

Low-hysteresis loss ferrite material for Low-THD xDSL modem transformers, DN70 material

THD : Total Harmonic Distortion

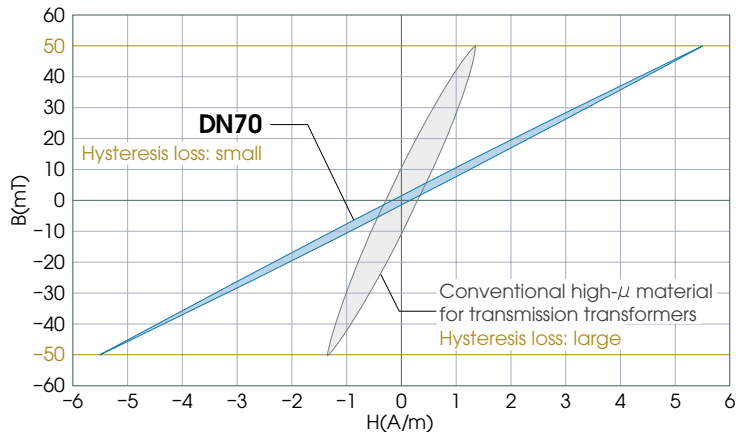
Conforming to RoHS Directive

Conformity to RoHS Directive:
This means that, in conformity with EU Directive 2002/95/EC, lead, cadmium, mercury, hexavalent chromium, and specific brominebased flame retardants, PBB and PBDE, have not been used, except for exempted applications.

This world's best hysteresis curve will alter the design of xDSL transmission transformers.

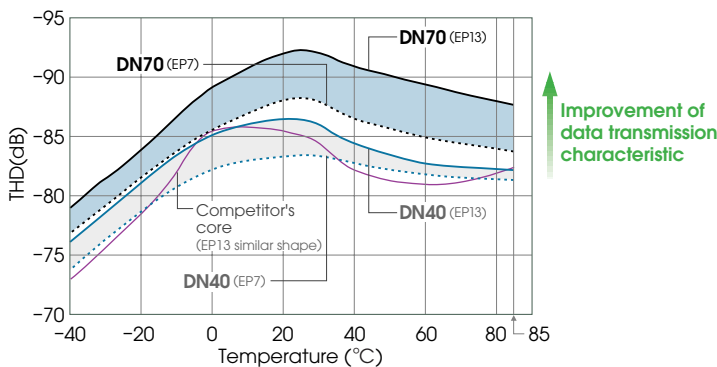
Achieving a hysteresis loss characteristic that's even lower than the DN40 material, which enjoys an industry-leading level of low THD (Total Harmonic Distortion) physicality. With a similar transformer specification, THD has been further reduced by about 5dB.

In the case where the D70 material is applied to a high-speed transmission transformer under the same driving conditions, with the same THD as the DN40 material, the number of coils can be reduced by about 25% and the core capacity by more than 40%.

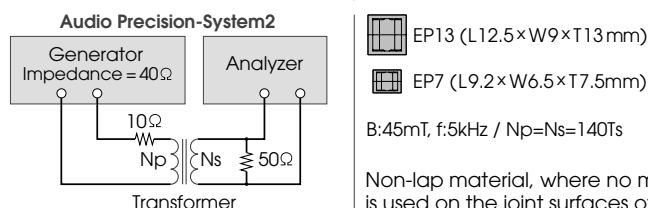


THD vs. temperature characteristic comparative example

Comparison of the conventional material (DN40 material) and a competitor's core with a similar shape



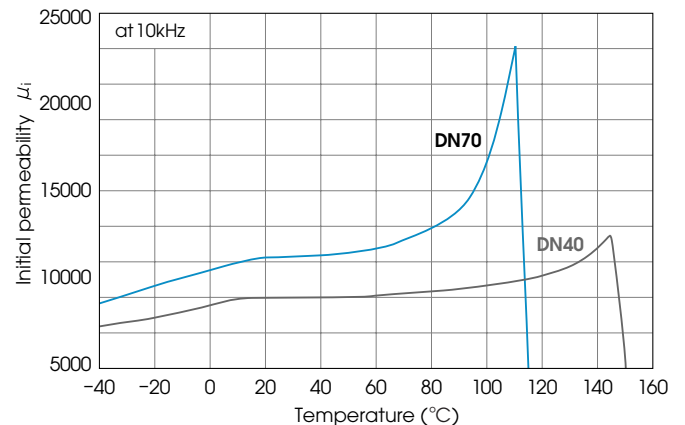
Measurement circuit of THD vs. temperature characteristic



Non-lap material, where no mirror finish is processed, is used on the joint surfaces of the DN70 and DN40 materials.

Initial permeability vs. temperature characteristic

Comparison with the conventional material (DN40 material)



Material characteristics / Core shape standard lineup

Representative example

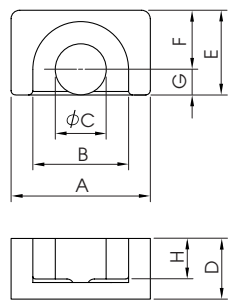
Material characteristic

comparative example with conventional material (DN40)

Material name	DN70	DN40
Initial permeability*1 μ_i	7500±25%	4000±25%
Loss coefficient*2 $\tan\delta/\mu_i$	<2.0×10 ⁻⁶	<2.5×10 ⁻⁶
Saturation magnetic flux density*3 Bs (mT)	390	405
Hysteresis coefficient η^B (°C)	<0.2×10 ⁻⁶ /mT	<0.8×10 ⁻⁶ /mT
Curie temperature Tc (°C)	105min.	138min.
Volume resistivity*4 ρV ($\Omega\cdot m$)	0.3	1.0
Bulk density db (kg/m ³)	5.0×10 ³	4.8×10 ³

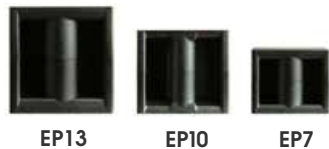
*1.at 25°C *2.at 25°C/10kHz *3.at 25°C/H=1000A/m
 *4.at 25°C/1.5 to 3.0mT/10kHz
 Operating temperature range : -30 to +85°C
 Operating humidity range : 0 to 90%RH
 (Maximum wet-bulb temperature: 38°C/Non-condensing)

Shapes and dimensions



A_L-value

	40	63	100	160	250	—	—
EP7	40	63	100	160	250	—	—
EP10	40	63	100	160	250	—	—
EP13	—	—	100	160	250	400	500



Dimensions in mm

Type	A	B	ϕC	D	E	F	Gmax.	H
EP7	9.2±0.2	7.4±0.2	3.4 ^{+0.0} _{-0.2}	3.75 ^{+0.0} _{-0.1}	6.5 ^{+0.0} _{-0.3}	4.6	1.8	2.5 ^{+0.2} _{-0.2}
EP10	11.5±0.3	9.4±0.2	3.45 ^{+0.0} _{-0.3}	5.2 ^{+0.0} _{-0.2}	7.85 ^{+0.0} _{-0.4}	5.83	1.95	3.6 ^{+0.2} _{-0.2}
EP13	12.5±0.3	10±0.3	4.5 ^{+0.0} _{-0.3}	6.5 ^{+0.0} _{-0.15}	9 ^{+0.0} _{-0.4}	6.43	2.5	4.5 ^{+0.2} _{-0.2}

Development background

The transmission transformer for the xDSL modem is used at a relatively higher magnetic flux density (several 10mT) than ordinary transmission transformers.

Essential conditions of the next-generation of high-speed transmission transformers

For the xDSL which offers communications up to several 10Mbps, high-quality, high-speed transformer performance of information signals are essential, as is substantial isolation between the primary and the secondary. In particular, reducing THD (Total Harmonic Distortion) and the resistance of the winding to less than half of the line impedance are very essential.

DN70 material

INFORMATION

The standard concerning "Total Harmonic Distortion" was added to the IEC standard under consideration titled "CORES MADE OF MAGNETICALLY SOFT FERRITES - MEASURING METHODS/Part 2: Magnetic properties at low excitation".

THD is a concept evaluating the transmission/conversion characteristics of transformers and converters and shows the ratio between the sum of effective values and the effective value of the fundamental wave in the higher harmonic elements in dB. The value changes depending on the core characteristic, number of coils, frequency, terminal resistance value, and so forth. Therefore, the standard THD coefficient (THDF) has been stipulated as a measuring condition of core material characteristics and publication in manufactures' catalogues of the measurement value based on this condition is currently under advisement*.

*Part 3: Guide on the format of data appearing in manufactures' catalogues of transformer and inductor cores



Also, as broadband networking becomes increasingly popular, integrating modems to small digital devices will be accelerated, resulting in further downsizing of transmission transformers.

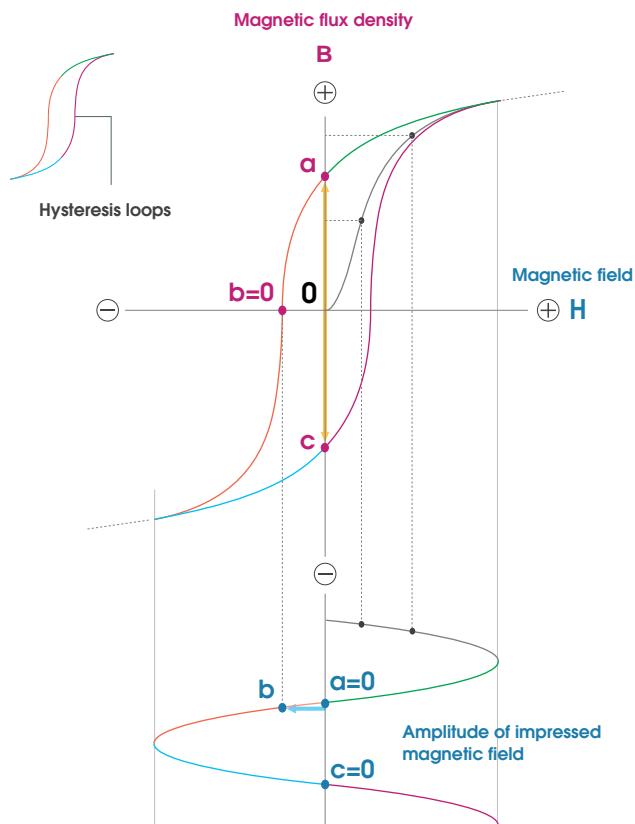
THD and ferrite-native magnetization mechanism

The THD of transmission transformers complexly involves diverse elements such as coil number, frequency, terminal resistance value, and so on, as well as core characteristics. In terms of ferrite cores, the main cause of THD is the hysteresis behavior where residual magnetization after the external magnetic field becomes zero during the magnetization proc-

ess by an externally-impressed magnetic field. In short, there will be a "gap" peculiar to the ferrite physicality between the change in external magnetic field (change in electrical current on the primary coil) and the change in the amount of magnetized ferrite core.

As a result, the B(magnetic flux density induced by the ferrite core) - H(strength of impressed magnetic field = electrical current value of the signal) characteristic is evidenced as a loop that's widened around

the original zero point(hysteresis loop), instead of a straight line directly penetrating the original zero point.



If the response characteristic can be made almost linear, the change in the signal (electrical current) impressed on the primary, and the change in the amount of ferrite magnetization, will accurately synchronize, and the waveform can be transmitted to the secondary without large distortions (although it may still be affected by other loss elements). However, in a real sense, the physical properties of ferrite make it impossible to have the area of a hysteresis loop (hysteresis loss) equal zero. In actual transmission transformers, THD is proportional to the size of the hysteresis loss. Thus the most critical and difficult design task is to maintain a thin loop when developing a ferrite material for high-speed transmission transformers.



DN70 material

In particular, the transmission transformers for xDSL, as described earlier, are used in a higher magnetic flux density area for a transformer. It is important in ferrite physical property control to develop methods for reducing the hysteresis loss (hysteresis "swell") occurring in several 10mT areas of magnetic flux.

However, the controlling factors cover a lot of ground and are deeply interrelated to each other. The DN70 material development project involved a drastic review of the basic composition, undertaking modifications that went much deeper than experienced with conventional materials.

Solving this difficult issue through nano-level crystal fine structure control

TDK rigidly selects and manages starting materials, control granulation during pre-sintering processes, and mol ratio combinations, and performs high-dispersion processes and the original high precision temperature profile control during the sintering process. TDK has built its unique control know-how and production facilities for mass production, as well as conducting the world's leading research program on ferrite physical properties and the development of new compositions.

This time, in response to increased downsizing needs, our efforts have been focused on creating a ferrite fine structure with characteristics that go beyond those of conventional materials which had previously been highly regarded for low THD transformers. As a result, a significantly improved method for the reduction of structure-sensitive hysteresis loss on a mass-production level has been established.

Fine structure of DN70 — Gist of the low hysteresis loss technologies

Minimizing the crystal magnet anisotropic coefficient K_1 which degrades permeability

Realizing small K_1 in a wide temperature range using composition control technology which optimizes the mol ratio of metal ion, displaying both positive and negative crystal magnet anisotropic coefficient K_1 .

Reduction of crystal grain vacancy and impurities

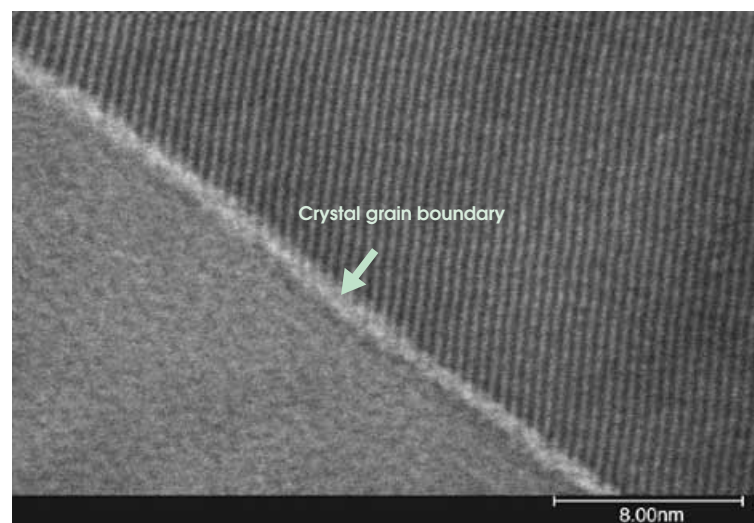
Strict control of the purity of starting materials. Temperature profile during the sintering process is controlled accurately because generated vacancies and minute amounts of additive (grain boundary component) can be induced at the grain boundary layer.

Reduction of intergranular stress and improvement of crystal density by optimizing grain boundary structure

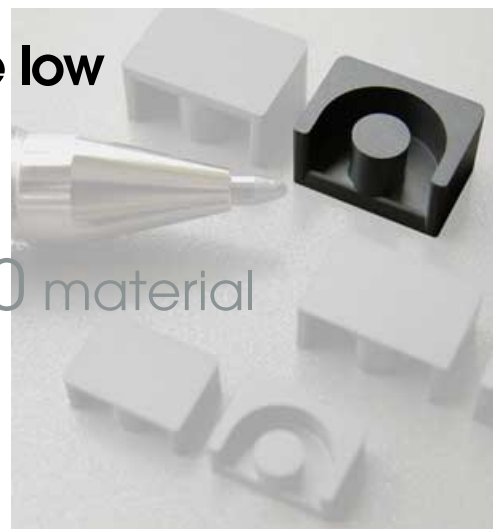
By optimizing additives, and their amounts, and strictly controlling the sintering temperature profile, the additives dispersed in the crystal grains and surplus oxygen (vacancies) can be induced to the grain boundary layer surely and equally. And by discharging the induced surplus oxygen externally, a fine structured, low stress grain boundary layer of constant composition is created that is free of gigantic vacancies which decrease crystal density.

Homogenization of crystal grain composition and equalization of crystal grain size

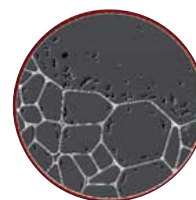
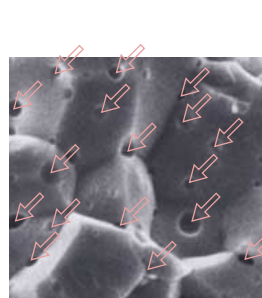
Through homogeneous dispersion of raw materials, compositional gradients between the crystal grains have been reduced. By optimizing the temperature profile during the sintering process, crystal grains are grown until they are of a size sufficient for target characteristics while avoiding non-uniformity of crystal grain sizes.



DN70 material

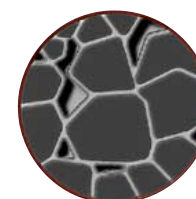


Control-failed crystal structure model A



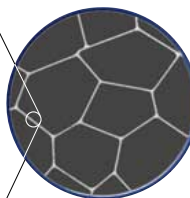
As well as a notable unevenness in grain size, many vacancies are dispersed in the crystal grains. These malfunctions become obvious when the temperature rises too quickly during the sintering process.

Control-failed crystal structure model B



A slow temperature increase can also cause such defect structures. Many gigantic vacancies (surplus oxygen) are left in the grain boundary layer, which causes a significant degradation of crystal density and μ value.

DN70 material crystal structure model



Most of the vacancies are removed and crystal grain sizes are comparable. The grain boundary layer is narrow and uniform, and there is no evidence of gigantic vacancies.

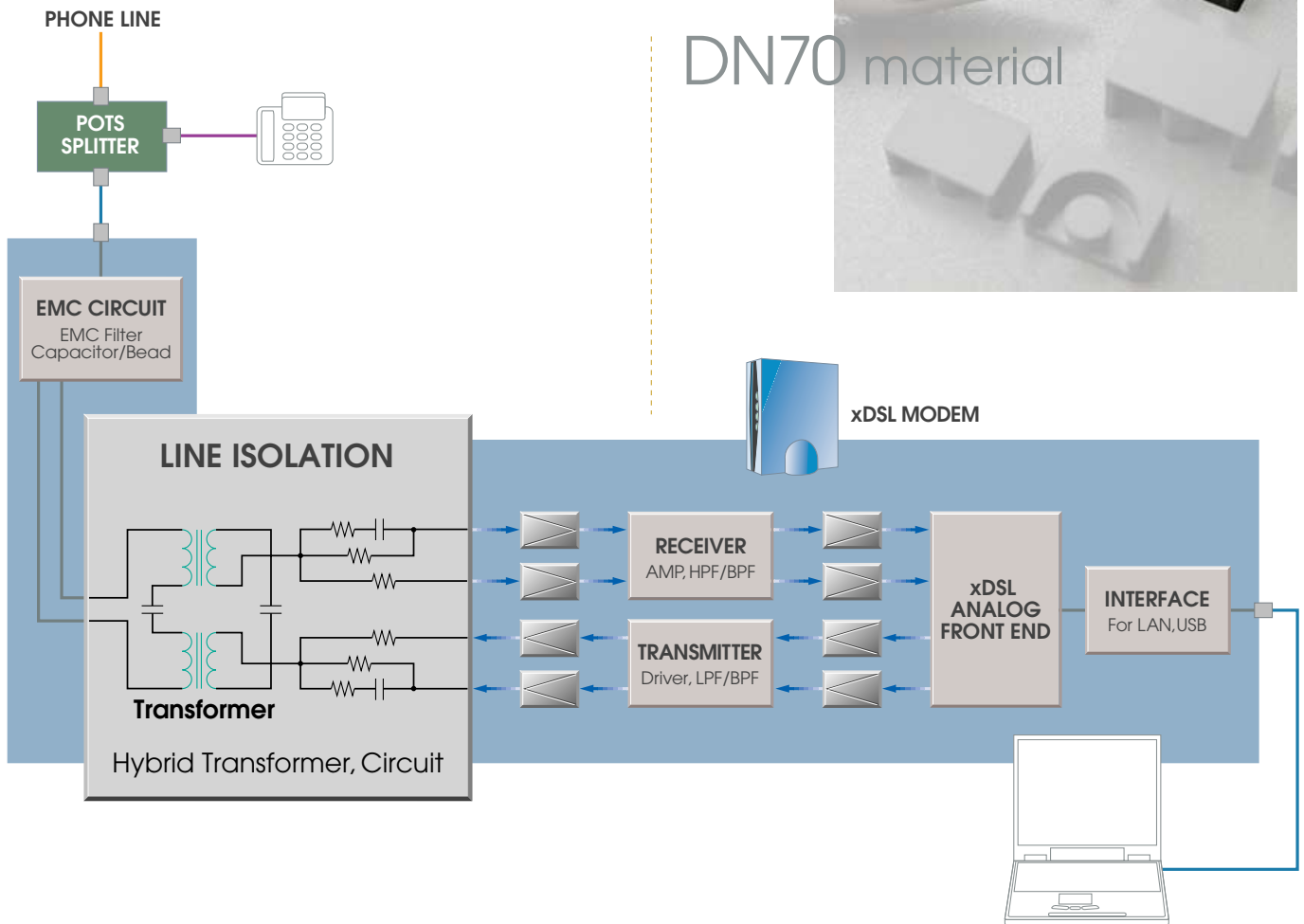
Scanning Transmission Electron Microscopy (STEM) image of DN70 material's crystal grains

Example of application

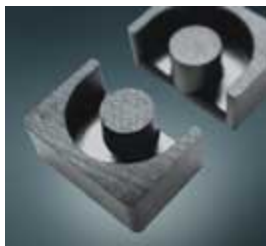
Transmission transformer for xDSL modems



DN70 material

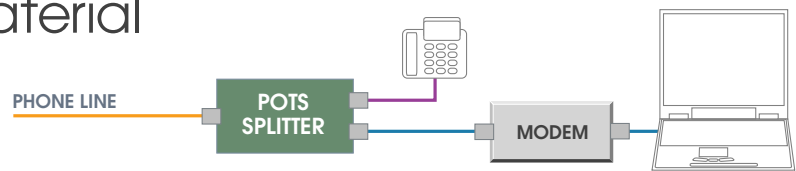


Information on related products



High saturation magnetic flux density material for POTS splitters/low-pass filters PC33 material

Diverse shapes, including EP7 type, are available.



Material characteristic

Material name	PC33
Initial permeability*1 μ_i	1400 \pm 25%
Amplitude permeability*2 μ_a	3500 typ. (at 25°C) 4500 typ. (at 100°C)
Core loss*2 P_{cv} (kW/m ³)	1350 max. / 1100 typ. (at 25°C) 750 max. / 600 typ. (at 100°C)
Saturation magnetic flux density*3 B_s (mT)	425 min. / 440 typ.
Curie temperature T_c (°C)	290 min.
Volume resistivity*1 ρ_V ($\Omega \cdot m$)	2.5 typ.
Bulk density d_b (kg/m ³)	4.8 $\times 10^3$ typ.

*1.at 25°C *2. 100kHz/200mT *3.at 100°C

Saturation magnetic flux density vs. temperature characteristic

