Materials Magic
Hitachi Metals Group

Nanocrystalline, Amorphous and Powdered Amorphous Cores

APEC 2019

Mark Rine
Director Sales and Marketing
Hitachi Metals America, Ltd.

Mark Rine Bio

BS Electrical Engineering – Purdue University
MBA – University of Southern Indiana

Companies

Siemens	17 years
Spectronics, Inc.	7 years
VAC Magnetics USA (Vacuumschmelze GmbH)	9 years
Hitachi Metals USA, Llc	2 years

Current Position – Director Sales & Marketing, Hitachi Metals USA. Responsible for NAFTA Nanocrystalline materials and components sales and marketing.

Past responsibilities include – Design Engineering, Manufacturing Engineering, Operations Management, Product Management, International and Domestic Sales and Marketing

Resides in Dallas, Texas

Languages – English, German

Amorphous Metals - How Are They Unique?

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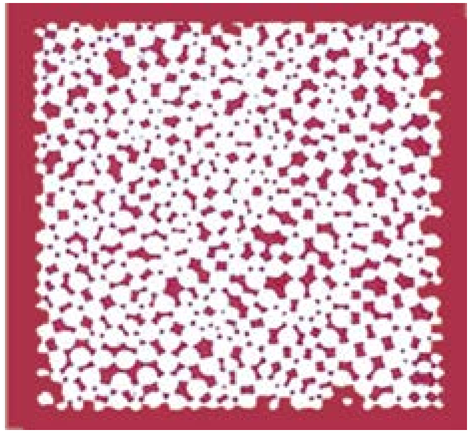
Metglas® Is Amorphous

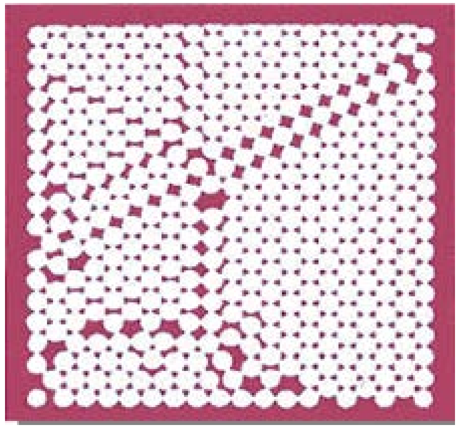
Structure Randomized by Process



- **Absence Of Structure Helps Magnetization Process**
- **Simple Heat Treatment Changes Directional Properties of Material or Core**

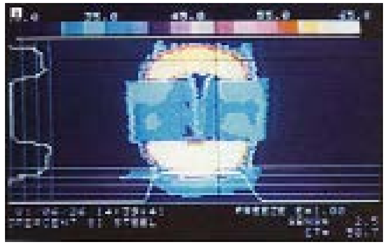
Metallic Solids Are Crystalline

Atomic Arrangement Is Regular & Periodic



- **Structural Anomalies in Atomic Arrangement Hinder Magnetization Process**
- **Structural Arrangement Modified By Thermo-mechanical (Hot Rolling) Grain Orientation**

a)



b)

Infrared Photographs of (a) Metglas® Amorphous Metal Transformer / Inductor Core & (b) Grain Oriented Steel
Heat Spectrum Radiated in Grain Oriented Core is significant compared to Metglas® Amorphous Metal Transformer / Inductor Core due to its significant core losses

Random Structure Gives Enhanced Performance

Rapid Solidification Material Casting Process

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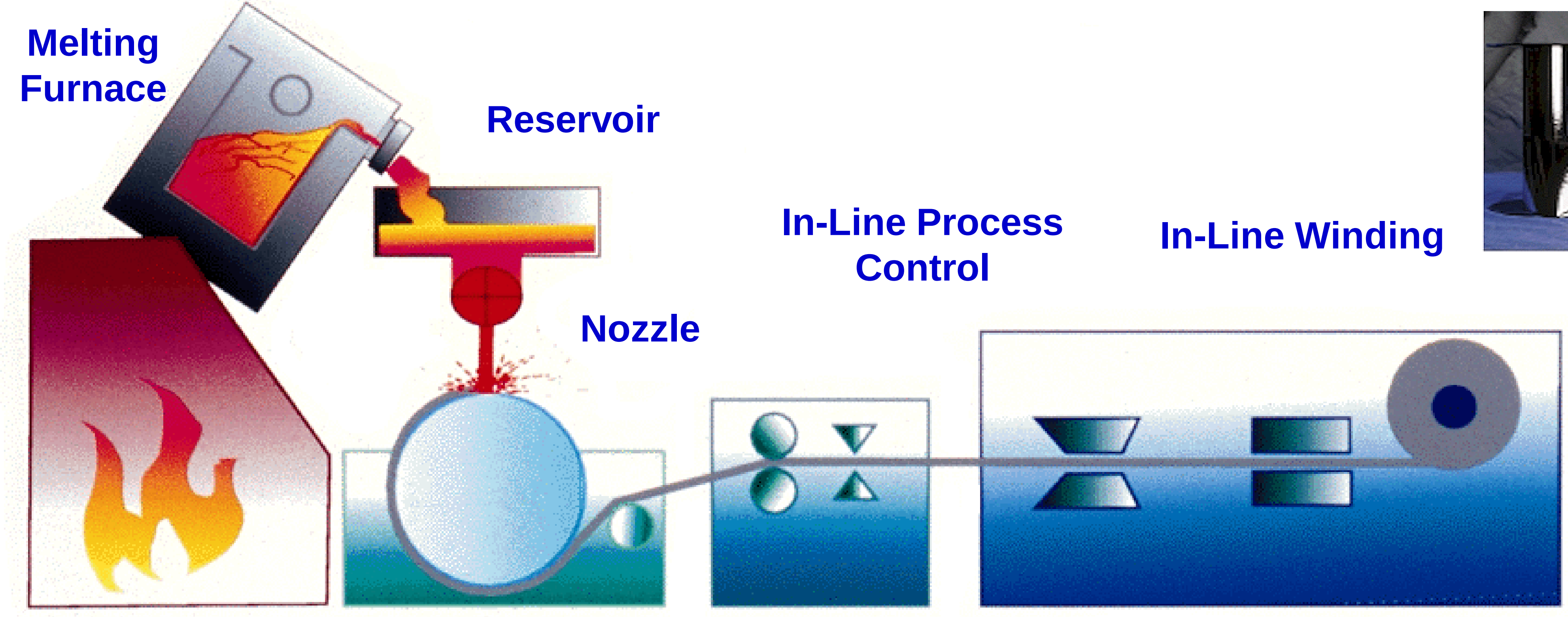
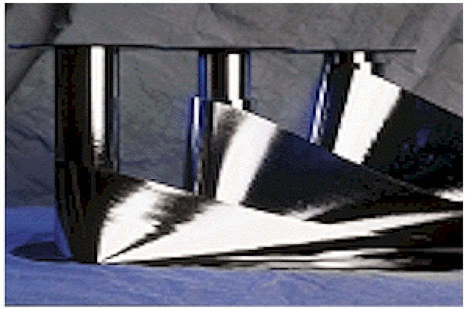
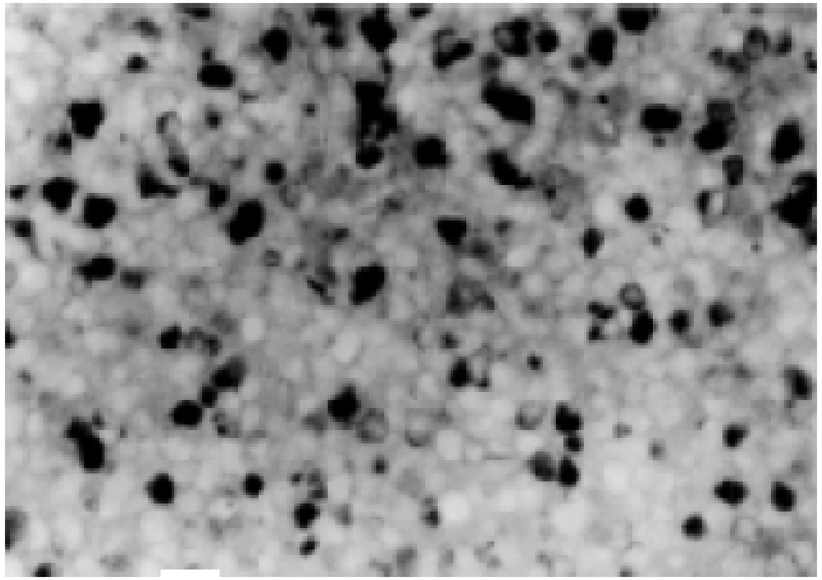




Unique Process Allows For Enhanced Properties

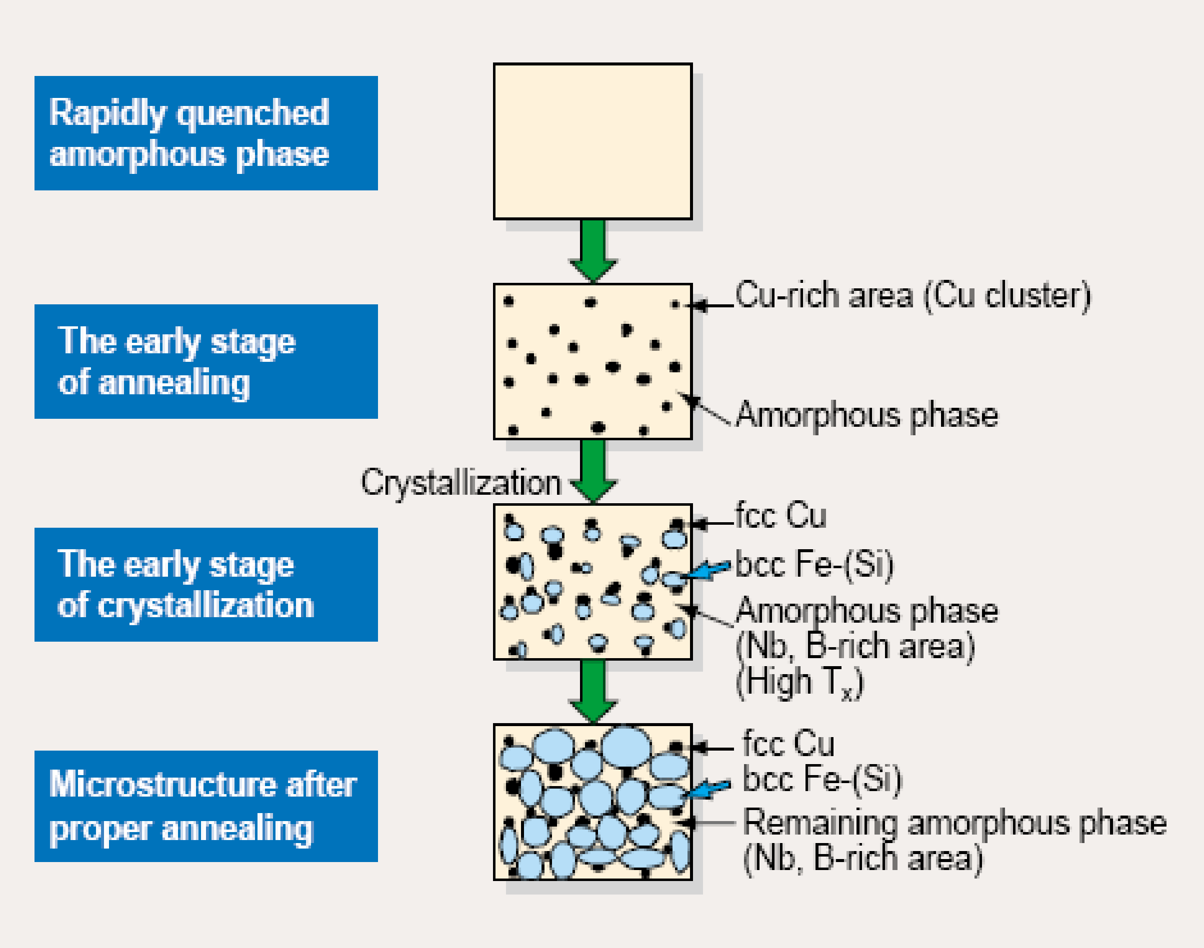
FINEMET® Soft Magnetic Material Products



j. 3 Microstructure of FINEMET®

20nm

Material Comparison	Chemical Composition	Crystal	Magnetic property
Crystal		Big	Normal
Amorphous	Fe, Si, B	None	Good
Nano-crystal FINEMET®	Fe, Si, B, Cu, Nb	Small (≒10nm)	Excellent



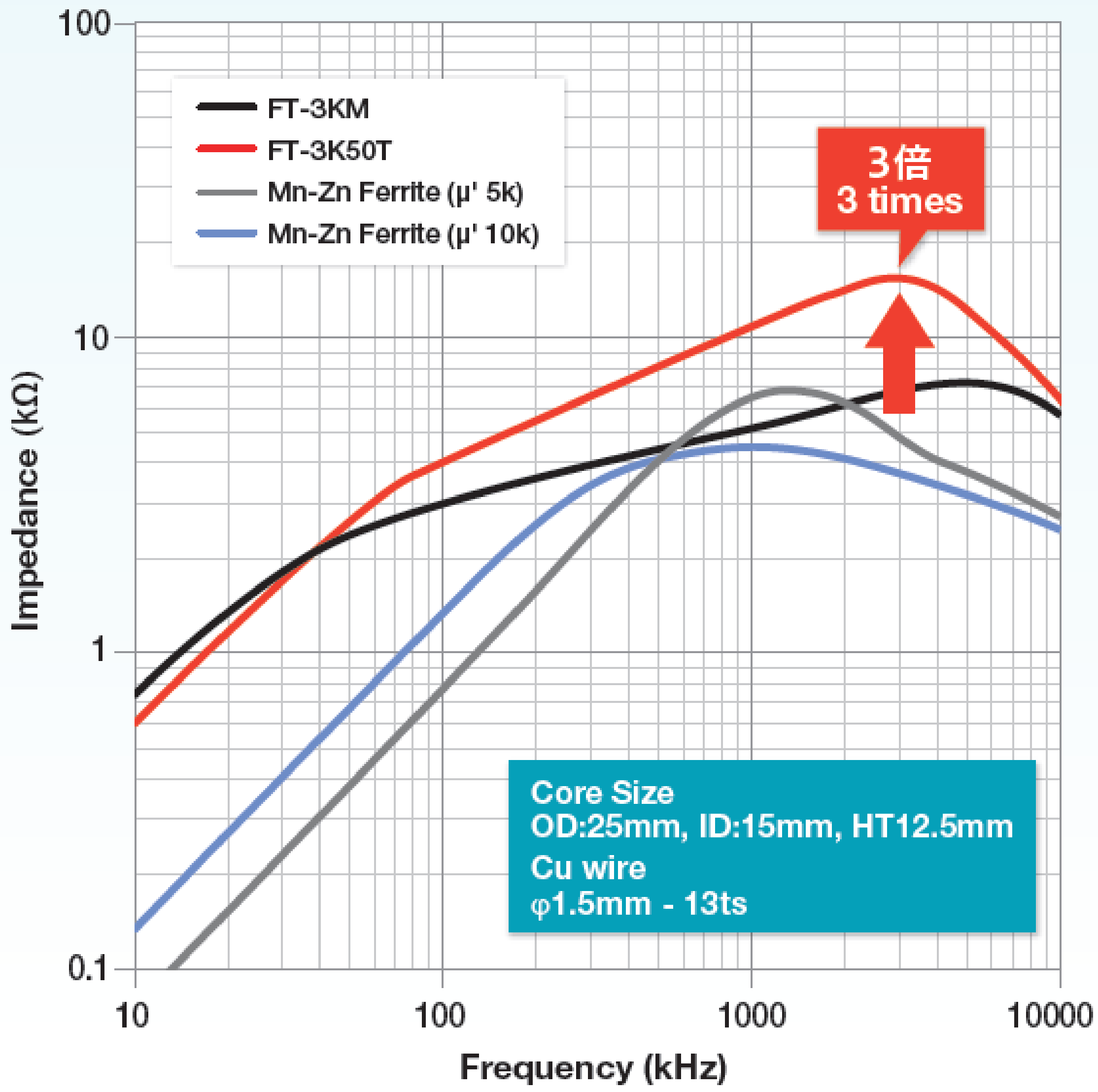
Key Magnetic Core Design Criteria

- Size and Weight
- Efficiency (Core Loss)
- Solution Cost

FINEMET versus Ferrite Material Properties

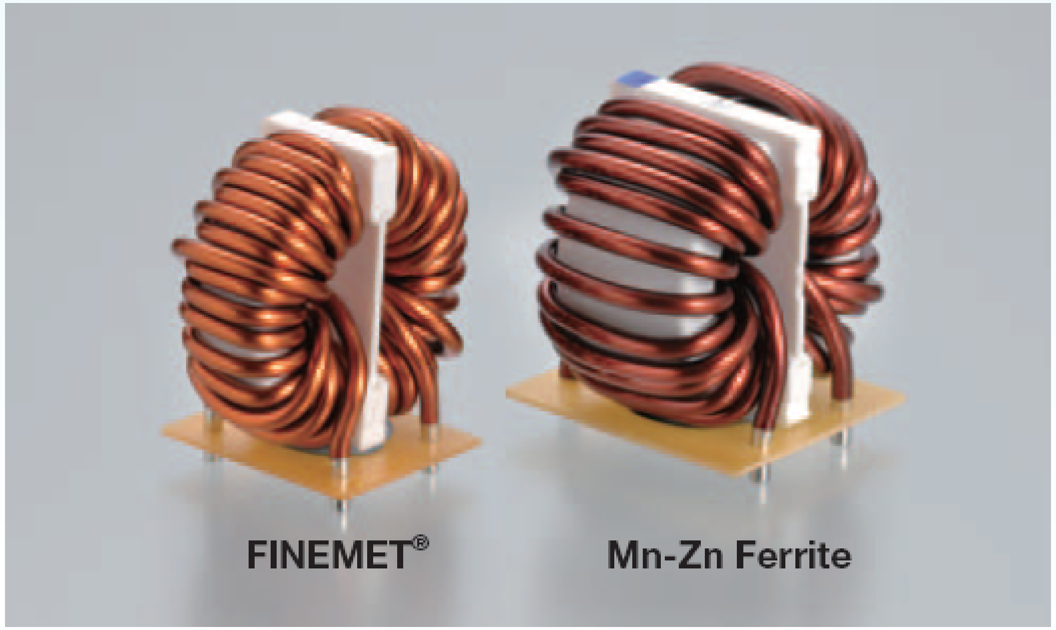
Material	FINEMET (Nanocrystalline)	Ferrite
Material Composition	Fe Si (75 / 25%)	MnZn
Permeability (max at 10Khz)	500 to 100,000	15,000
Saturation Induction Bsat	1.2 Tesla	0.4 Tesla
Core Loss W/Kg (100Khz, 0.2T)	20 (FT-3K50T) and 35 (FT-3KL)	120
Curie Temperature	550- 570 deg C	200-300 deg C
Max Continuous Operating Temperature	150 deg C	100 deg C

FT-3K50T Impedance vs Frequency



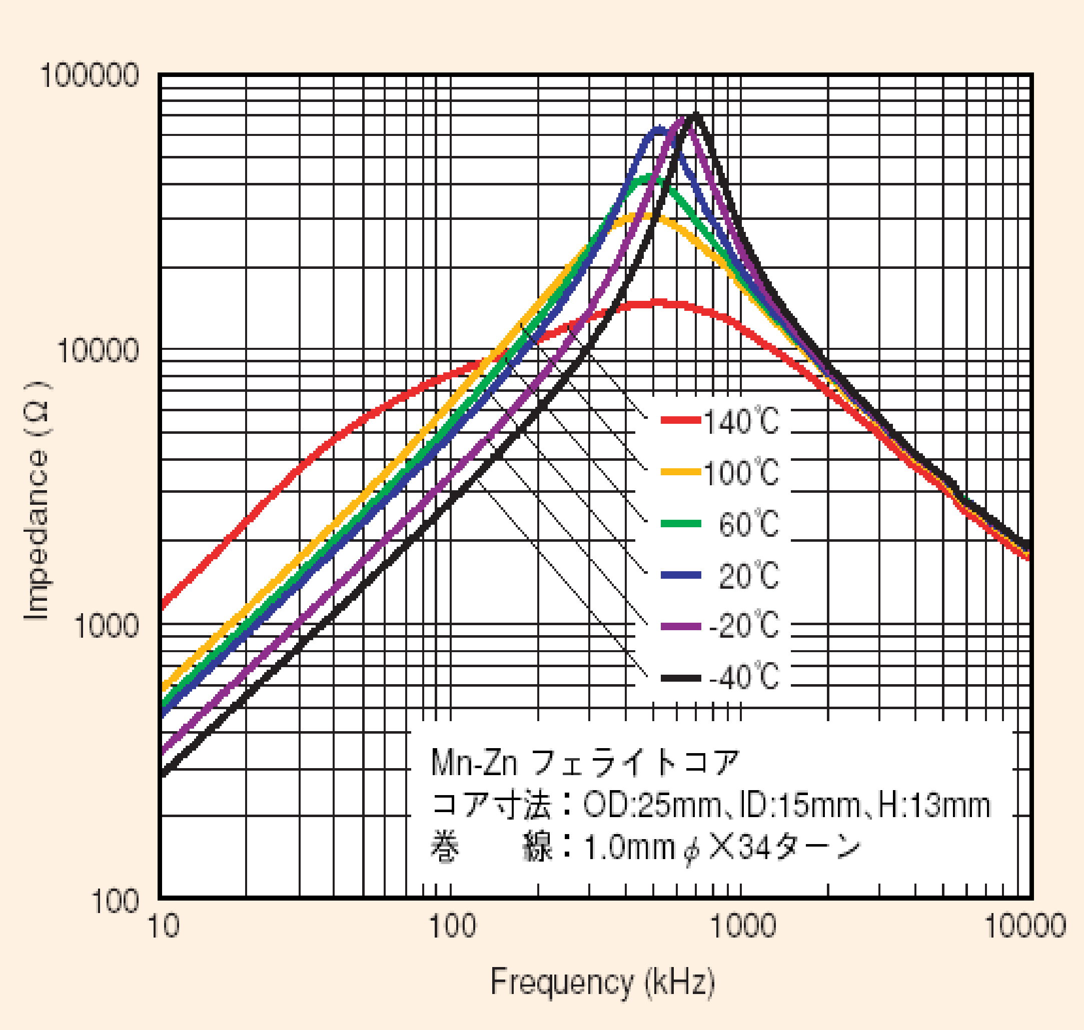
	FT-3K50T	Mn-Zn
Volume	24cm³ (55% of Mn-Zn)	44cm³
Weight	55g (53% of Mn-Zn)	104g

Spec.; Rated Current 20A, 3mH at 100kHz

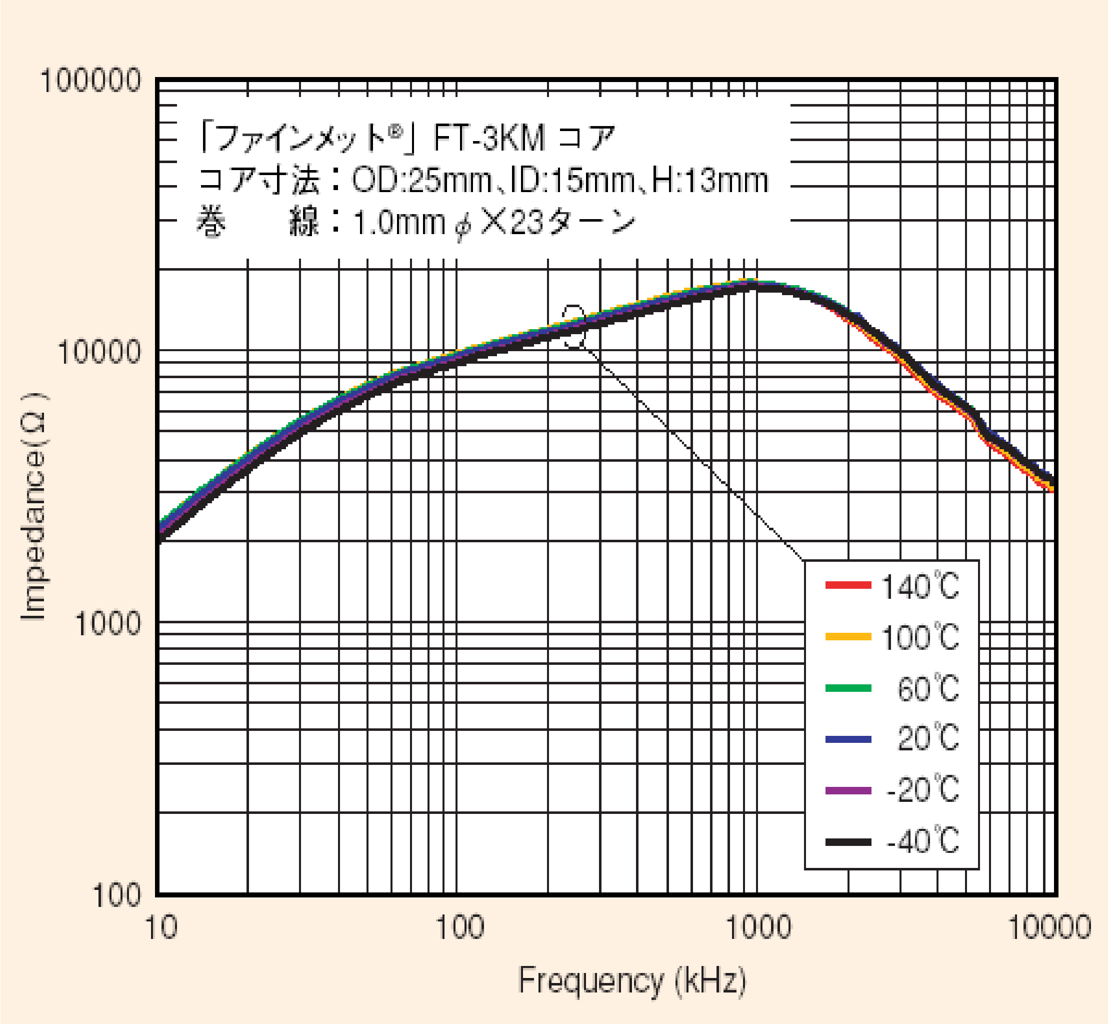


FINEMET Temperature Stability vs Ferrite -40 deg C to +140 deg C

MnZn Ferrite CMC



FINEMET CMC



FINEMET Advantages

- Filter Order Reduction (excellent low frequency and high frequency performance)
- Core Size Reduction
- Core weight reduction
- Thin ribbon material offers high frequency higher permeability than competitive nanocrystalline tapes offering same L with less cross sectional area (lower cost, small size / weight)
- Energy efficiency (reduced core loss -transformers, lower DCR-CMC)
- Ease of design (constant u over temperature)
- Mechanical shock / vibration (no chip and crack specification)
- Improved conduction emissions performance can sometimes lead to reduced radiated emissions.

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FINEMET Applications

- Common Mode Chokes
  - High frequency attenuation across FCC/CISPR range (150 kHz – 30 MHz)
  - Size / Weight reduction (high permeability material)
  - Can be cost reduction (Filter order reduction)
  - High temp capability / Consistent temp performance

- Medium Frequency transformers
  - High Bsat (1.2) = reduced core size
  - Low core loss compared to ferrite
  - Effective in 10 kHz – 80 kHz frequency range

- Wireless Charging Receiver / Transmitter Core (Qi standard)
  - High Bsat (1.2) = less magnetic material required. Thin package profile.
  - Thin tape construction / packaged in laminated sheet form

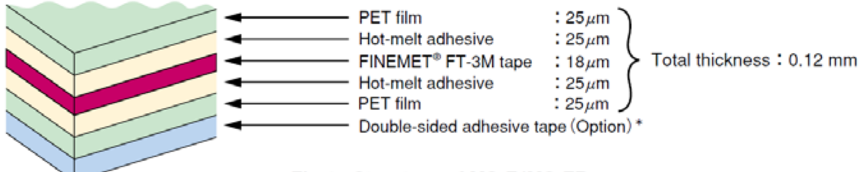

Fig.1 Structure of MS-F/MS-FR

- Current Transformer
  - High permeability and low core loss = low amplitude error and low phase angle error so can meet ANSI / IEC 0.2 / 0.5 accuracy standards for energy metering with calibration.
  - Capable of <1% uncalibrated accuracy for datacenter monitoring.

Option 2

Metglas® Amorphous Metal – 2605HB1M Alloy

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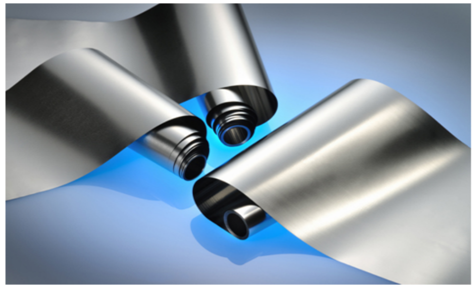
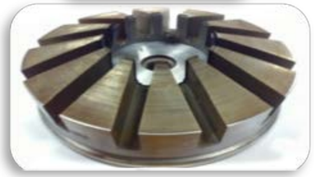
Metglas® Amorphous Metal



Transformers

Distribution Transformers, Industrial Transformers



Motors

Amorphous Electric Motor, Stator, EV

Renewable Energy

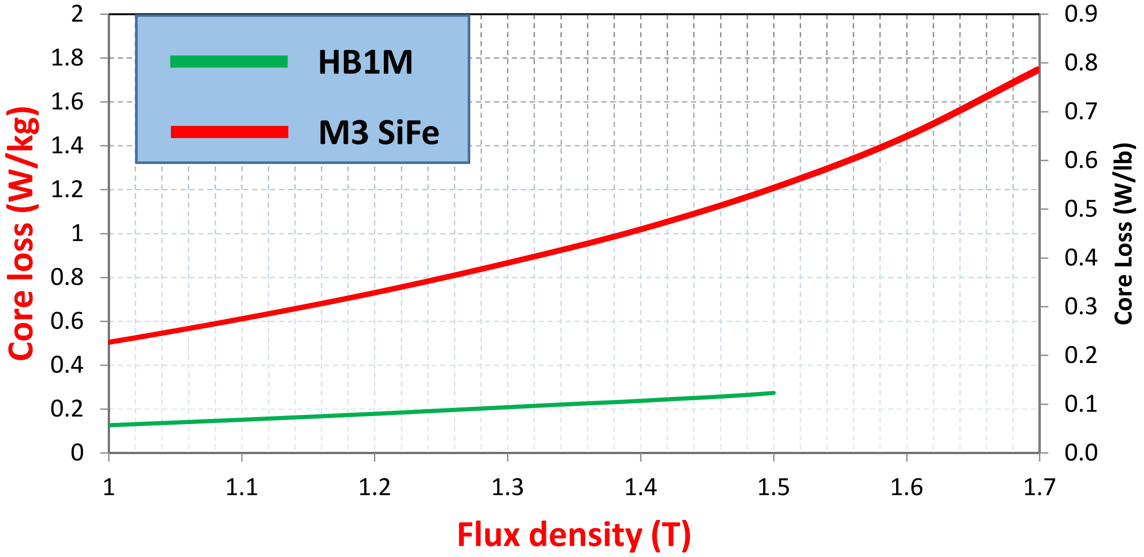
Wind Turbines, High Efficiency Inverters, C-Cores

Soft Magnetic Materials with:

- Extremely Low Core Loss, 35% of M3-Grade GOES core loss in finished cores
- High Permeability
- High Efficiency
- Smaller Size and Weight

Electromagnetic Properties for 2605HB1M Alloy

Saturation Induction (T)	Electrical Resistivity (μΩm)	Magnetostriction (x10-6)	Curie Temperature (°C)
1.63	1.2	27	364



POWERLITE® - Amorphous Metal Cut Cores

Physical Properties METGLAS Alloy 2605SA1

Ribbon Thickness (µm)	.25
Density (g/cm3)	7.18
Thermal Expansion (ppm/°C)	7.6
Crystallization Temperature (°C)	505
Curie Temperature (°C)	392
Continuous Service Temperature (°C)	150
Tensile Strength (MN/m2)	1k-1.7k
Elastic Modulus (GN/m2)	100-110
Vicker's Hardness (50g load)	860

Application - Differential Mode Chokes / Transformer

- Alternative Energy Power Supplies
- UPS system magnetic components
- Electric Vehicle
- Welding and Plasma cutting
- Medical

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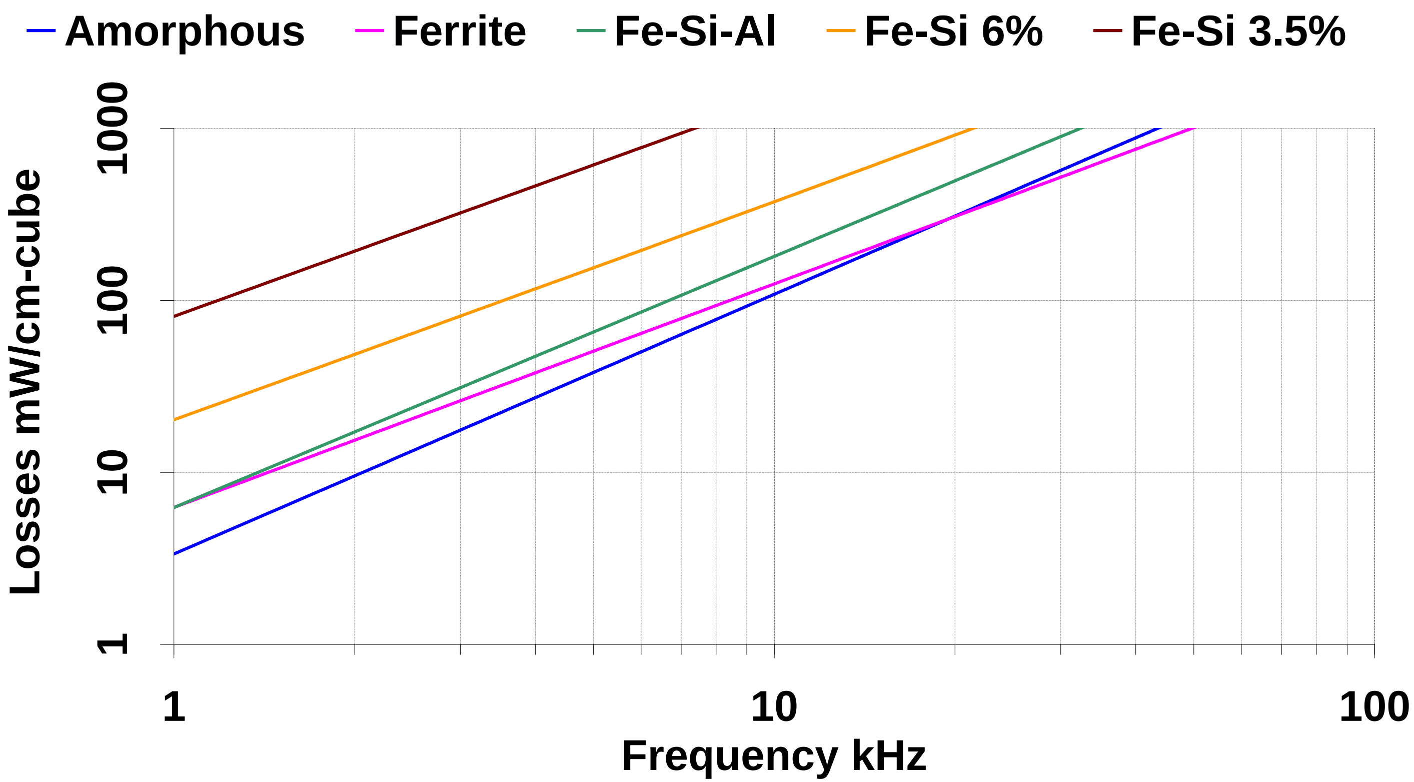
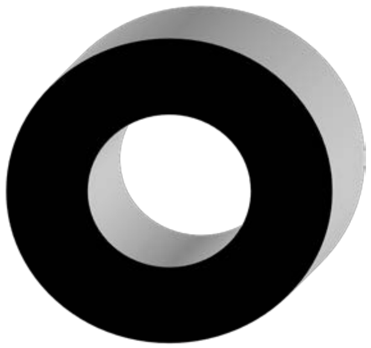
Magnetic Properties METGLAS Powerlite Cores

Saturation Flux Density (Tesla)	1.56
Permeability (depending on gap size)	VARIABLE
Saturation Magnetostriction (ppm)	27
Electrical Resistivity (µ Ω cm)	137



Microlite Distributed Gap Cores



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Unique combination of high saturation flux density & low loss make Microlite the first choice for all energy storage applications while there distributed gap format renders a distinct RFI advantage to conventional air gap cores enabling the designer to achieve both size & system cost reduction

• Higher Bsat for smaller component size	B_{sat} 1.56 Tesla
• High permeability	u ~ 250 Less turns, lower Cu loss
• Extended Bias property	Better retention (%L vs. DC bias)
• Lower Magnetic Losses	85 W / kg @ 100kHz, 1000 Gauss
• Higher thermal conductivity	Ensures good heat dissipation
• Higher Curie temperature	395 C
• Excellent permeability @ high frequency	95% @ 1000kHz
• High continuous Service Temperature	150 C

Parameters	Microlite	Iron Powder	MPP	Kool Mu	Ferrite
Bsat	1.56	1.0-1.4	0.75	1.1	0.35
Permeability	245/380	75	125	125	Gap Based
Core Loss (W/kg)	<80/60	680	65	140	<65
% Perm	50	50	50	50	<25
Turns	1	1.8	1.1	1.1	2.1

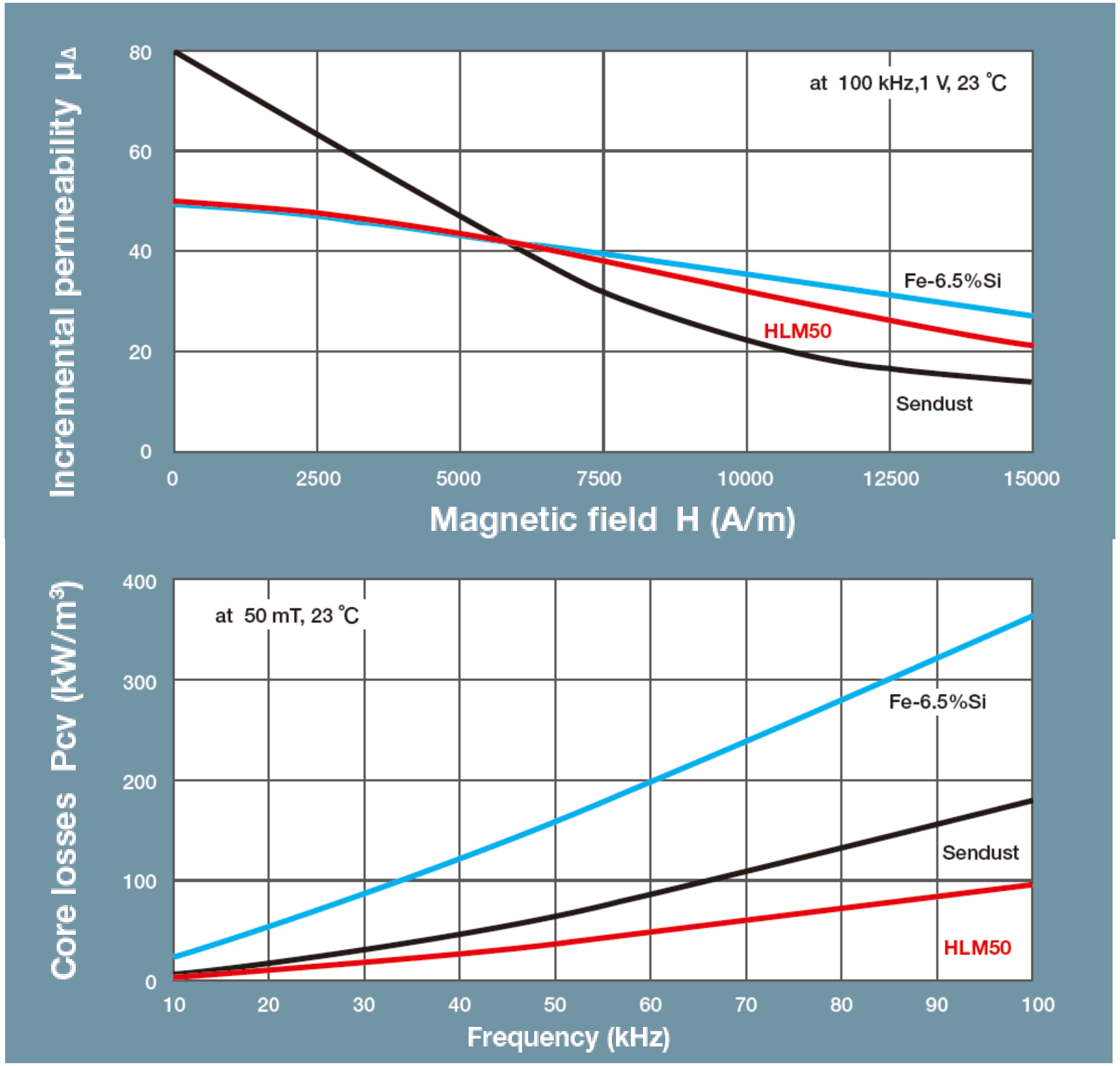
Applications

- Output Inductor
- Input Differential Mode Inductor
- Flyback Transformer
- Power Factor Correction Boost Inductor

Powdered Amorphous Cores

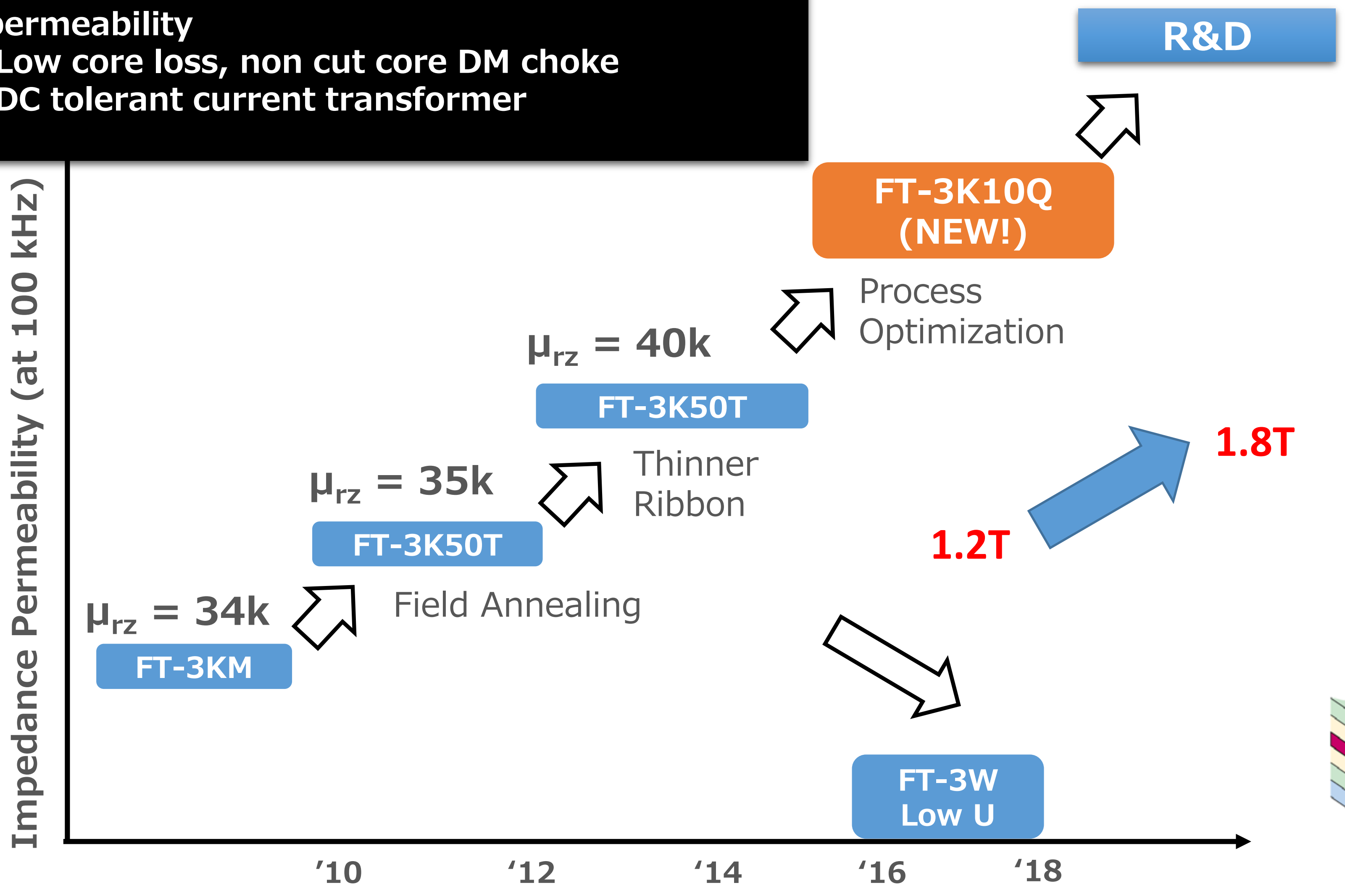
HLM50 series have low loss, high magnetic flux density, and high reliability using our uniquely processed amorphous powder.
This series is suited to coils for higher switching power electronics applications. (Power Factor Correction)

- High Saturation Flux Density Bs
  Higher saturation flux density compared to Sendust powder core.
- Low Core Loss.
  Lower core loss than Sendust powder core.
- Suitable for PFC Circuit and Boost/Buck Converter.
- Three Types of Core are in Production Lineup
  Bare core, cased core and over-coated core can be applied depending on customer requirement.



Tech Roadmap – Electrical and Mechanical

- Road Map (High Impedance) for Noise Attenuation
  - =>High Performance and/or Size Reduction
- Saturation Induction Increase
  - =>Transformer size reduction
- Low permeability
  - =>Low core loss, non cut core DM choke
  - =>DC tolerant current transformer



Mechanical Packaging of Amorphous and FINEMET material for applications such as motor stators and wireless charging

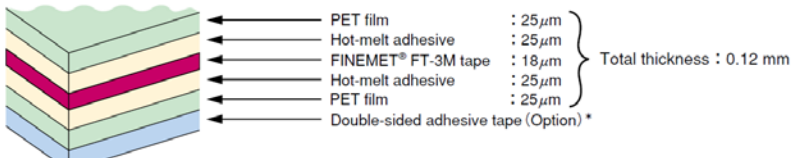


Fig.1 Structure of MS-F/MS-FR

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