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Hitachi Metals Group

Nanocrystalline Thin Ribbon

PSMA 2020

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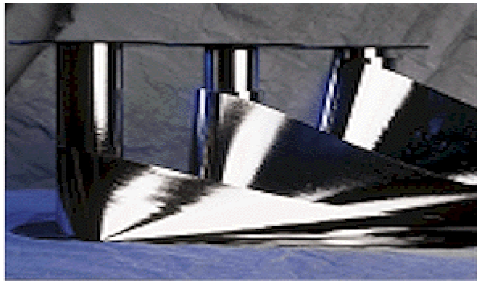

Amorphous Metals - How Are They Unique?

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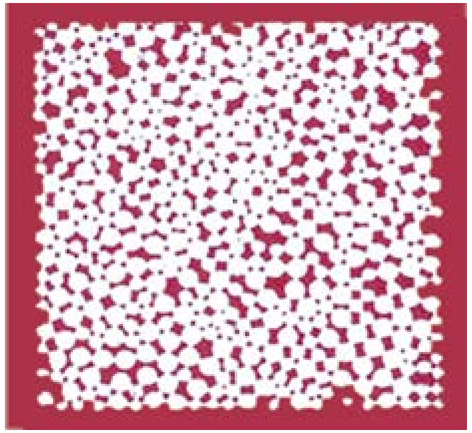
Metglas® Is Amorphous

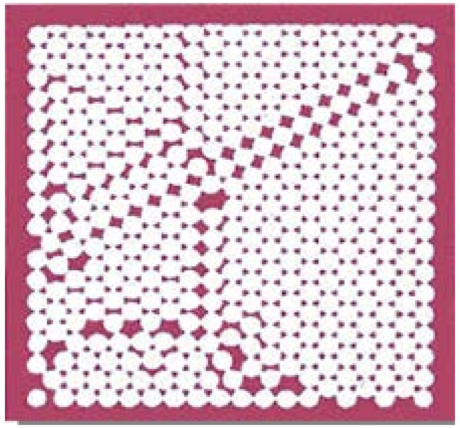
Structure Randomized by Process



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

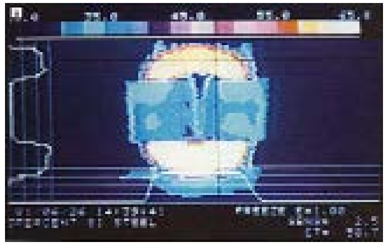
Metallic Solids Are Crystalline

Atomic Arrangement Is Regular & Periodic



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

a)

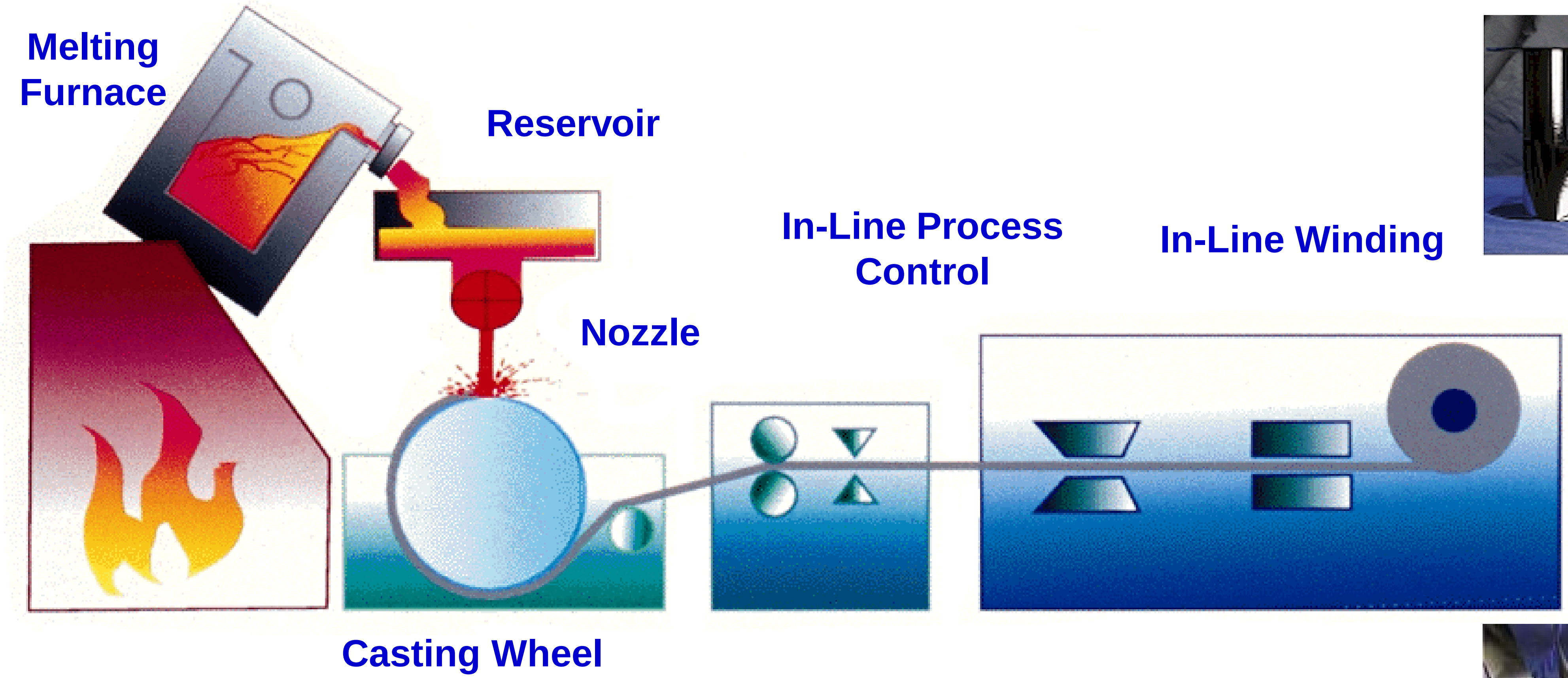


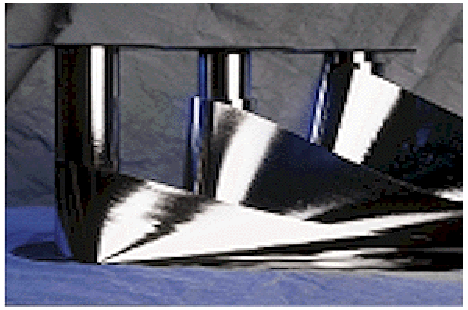
b)

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

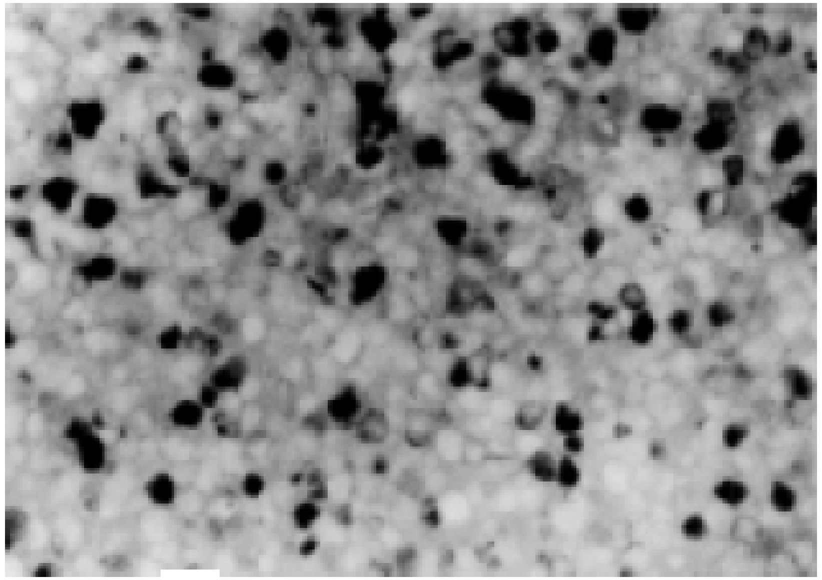
Rapid Solidification Material Casting Process



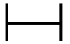


Unique Process Allows For Enhanced Properties

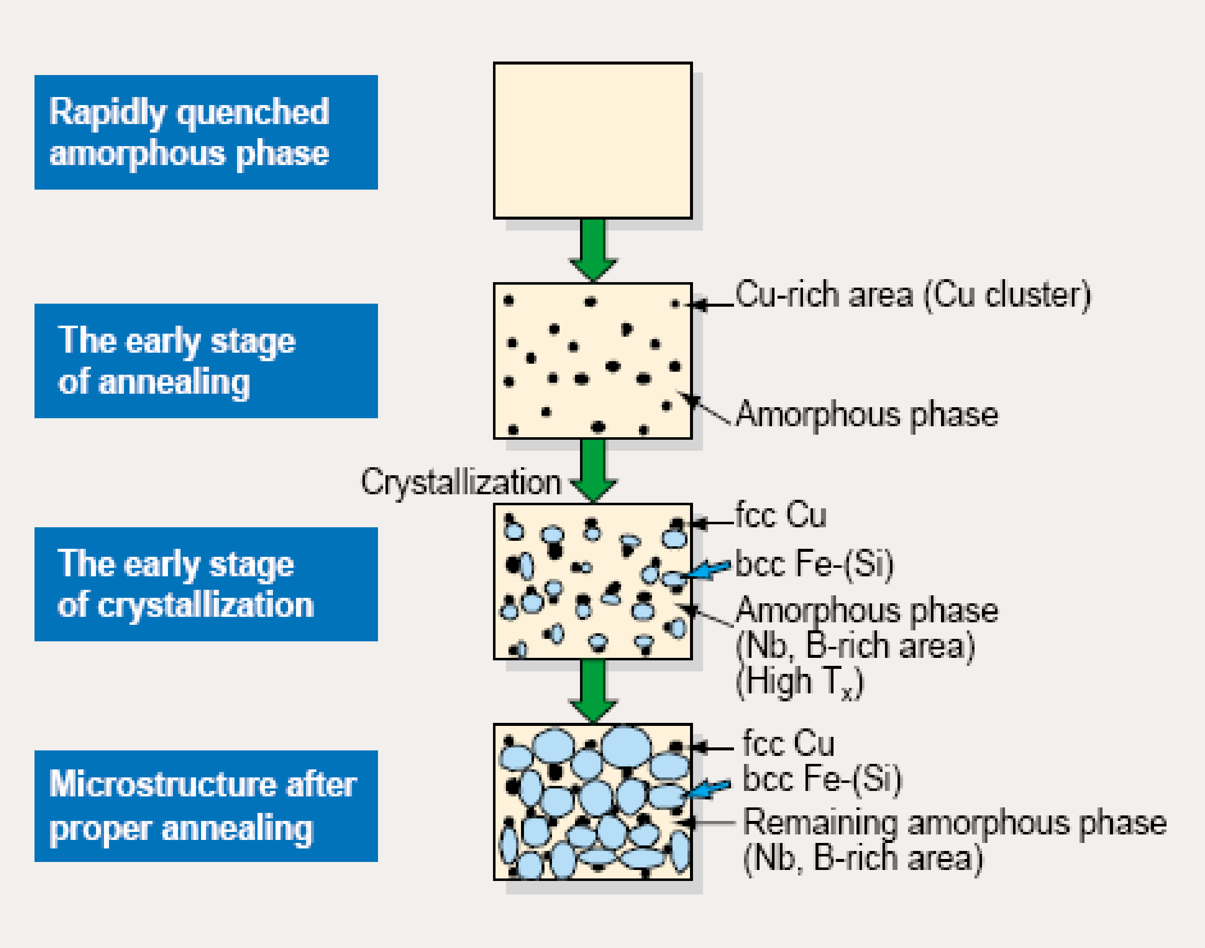
FINEMET ® Soft Magnetic Material Products



j. 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

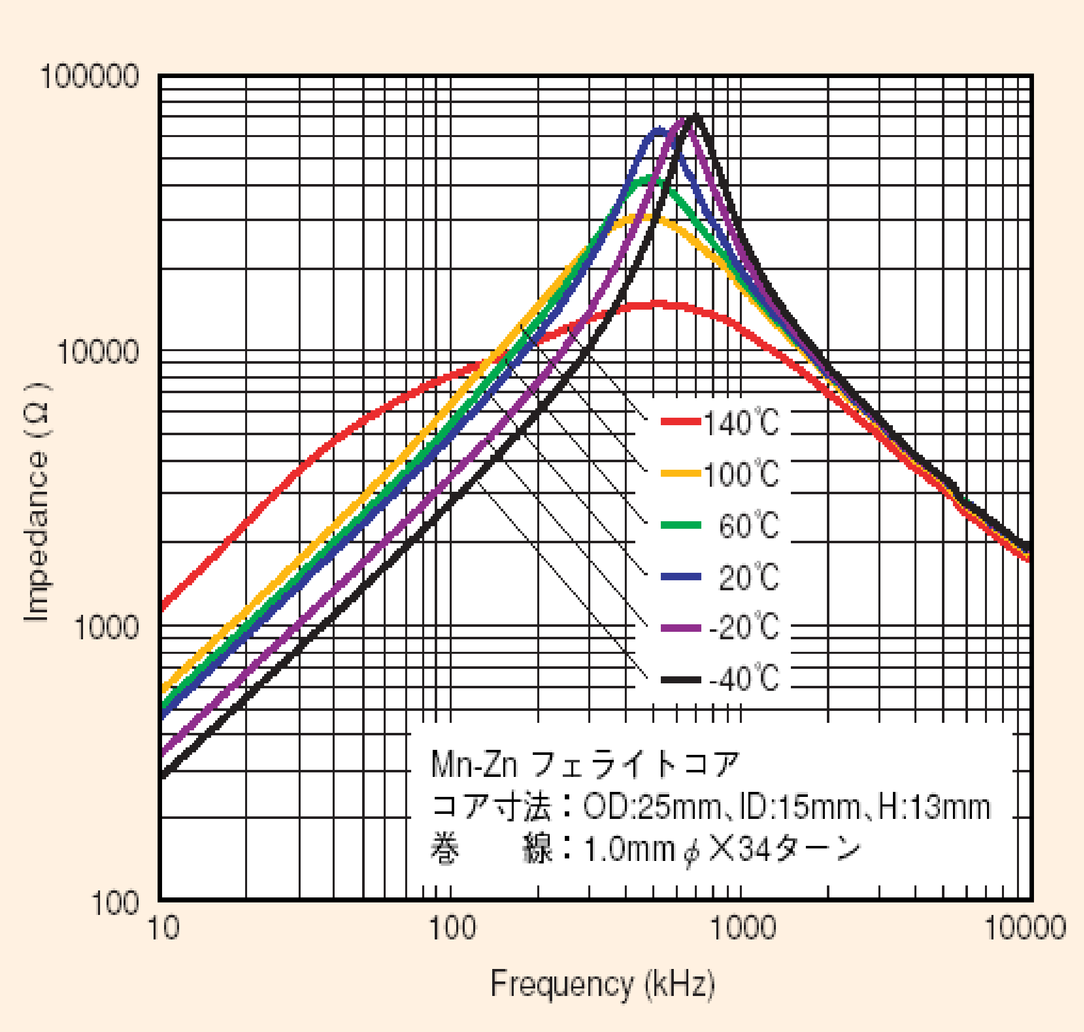


FINEMET versus Ferrite Material Properties

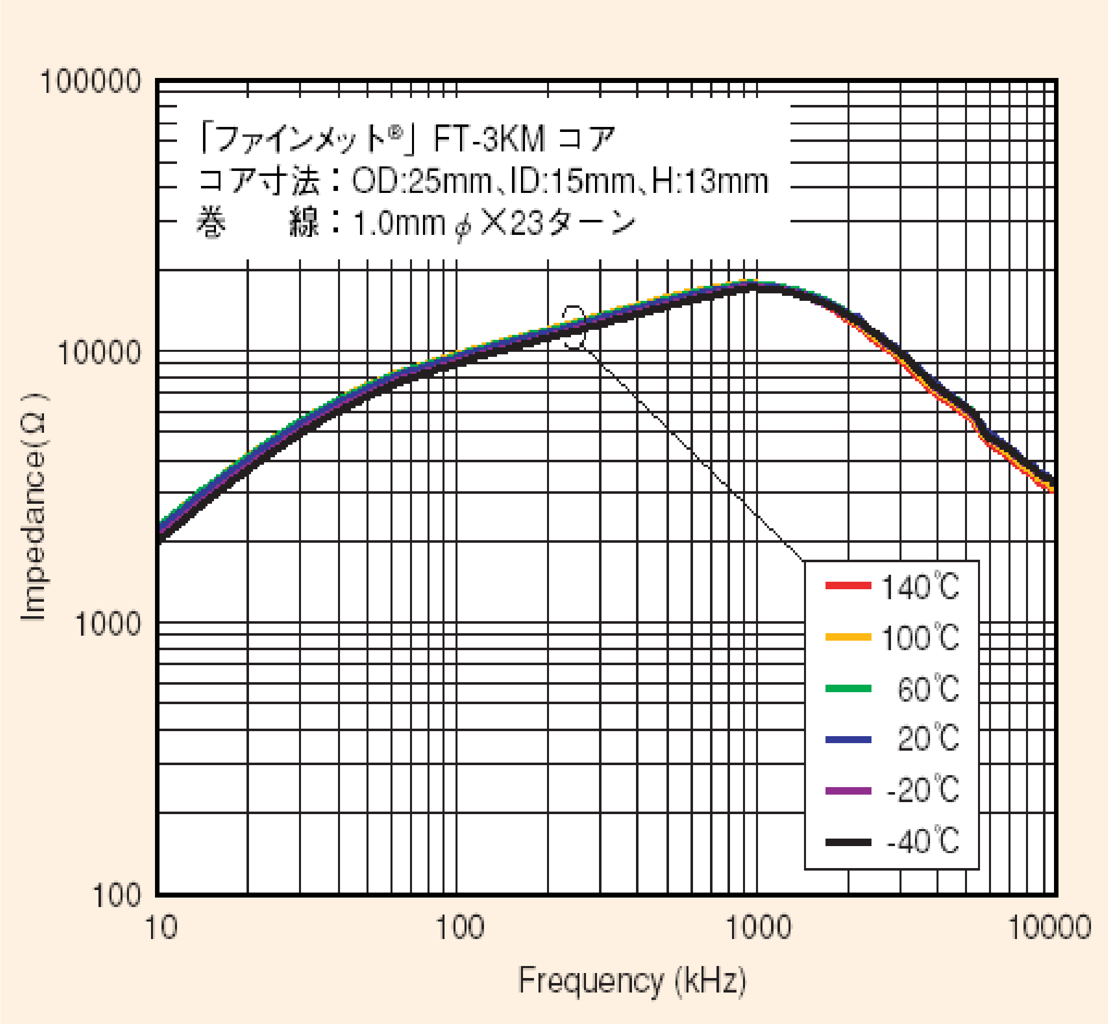
Material	FINEMET (Nanocrystalline)	Ferrite
Material Composition	Fe Si (75 / 25%)	MnZn
Permeability (max at 10Khz)	500 to 100,000	15,000
Saturation Induction Bsat	1.2 Tesla	0.4 Tesla
Core Loss W/Kg (100Khz, 0.2T)	20 (FT-3K50T) and 35 (FT-3KL)	120
Curie Temperature	550- 570 deg C	200-300 deg C
Max Continuous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

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

MnZn Ferrite CMC



FINEMET CMC



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

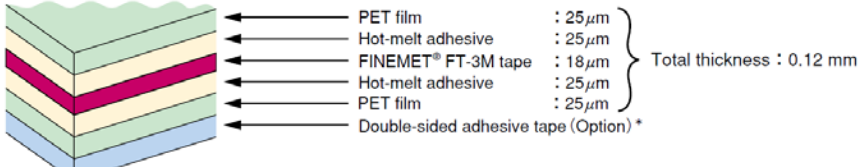


Fig.1 Structure of MS-F/MS-FR

- 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.

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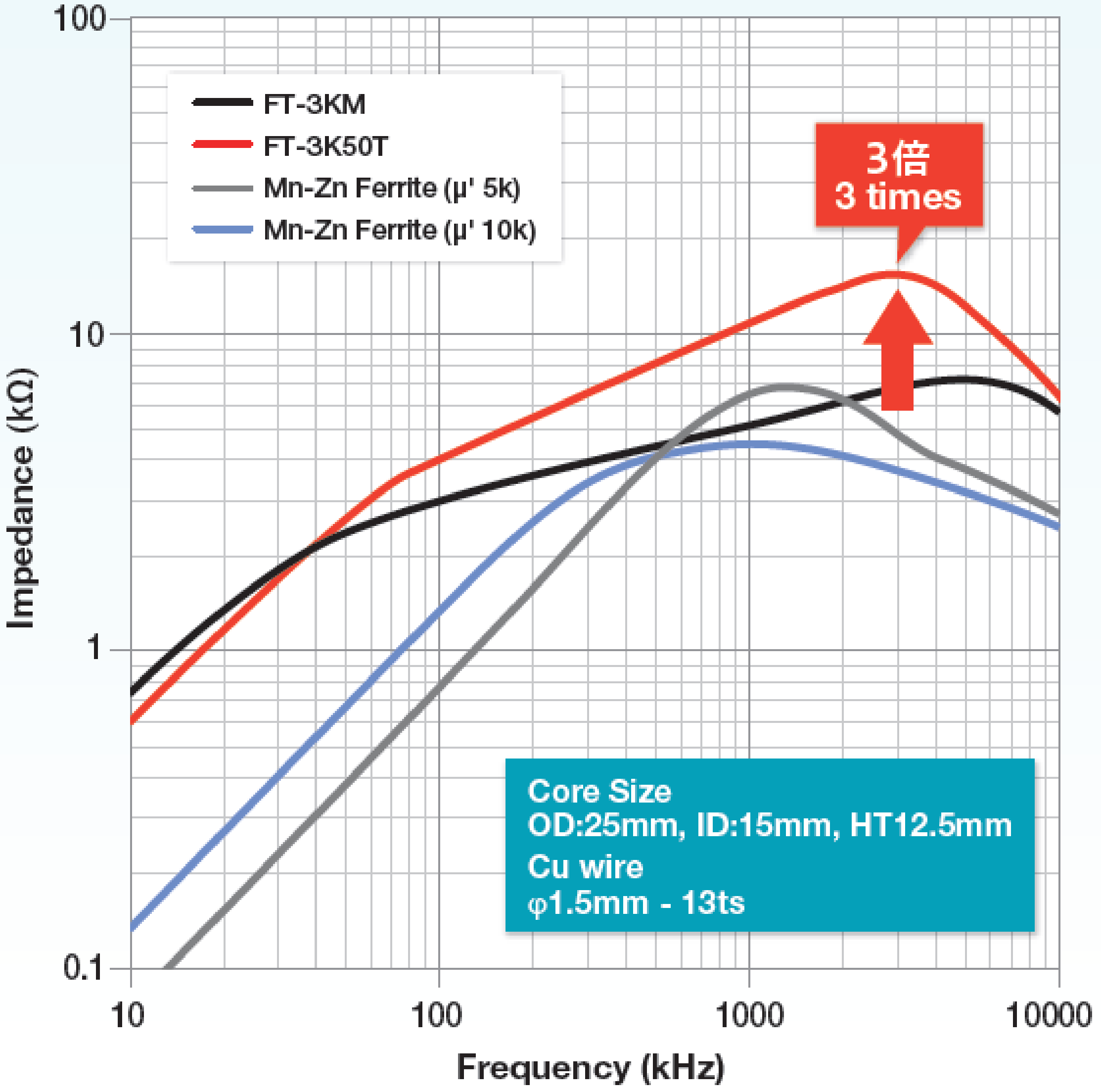
FINEMET Advantages

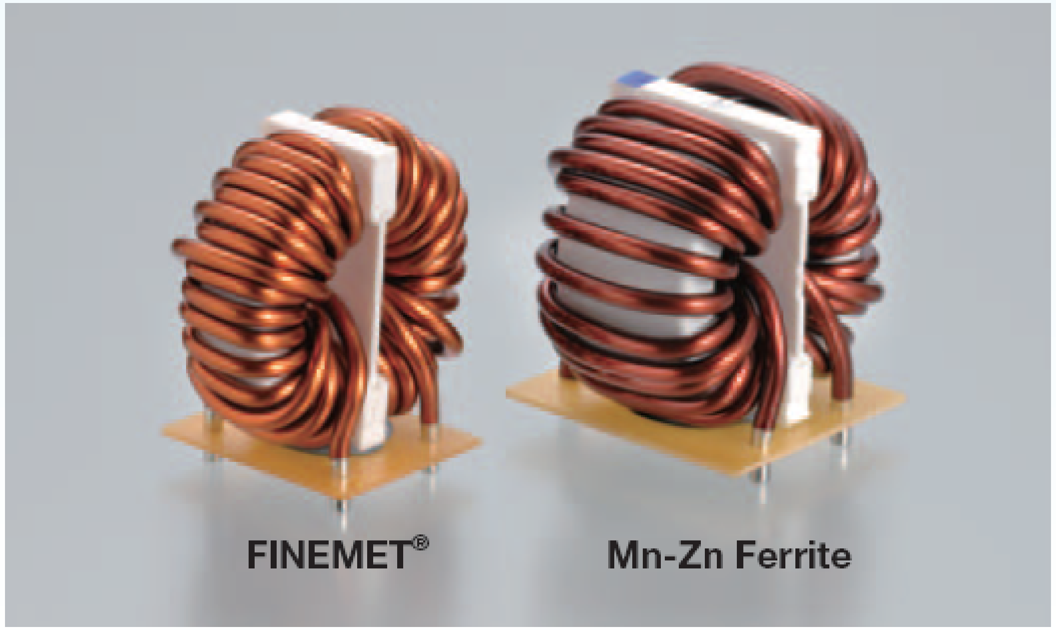
- Filter Order Reduction (excellent low frequency and high frequency performance)
- Core Size Reduction
- Core weight reduction
- Thin ribbon material offers high frequency higher permeability than competitive nanocrystalline tapes offering same L with less cross sectional area (lower cost, small size / 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.

FT-3K50T Impedance vs Frequency



	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



Permeability vs Frequency

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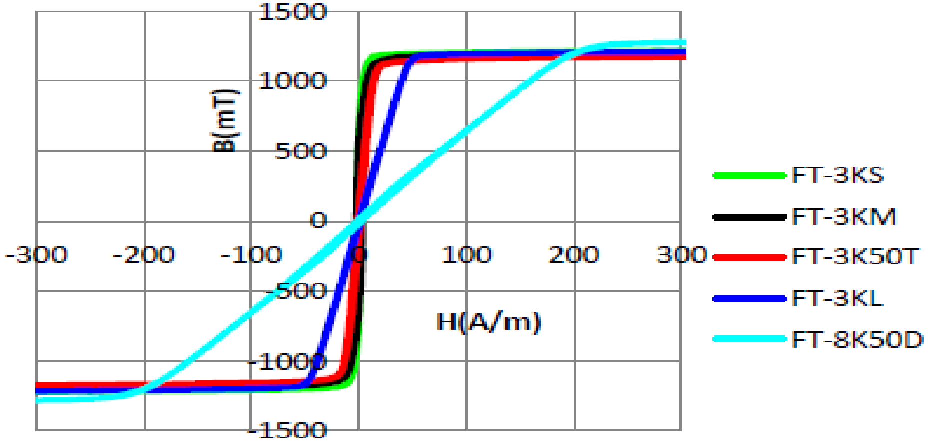
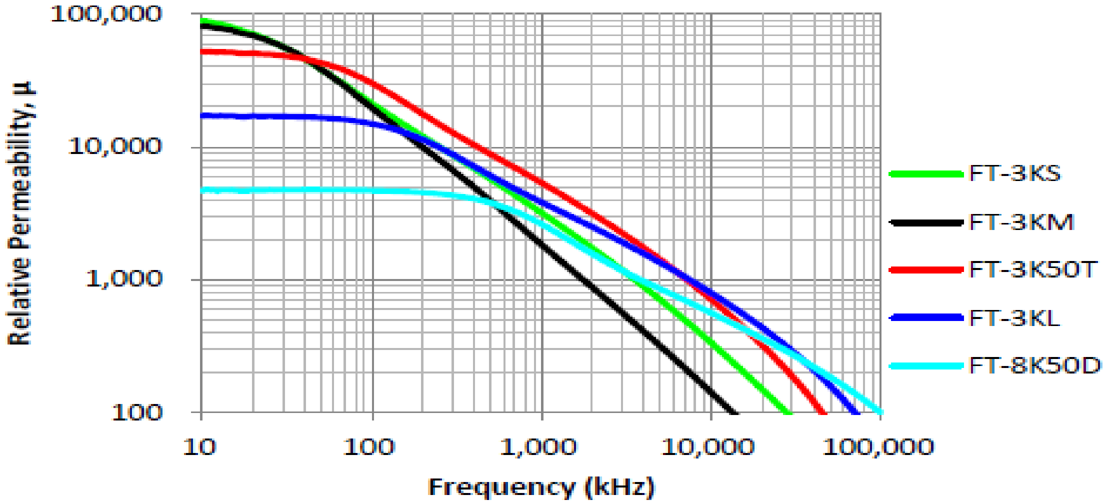
FT-3K50T *and* *FT-8K50D* are brand new materials, controlled by applying a magnetic field during annealing.
- FT-3K50T having high relative permeability μr over than 100 kHz range compared to standard material, FT-3KM. (Fig.2)
- FT-8K50D having excellent saturation characteristics compared to FT-3KL. (Fig.3)

Material code	Bs (T)	Br/Bs (%)	Hc (A/m)	μr (10kHz) (x 10^3)	μr (100kHz) (x 10^3)	λs (x 10^{-6})	Tc (deg.C)
FT-3KS	1.23	40	1.5	100	20	< 1	~ 570
FT-3KM		50	2.5	70	15		
FT-3K50T		10	1.2	50	31		
FT-3KL		5	0.6	27	17		
FT-8K50D	1.32	0.7	1.4	5	5	< 8	~ 550

DC B-H (Fig.1)



Permeability vs. Frequency (Fig.2)



Core loss vs Frequency

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Frequency kHz	B(mT)	Hitachi Metals 18um FT-3KM	Hitachi Metals 18um FT-3KL	Hitachi Metals FT-3K50T (Thin Ribbon)	Competition 20um Ribbon
		CL W/kg	CL W/kg	CL W/kg	CL W/kg
25kHz	100	0.85	0.6	0.4	0.85
50kHz	100	3	2.3	1.5	3
100kHz	100	10	9	5	10

Frequency kHz	B(mT)	Hitachi Metals 18um FT-3KM	Hitachi Metals 18um FT-3KL	Hitachi Metals FT-3K50T Thin Ribbon	Competition 20um Ribbon
		CL W/kg	CL W/kg	CL W/kg	CL W/kg
25kHz	200	3.5	2.5	2	3.5
50kHz	200	13	9	6	13
100kHz	200	40	35	20	40