NIOBIUM APPLICATIONS IN E- MOBILITY : NANOCRYSTALLINE SOFT MAGNETIC MATERIALS & BATTERY MATERIALS

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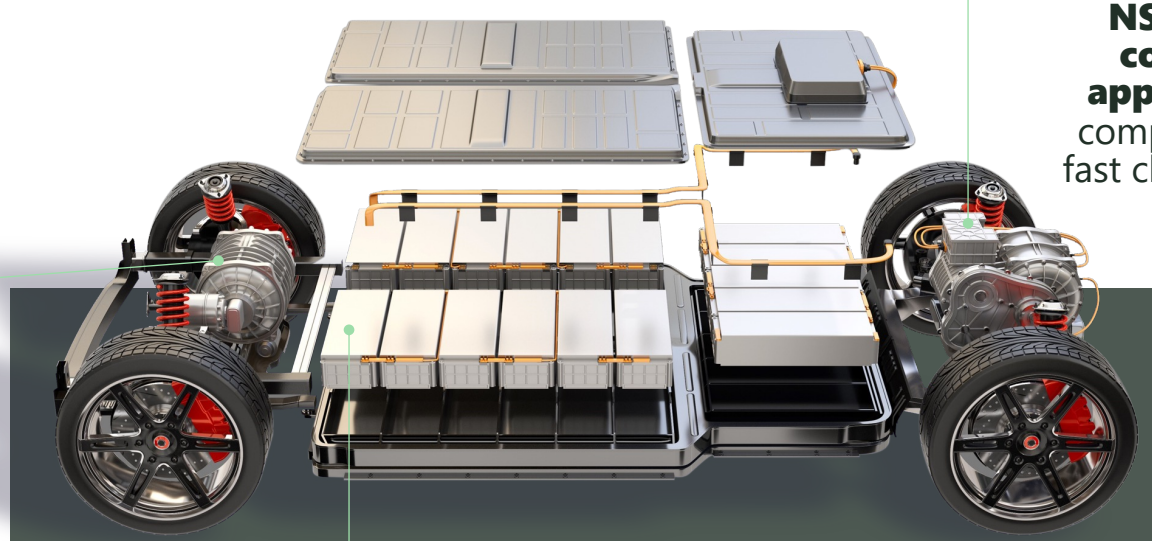
APPLICATIONS IN E-MOBILITY

Niobium drives the efficiency and safety in key applications in EVs enabling more reliable, more sustainable e-mobility sector

Onboard charger: Power range: 3.3/6.6 /11/22/44 KW; Magnetic components: CMC filters (AC side and DC side)

E-motor drive systems: Magnetic components: Inverter EMC cores for Motor protection: Inverter Input side (DC) /Inverter output side (AC)



Battery materials: A diverse portfolio of active materials used in cathode and anode application to enable the next generation of Li -ion batteries

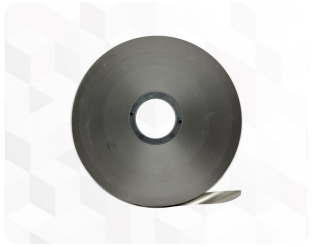
NSMM magnetic components are applied in different components of a DC fast charging stations

Source : Innolectric Whitepaper and Magnetec

NANOCRYSTALLINE SOFT MAGNETIC MATERIALS (NSMM)
DEVELOPMENT PROGRAM

FeNb

Nano Ribbon

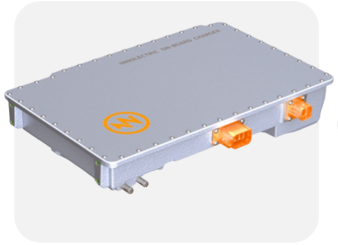


Core

Magnetic Component

Common mode choke filters, high frequency transformers, current transformers

Power Component



Power converter devices

Application

Ev's, e-mobility infrastructure

CBMM CAN OFFER:

01

Contact with **all the top players of the supply chain** involving nanocrystalline solutions

02

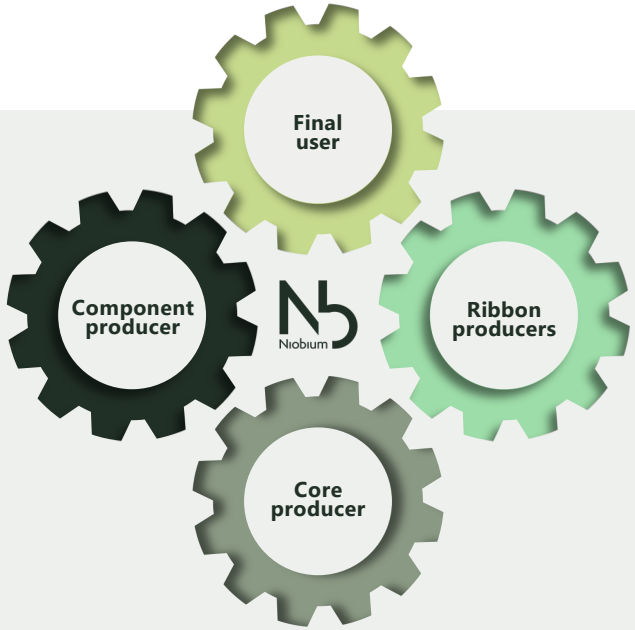
Supply chain diversification and transparency

03

Bring in **strategic partnerships** with universities and companies for developing advanced magnetic solutions with nano

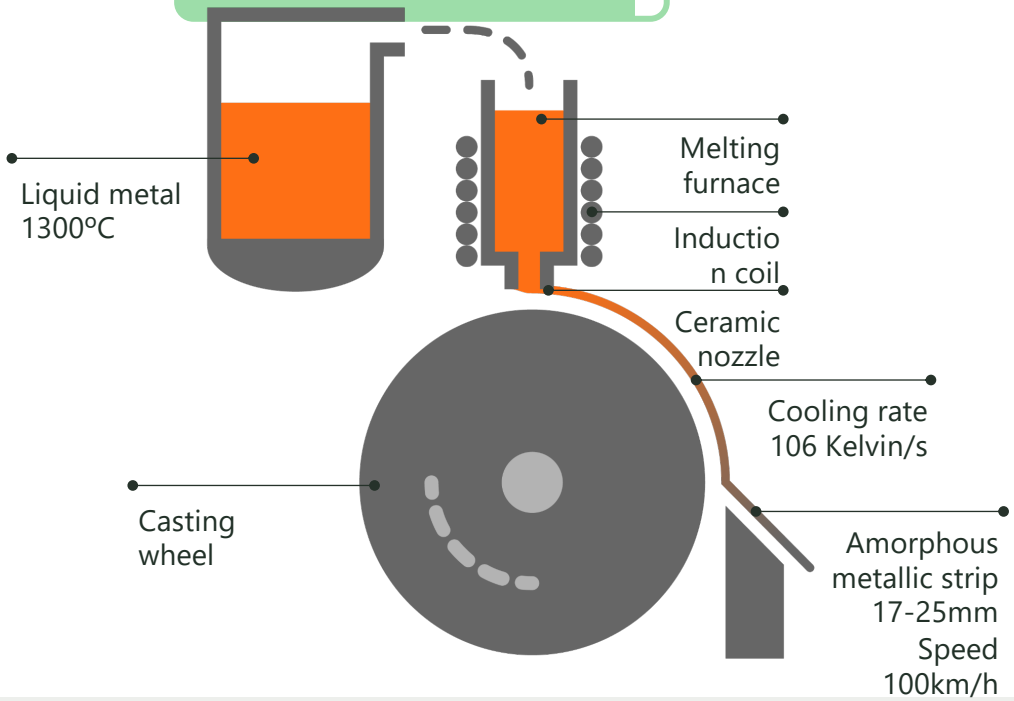
04

Contact with **potential end-users** of power electronics systems

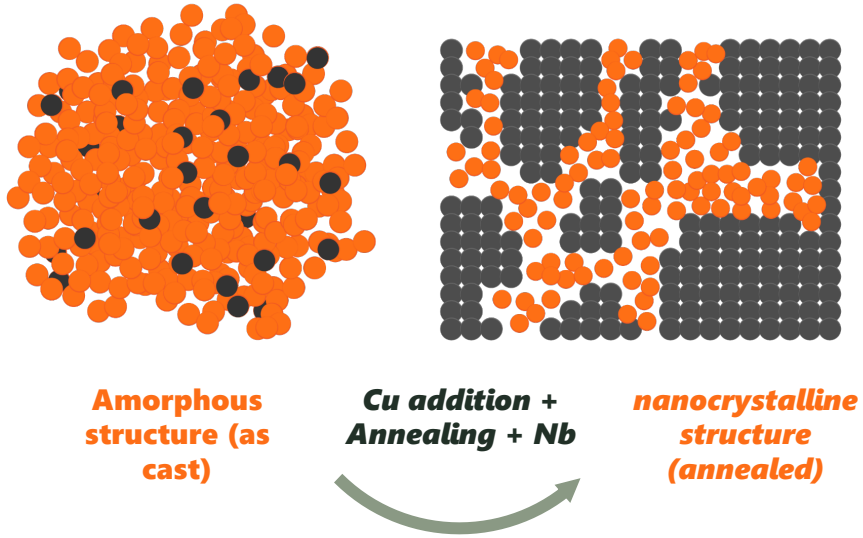


NANOCRYSTALLINE PRODUCTION PROCESS

Melt spinning



Annealing



Standard chemical composition (small variations)

[(Fe)]83.4 [(Nb)]5.6 [(Cu)]1.3 [(Si)]7.7 [(B)2] – traditional FINEMET® chemical composition (wt %)

Usually, 5.5 to 6% of Nb in Chemical composition (wt %)

Grains extremely small (~10nm) and uniform distribution

Source : VAC and Proterial

NSMM has potential in several markets with four main components

01 **CMC and Transformers**
(Including Inductors: DC-DC/PFC)
Proxy to SiC due to the need for high frequency and low loss characteristics

02 **Current Transformers and Sensors**
High-speed breakers for industrial power applications, and situations that require high precision (<1%)

03 **Wireless Power Transfer**
(Including Magnetic Shielding)
Wireless power transfer in markets sensitive to size, and nano shielding in wireless power transfer.

Market	CMC and Transformers	Current transformers	Wireless Power Transfer
Aerospace	✓	✓	
Rail	✓	✓	
EV	✓	✓	✓
Maritime	✓	✓	
Charging Station	✓	✓	✓
HVDC	✓	✓	
Power Supply	✓	✓	
HVAC	✓		
Consumer Electronics	✓	✓	✓
Data Center	✓	✓	
Robotics	✓	✓	
Biomedical imaging	✓	✓	

✓ Market size not material[2] ✓ Applicable Not applicable

CMC DESIGN ADVANTAGE
WITH NANOCRYSTALLINE CORES

Source Images: Amogreentech 2023 Product presentation

Application Advantages	Technical product characteristics
Small size	High μ, high BS
Suitable for high-current And/or high-voltage	High μ, high BS, optimized core design
Single-stage filter concepts possible	▪ Extreme broadband attenuation behaviour, ▪ High permeability, low capacitance designs, ▪ Slow μ decline towards higher frequencies, ▪ Low Q factor in the 150 khz range
High efficiency, low dissipation loss	The low number of windings is necessary for high L, filter stage reduction
Suitable for high and low ambient temperatures and high operating temperatures	▪ High curie temperature, material properties ▪ (μ, BS, λs) virtually independent of temperature
Simplified filter design	Material properties (μ, BS, λs) are virtually independent of temperature, constant impedance over a wide common mode current range due to linear magnetization curve

$$L = N^2 A_L = N^2 \mu_0 \mu \frac{A_{Fe}}{l_{Fe}}$$

$$|Z| = \sqrt{(\mathrm{Re}(Z))^2 + (\mathrm{Im}(Z))^2} \approx \sqrt{R_{s,core}{}^2 + (\omega L_{core})^2}$$

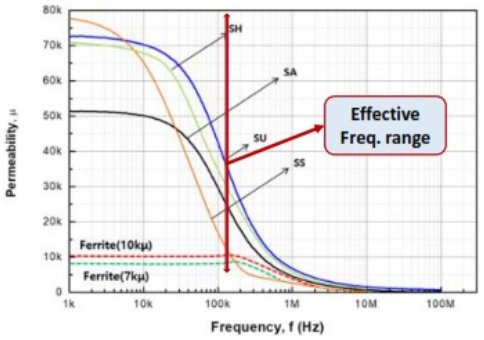
$$R_{s,core} = \omega \mu_0 \mu_s'' \cdot N^2 \cdot \frac{A_{Fe}}{\ell_{Fe}}$$

$$L_{core} = \mu_0 \mu_s' \cdot N^2 \cdot \frac{A_{Fe}}{\ell_{Fe}}$$

Common mode choque core (CMC)

Strength of AMFN-series

High & Wide range of permeability



[Permeability dependence on Fre (AMFN-series Vs Ferrite)]

*Adjustable at 10 kHz

Material Grade	Permeability (μ) @10kHz	Permeability (μ) @100kHz
SU	50,000	35,000
SH	50,000	28,000
SA	60,000	23,000
SS	80,000	18,000

Propreties	AMFN™ series	Ferrite (Mn-Zn)
Curie Temp (C)	570	150
Operating Temp(C)	≥150	~100

CASE STUDY:
Onboard charger 22KW

PARTNERSHIP WITH INNOLECTRIC AG (GERMANY)

Magnetic components tested:

- PFC Grid Filters
- PFC Main inductor
- Input 4phase CMC
- Output DC CMC chokes

CHALLENGES FOR THE EV MARKET

- The installation space is severely limited, and every additional weight affects EV's performance.
- On-board charger design is critical for the operating costs and energy consumption - an OBC with high thermal losses requires a larger cooling system to dissipate this wasted energy.
- Components with magnetic cores and windings can easily account up to 15% of the total weight of power electronics in EVs, such as the On-board charger.

The power of nanocrystalline soft magnetic materials

The adoption of soft magnetic nanocrystalline materials enabled innolectric AG to successfully reduce the size and weight of common mode chocke (CMC) to be used in on-board chargers.

Results include:

54% reduction in the core volume

62% reduction in the choke weight

Not compromising high efficiency and electromagnetic compatibility

Source: CBMM and Innolectric launched whitepaper December 2023

CASE STUDY:
Onboard charger 22KW

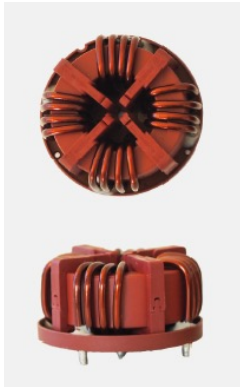
AC INPUT (SINGLE PHASE)

PARTNERSHIP WITH INNOLECTRIC AG (GERMANY)

Comparison of AC Common Mode Chokes

Realistic size comparison

AC CMC: Widely used version with nanocrystalline core



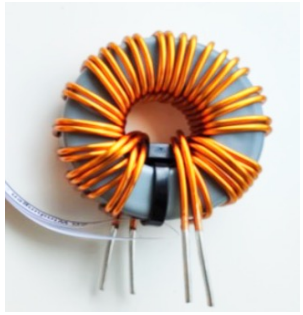
AC CMC: Ferrite based solution

Core material	Nanocrystalline	Ferrite
Supplier	Europe; of the shelf product	North America; Prototyping to Series Production; Custom built
Dimensions	50 mm*	62 mm*
	18 mm*	26 mm*
Weight(g)	165 g	430 g

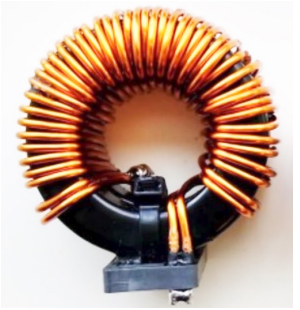
AC CMC

- **60%** reduction in weight
- **50%** reduction in volume
- Better **thermal stability**
- TCO of onboard charger with new solution is reduced

Comparison of PFC Inductor

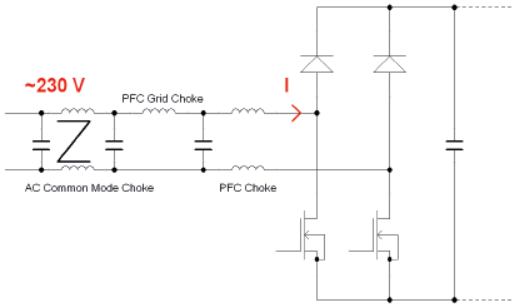


Nano powder core



Sendust powder core

AC Input (Single Phase)



Core material	Nanocrystalline powder Core	Sendust powder core
Supplier	Nanoamor	Ro-Lo
Dimensions	57.15 mm*	57.15 mm**
	15.24 mm**	2 × 13.97 mm**
Weight(g)	219 (2.5g/1W)	362

Source: CBMM and Innolectric launched whitepaper December 2023

AC CMC

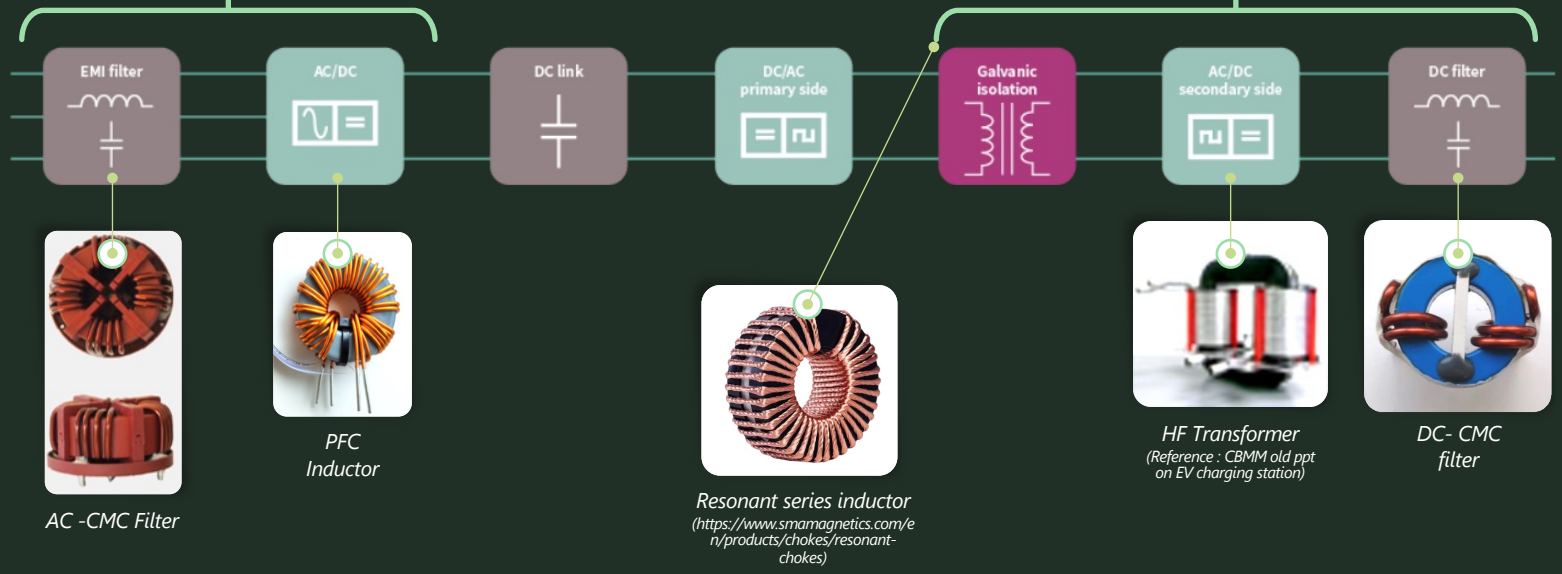
- **60%** reduction in weight
- **50%** reduction in volume
- **19%** reduction in operating temperature

Offboard applications in E-Mobility

NSMM magnetic components are applied in different components of a DC fast charging station

Front End AC-DC power module (25KW- 1MW):
Magnetic components:
Input side -LCL filters/CMC filters, PFC inductor;

DC-DC power module (25KW-75KW):
Magnetic components:
HF Transformer, Resonant Inductor, DC side filter ;



AC -CMC Filter

PFC Inductor

Resonant series inductor
(https://www.smamagnetics.com/en/products/chokes/resonant-chokes)

HF Transformer
(Reference : CBMM old ppt on EV charging station)

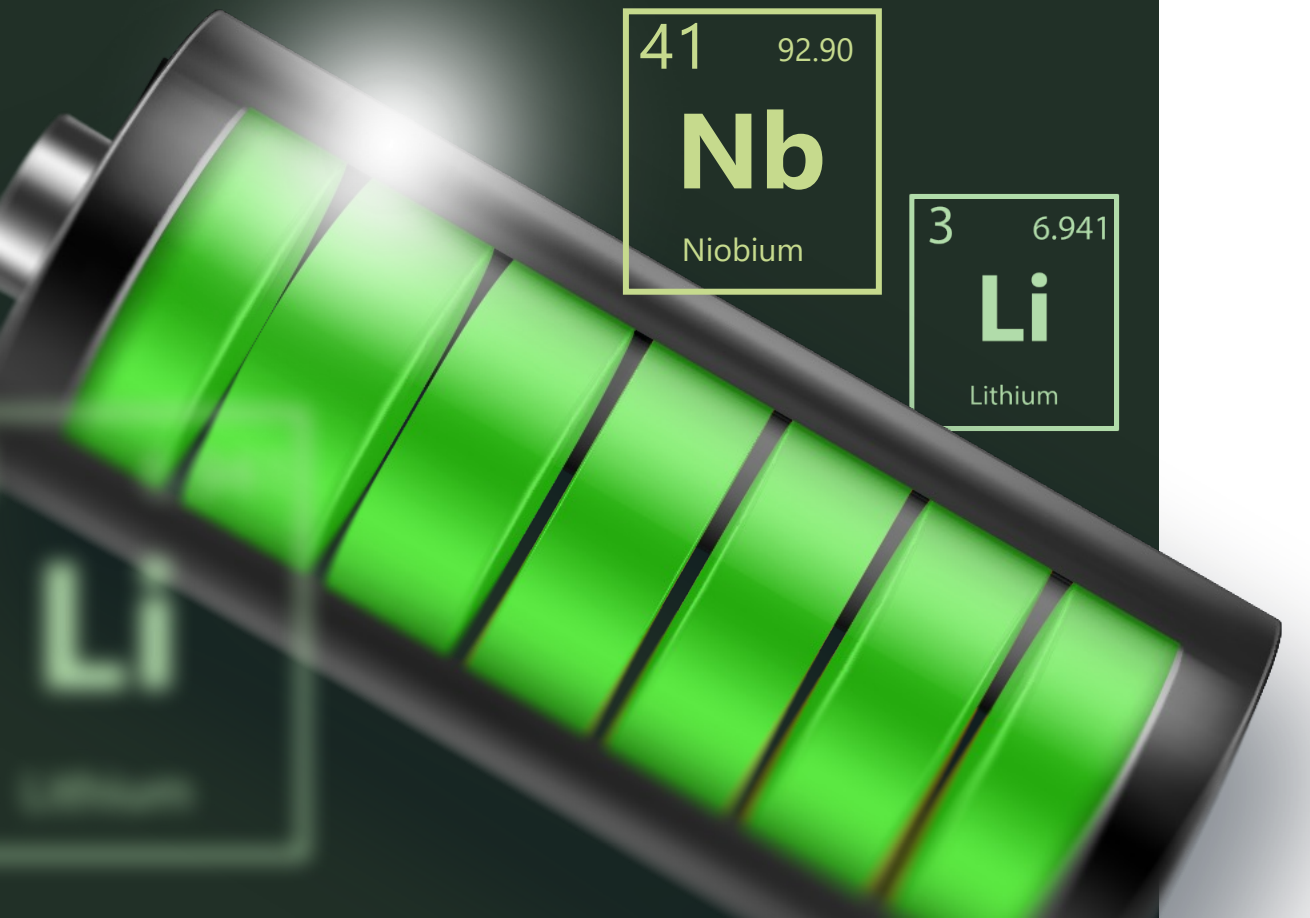
DC- CMC filter

Reference:
https://www.infineon.com/cms/en/applications/industrial/ev-charging/chargers-from-50kw-to-350kw/

**Development in progress: CBMM is working with strategic partners to develop nano-based solutions to show benefits compared to traditional materials like Iron powder and Ferrites: PFC inductors and Resonant inductors (Stress annealed low mu nano cores), and HF transformers (HF nano cores)*
Source : Innolectric Whitepaper and Magnetec

NIOBIUM IN ADVANCED

LITHIUM BATTERIES



Niobium is being used to develop reduced or cobalt-free lithium batteries with higher energy densities and durability

Fast-charging batteries, safety and high energy densities are being possible with the use of Niobium in the formulation of new anodes already in industrial tests

Niobium is becoming a promising element for the development of **solid state batteries**, the ideal solution for lithium battery technologies

Cathode

Chemistry

Dopant

Coating

Anode

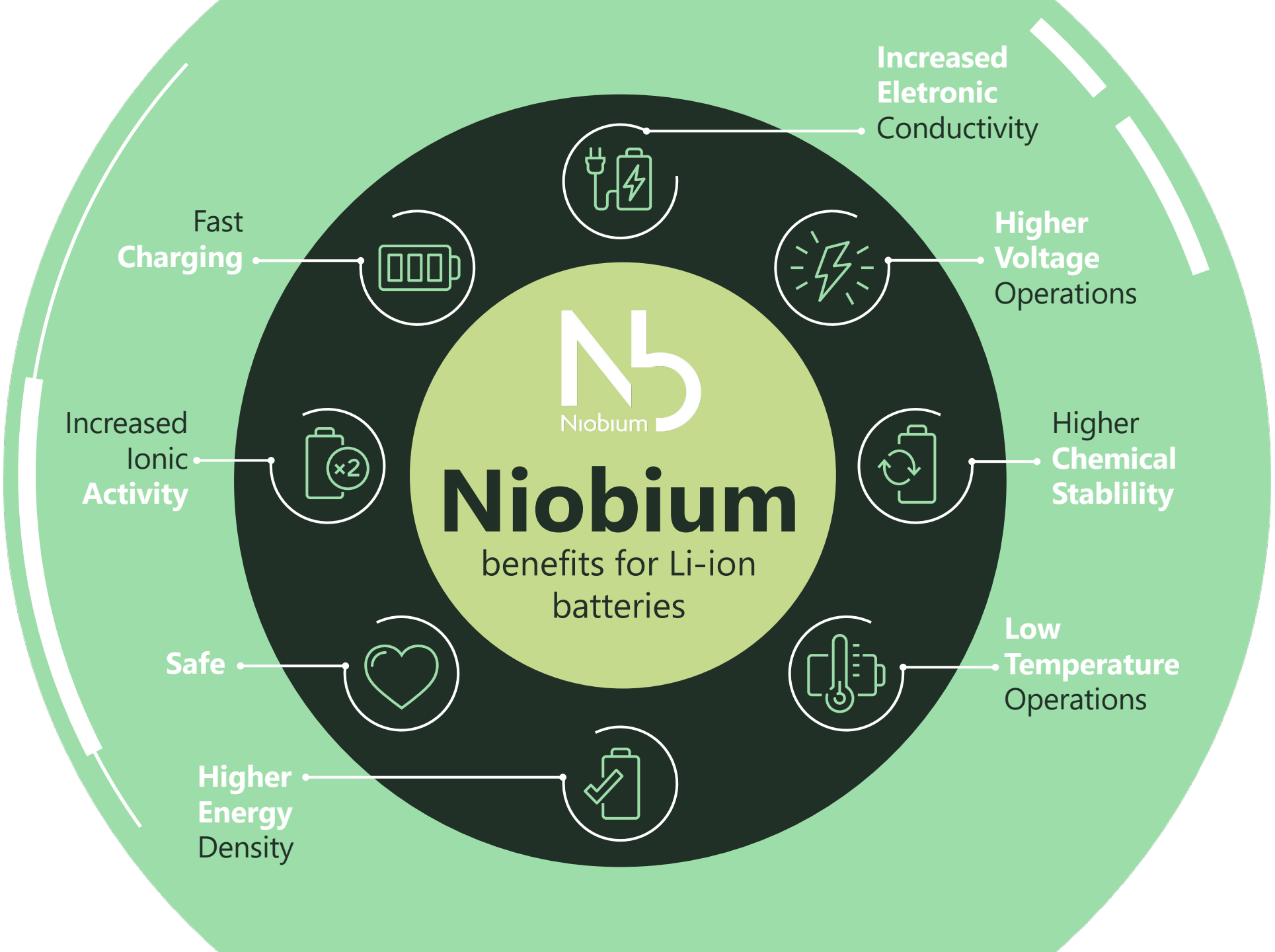
Chemistry

Dopant

Solid state

Electrolyte chemistry

Interface Coating



NTO
Niobium
Titanium
Oxides

NWO
Niobium
Tungstein
Oxides

DR-Nb
Niobium
Disordered
Rock Salt

LNO
Lithium
Niobates

INNOVATION IN MOVEMENT

Over our history, we have been investing in strategic partnerships with a focus on the research and development of new **Niobium** applications aligned with the global macro trends of electrification, urbanization, digitalization, and sustainability

Since the beginning of the studies by Prof. John B Goodenough some decades ago, **Niobium** has proven to be a promising material for developing the next generation of lithium-ion batteries, grating unique capabilities of ultra-fast charging and increased safety

2014

Beginning of the technical discussions between CBMM and Toshiba of the use of Niobium in batteries

2017

Assessment of the potential of Niobium applied to batteries

2018

CBMM Signs the first contract of technical cooperation with Toshiba for:

Development of Niobium oxide battery grade

Construction of the NTO Batteries Pilot Plant in Japan

2019

CBMM inaugurates battery materials laboratory

First sale of Niobium for cathodes in Japan

CBMM works in collaboration with Prof. John B. Goodenough, Nobel Prize in Chemistry 2019 for the development of lithium-ion batteries

2020

First cell production at Toshiba

First sale of Niobium for cathodes in China

MOVEMENT

INNOVATION IN

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2021

Second industrial cell production at Toshiba

Pilot Plant in Araxá

2022

Diversification in the Battery Product Portfolio

Advancement in contributions to the Technology Program:

R$ 72 million in lithium-ion batteries

R$ 306 million in the expansion of the NB oxide production line

Strengthening partnerships with Echion Technologies, Skeleton, BSI and cathode producers

2023

Implementation of the battery grade oxide production capacity at CBMM

First commercial sales of mixed oxides for anodes

2024

Inauguration of the Industrial Plant of Mixed Oxides for Batteries

Focus on applications in ultra-fast and safe charging technologies, with high power and longer life cycle

INNOVATION FOR MORE SUSTAINABLE URBAN MOBILITY

CBMM, Toshiba and Volkswagen Truck & Bus teamed up to develop and use Niobium lithium-ion batteries to boost electrification worldwide, thus contributing to more sustainable urban mobility

Niobium products for Lithium-ion batteries that enable:

Increased safety

High performance

Longer lifespan

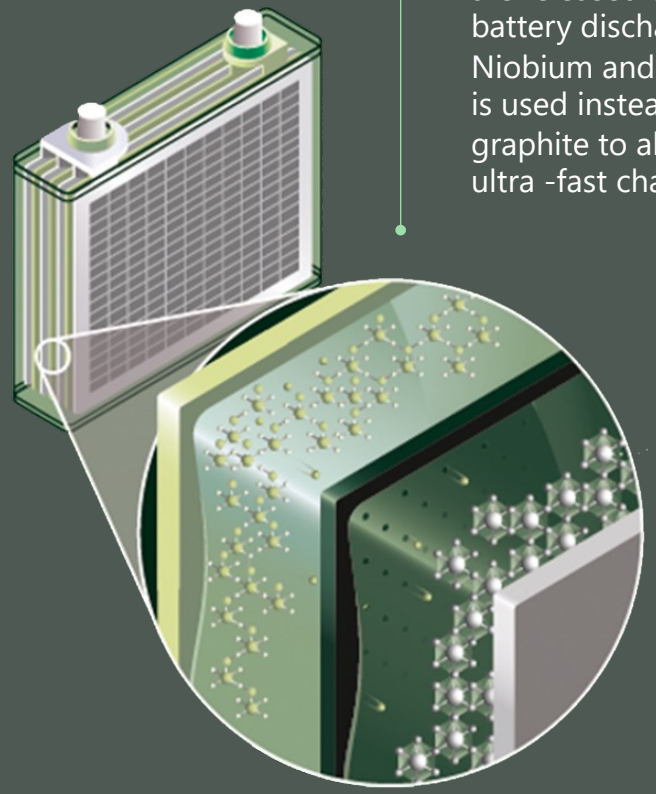
Niobium-based ultra-fast charging batteries are the result of 5 years of research and development with Toshiba Corporation

Volkswagen Truck & Bus integrate SCiB™ Nb batteries in a concept, 100% electric bus

SCiB™ Nb batteries use cell with Niobium materials in the chemical makeup of anode

Anode

It is the electrons are released during battery discharge, Niobium and where is used instead Of graphite to allow for ultra -fast charging



THE BENEFITS OF USING SCiB™ Nb BATTERIES

Simple management system due to the increased chemical and thermal stability of the battery

Highly safe, excellent thermal stability

10,000 charge cycle:

SCiB™ batteries have greater energy efficiency and can operate

0% to 100%

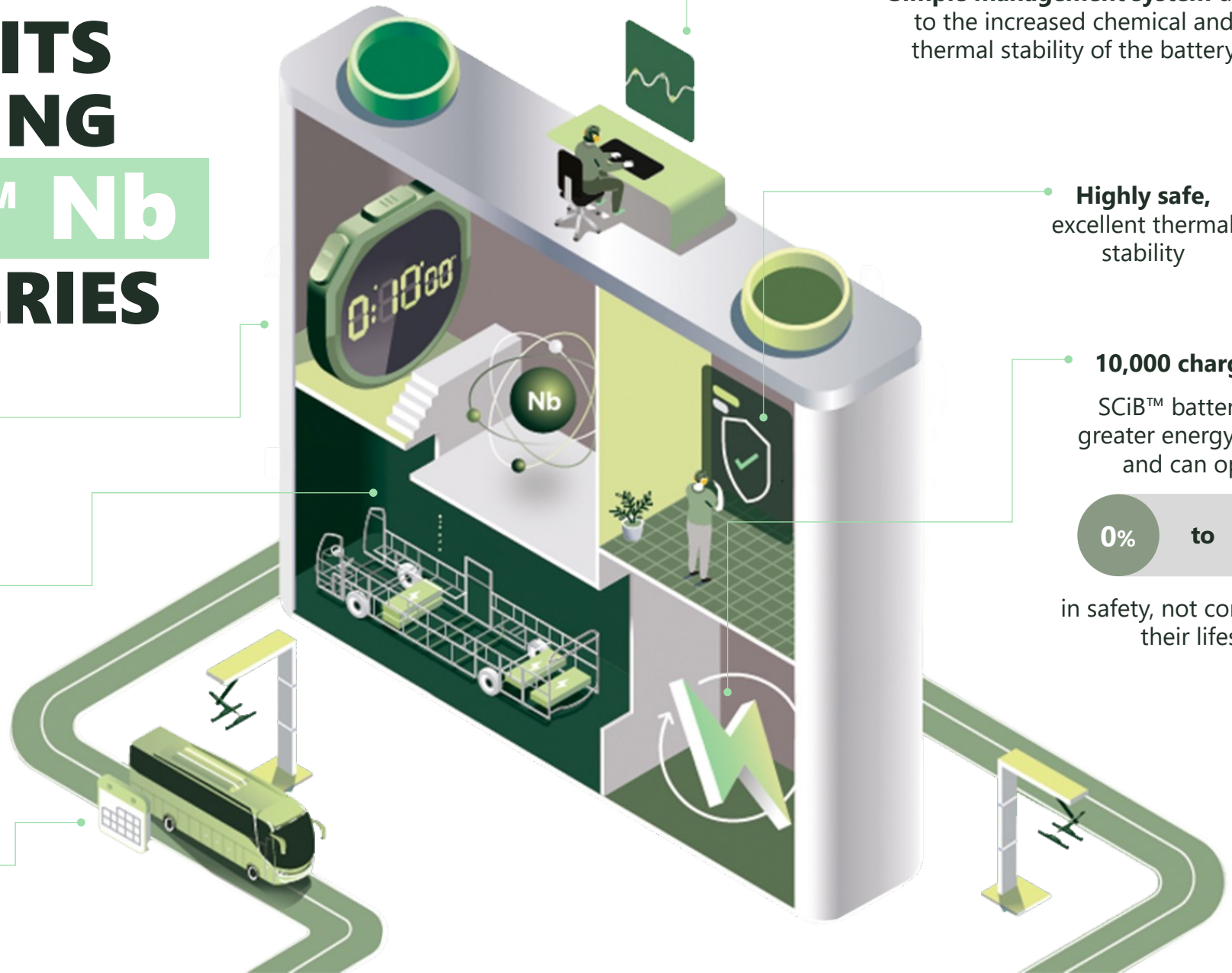
in safety, not compromising their lifespan

0% - 80%

Charge in under **10 minutes**

Potential reduction of the battery size of **up to 3x** = more room for cargo and passengers

1 bus **operating 24x7**



LEARN MORE AT
www.niobium.tech

Thank you!

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