

TDK IR Event Tech Conference 2023

Attracting Tomorrow



TDK Corporation
IR&SR Group
November 29, 2023

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Opening

Noboru Saito,
President & CEO

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Technology development at TDK

Shigeki Sato,
Senior Vice President,
General Manager, Technology and
Intellectual Property HQ

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**Overview of
Passive Component Technology**

Masahiro Oishi,
General Manager, Development &
Engineering Group, Electronic Components
Business Company

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**Overview of
Sensor Technology**

Takao Tsutsui,
Vice President,
CEO, Sensor Systems Business Company

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**Overview of
Battery Technology**

Atsushi Sano,
Department Head, Energy Devices Business
Group, Energy Solutions Business Company

Technology Development at TDK

Shigeki Sato,
Senior Vice President,
General Manager, Technology and Intellectual Property HQ

The history of TDK - Our venture spirit

1930: Dr. Yogoro Kato and Dr. Takeshi Takei invented “Ferrite,” a magnetic ceramic compound containing oxides of iron and other materials.



Dr. Yogoro Kato (left)
Dr. Takeshi Takei (right)

1935: Dr. Kato’s statement that *“innovative work is the source of true industry,”* inspired **Kenzo Saito** to found TDK Corporation.



Kenzo Saito
First president of TDK

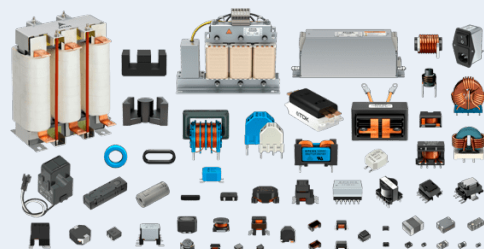
1937: “Ferrite core” was produced and applied for the first time worldwide in a number of Japanese wireless communication units and radios.



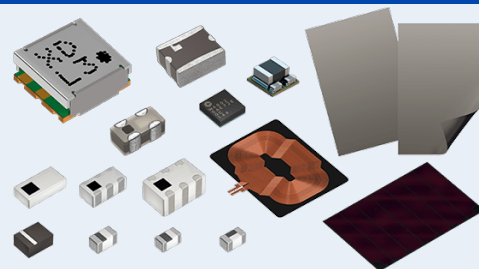
Ferrite core

Our product categories

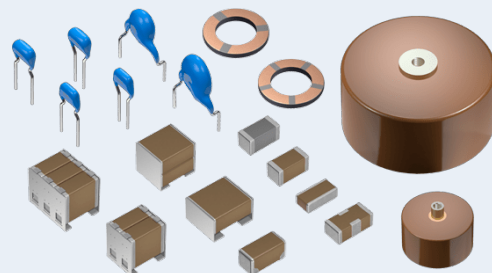
Passive Components



Inductive devices



High-frequency components



Ceramic capacitors



Aluminum electrolytic capacitors /
film capacitors



Piezoelectric material products /
circuit protection components

Sensor Application Products

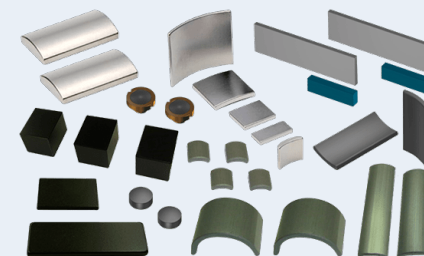


Sensors / MEMS

Magnetic Application Products



HDD heads /
HDD suspension assemblies



Magnets

Energy Application Products



Energy devices



Power supplies

Others



Flash Memory
Applied Devices



EMC & RF
Engineering



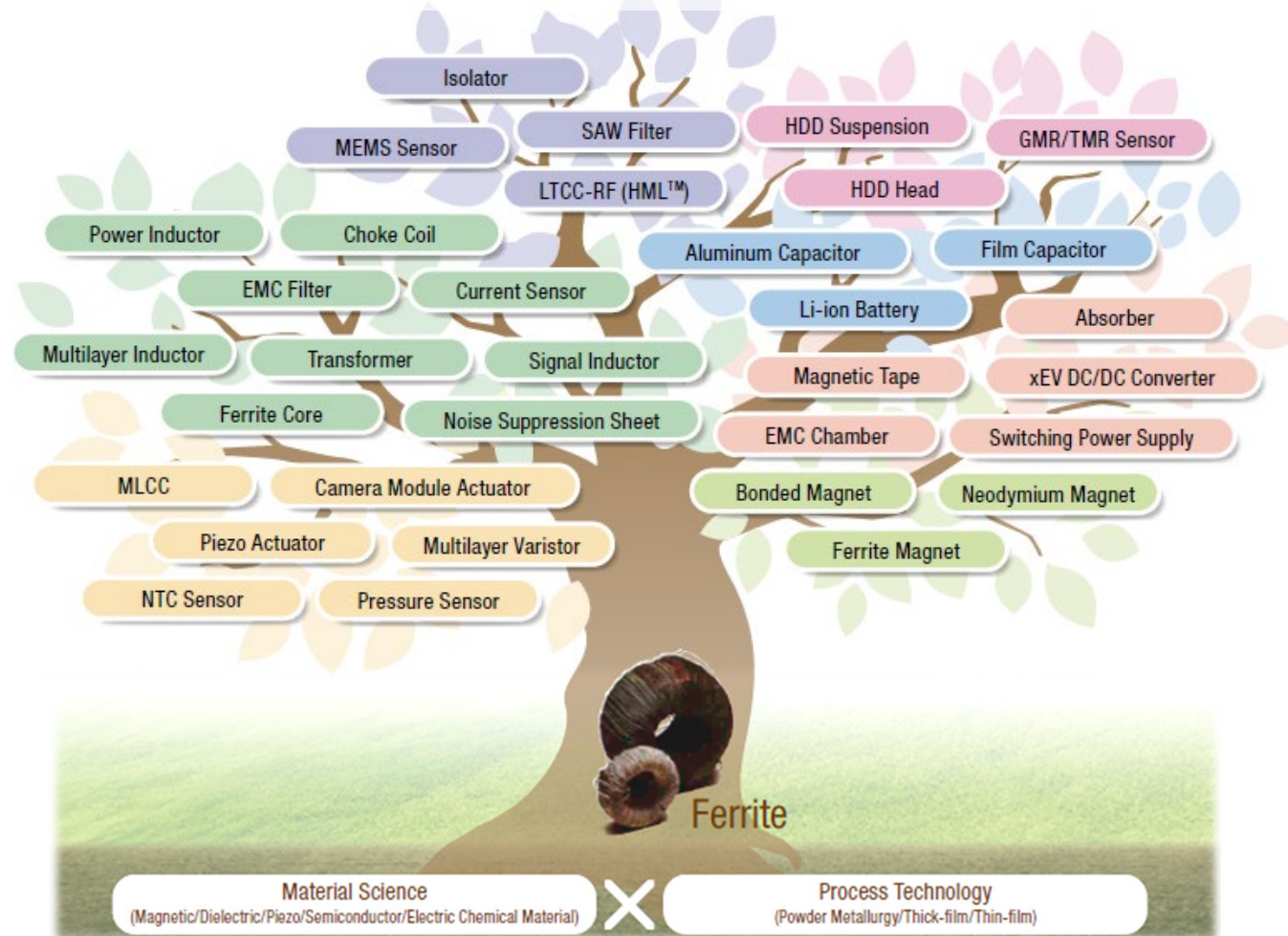
Micro-actuator
Solutions & Others



Software

TDK Ferrite Tree

- TDK started from the invention and practical application of the magnetic material "ferrite" which was expanded to inductors, piezoelectric materials and semiconductors. "Ferrite" has been applied to a wide range of technologies and products which are shown as the "Ferrite tree".



TDK Seven Seas

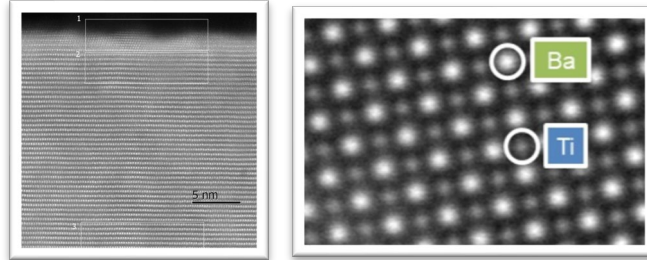
- “TDK Seven Seas” indicates the focus areas of a long-term strategy based on the sustainability vision of “Technology for the well-being of all people”.



5 core technologies

Materials technology

The culmination of over 88 years of experience and know-how.



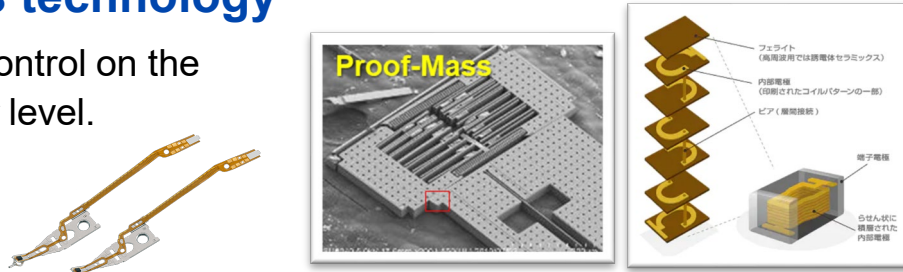
Production engineering technology

Outstanding facilities developed and manufactured in-house



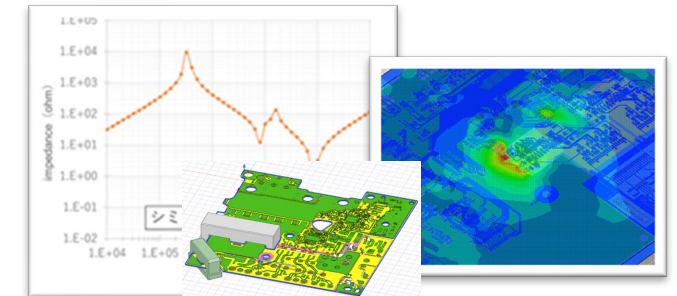
Process technology

Realizes control on the nanometer level.



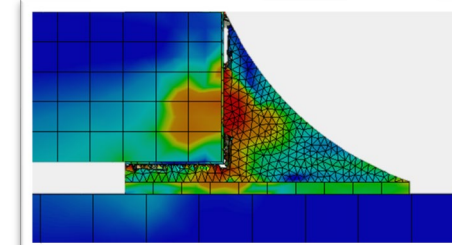
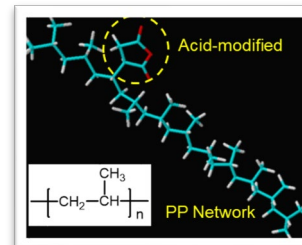
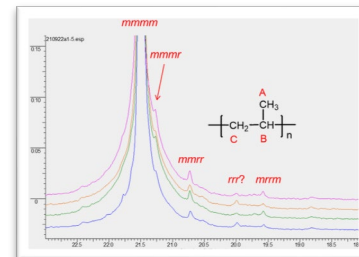
Product design technology

Creating product value with accumulated know-how and new ideas.



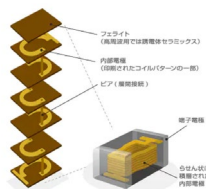
Evaluation and simulation technology

Applied to accurately measure and analyze ultra-fine structure and noises by electronic devices.



Our strength - materials and processes to products -

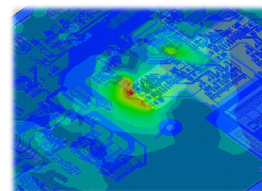
Attracting Tomorrow **TDK**



Multilayer / Roll to Roll processes



Thin film / MEMS



Product design technology



Production engineering technology



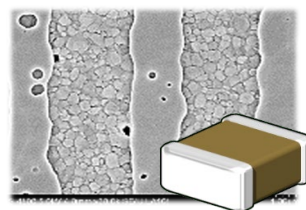
Film capacitors

Organic materials



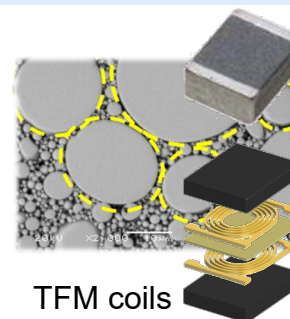
Haptics

Piezoelectric materials

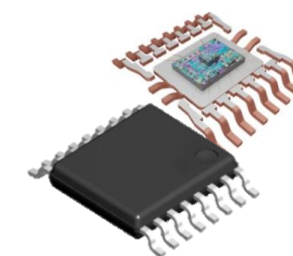


High-reliability capacitors

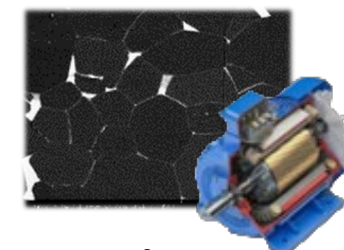
Dielectric materials



TFM coils



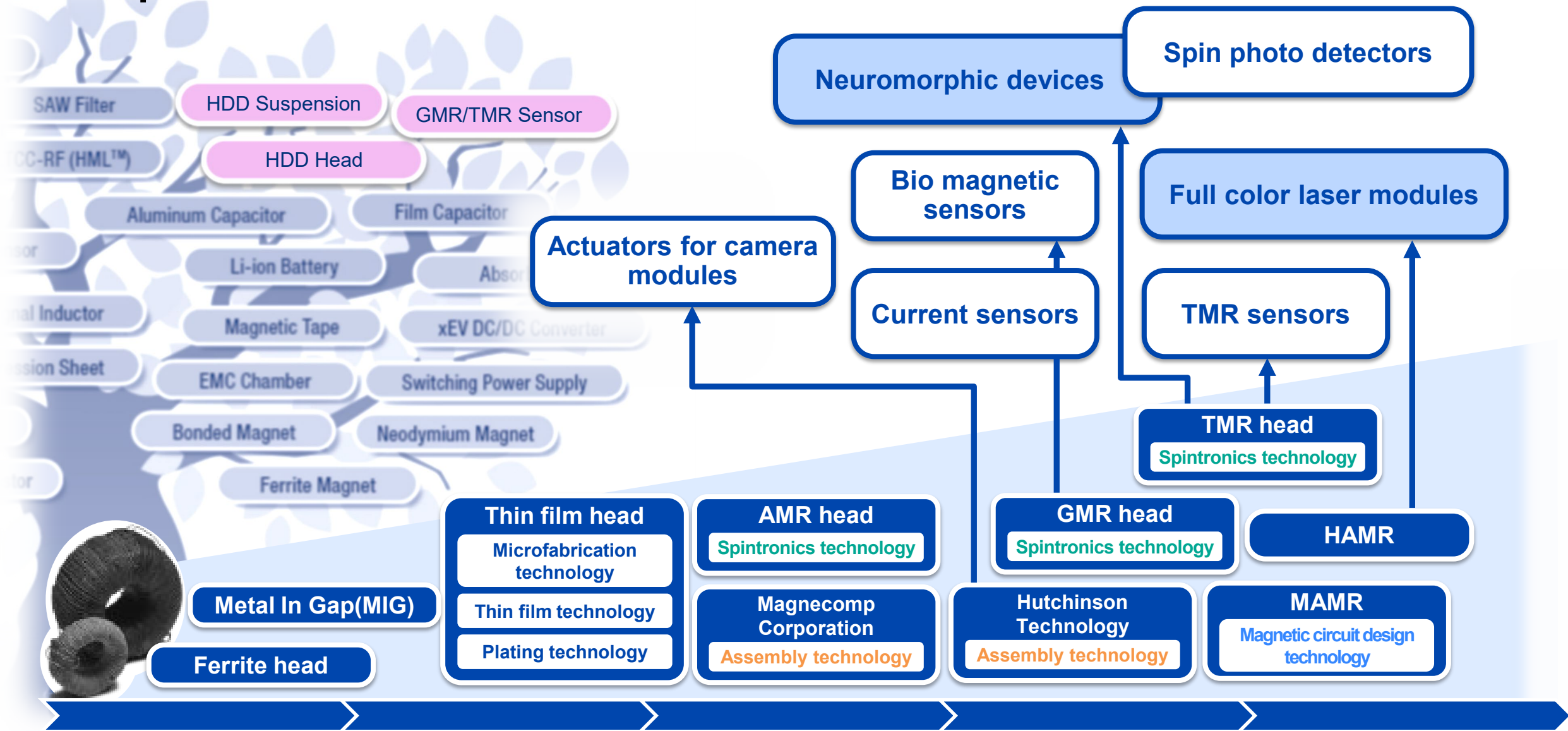
TMR current sensors



Magnets for motors

Magnetic materials

Pursuit and expansion of the technologies of magnetic and spintronics



Overview of Passive Component Technology

Masahiro Oishi,
General Manager, Development & Engineering Group,
Electronic Components Business Company

TDK Ferrite Tree and expansion of passive component technology

Passive component products on Ferrite tree

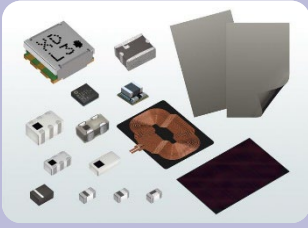
Ceramic capacitors



Inductive devices



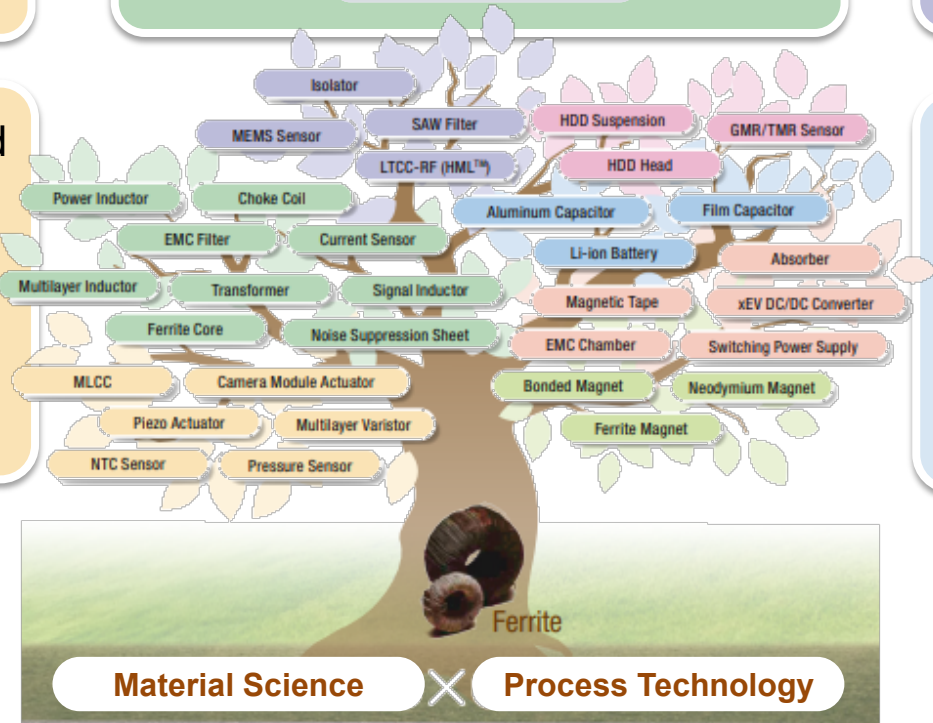
High-frequency components



Piezoelectric material products and circuit protection components



Aluminum electrolytic capacitors and film capacitors



Strengths of TDK electronic components business

Material

Magnetic

Ceramic

Piezo

Film

Powder/Grain

Resin



Process

Multilayer

Winding

Plating

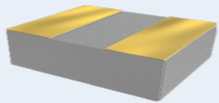
Printing

Sintering

Molding

Next Gen

Embedded
High power magnetics
into Substrate



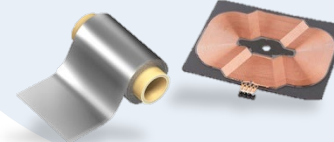
TDK Original

High-definition actuators



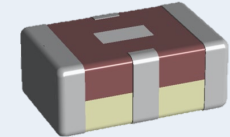
TDK Original

Ultrathin magnetic sheet and
applied products



TDK Original

Integrated
Magnetic and Ceramic



Sales

ICT

Automotive

Industrial

China

Asia

Europe

America



Production

Quality

Logistics

Volume

China

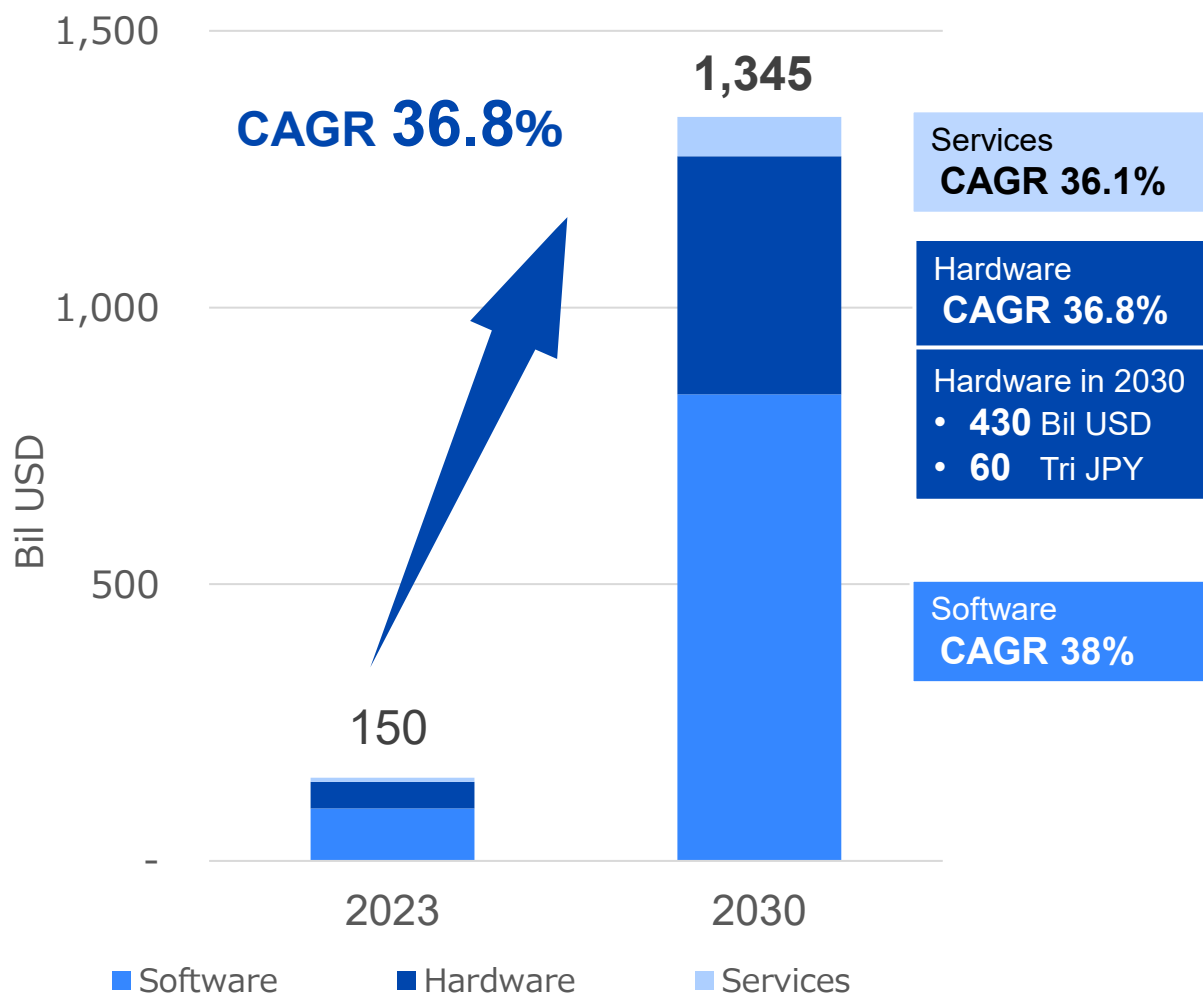
Asia

Europe

America

AI market trend

- The AI Computing market is expected significant growth not only in software and services but also in hardware segment



Generative AI



By Technology

- Machine Learning
- Natural Language Processing
- Context Awareness
- Computer Vision

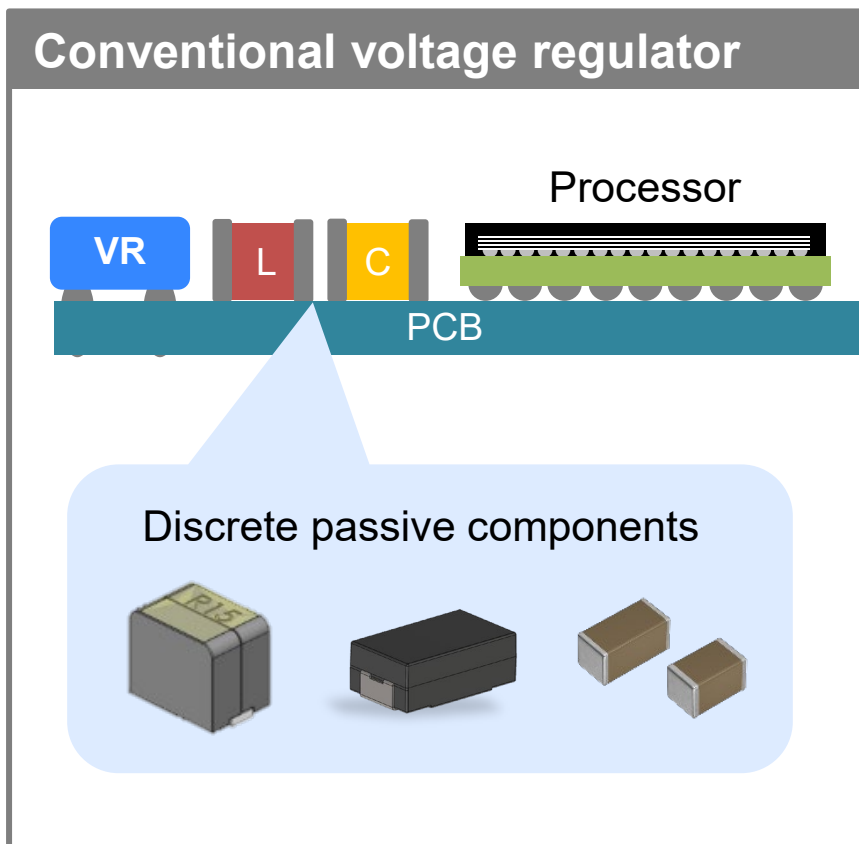
By Category / Usage

- BFSI (Banking, Financial services and Insurance)
- Retail and E-Commerce
- Manufacturing
- Healthcare Life Sciences etc.

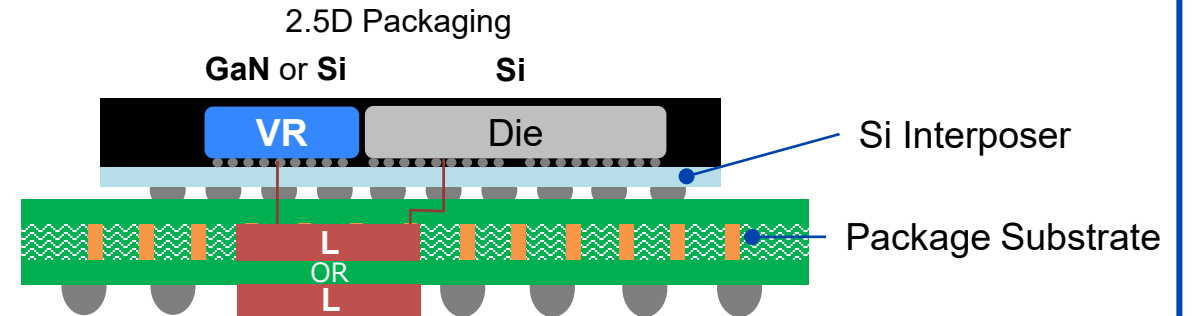
Trend of power supply

■ Opportunities for inductors using new power supply systems

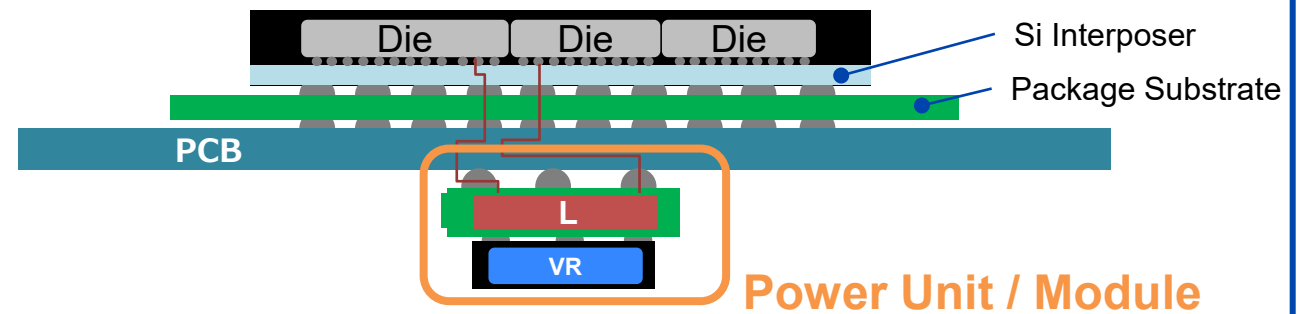
- Customized embedded inductors
- Low profile inductors etc.



Integrated Voltage Regulator (iVR)

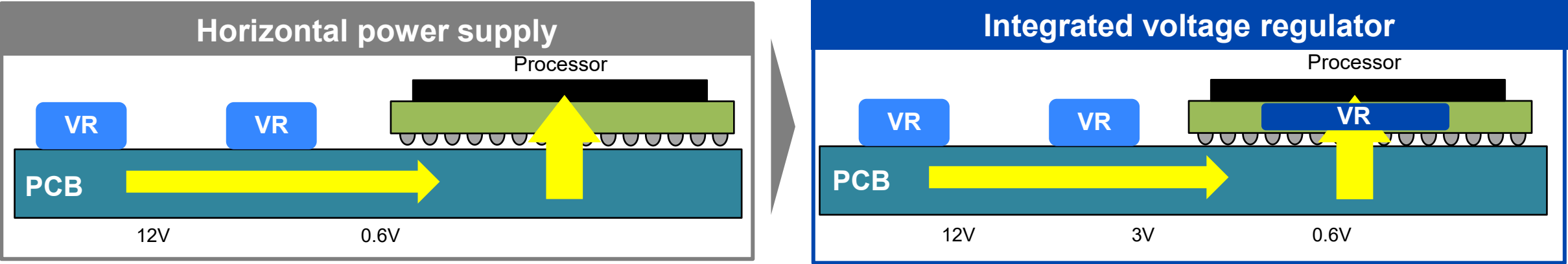


Vertical power supply

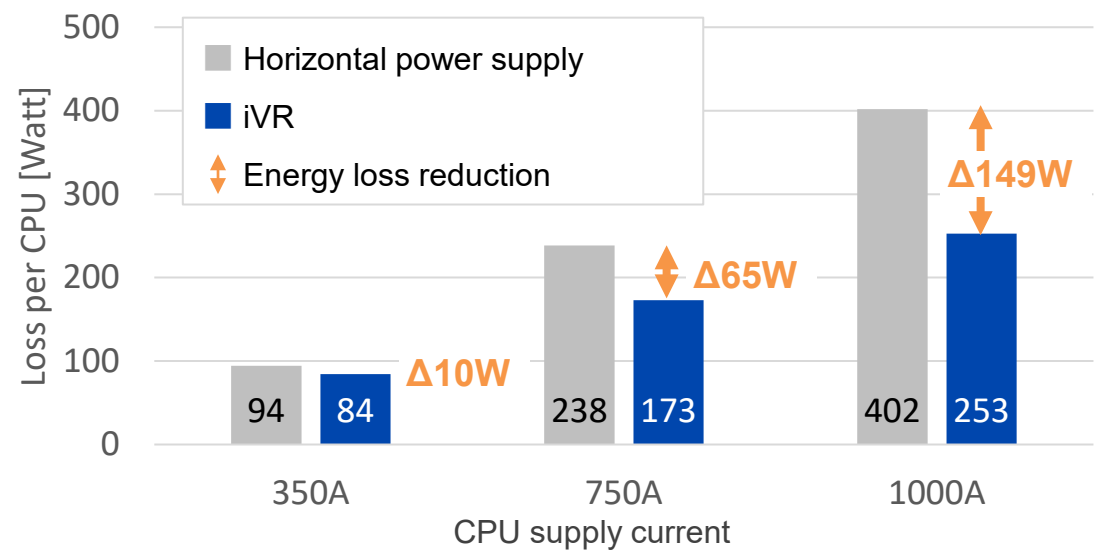


Loss comparison for CPU

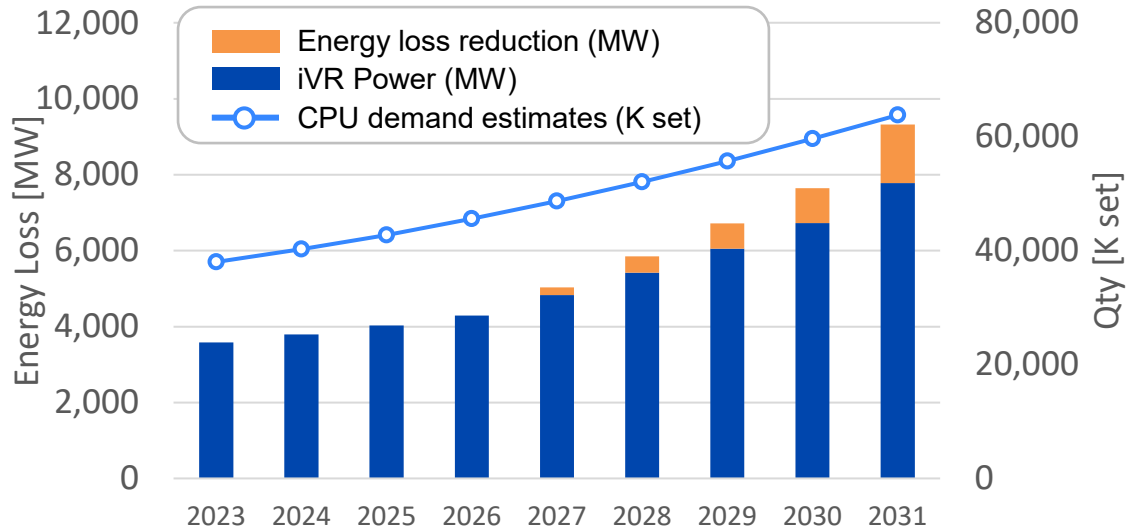
- Integrated voltage regulator may contribute to energy loss reduction



Energy loss reduction of CPU peripheral circuit

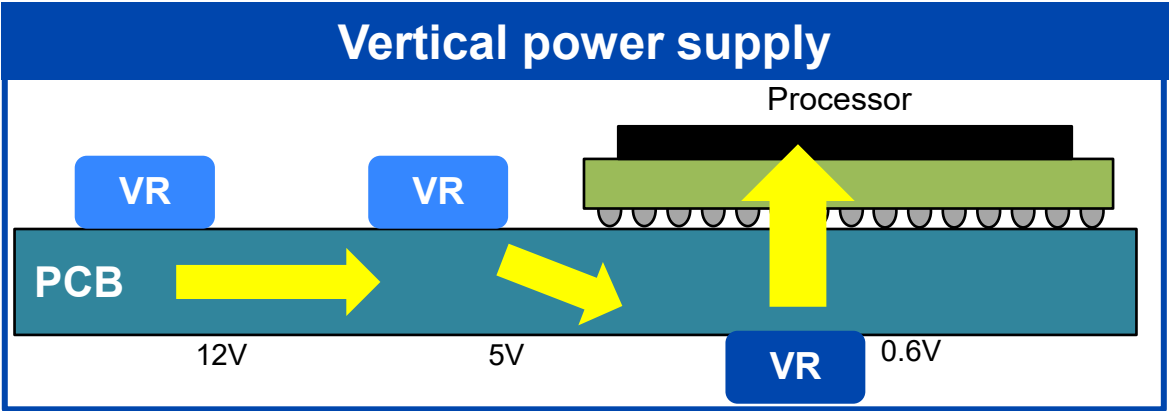
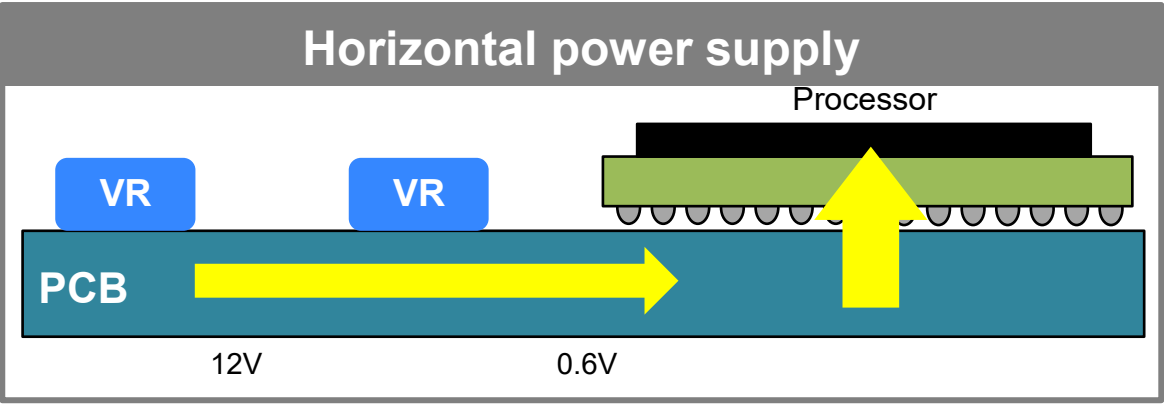


CPU demand and energy loss reduction estimation

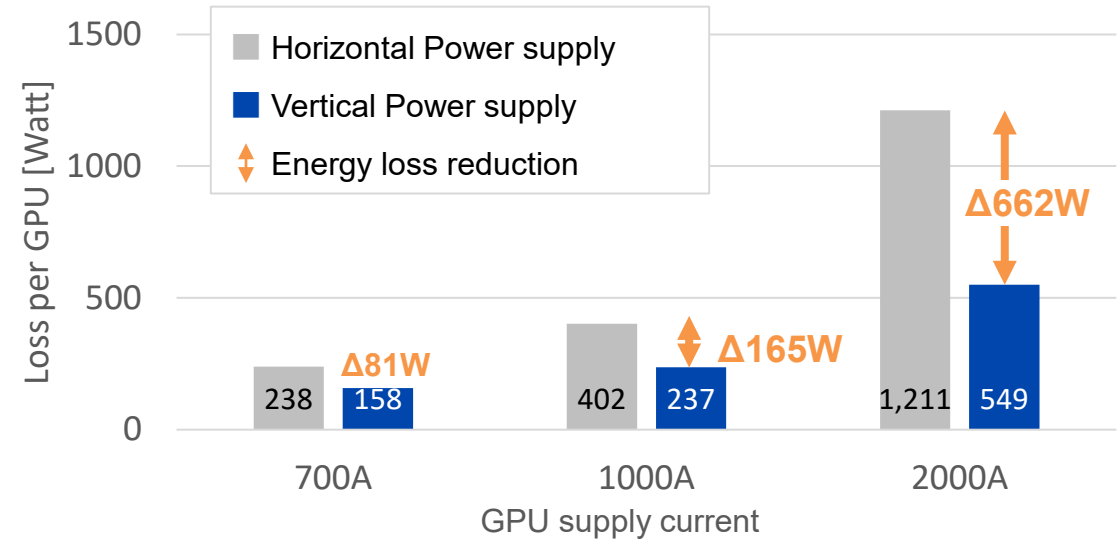


Loss comparison for GPU

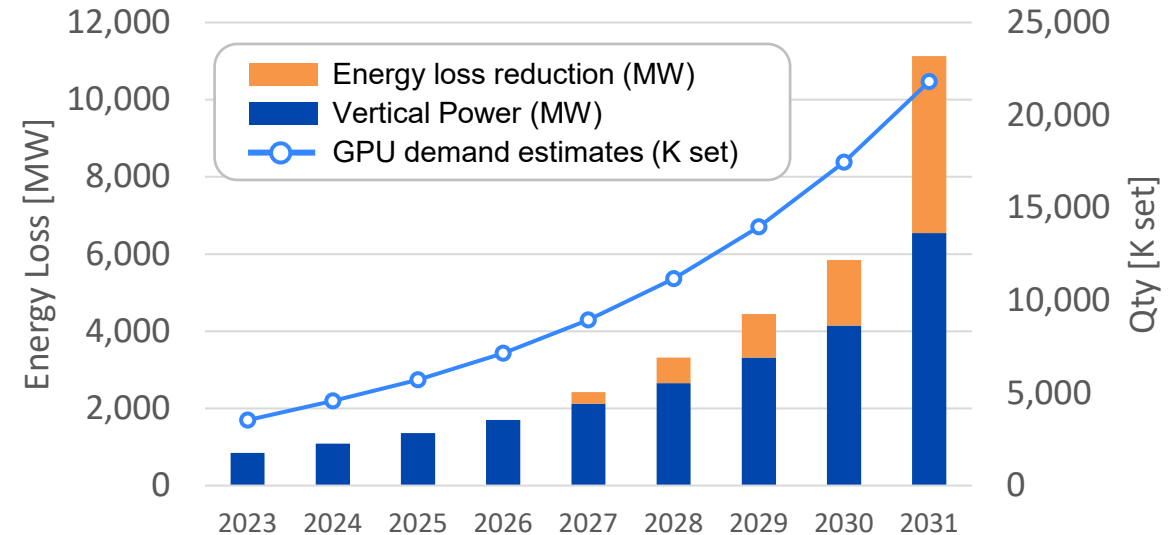
- Significant energy loss reduction is estimated by adopting vertical power supply



Energy loss reduction of GPU peripheral circuit



GPU demand and energy loss reduction estimation

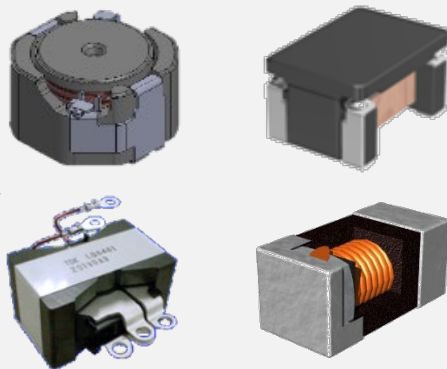


Three construction methods for magnetics products according to the application

- Product for application (required characteristics) = Materials technology (ferrite, metal) + Optimal process technology

Wire wound

Inductor, EMC filter,
Transformer



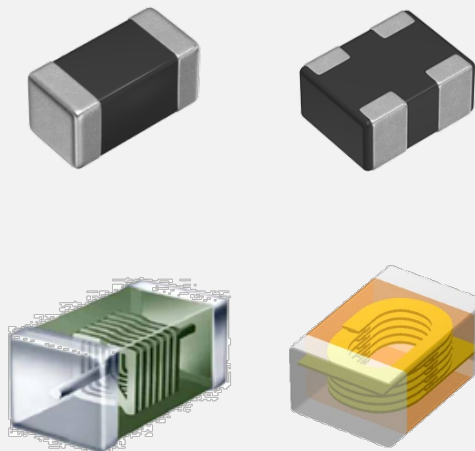
vs. 0.5mm tip of pencil



- Precision molding technology
- Winding technology / End electrode formation technology

Multilayer

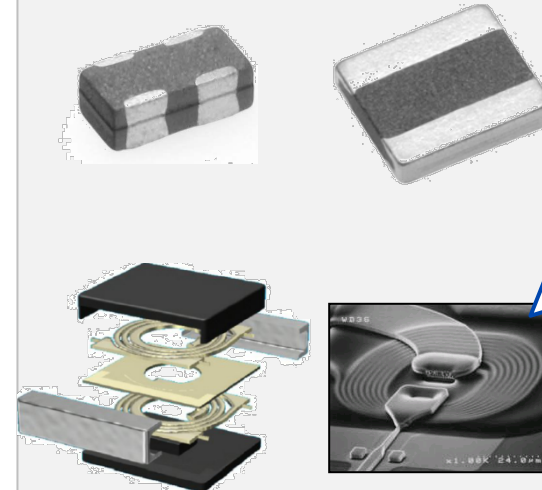
Multilayer inductor



- Precision multilayer technology
- Different materials co-firing technology

Thin film

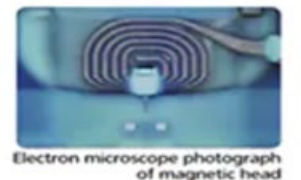
Thin film power use inductor



- Plating technology
- Fine pitch patterning technology

Head micro
technology
conversion of
coils

Thin-film HDD heads

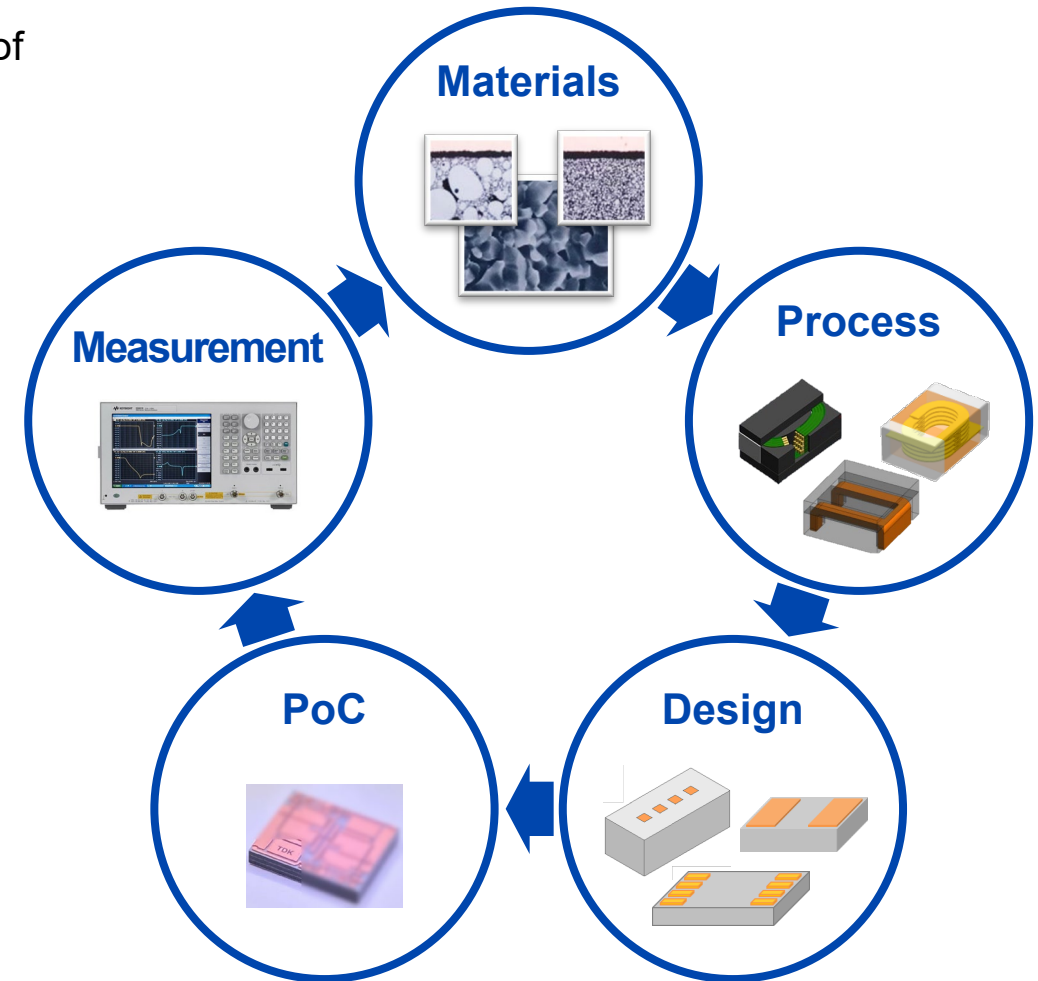
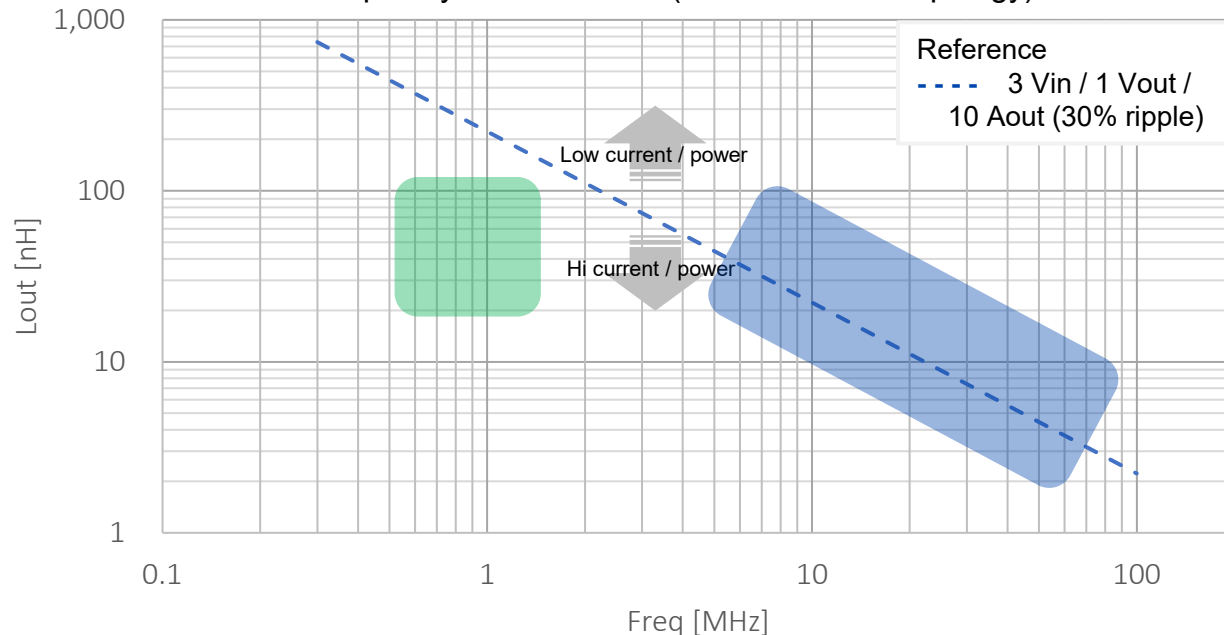


Inductors for next generation VR: Technology Approach

- Materials, processes, and design capabilities that can meet required specifications such as frequency characteristics and inductance.
 - Optimum process selection to make inductor depending on the type of voltage regulator
 - Flexible design capability to meet customer requirement
 - Proof of concept of inductor using SESUB technologies

Inductors inquired for next generation voltage regulator

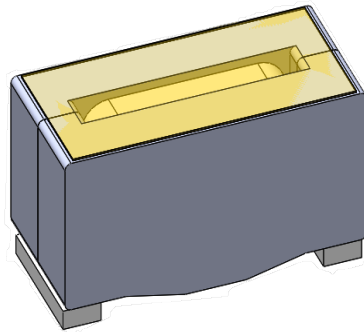
Frequency vs Inductance (Buck converter topology)



Introduction of power inductors

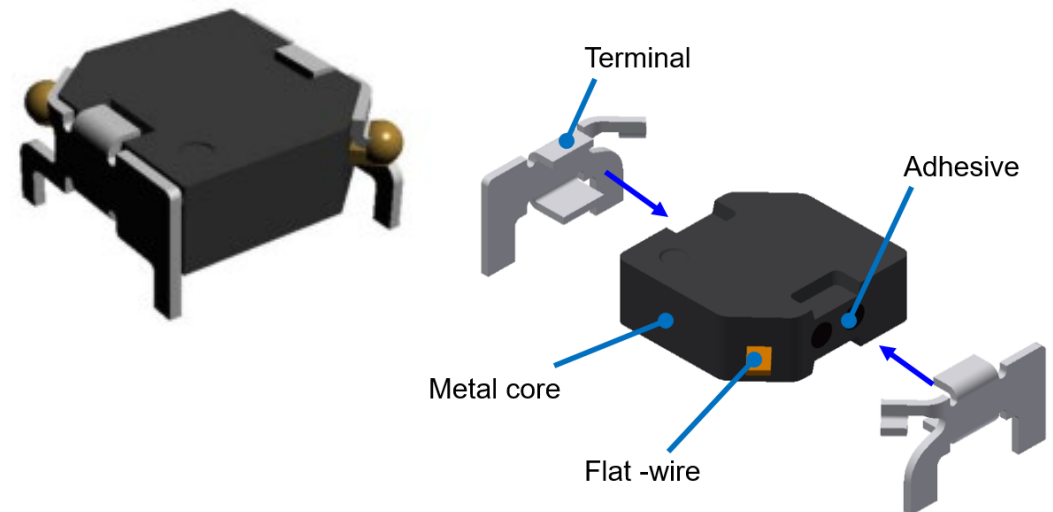
Power Inductor: VLBUC series

Demand of high-performance servers that can process large amounts of data are increasing to respond to Digital Transformation (DX). The number of inductors used in power supply circuits for high-performance server is also increasing. At the same time, demand for smaller size and higher performance inductor are increasing. We are currently developing the dual coil power inductor VLBUC series for TLVR (Trans-Inductor Voltage Regulators), which improves the load response of power supply circuits.



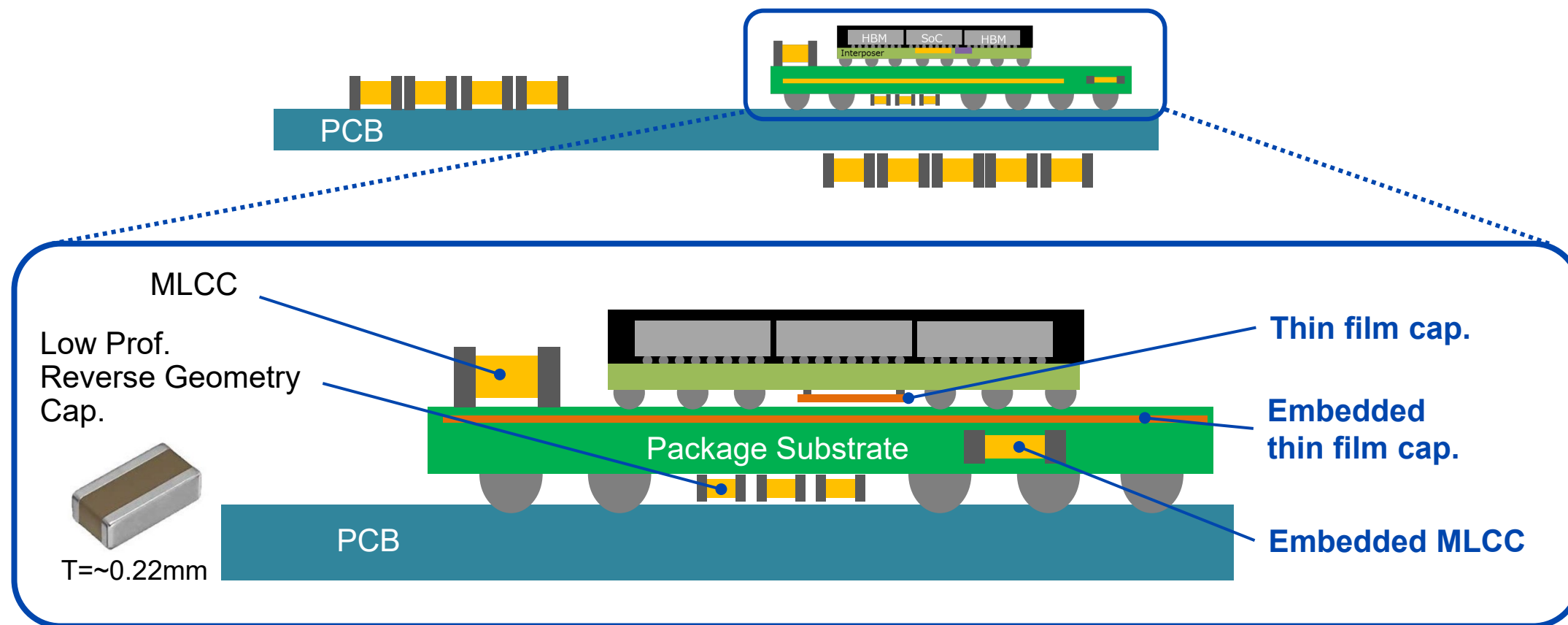
Power Inductor: SPM6020T-R68M-LE

There is an increasing demand for base station power supply boards to mount other components in the space below the inductor in order to reduce the mounting area. This product contributes to space saving on the mounting board by optimizing the shape of the external electrode and raising the inductor.



Opportunity of capacitor for new-gen. processor

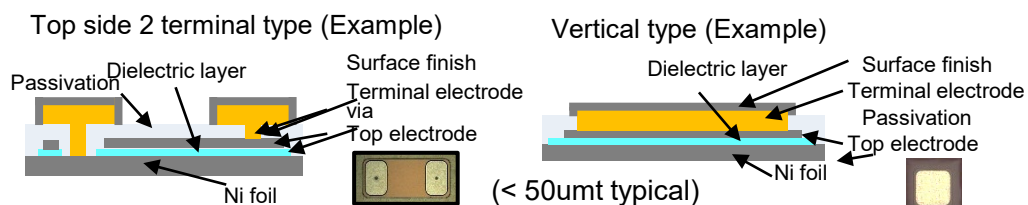
- Location of Capacitors close to Processor



Introduction of thin film capacitors

Low inductance thin film capacitors for high voltage

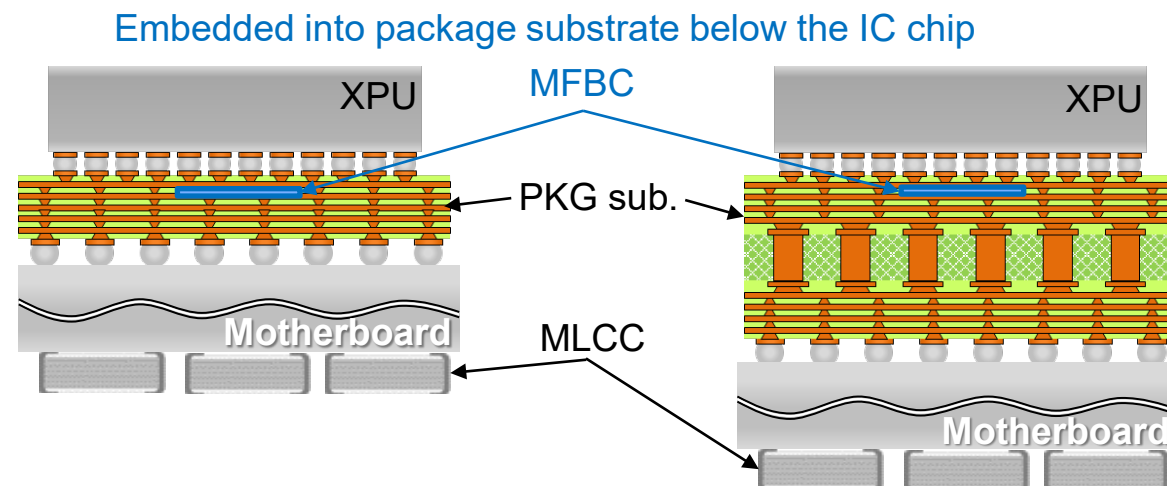
Surge and ringing voltages in high-speed switching power supply lines can be a major problem in terms of FET destruction and external noise generation. Low-inductance snubber capacitors mounted near the FETs reduce voltage fluctuations and contribute to low noise and low power consumption in power semiconductor applications. noise and low power consumption in power semiconductor applications.



Discrete capacitor

Metal foil based thin film capacitor (MFBC)

MFBCs are made using thin-film manufacturing technology cultivated in the manufacture of HDD heads and TDK's core materials technology. It features a dielectric formed on a metal foil, resulting in low ESL, high capacitance density, and low-profile that allows integration into substrates. MFBCs contribute to low noise and low power consumption as decoupling capacitors mounted directly under ICs.



Overview of Sensor Technology

Takao Tsutsui,
Vice President,
CEO, Sensor Systems Business Company

社は創造によって
文化産業に
貢献する

Contribute to culture and industry
through creativity



センサテクノロジーで
すべての人を幸福に

Sensor Technology
for the well-being of all people

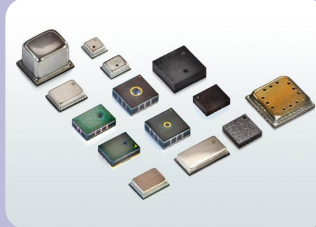
TDK Ferrite Tree and expansion of sensor technology

■ Passive component products on Ferrite tree

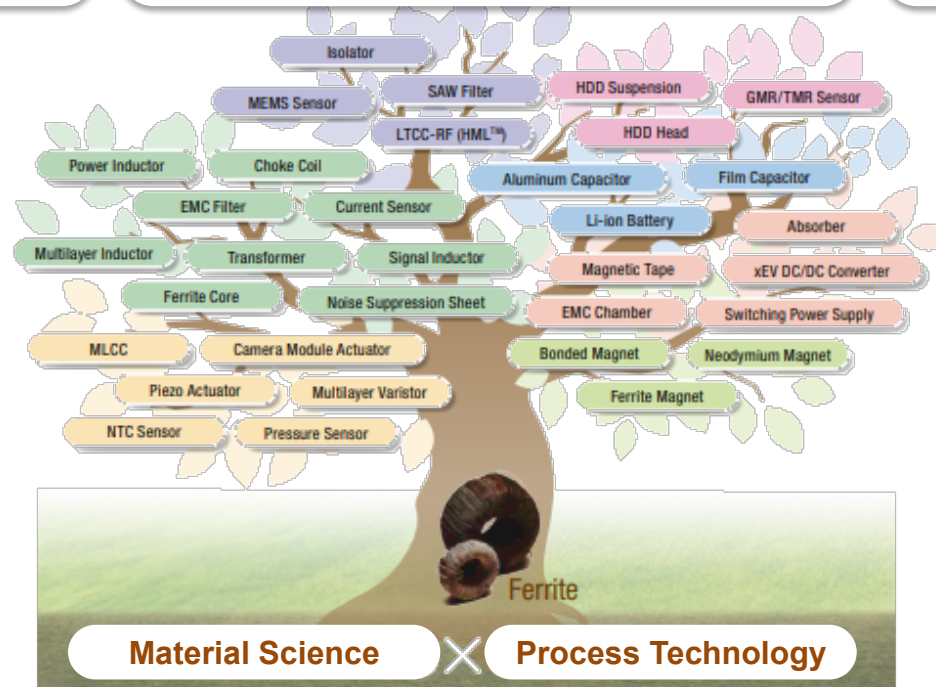
Temperature & Pressure sensor



MEMS IMU sensor & Microphone

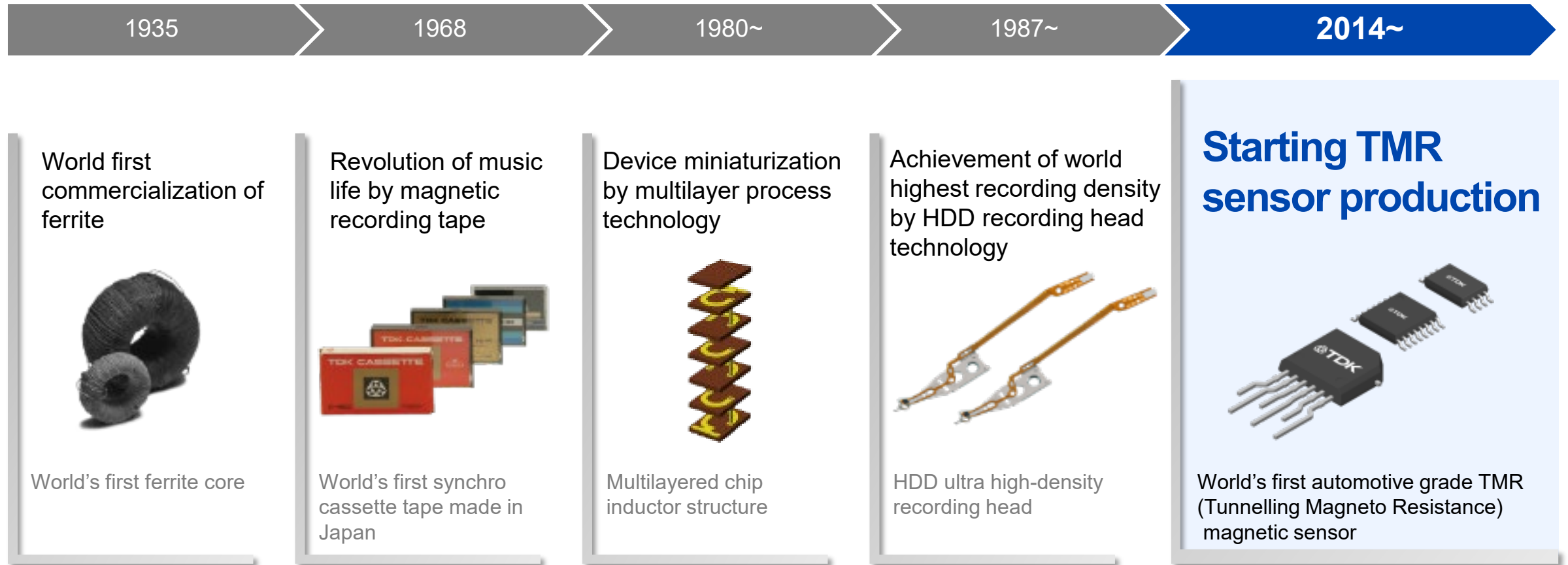


Magnetic sensor (TMR & Hall)



TDK history of market creation

■ Market creation by "Magnetic material technology and Process technology"

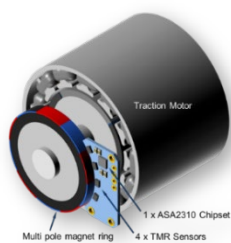


TDK TMR sensor product market

TMR application product in our life

Automotive product

Basic function: Drive, Steer, Stop



e-axis / Traction motor

- Motor angle sensor



EPS steer by wire

- Steering angle sensor



Battery management system On board charger Inverter

- Current sensor



Electric mechanical brake system

- Angle sensor for brake motor

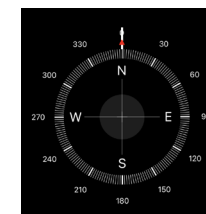
Consumer product

Smartphone, and Wearable device



Smartphone camera

- Autofocus sensor
- Image stabilization sensor



Electric compass

- Geo field magnetometer



Thermostat

- Rotation encoder sensor



Crown

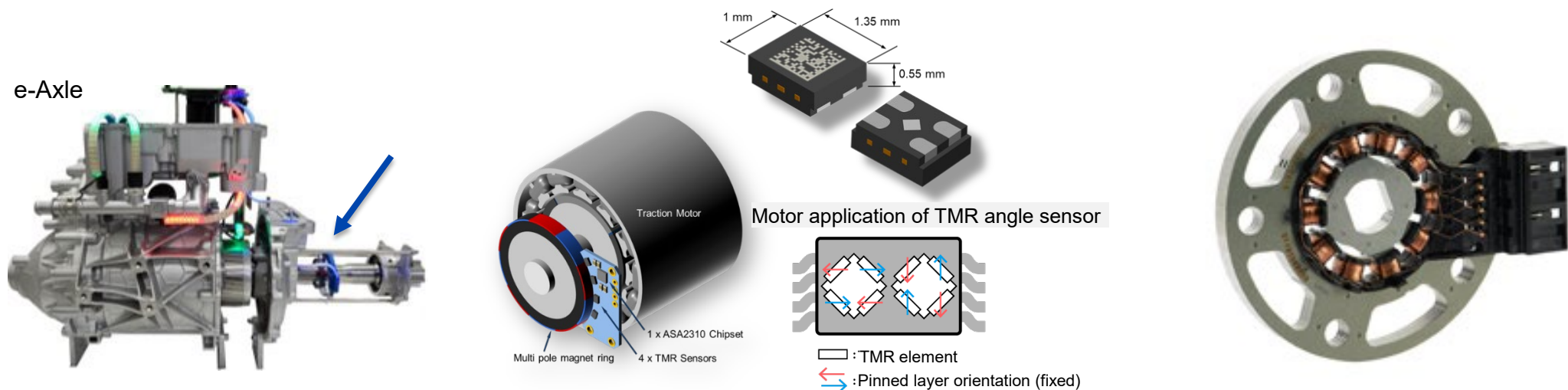
- Angle sensor

Angle sensor comparison for e-Axle – TMR sensor vs Resolver

Attracting Tomorrow



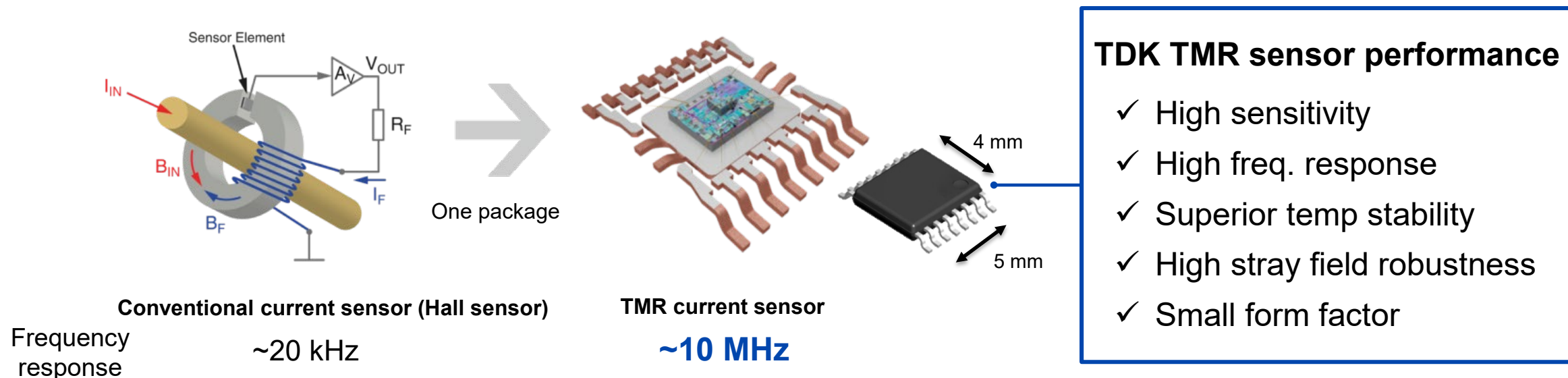
■ Device evolution by TDK TMR sensor technology



	TDK TMR angle sensor (Digital)	Resolver (z*VR Type, Stator 5X)
Angle error	$\pm \sim 0.2\text{deg}$	$\pm \sim 0.4\text{deg}$
Operation temp. range	-40 ~ 150 deg.C	-40 ~ 150 deg.C
Current consumption	13 mA	45~55 mA
Max allowable rotation speed	50,000 rpm	20,000 rpm
Redundancy	High	Low

Market creation by sensor technology

■ Energy Transformation – EX by TDK TMR current sensor technology



High accuracy, High frequency response TMR current sensor for EX

VVVF motor (Variable Voltage Variable Frequency)	High accuracy torque & speed control, Overcurrent detection
Battery EV	Battery current control, On-board charger current control, Inverter control
Power unit for industrial	High accuracy inverter control (Improve the power loss for renewable energy), Overcurrent detection

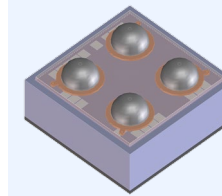
Software technology: Market creation by sensor technology

- New position sensor : Sensor fusion at system level

SmartMotion × TMR Compass

High performance 6-axis IMU sensor

- ✓ Balanced gyro design
- ✓ Low power consumption
- ✓ Low noise
- ✓ Firmware and On-chip embedded system control software (IMU + Compass)



TMR e-compass

- ✓ Ultra low power consumption
- ✓ High accuracy and low noise
- ✓ Robust on external magnetic shock

Application of indoor navigation system using magnetic field mapping

- ✓ Integration with navigation software technology
- ✓ Expansion into application software

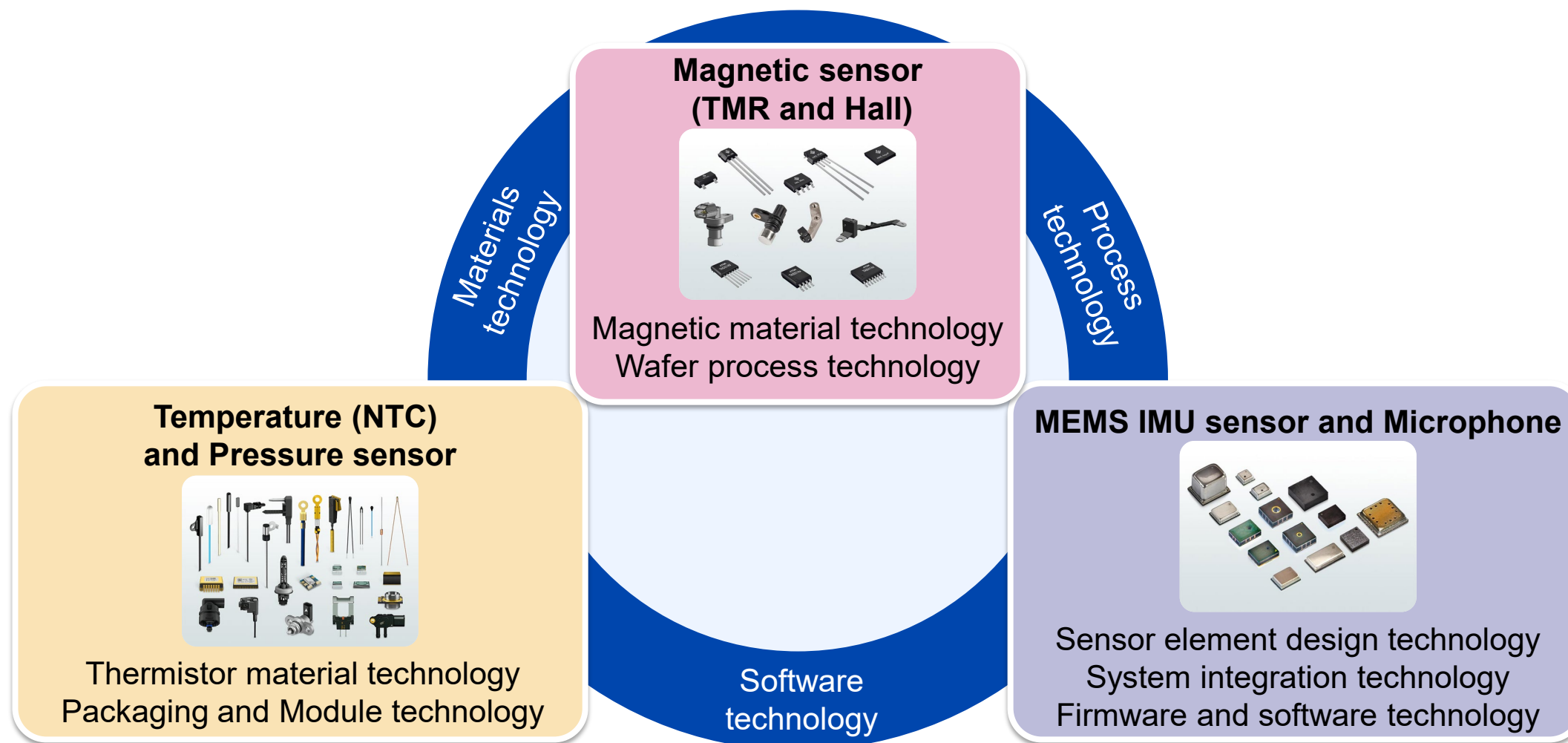


VENUE

Indoor positioning solution being developed by TDK Trusted Positioning (Calgary, Canada)

Beyond TMR, Beyond "Sensor"

- Exploit core competence of TDK SSBC business group
Market creation by — materials, process, and software technologies —



Overview of Battery Technology

Atsushi Sano,
Department Head, Energy Devices Business Group,
Energy Solutions Business Company

Energy Transformation (EX): 3 business groups driving our energy business

Attracting Tomorrow



Energy Solutions Business Company

Energy Devices Business Group

- Lithium-ion batteries etc.



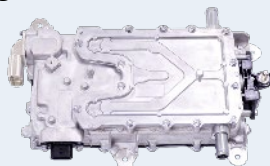
Power Systems Business Group

- Switch mode power supplies
- Power line EMC filters



Energy Systems Business Group

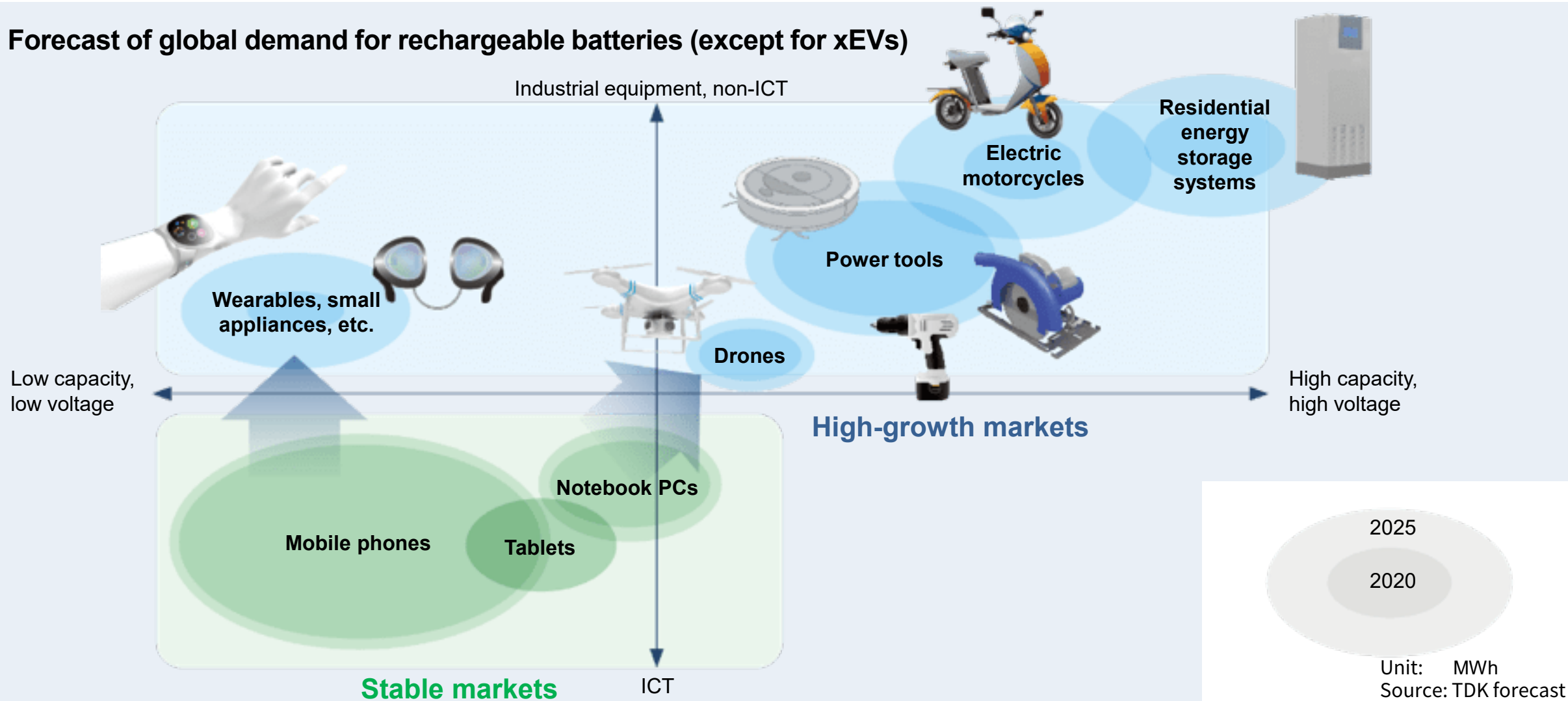
- DC-DC converters for xEVs



ATL's main plant, Ningde site (Fujian province)

Energy Transformation (EX): Expanding demand for lithium-ion batteries (LiB) in mini cell and power cell markets

Forecast of global demand for rechargeable batteries (except for xEVs)

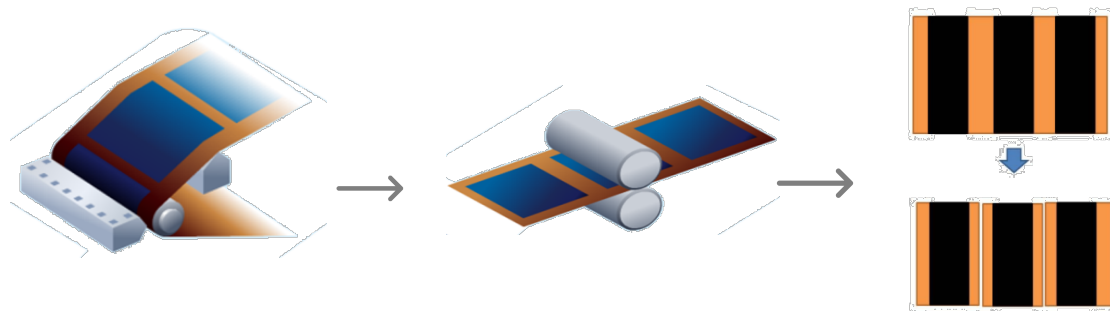


Leveraging our technology for battery production technology: Roll to Roll process

- Expanding magnetic tape manufacturing technology into electrode production technology

Mixing and Coating

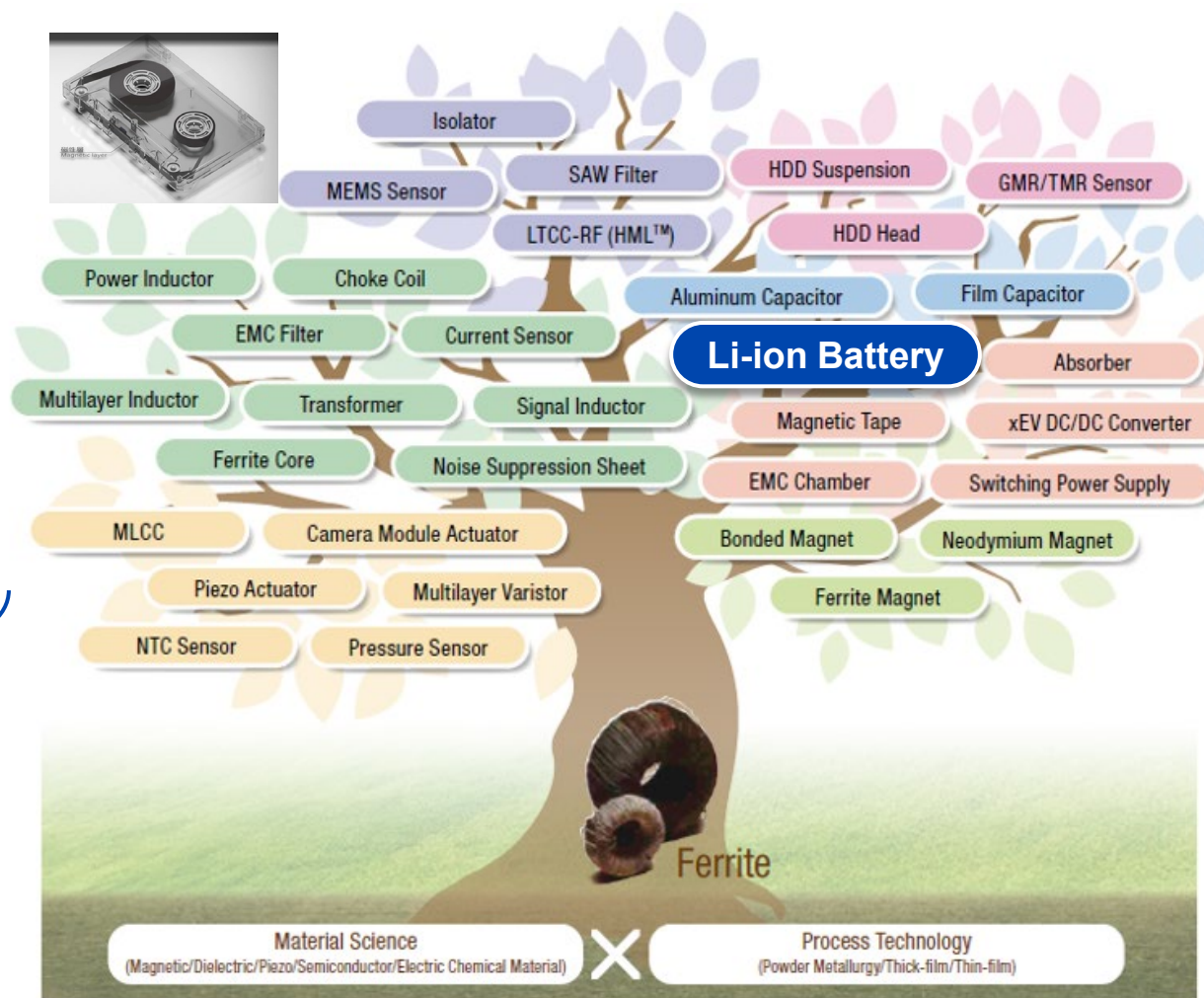
Calendering and Slitting



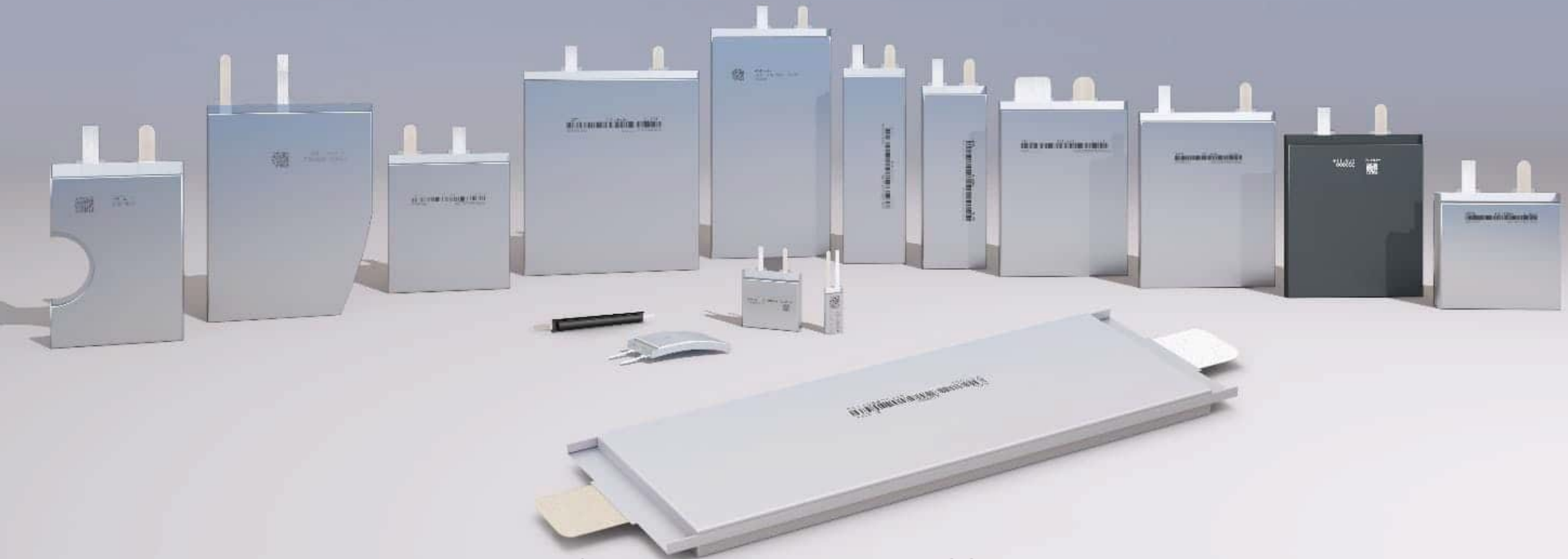
Tape and battery manufacturing share similar production processes

Applying high-precision and high-speed coating processes to battery production process

TDK Ferrite Tree



Full Range of Products ^{*Cell}



Be it tablets, smartphones, drones, AR/VR devices or household ESS, we are always switched on, and on the go. ATL is proud to design the batteries that power these electronic devices and empower the lives of countless people that have come to rely on them.

Features and 3 core technologies of small cells



High Energy Density

The energy density of cells is what determines the standby time and single charge range of such essential devices as mobile phones, laptops and tablet PCs

Silicon anode technology



Miniaturization, thinning,
and long-term use



Fast Charge

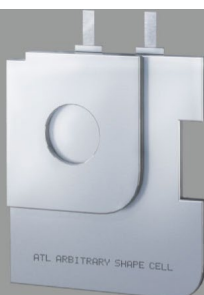
Fast charge has become an essential requirement in smart hardware development, something we have known for a while

Stacking technology

MTW technology



Ultra fast charge



Arbitrary Shaped Cell

Life is only going to get smarter. Thanks to mankind's many unthinkable technological feats, AR/VR and wearable devices

Stacking technology



Miniaturization, thinning,
and long-term use



High Power

ATL is the pioneer in High-power lithium cell technology, which is used extensively in consumer

Stacking technology

MTW technology



Long continuous use and
long life

3 core technologies of small cells

Silicon anode technology

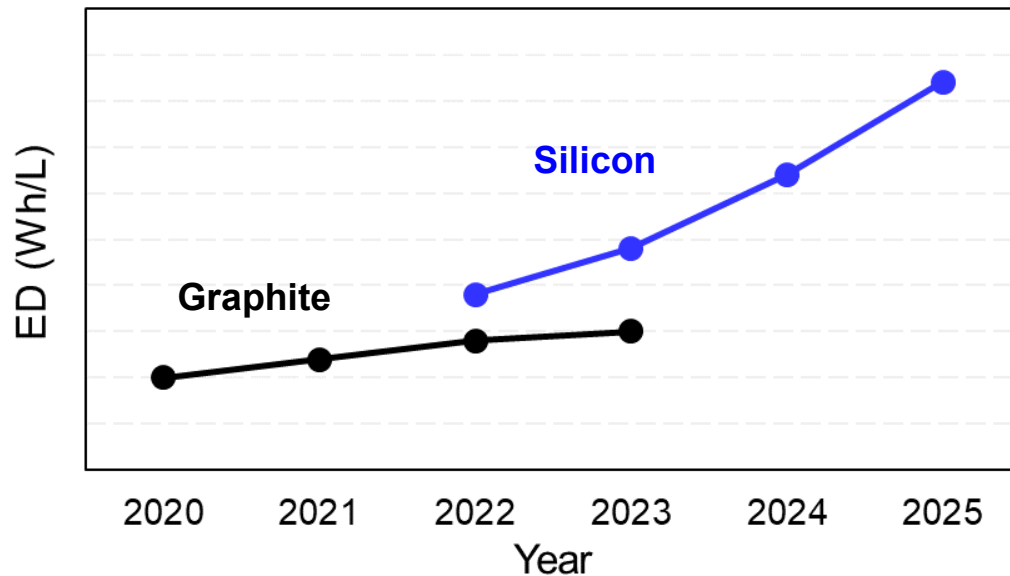
Attracting Tomorrow



■ 5% increase in energy density with silicon anode

- Potential to improve energy density by 30-40% in the future

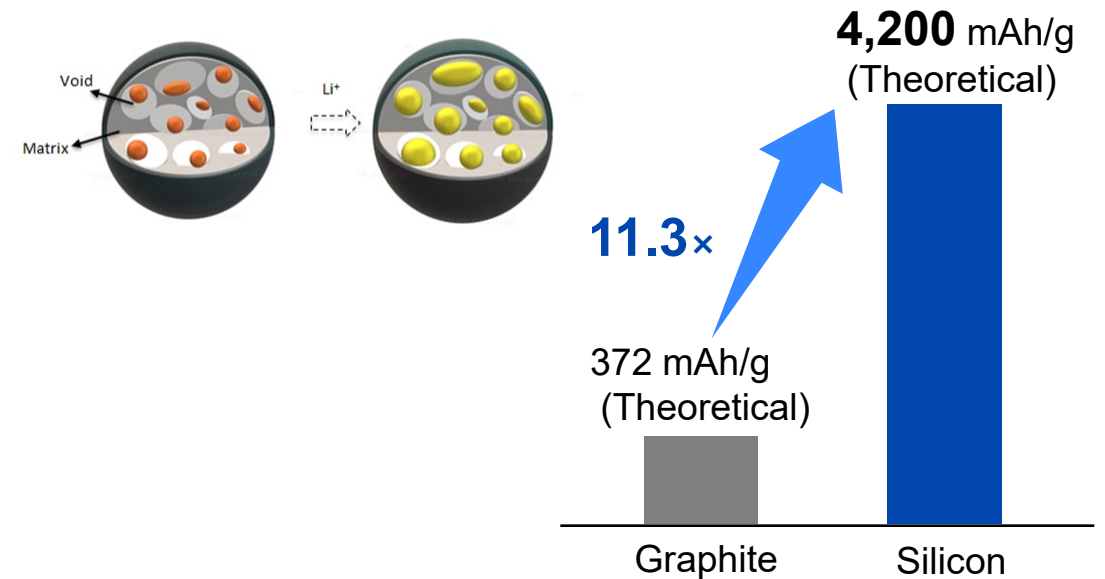
Road map of energy density



■ Innovation of silicon anode

- New structure of silicon improves stability during charging and discharging
- Design of electrode and electrolyte

Schematic of silicon anode



3 core technologies of small cells

MTW technology

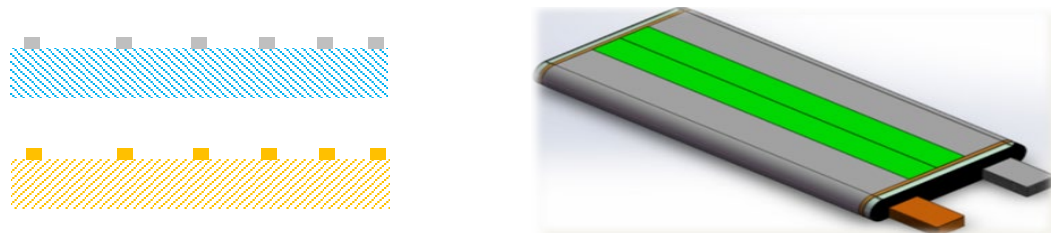
Attracting Tomorrow



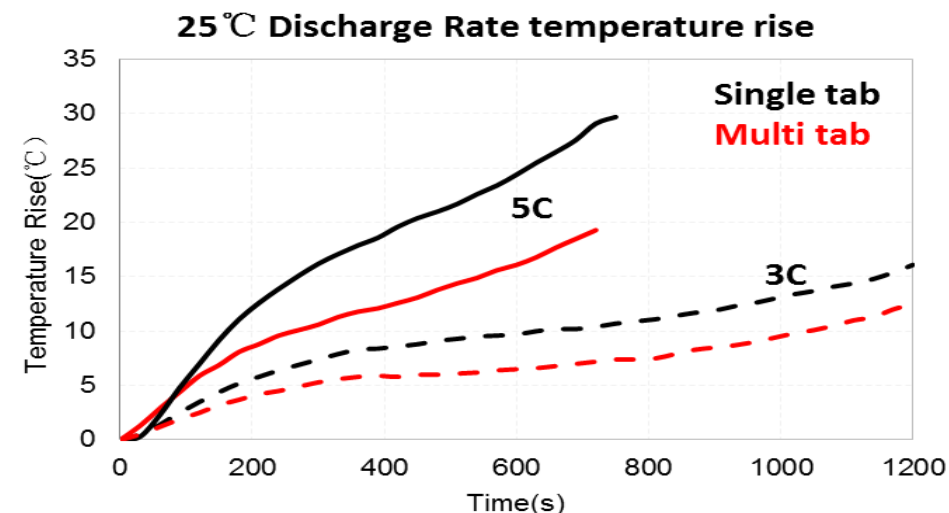
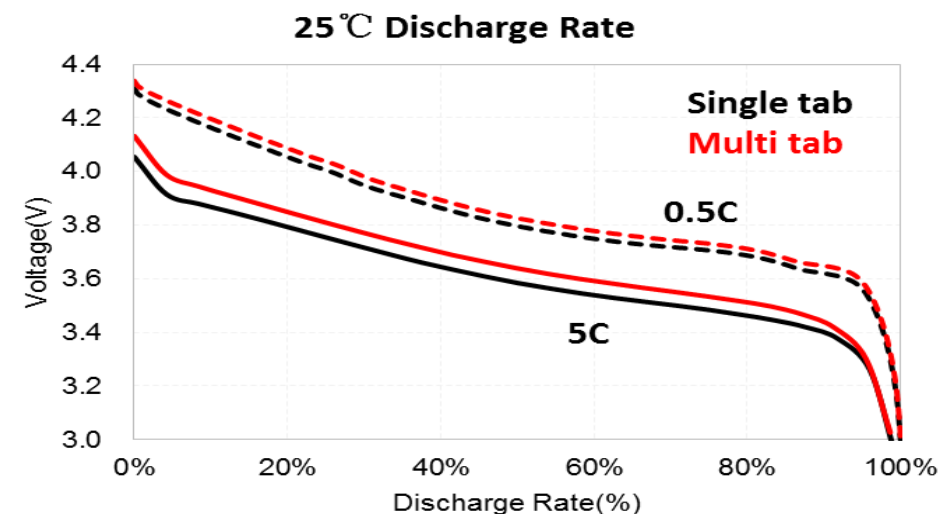
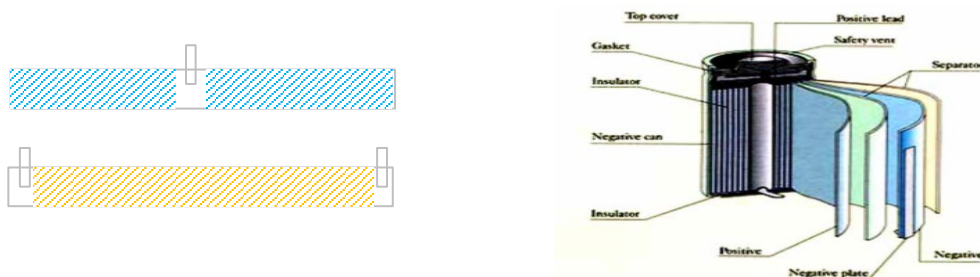
Strength of multiple-tab winding (MTW) technology

- Suppression of temperature rise
- Realize high power, long time continuous discharge, long life

Multiple Tabs Winding Structure (MTW, ATL^{IP})



Single Tab Structure



Full Range of Products *Non- ICT Pack

Dedicated on the battery of ESS, E-mobilities, Drones, Cleaners and Power Tools, Ampace provides the total solution with super safety and high reliability, high power, long life to our customers.



Features and core technologies of medium size LiB

Ultra long life of LFP cathode

Energy storage systems (ESS)

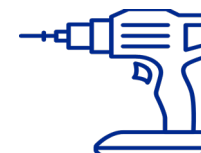
- Ultra long life (15 years→25 years)
- High safety



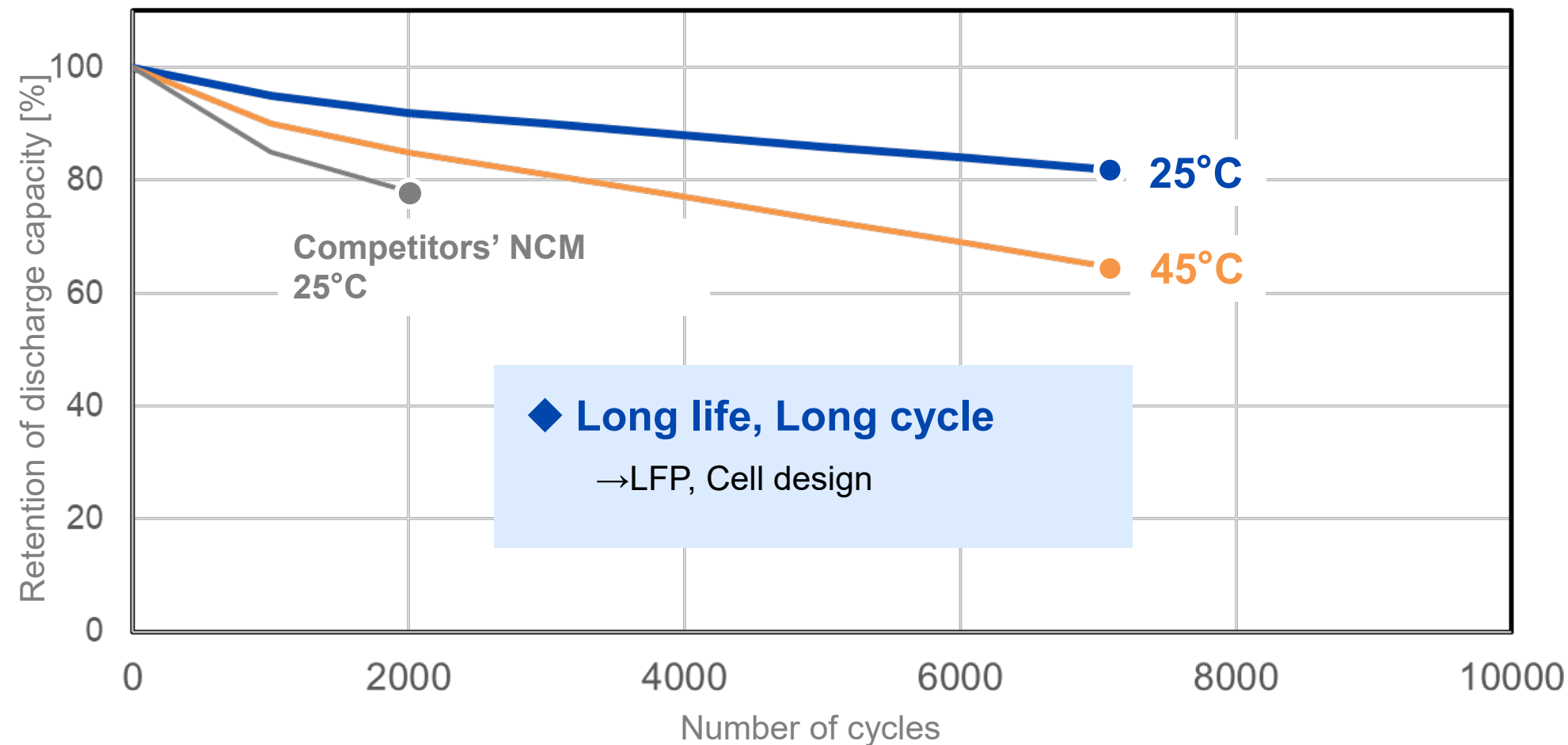
Jumbo-Power (Tab-less structure)

Industrial use batteries (Power tools, electric motorcycles, drones etc.)

- Super fast charge, high power (20 minutes charge)
- Low temperature charge/discharge (-10°C charge, -20°C discharge)
- High safety



Cycle performance of LFP cells for residential ESS



Core technologies of medium size LiB

Jumbo-Power
(Tab-less structure)

High power cylindrical lithium-ion battery Jumbo-Power 21700(JP40)



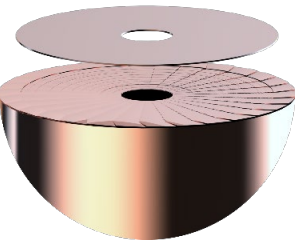
- Extremely low internal resistance through unique tab-less technology
- Long life of more than 600 cycles
- Low temperature charging ($\geq -10^{\circ}\text{C}$) and discharging ($\geq -20^{\circ}\text{C}$ @40A)
- Super fast charge of up to 80%SOC at 25°C

Major applications

- Power tools, vacuum cleaners, robots etc.

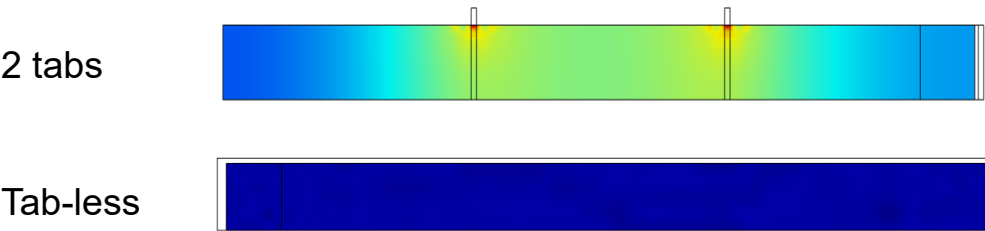
Standard discharge capacity* [mAh]	4,000
Nominal Voltage [V]	3.7
Max. Charge Rate [C]	2
Max. Continuous Discharge current [A]	45(Without temperature cut) 60(With 80°C temperature cut)
Weight (Max.) [g]	70

Features of tab-less structure



- Ultra low internal resistance (avg.2.8mΩ)
- Outstanding rate performances

Temperature rise simulation



- Compared to the 2-tab structure, Tab-less structure has a uniform and small temperature rise.

Cautionary statements with respect to forward-looking statements

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