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Nanocrystalline Soft Magnetic Materials for Today's Electronic Designs

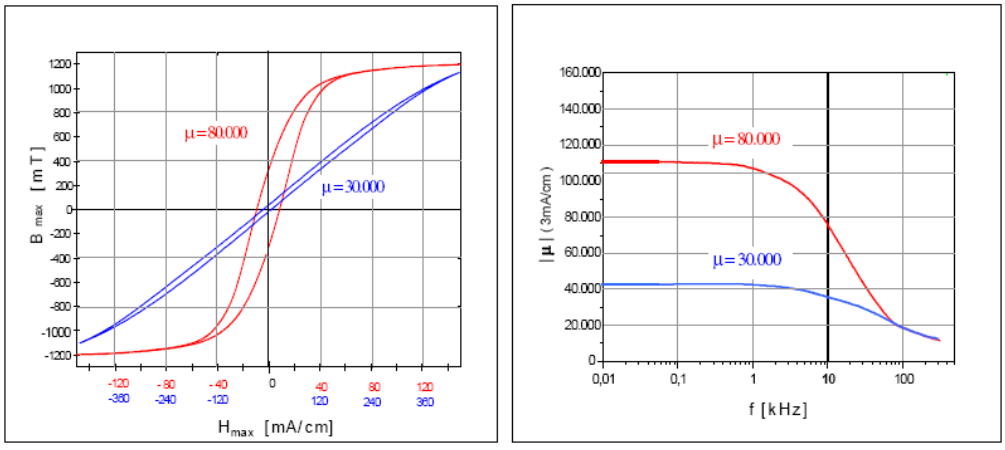
Multi purpose nanocrystalline soft Magnetic cores reduce size of Inductive Components

Iron-Based nanocrystalline materials have enjoyed more acceptance in modern electronic designs only in the past few years. Nanocrystalline materials have a proven record of high performance, there has been improved reliability in the manufacturing process and this material in now available from multiple sources. Nanocrystalline soft magnetic materials are now superior to permalloys, ferrites and even amorphous cobalt based alloys in a growing range of applications. The table below identifies different properties of the various soft magnetic materials that are available today.

Material	Alloy Composition	Strip Thickness (µM)	Losses (20KHz 200mT (W/Kg)	Saturation Bsat (mT)	Magne-tostriction λ_s (10^{-6})	Permeability (50Hz)
Standard Crystalline Permalloy	$Ni_{60} Fe_{40}$	50	45	1,200	10	20,000-30,000
Advanced Crystalline Alloy	$Fe_{93.5} Si_{6.5}$	50	40	1,300	0.1	16,000
Amorphous Alloys	$FE_{76} (Si,B)_{24}$	25	18	1,500	25	6,500—8,000
High Performance Ferrite	MnZn	-	17	500	-	1,000-30,000
Advanced Crystalline Permalloy	$NI_{80} FE_{20}$	30	14	800	1	100,000-300,000
Amorphous Alloy IIa	$Co_{73} (Si,B)_{27}$	25	5	550	< 0.2	100,000-150,000
Amorphous Alloy IIb	$Co_{77} (Si,B)_{23}$	25	6.5	1,000	< 0.2	2,000—4,500
Amorphous Alloy IIc	Co 80 (Si,B) 20	25	6.5	1,000	< 0.2	1,000—2,500
Nanocrystalline Alloys	$F3_{73} (Si,B)_{24}$	20	4	1,200	0.1	20,000-200,000

Applications:

By variation of the annealing parameters the required properties such as shape of the B/H-Loop and permeability can be adjusted in a wide range (Figure Below). As a result, the spectrum of applications in power electronics ranges from chokes and filters to power transformers.



Graphs demonstrating the variable range of Hysteresis Loops and Permeability Levels

The benefits gained from using Nanocrystalline over ferrite or permalloy is:

1. Significant Reduction of Build Volume of Inductive Component
2. Less Heat Dissipation due to Reduced Number of Turns
3. Stable Operation in a Temperature Range of –25 to +120°C.
4. Larger Safety Margins
5. Variable Toroidal Geometries—Tooling costs may apply

The primary application for the nanocrystalline material so far is common mode chokes for EMI Off-line (Mains) filters for any kind of switched mode power converters and inverter drives. Here the most significant design consideration is the reduction of build volume achieved because of both relevant material parameters (permeability and flux swing) are significantly higher then with Ferrite.

Secondary mainstream applications are

1. Power transformers in push-pull converters (full wave) from a few hundred watts to several KW
2. Trigger transformers for IGBT-driven converters
3. Current Transformers
4. Transformers for Passive Earth Leakage Circuit Breakers (Europe primarily)

General Specifications:

Saturation Flux Density	1,200 mT
Permeability	25,000—90,000 @ 10KHz
Saturation Magnetostriction	< 0.5 ppm
Spec. Electrical Resistivity	115 μΩcm
Density	7.35 g/cm^3
Curie Temperature	600°C
Max. Operating Temperature	120°C
Core Losses (100KHz, 300mT, sine wave)	> 110 W/kg
Alloy Composition	$Fe_{73.5} Cu_{1} Nb_{3} Si_{15.5} B_{7}$

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Distributed By:
MH&W International Corp, 14 Leighton Place, Mahwah, NJ 07430, USA
WEB: www.mhw-intl.com EMAIL: salesm@mhw-intl.com
Phone: + 1 - 201 - 801 - 8800 Toll Free Within USA: 866 - MHW - CORE

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Standard Range Nanocrystalline Toroidal Tape Wound Cores NANOPERM®

Type	Dimensions Nominal OD x ID x TH (mm)	Dimensions Physical OD x ID x TH (mm)	Mass (gm)	Path Length l_e (cm)	Core Area A_e (cm^2)	Al Value (µH)	Finish C=Case E=Epoxy
µ = 80,000 (@ 10 KHz)							
M-017	16 x 10 x 6	17.8 x 8.2 x 8.0	4.3	4.0	0.14	30.0 -60.0	C
M-059	20 x 12.5 x 8	22.3 x 10.3 x 10.0	9.0	5.1	0.24	33.0 –67.0	C
M-053	25 x 20 x 10	27.6 x 17.8 x 12.5	10.5	7.1	0.20	21.2 –41.3	C
M-003	25 x 16 x 10	28.0 x 13.2 x 12.4	17	6.4	0.36	45.0 –89.0	C
M-102	30 x 20 x 10	32.7 x 17.8 x 12.6	23.1	7.8	0.40	40.0 –80.0	C
µ = 30,000 (@ 10 KHz)							
M-036	16 x 10 x 6	17.8 x 8.0 x 8.0	4.3	4.0	0.14	8.0 –18.0	E
M-042	20 x 12.5 x 8	21.5 x 10.5 x 10.1	9.0	5.0	0.24	12.6 –25.3	E
M-033	25 x 16 x 10	26.6 x 13.7 x 12.3	17.1	6.3	0.36	12.6 –28.0	E
M-030	30 x 20 x 15	32.3 x 17.5 x 17.3	33	7.9	0.57	17.4 –39.0	E
M-014	40 x 32 x 15	42.3 x 29.1 x 17.3	40	11.3	0.48	10.7 –21.4	E
M-011	50 x 40 x 20	52.3 x 37.1 x 22.3	83	14.1	0.80	12.6 –28.4	E
M-012	60 x 40 x 15	62.3 x 37.1 x 17.3	138	15.5	1.20	17.4 –39.0	E
M-018	63 x 50 x 20	65.5 x 46.6 x 22.8	129	17.8	1.00	13.2 –29.7	E
M-022	80 x 63 x 20	83.0 x 59.5 x 22.8	213	22.5	1.24	13.8 –31.0	E
M-226	100 x 80 x 20	104 x 75.0 x 23.0	333	28.3	1.60	12.6 –28.3	E
M-028	130 x 100 x 25	134.5 x 95.0 x 28.5	757	36.0	2.85	18.6 –42.0	E
NANOPERM® Low Cost Cores for Small EMI Filter Chokes							
M-306	16 x 11 x 5	18.4 x 8.6 x 7.0		4.2	0.1	5.9 –11.8	C
M-307	20 x 15 x 5	22.4 x 12.6 x 7.5		5.5	0.1	4.5 –9.1	C
M-308	25 x 20 x 5	27.7 x 17.1 x 7.5		7.0	0.1	3.5 –7.0	C
M-309	30 x 25 x 5	32.7 x 22.0 x 7.5		8.6	0.1	2.8 –5.7	C
M-310	40 x 35 x 5	42.5 x 31.8 x 7.5		11.8	0.1	2.1 –4.2	C
M-333	50 x 45 x 5	52.2 x 41.8 x 7.5		14.9	0.1	1.6 –3.3	C
M-334	60 x 55 x 5	62.0 x 51.6 x 7.5		18.1	0.1	1.3 –2,8	C
M-335	70 x 65 x 5	72.0 x 61.4 x 7.5		21.2	0.1	1.1 –2.3	C

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WEB: www.mhw-intl.com EMAIL: salesm@mhw-intl.com

Phone: + 1 - 201 - 891 - 8800 Toll Free Within USA: 866 - MHW - CORE