



Materials Mag!c

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

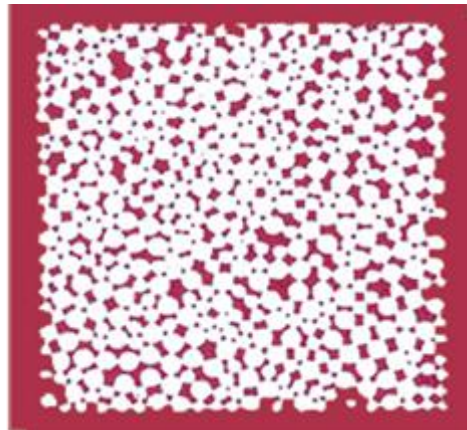
Languages – English, German



Amorphous Metals - How Are They Unique?

Metglas® Is Amorphous

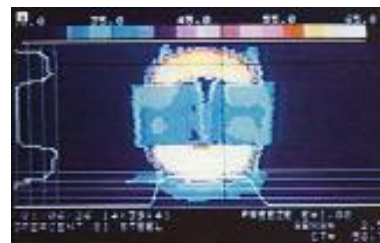
Structure Randomized by Process



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



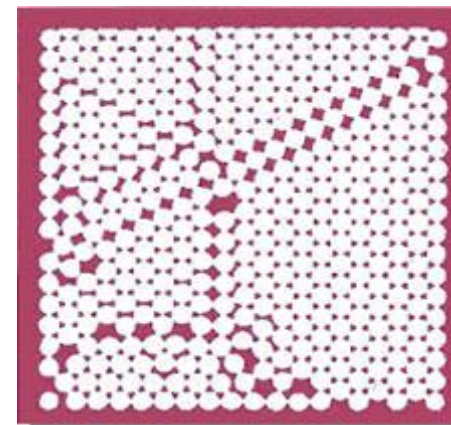
a)



b)

Metallic Solids Are Crystalline

Atomic Arrangement Is Regular & Periodic



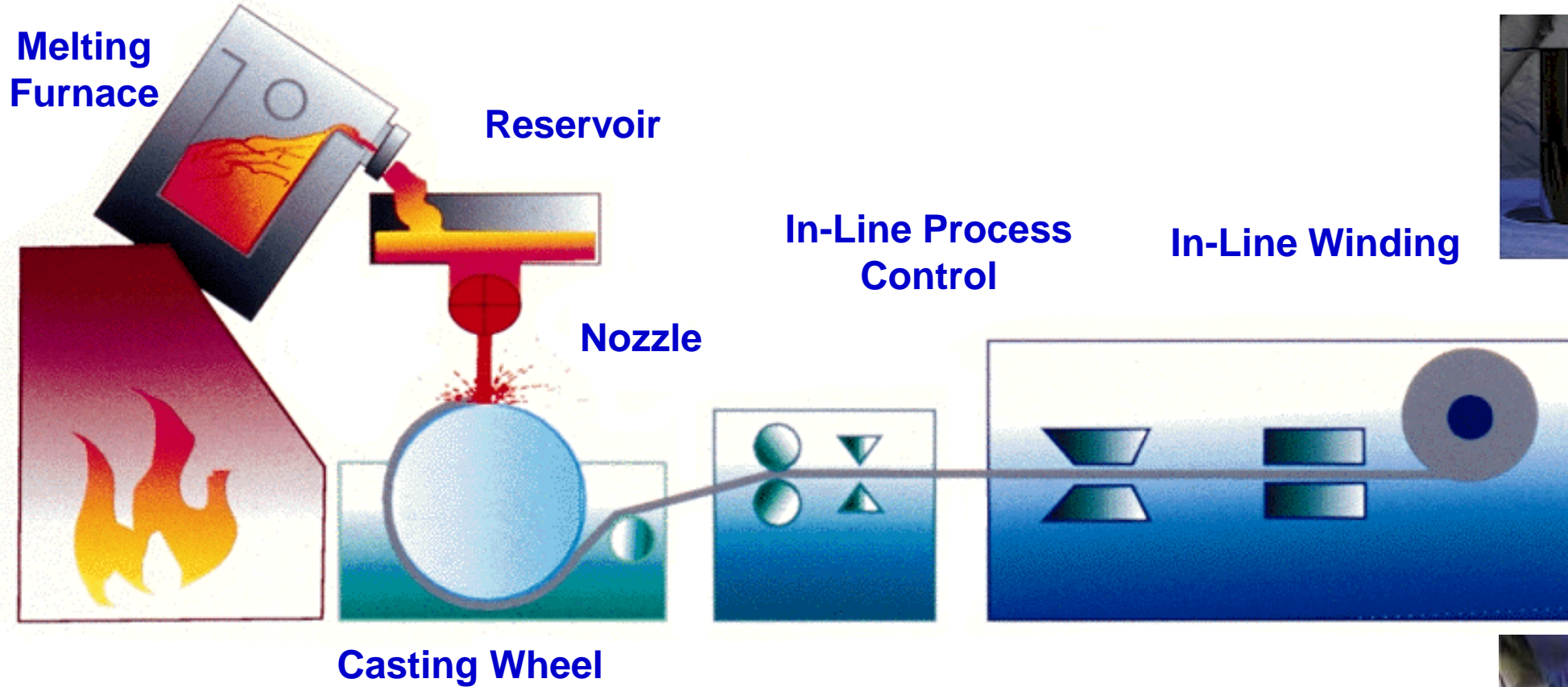
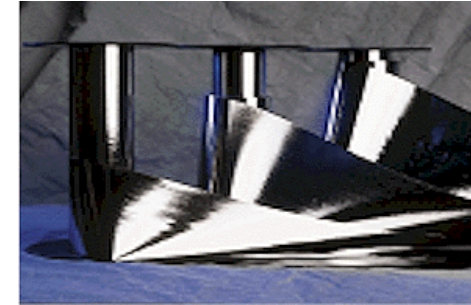
- **Structural Anomalies in Atomic Arrangement Hinder Magnetization Process**
- **Structural Arrangement Modified By Thermo-mechanical (Hot Rolling) Grain Orientation**

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



Unique Process Allows For Enhanced Properties

FINEMET[®] Soft Magnetic Material Products



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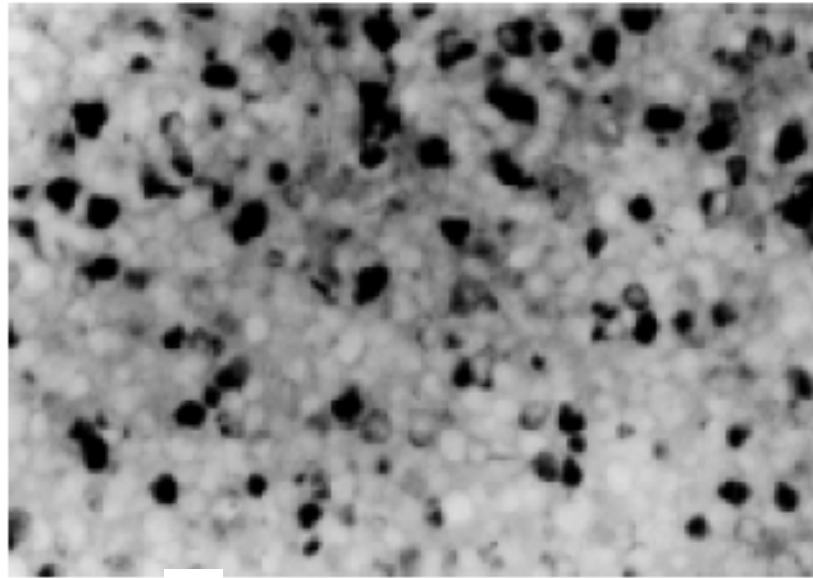
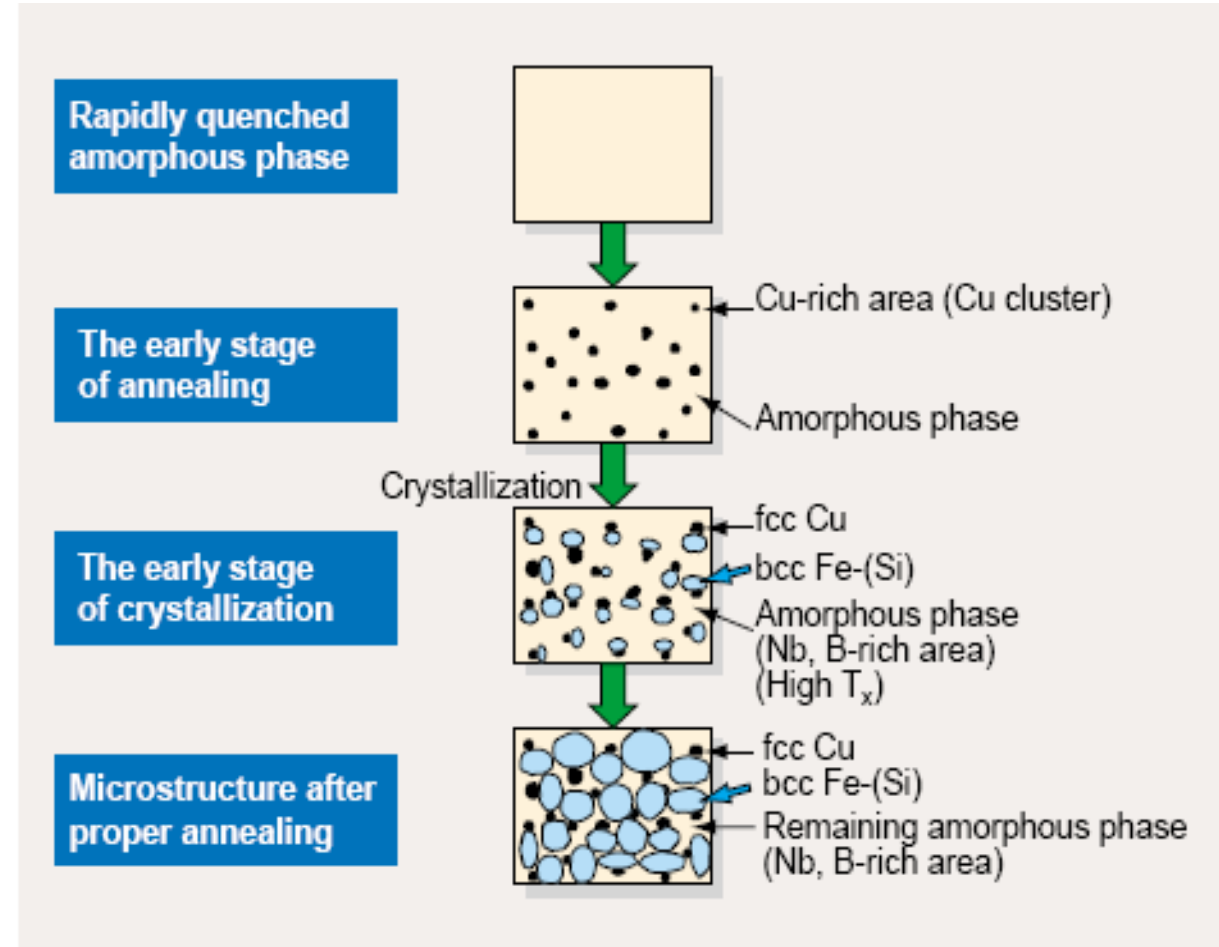


Fig. 3 Microstructure of FINEMET[®]



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



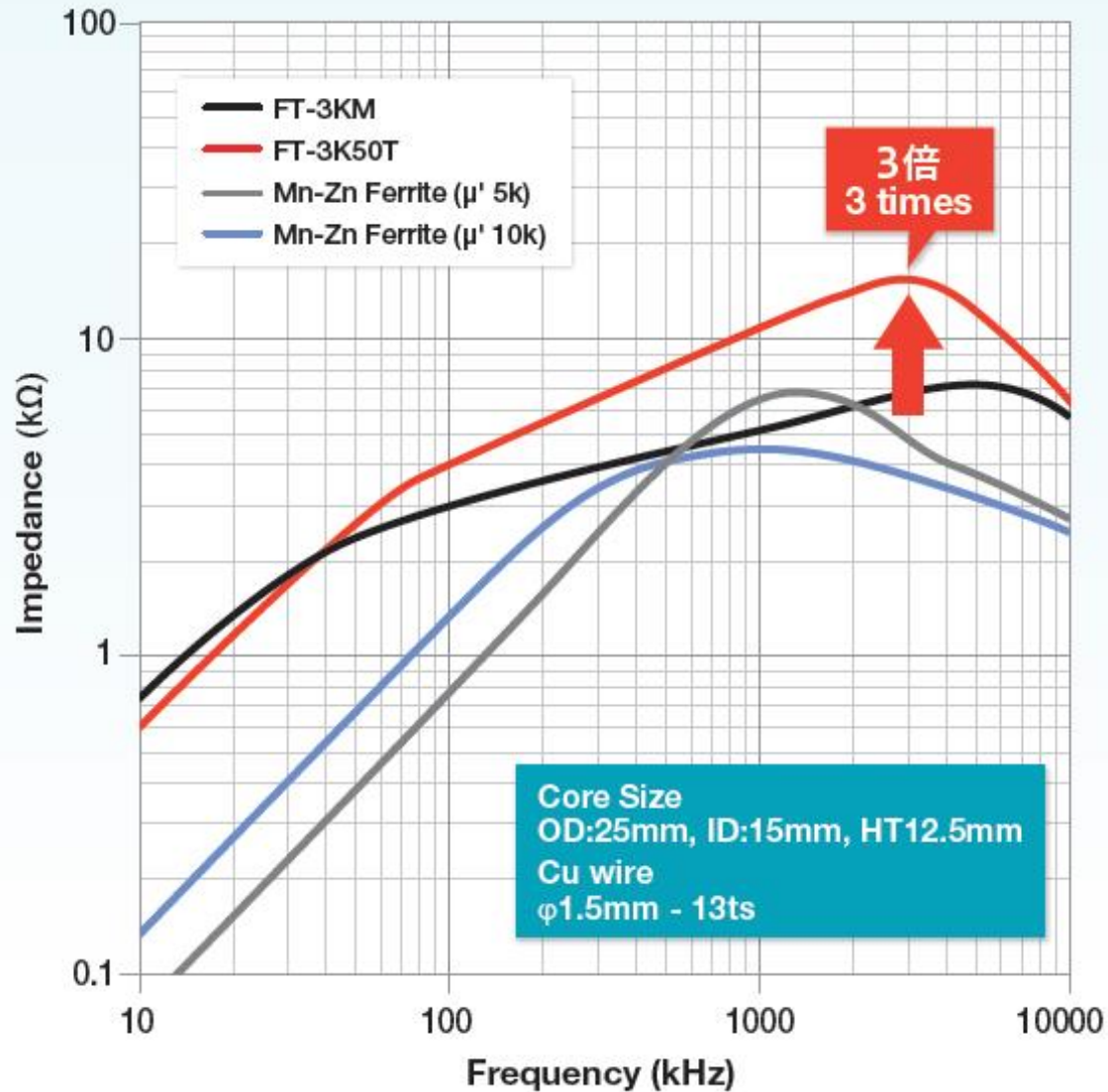
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Material	FINEMET (Nanocrystalline)	Ferrite
Material Composition	Fe Si (75 / 25%)	MnZn
Permeability (max at 10Khz)	500 to 100,000	15,000
Saturation Induction Bsat	1.2 Tesla	0.4 Tesla
Core Loss W/Kg (100Khz, 0.2T)	20 (FT-3K50T) and 35 (FT-3KL)	120
Curie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

FT-3K50T Impedance vs Frequency

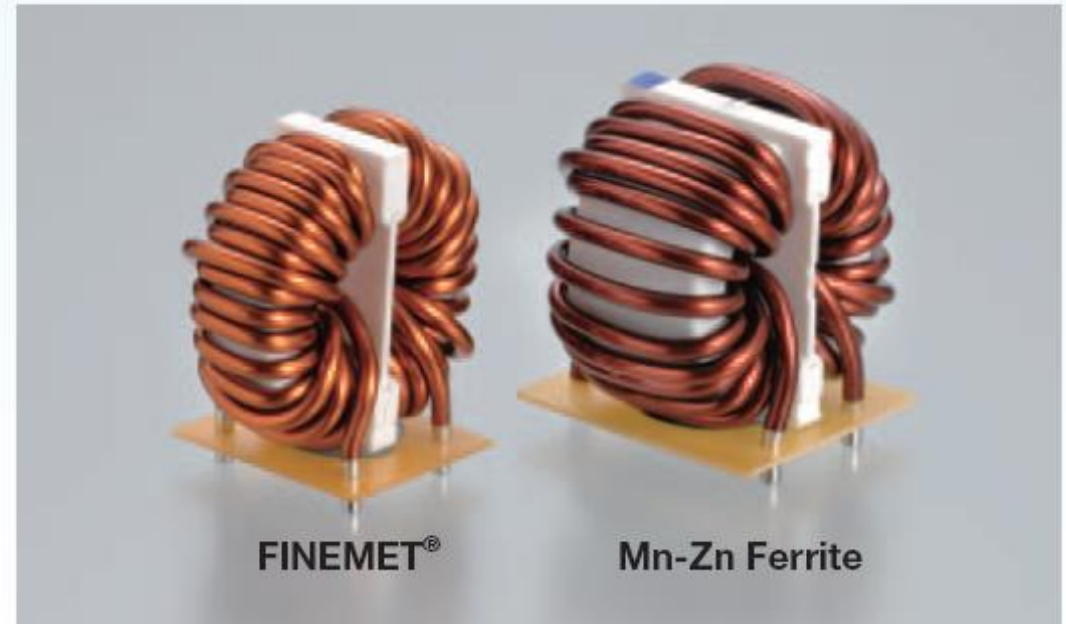


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	FT-3K50T	Mn-Zn
Volume	24cm ³ (55% of Mn-Zn)	44cm ³
Weight	55g (53% of Mn-Zn)	104g

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



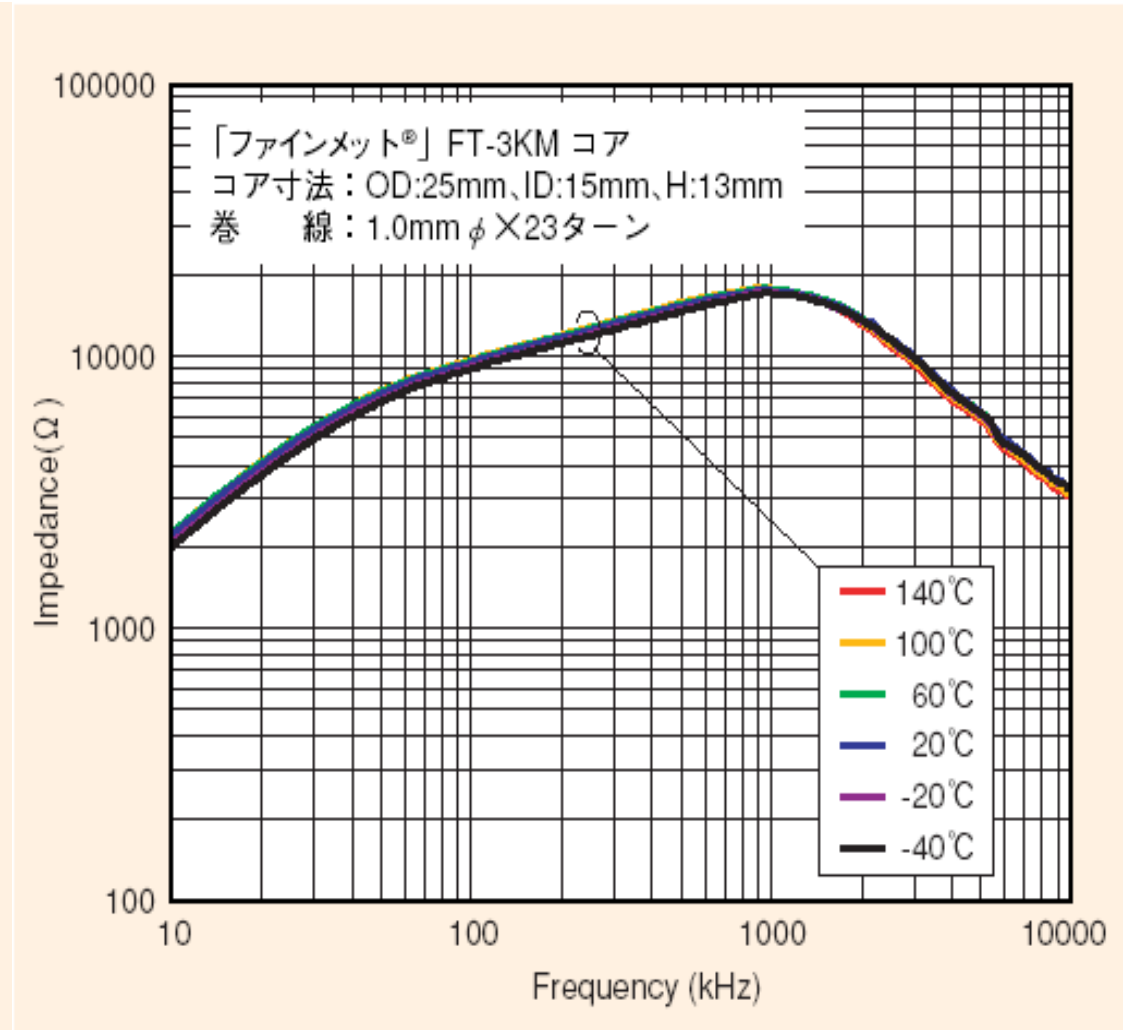
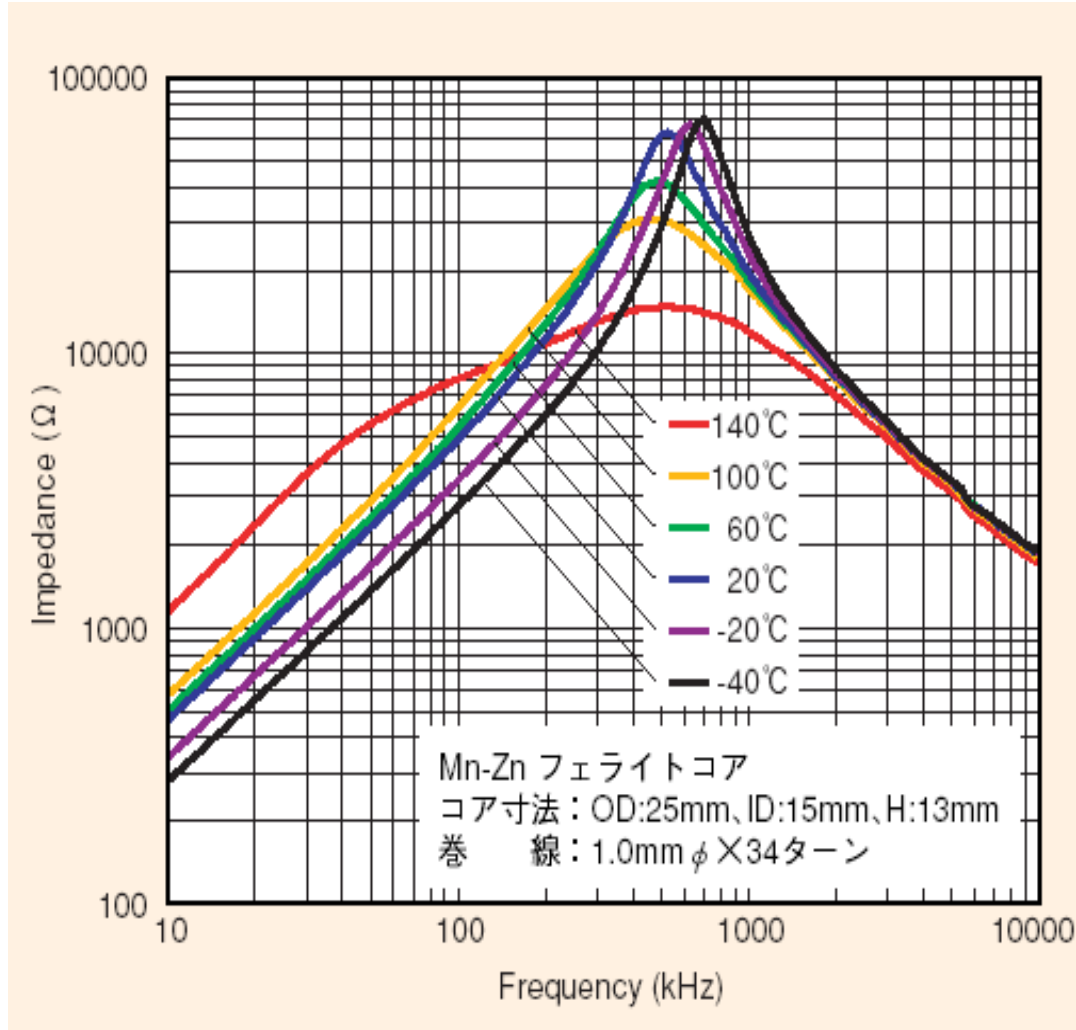
FINEMET Temperature Stability vs Ferrite -40 deg C to +140 deg C



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MnZn Ferrite CMC

FINEMET CMC



FINEMET Advantages



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- 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 μ over temperature)
- Mechanical shock / vibration (no chip and crack specification)
- Improved conduction emissions performance can sometimes lead to reduced radiated emissions.



FINEMET Applications



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- 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 B_{sat} (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 B_{sat} (1.2) = less magnetic material required. Thin package profile.
 - Thin tape construction / packaged in laminated sheet form
- 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.

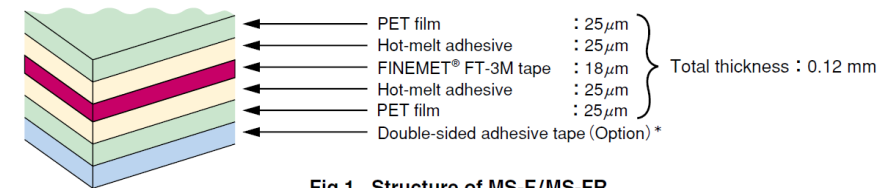
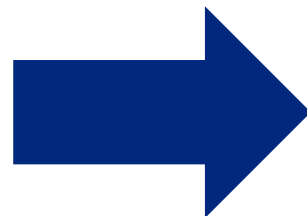
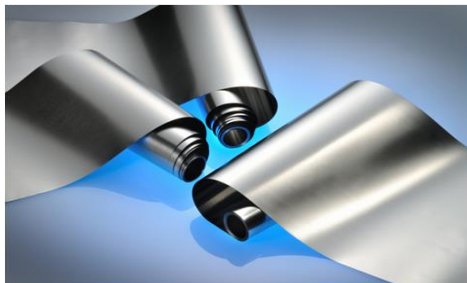



Fig.1 Structure of MS-F/MS-FR

Metglas® Amorphous Metal





Transformers
Distribution Transformers,
Industrial Transformers





Motors
Amorphous Electric Motor,
Stator, EV





Renewable Energy
Wind Turbines, High Efficiency
Inverters, C-Cores

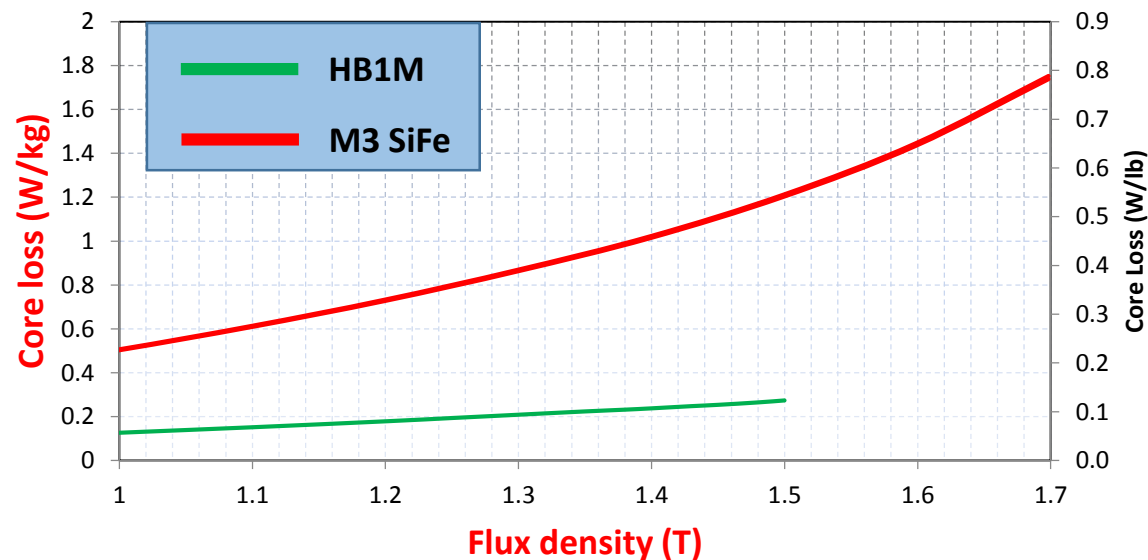


Soft Magnetic Materials with:

- 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 ($\mu\Omega\text{m}$)	Magnetostriction ($\times 10^{-6}$)	Curie Temperature ($^{\circ}\text{C}$)
1.63	1.2	27	364



POWERLITE® - Amorphous Metal Cut Cores



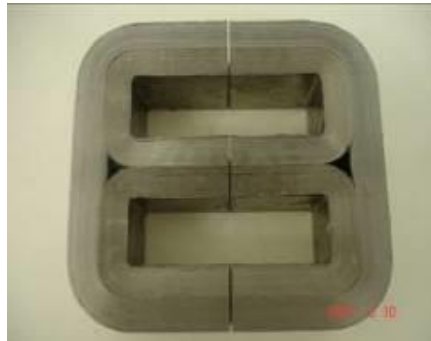
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Physical Properties METGLAS Alloy 2605SA1

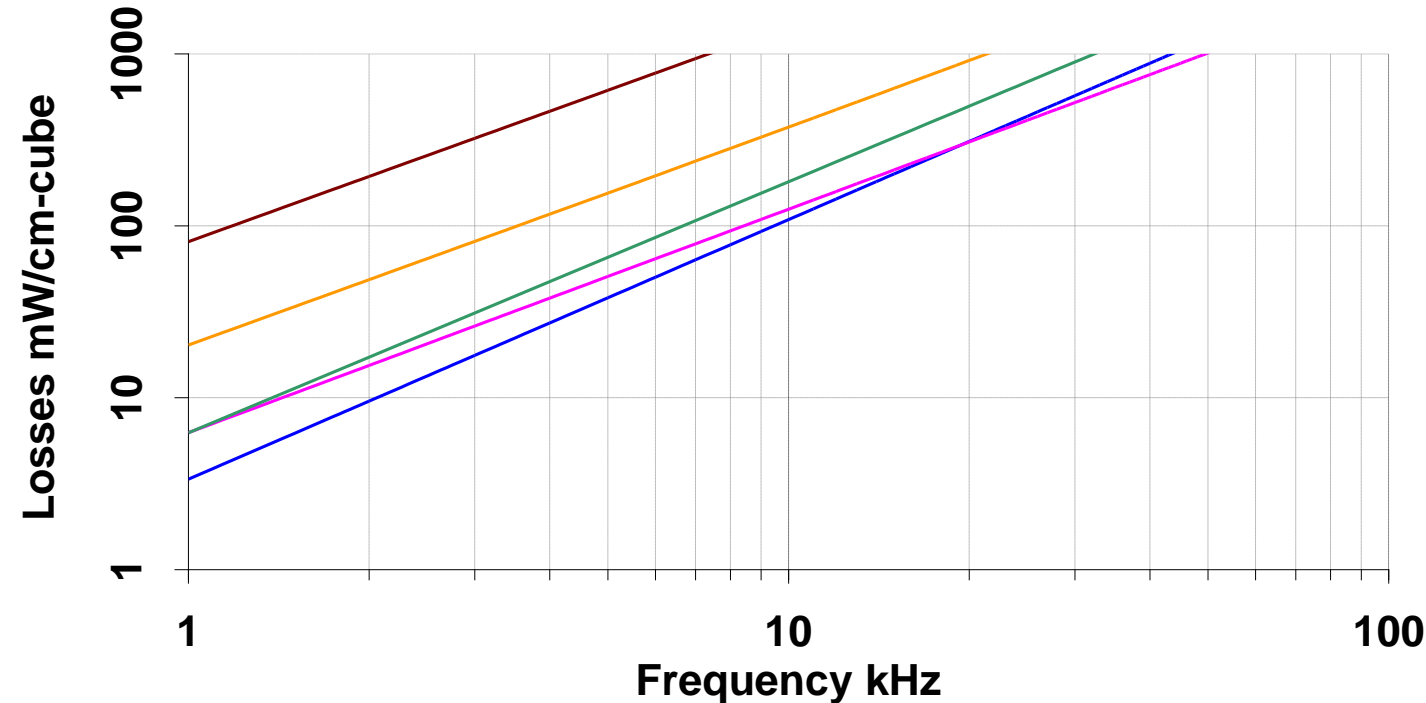
Ribbon Thickness (μm)	.25
Density (g/cm ³)	7.18
Thermal Expansion (ppm/°C)	7.6
Crystallization Temperature (°C)	505
Curie Temperature (°C)	392
Continuous Service Temperature (°C)	150
Tensile Strength (MN/m ²)	1k-1.7k
Elastic Modulus (GN/m ²)	100-110
Vicker's Hardness (50g load)	860

Magnetic Properties METGLAS Powerlite Cores

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



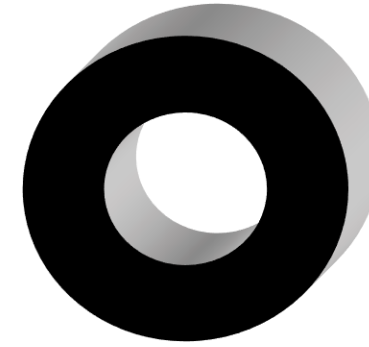
— Amorphous — Ferrite — Fe-Si-Al — Fe-Si 6% — Fe-Si 3.5%



Application - Differential Mode Chokes / Transformer

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

Microlite Distributed Gap Cores



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 B_{sat} for smaller component size B_{sat} 1.56 Tesla
- High permeability $\mu \sim 250$ 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
B _{sat}	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

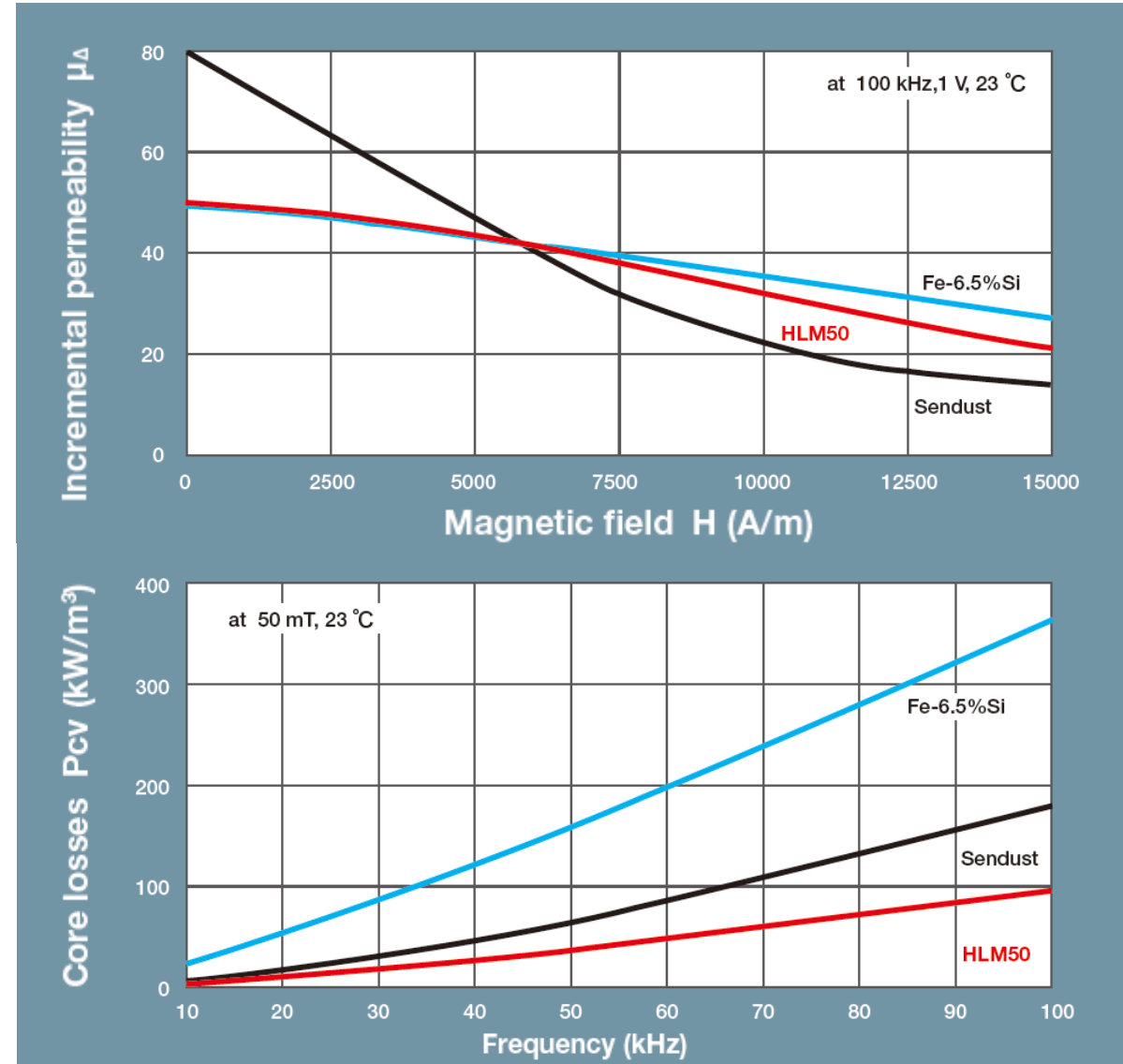


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HLM50 series have low loss, high magnetic flux density, and high reliability using our uniquely processed amorphous powder.

This series is suited to coils for higher switching power electronics applications. (Power Factor Correction)

- High Saturation Flux Density B_s
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.

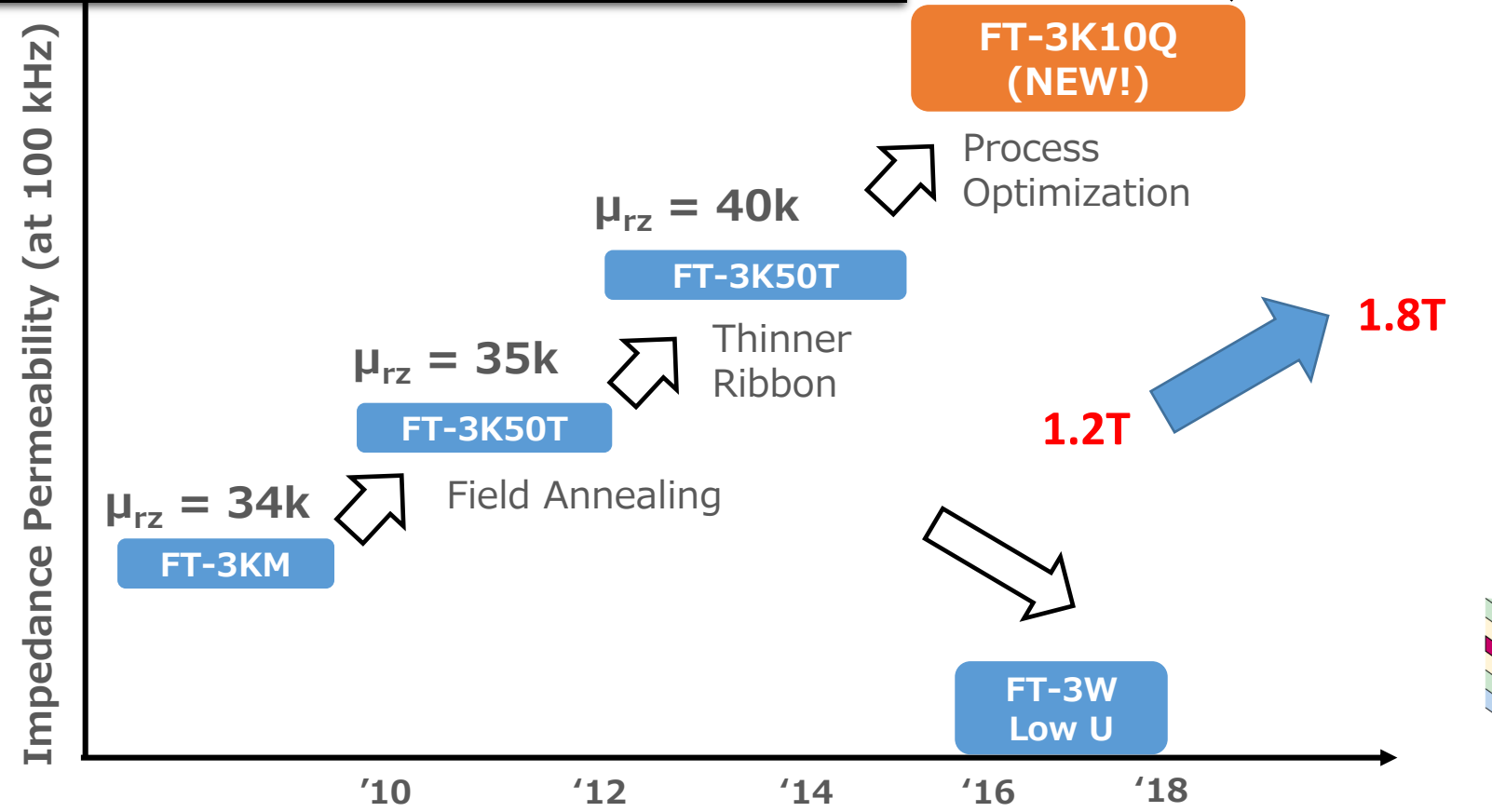


Tech Roadmap – Electrical and Mechanical



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- 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

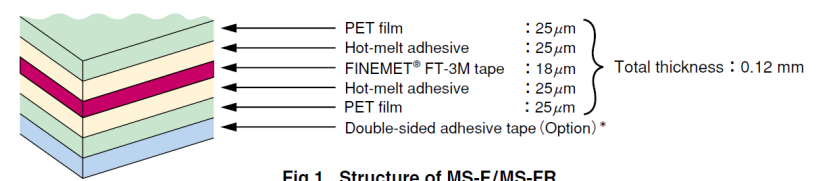


Fig.1 Structure of MS-F/MS-FR