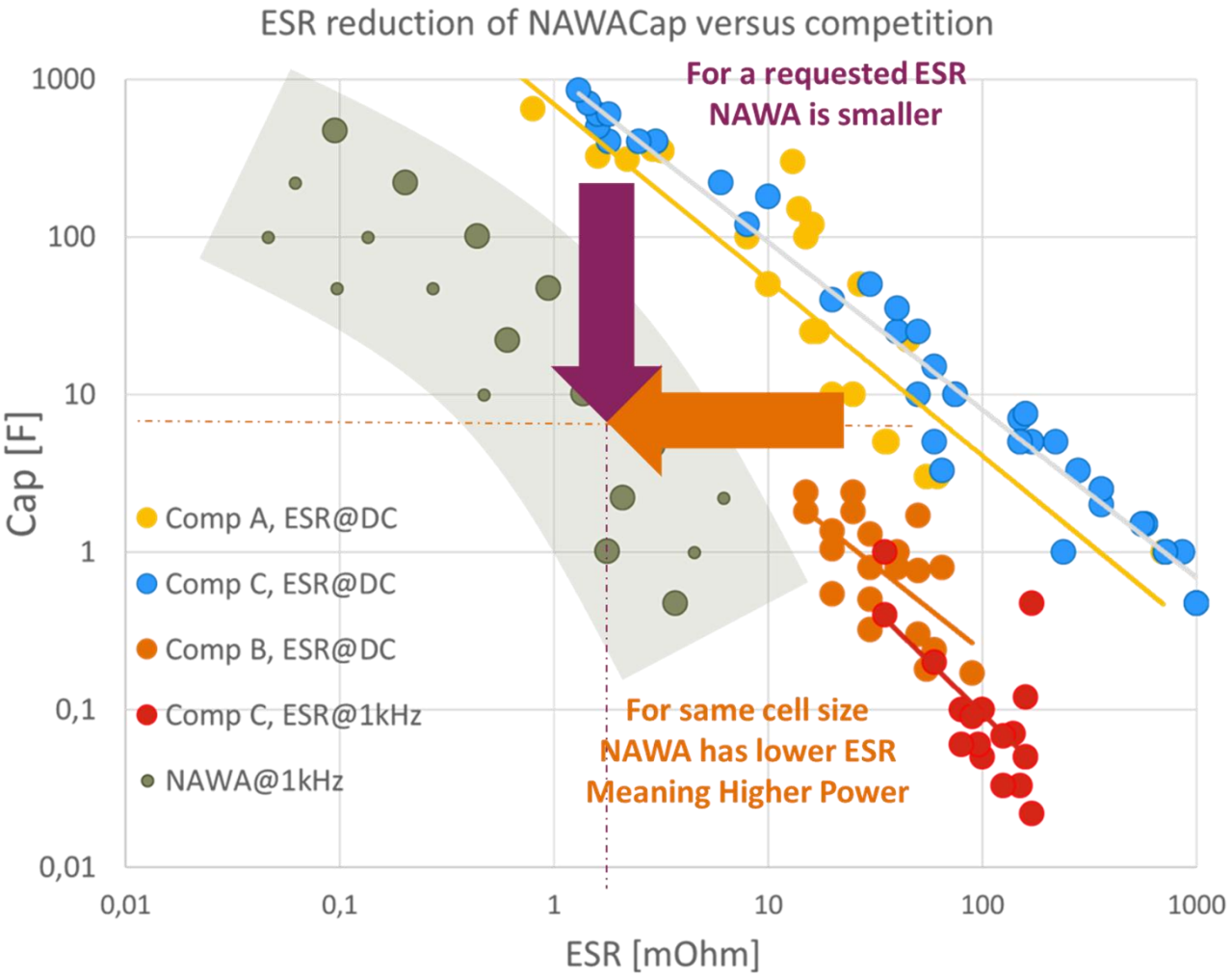
Pseudo EDLC
Higher Energy Density due to VACNT coating
Higher Power Density
Asymetrical



3

TECHNOLOGY COMPETITIVE LANDSCAPE

NAWACAP POWER: LOWEST ESR -> HIGHEST POWER AND FREQUENCY RESPONSE

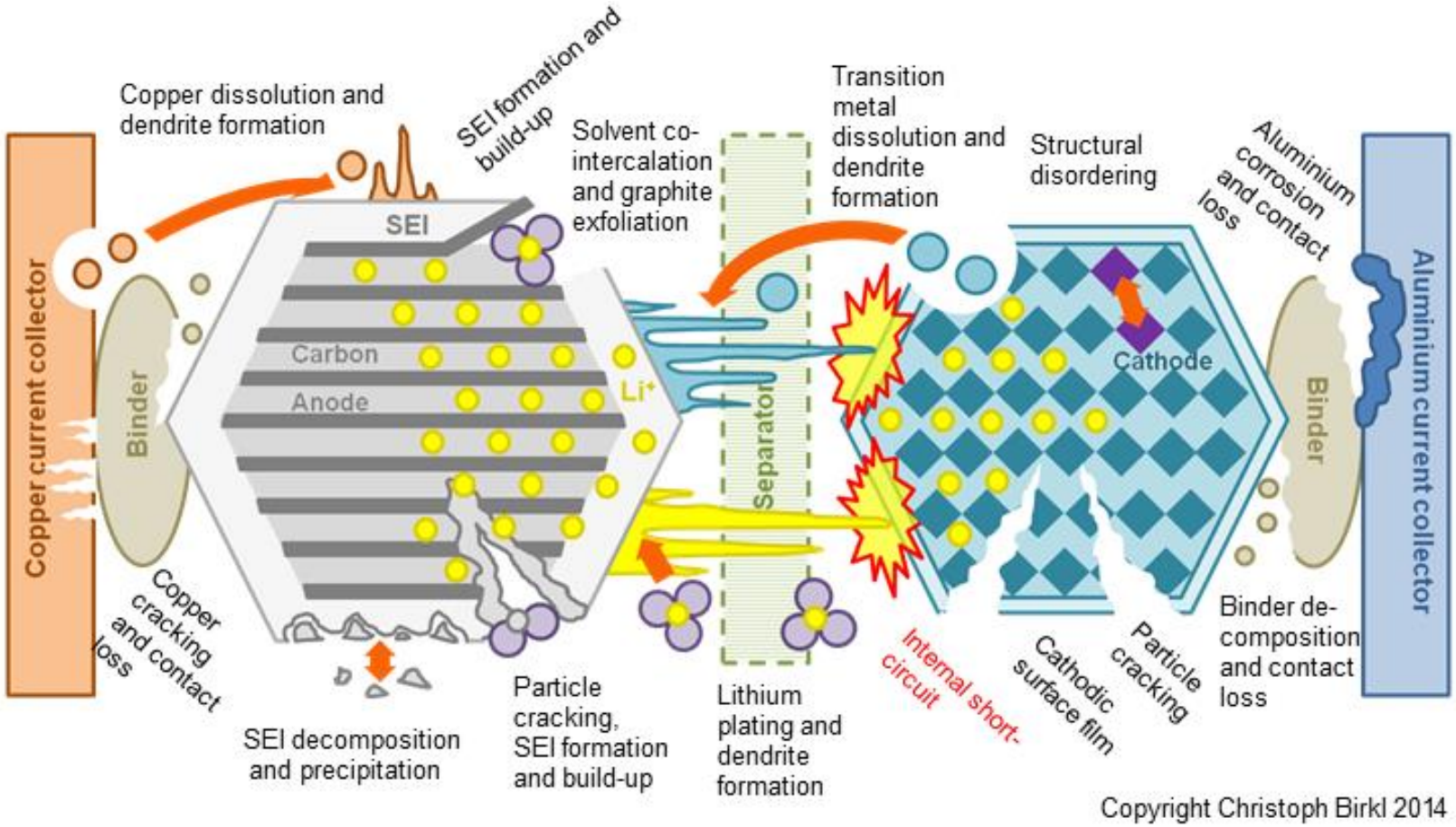


4

VACNT FOR LITHIUM BATTERIES

WHY BATTERIES FAIL

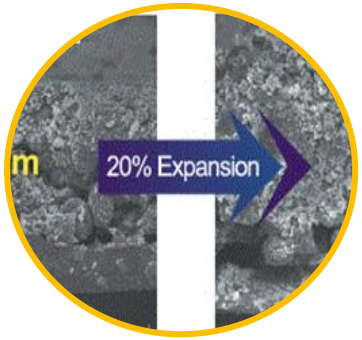
80% COMES FROM POWDERS



4 NAWA'S ELECTRODE TECHNOLOGY CAN SOLVE 80% OF LIB LIMITATIONS

VOLUME EXPANSION

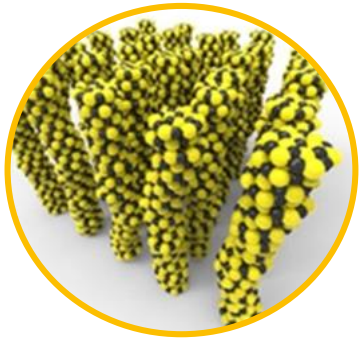
Lithium aggregrates increase their volume up to 20% while charging (ion insertion in the lithium crystals)



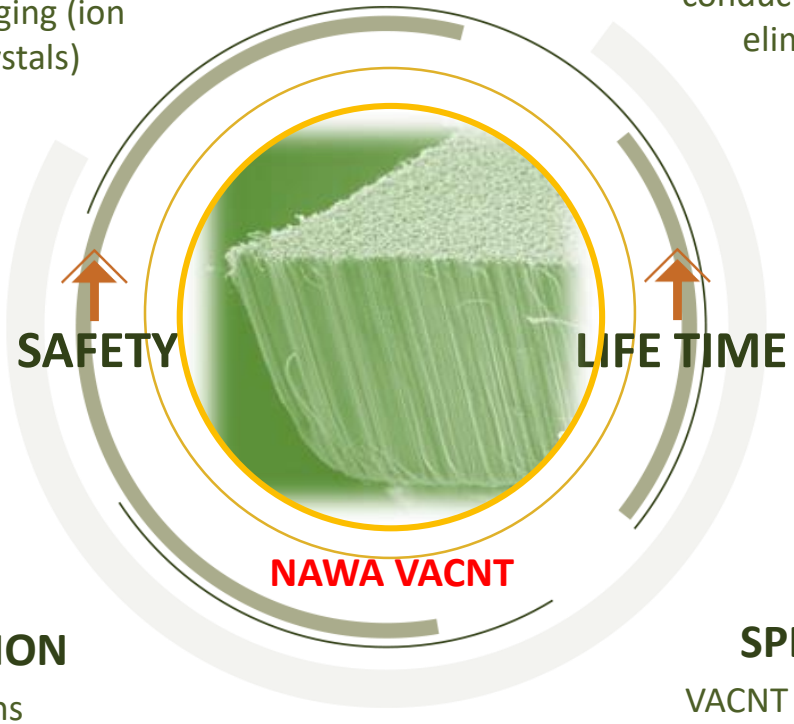
Volume expansion

HEAT DISSIPATION

VACNT have very high thermal conductivity to reduce hotspot and eliminate thermal runaway



VACNT as a cage for Lithium



ELECTRICAL PERCOLATION

No losses at boundary grains
Anisotropy favors straight conductivity and reduces dendrites formation
Homogeneity reduce aerial Li

SPECIFIC SURFACE

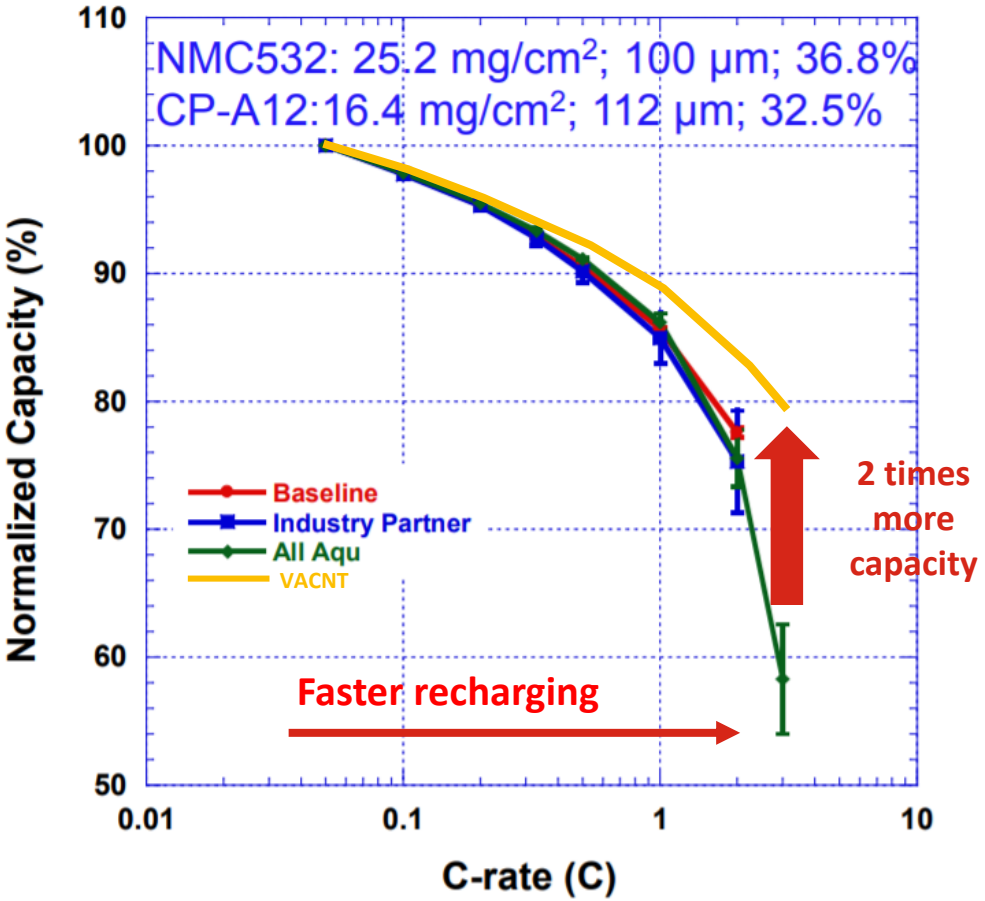
VACNT is a cage where lithium is trapped and maintained
VACNT have high specific surface so they can be coated by various means

4

INITIAL RESULT OF BETTER RETENTION CAPACITY

Raw VACNT

Replace Graphite Electrode
Save more capacity (>2)
at high C-rates (>2)
Increase lifetime



The faster you recharge, the more
Capacity you can retain from the battery

5

INDUSTRIALISATION

5 SIMPLIFYING THE PROCESS OF MANUFACTURING ULTRACAPACITORS

REDUCTION IN THE MANUFACTURING COST AND MATERIALS

NAWA TECHNOLOGIES

No preparation
No Powders

VACNT Growth

Functionalization

Common steps

separator

Slitting
Punching
Rolling
Stacking

Welding casing

Electrolyte

Maxwell TECHNOLOGIES

Mixing AC+CB+Ilink

Substrate preparation

Coating

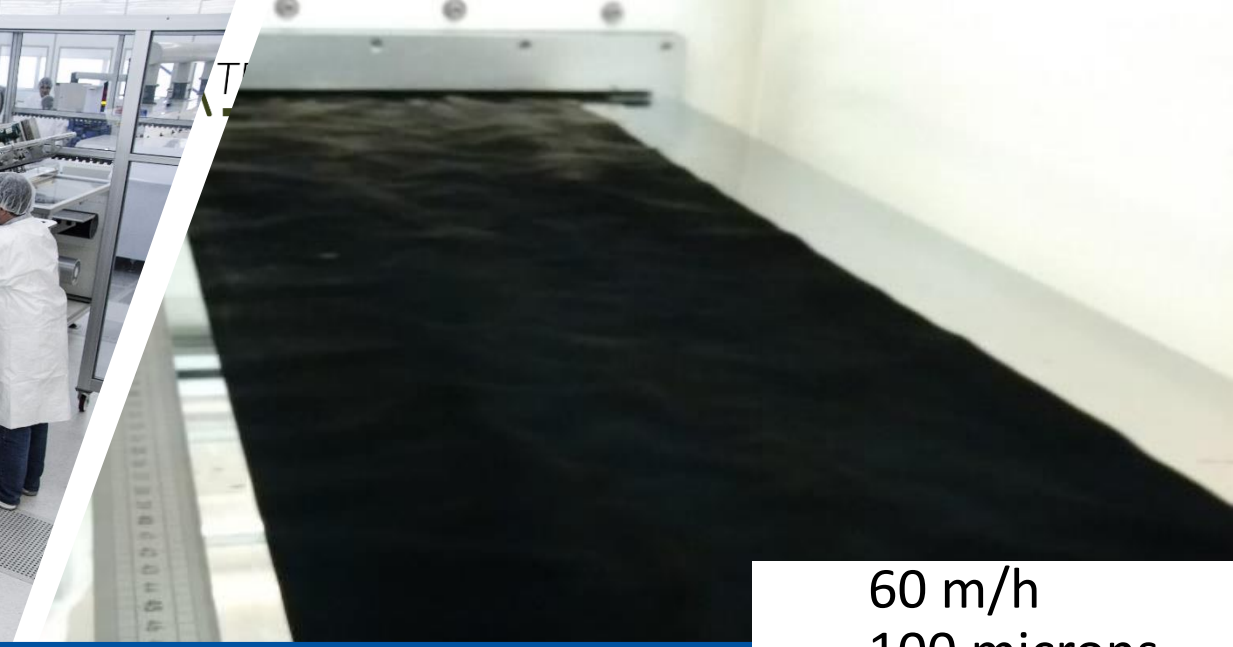
Press

separator

Slitting
Punching
Rolling
Stacking

Welding casing

Electrolyte



5 m/h
100 microns
< 600 °C
1000 m^2/y
2000 c/y

1 000 m^2 Production Facility
Clean and Safe Production

60 m/h
100 microns
< 600 °C
0,5 Mm^2/y
1 000 000 c/y

WHY NAWA HAS A DIFFERENT COST BREAKDOWN AND LEARNING CURVE

- BOM
  - Less number of raw materials (< 10)
  - Abundant and low price volatility
  - No expensive and rare raw materials
  - No powder manipulation and mixing process
  - Less chemistry
- CAPEX
  - Simplified APCVD process
  - No formation step
  - Benefit from PV cost reduction experience
- Utilities
  - No Dry room needed
  - Less equipment, R2R => less maintenance costs

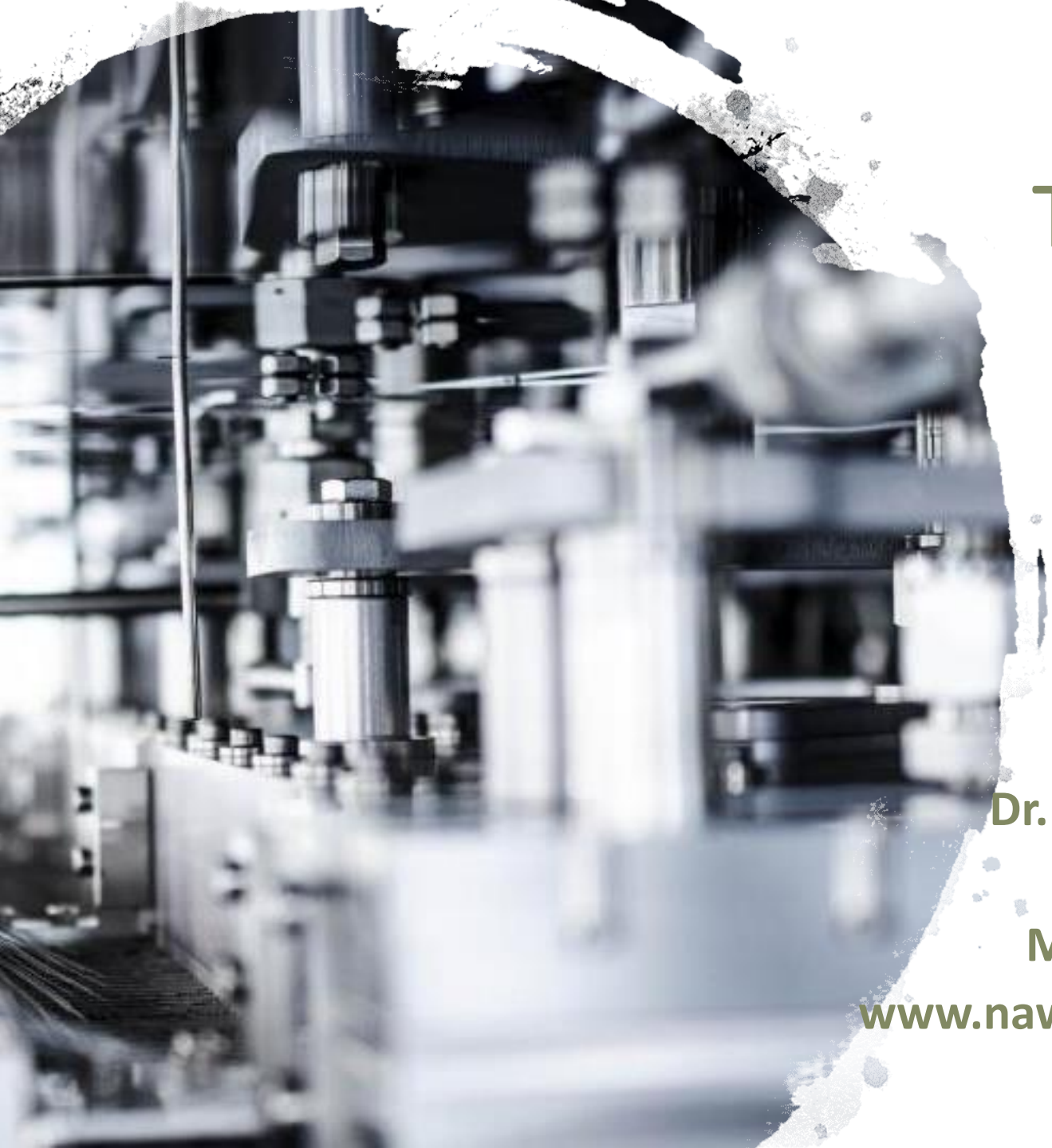
NAWA's cost structure is closer to PV than to LiB

6

CONCLUSIONS

VACNT A BREAKTHROUGH IN ENERGY TRANSITION

- VACNT electrodes have high potential to solve Capacitors/Ultracapacitors/Batteries limitations
- NAWA made this technology available for industry at costs on par with LIB electrode (mass production)
- NAWA is pushing VACNT in ultracapacitors because it's good for the planet
- NAWA open the road for other applications (fuel cells, membranes, wires, yarns, composites …)



THANK YOU

Dr. Pascal BOULANGER

CTO-COO-COB

Mob: +33 670933929

www.nawatechnologies.com