„FOLLOW US INTO OUR COOL WORLD AND LET US SOLVE YOUR TASKS!“

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SPAETER raw materials
A company of the SPAETER Group

STAYING COOL IS IN OUR NATURE

Hi-Cool Thermally Conductive Fillers

HI-COOL TCF

Thermally Conductive Fillers

Plastic materials are used in a wide variety of applications due to their unique capability of providing diverse and specific features and properties. Excellent processability, low weight and cost-efficiency in production allow high degrees of freedom with regard to design and modeling in many technical areas. However, today's trends in automotive, electrical and electronics industries result in additional requirements. One of the most obvious shortcomings of plastics appears to be the low thermal conductivity.

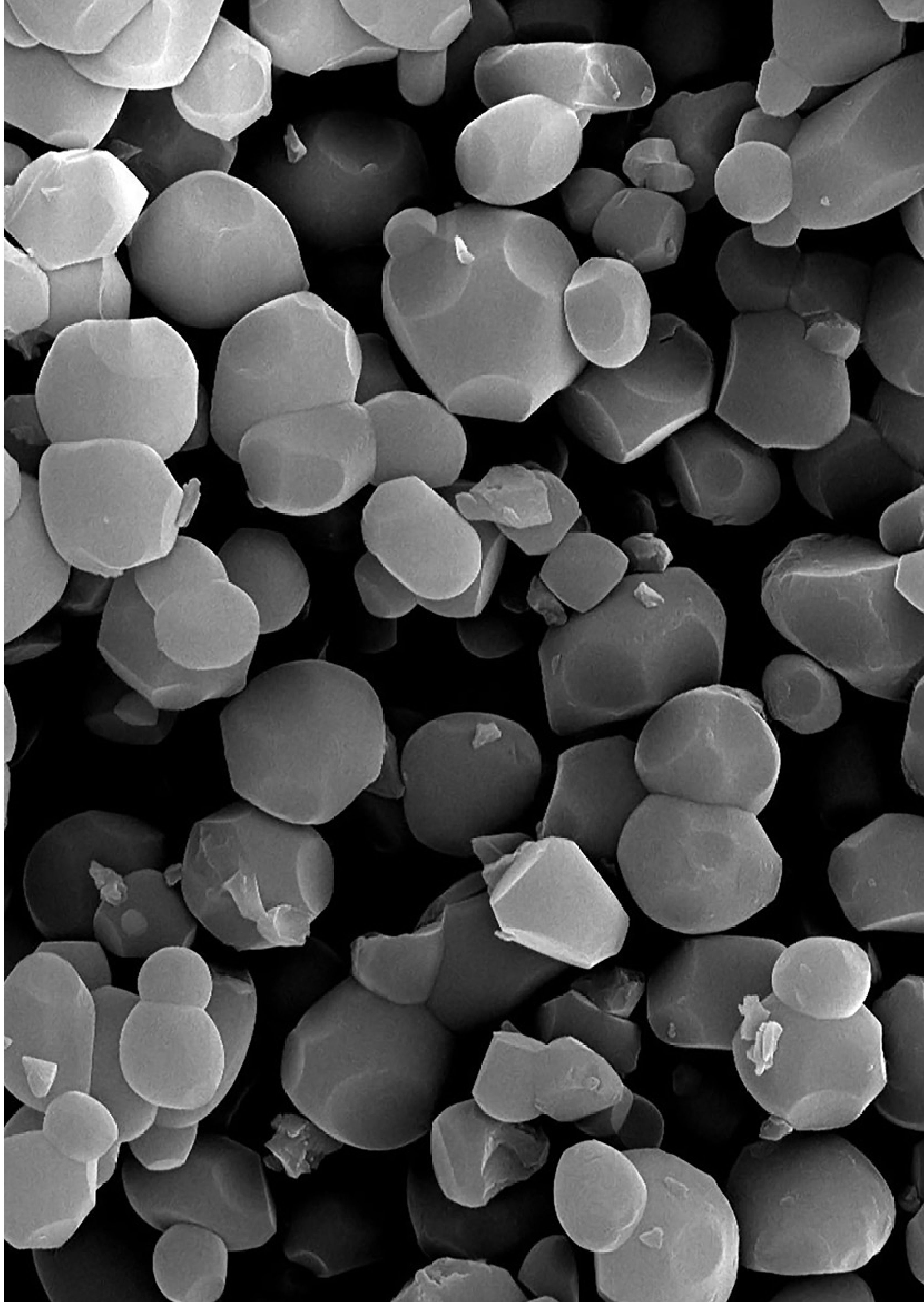
Power and high-performance electronics or electrical drive components require an excellent heat management. Specifically designed mineral filler additives are the solution to keeping the technological capabilities of plastics and enhancing the thermal properties equally.

Hi-Cool TCF thermally conductive filler series, based on aluminas and boron-nitrides, meet the demanding requirements for complex components. They are excellent tools to manage the balancing act between heat dissipation, electrical insulation, mechanical and rheological compound properties.

Particle morphology, particle size and distribution as well as the crystal structure are key factors for the functionality and the optimal incorporation in all kinds of plastic systems, such as thermoplastics, thermosets, and rubbers/elastomers.

The surface of **Hi-Cool TCF** is conditioned for specific functionalizing of the filler substrate with compatibilizers, adhesion promoters or other additives. Cost-effective in-situ application of additives is possible as well as ready-made coatings on request.

Furthermore, **Hi-Cool TCF** products are ideally suited to be combined with particular grades of Hidromag magnesium hydroxide fillers for flame retardancy without impairing the objective of thermal conductivity but extending the property profile of plastic compounds.



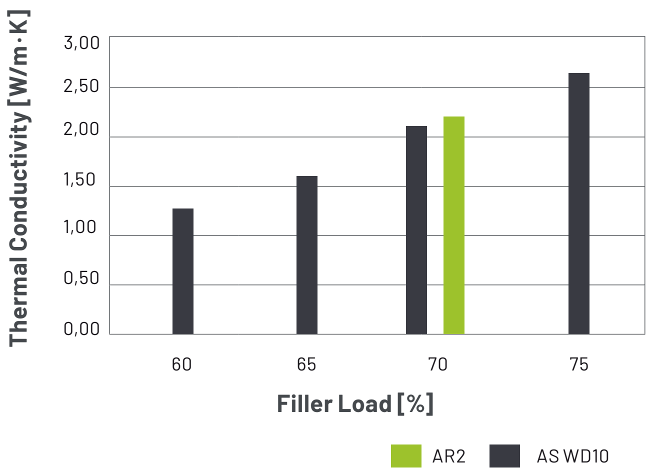
HI-COOL TCF ALUMINA

Alumina-based thermally conductive fillers

While polymers intrinsically have a low thermal conductivity in the range of 0.2 W/m·K, aluminas with particularly high content of the α-modification show thermal conductivities of rather 30 W/m·K. Specific calcination and purification processes are responsible for the formation of the beneficial trigonal crystal structure and a high density of about 3.9 g/cm³. An evenly structured, undisturbed crystal lattice is decisive for the heat conduction by atom oscillations (phonon theory for heat conduction in solid phases).

Hi-Cool TCF aluminas are manufactured in two different processes leading to either micron-sized near-spherical particles or pure spheres with median particle diameters between 1 µm to 120 µm. The spherical morphology of both lines allows high packing densities or high filler loads respectively to boost the compound conductivity. Filler loads up to 75 wt.% are realistic in thermoplastics, while pastes and other thermal interface materials can even be filled up to 90 wt.%. The spherical structure of both series of **Hi-Cool TCF** aluminas leads to almost isotropic behavior. In-plane and through-plane thermal conductivities show rather equal values. This effect allows a direction independent heat dissipation rate and eases the design of electrical and electronic components.

Thermally Conductive Aluminas
through-plane, LFA method



Experimental Conditions:
- Alumina-filled PA 6.6 compounds (Ultramid A27E)
- Processed in Coperion TSE 26 Mc
- Specimens injection molded in Arburg Allrounder 270A
- TC measurement with Netzsch, LFA 467 Light-Flash-Analyzer

Typical Characteristics of Hi-Cool α-Alumina Products

Property	Unit	Value
Thermal Conductivity	W/m·K	25-35
Specific Heat	J/g·K	0,8
Thermal Expansion Coefficient	1/K	$5{,}4 \cdot 10^{-6}$
Volumetric Resistivity	Ω·m	10^{14} - 10^{15}
True Density	g/cm³	3,85-3,90
Porosity	%	0,2-1,5
Chemical Composition		
Al_2O_3	%	> 99,9
SiO_2	ppm	< 300
Fe_2O_3	ppm	< 90
Na_2O	ppm	< 20

DID YOU KNOW ...?

Thermal conductivity of aluminas depends on α-alumina content and optimized morphology.

HI-COOL TCF ALUMINA

AR Grades

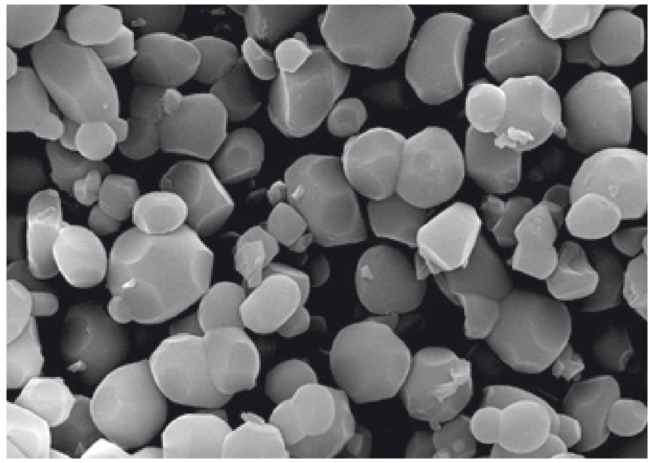
AR grades are specifically calcined and purified aluminas in micron to submicron size with near-spherical and uniform shape. The overall characteristics exhibit a universal, flexible utilization to create high-performance compounds for versatile applications.

KEY FEATURES

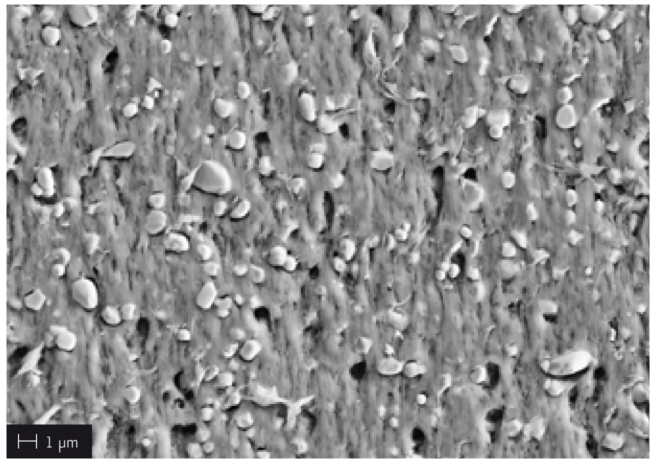
- High crystallinity and α-phase alumina portion for excellent thermal conductivity
- Low soda and iron content for perfect electrical insulation and tracking resistance
- Near-spherical particles with smooth surface lead to outstanding fluidity and dispersibility as well as high filler loads at low viscosity
- Spherical shape and small particle size avoid mechanical wear
- Very fine particle size and narrow distribution provide a basis for balancing appropriate mechanical compound properties, an easy integration of the products into thin-wall parts and even films

MAJOR APPLICATIONS

- Thermal interface materials: heat sink sheets, heat dissipation boards, heat dissipation greases, semiconductor sealing resins, silicone-based heat dissipation adhesives
- Thermal engineering plastics: LED lamp sockets and covers, heat sinks, cooling elements, housing parts and shells
- High thermal conductivity circuit boards for power electronics



Hi-Cool TCF AR-2 particles



Hi-Cool TCF AR-2: 70 wt. % filler integrated into polyamide 6.6 matrix

HI-COOL TCF ALUMINA

AS Grades

AS grades comprise of spheroidized alumina, manufactured from calcined alumina powder in a high temperature bubble-jet process. The specific procedure allows to control a remarkable sphericity, a spheroidization rate of more than 98 %, the particle size and the physical material properties, such as content of α-alumina phase being important for the thermal conductivity.

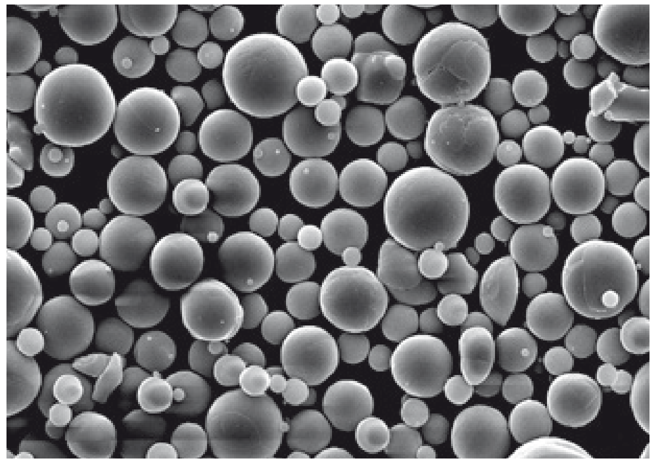
AS grades are available in narrow particle size distributions providing lowest viscosities in plastic systems, but also multimodal distributions for highest packing densities by filling the gaps between spheres

KEY FEATURES

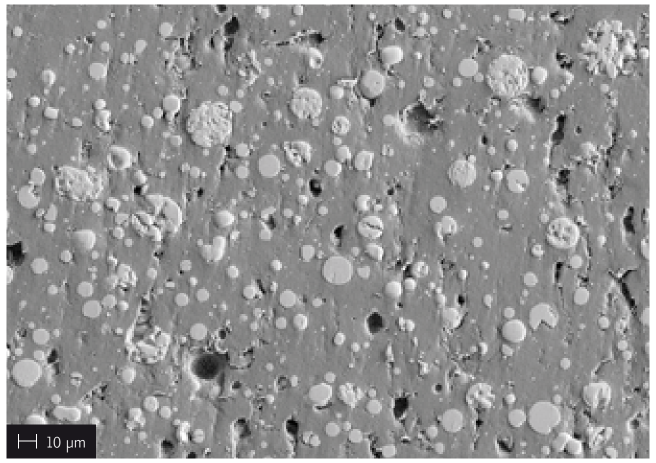
- The perfect spherical structure results in excellent rheological properties of plastic compounds. Flow path and MFR values are many times higher in comparison to more irregularly shaped fillers. Lower viscosities increase the filling capacity.
- The high degree of sphericity leads to a multidirectional, quasi-isotropic heat transfer.
- Very low abrasion in mixers, compounding equipment and injection molding
- Reduces energy consumption in processing

MAJOR APPLICATIONS

- Silicone and epoxy resins requiring low viscosities at high filler loads
- Thermal engineering plastics, particularly for injection molded parts
- CCL and MCCL laminates
- Adhesives and sealant materials for electronic and electrical components



Hi-Cool TCF-AS WD-10 particles



Hi-Cool TCF-AS WD-10: 70 wt. % filler integrated into polyamide 6.6 matrix

DID YOU KNOW ...?

A combination of flaky and spherical boron nitride particles is boosting thermal conductivity significantly.

HI-COOL TCF BORON NITRIDE

Boron Nitride-based thermally conductive fillers

Hexagonal boron nitride (hBN or α-BN) is a synthetic, high-polymer material with graphite-like sheet structure. However, in contrast to graphite, there are covalent bondings between the atoms and the electrons are localized resulting in high electrical resistivity and white color. Furthermore, hBN is an excellent thermal conductor; it is chemically inert and stable up to 1.000 °C.

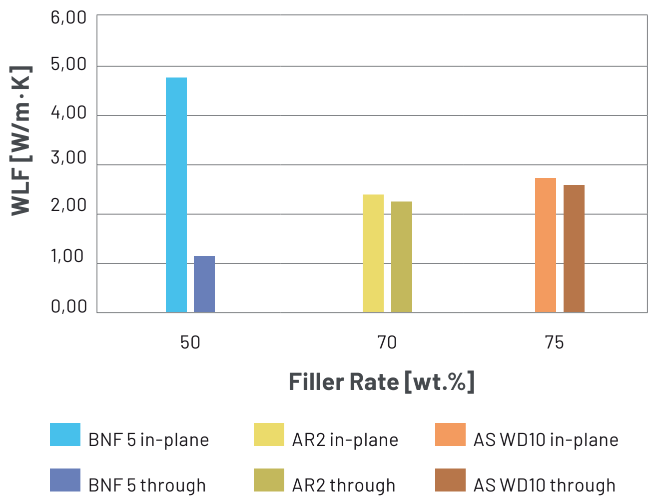
The hexagonal platy lamellar structure of boron nitride is responsible for the high anisotropy of thermal conductivity. The in-plane thermal conductivity ranges up to 300 W/m·K, while through-plane thermal conductivity shows values of about 30 to 40 W/m·K. Since platelets usually align themselves in flow direction of polymer masses, this has to be regarded if BN-filled plastics are designed.

A comparison with alumina fillers shows the directional differences. However, the high thermal conductivity potential of boron nitride at substantially lower filling rates becomes obvious also. The high anisotropy of boron nitride platelets (flakes) might be disadvantageous in particular applications, such as thermal interface materials, silicones as well as impregnation and potting resins.

High-Cool TCF spherical boron nitride agglomerates overcome this shortcoming by keeping BN particles in a random orientation and by making in consequence the material rather isotropic. The through-plane thermal conductivity is increased by factor 3 to 4.

Thermal Conductivity, dependent on Direction

BN-Flakes vs. various Aluminas in PA 6.6 Compounds



Typical Characteristics of Hi-Cool Boron Nitride Products

Property	Unit	Value
Thermal Conductivity longitudinal/cross	W/m·K	300/30-40
Specific Heat	J/g·K	0,8
Thermal Expansion Coefficient longitudinal/cross	$K^{-1} \cdot 10^{-6}$	1,1/4,0
Volumetric Resistivity	Ω·m	10^{8} - 10^{13}
True Density	g/cm^3	2,25
Chemical Composition		
BN	%	> 99,5
Oxygen	%	< 0,3
Carbon	%	< 0,1
B_2O_3	%	< 0,05

HI-COOL TCF BORON NITRIDE

BNF Grades

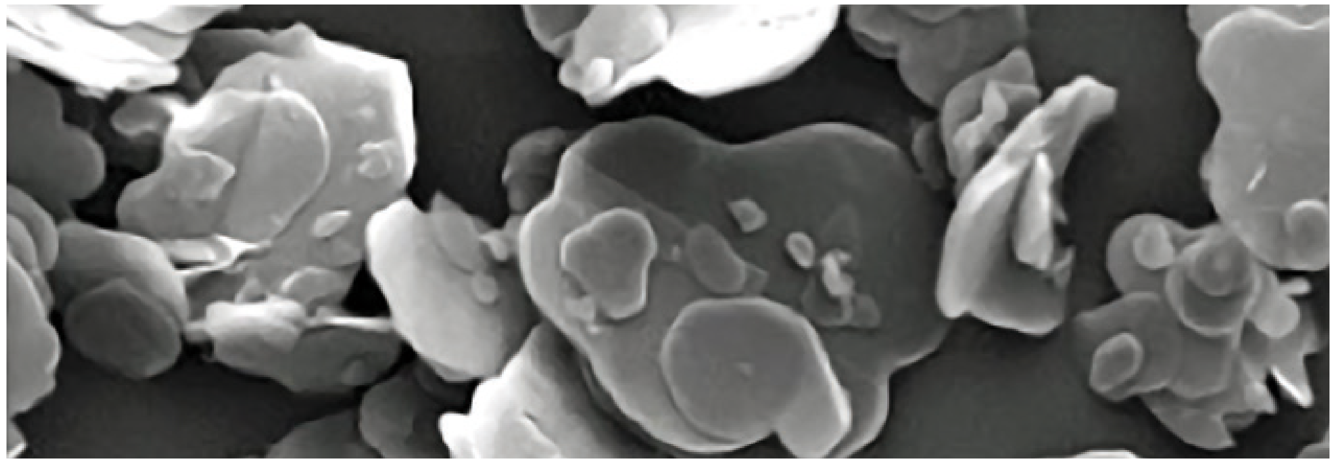
BNF grades are fillers with high aspect ratios of 2:1 up to 30:1 and a flaky morphology. The products are offered with median sizes varying from 5 µm up to 25 µm. Particle size, distribution and low specific surface areas allow an excellent thermal management profile and provide good workability at low viscosities in polymers equally. BNF flakes perfectly meet the requirements for injection molding and high-shear processing. The BNF portfolio includes standard surface treatments for essential polymer systems. Compatibilizing of the particle surface to specific customer needs can be rendered on request.

KEY FEATURES

- Very high thermal conductivity, providing excellent heat dissipation
- Low thermal expansion coefficient, comparable to mineral fillers
- High volume resistivity and low dielectric constant
- Low specific density, allowing lightweight performance plastics
- Low hardness (Mohs < 2), avoiding wear of machines, tools and molds
- Standard and customized surface treatments are available

MAJOR APPLICATIONS

- Organosilicones and epoxy resins
- Thermal engineering plastics, injection molded parts
- Thermal interface materials, greases, pads, adhesives
- E-mobility, battery cell housings, power electronic cases and parts



Hi-Cool TCF BNF 30

HI-COOL TCF BORON NITRIDE

BNS Grades

BNS grades are randomized agglomerates of boron nitride platelets with spherical shape. Since natural crystalline orientation of hBN is overridden, particles show a rather isotropic behavior. The spherical agglomerates have uniform size and a narrow distribution. Median particle sizes of the various products range from 65 µm to 180 µm. The specific surface area is kept on a very low level.

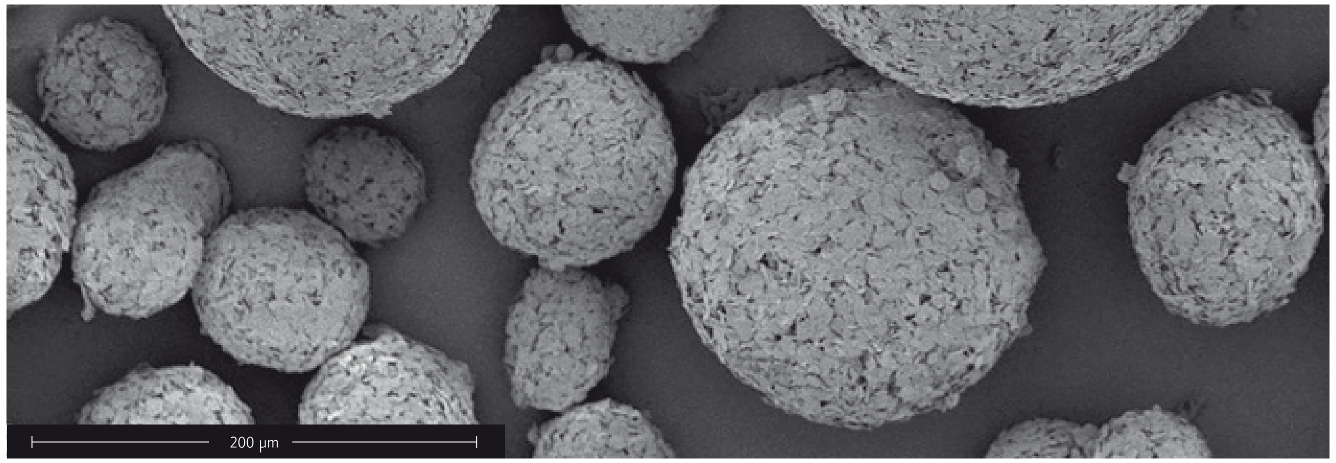
BNS grades exhibit outstanding workability, high flowability and excellent rheological properties in thermosets and thermoplastics. If BNF and BNS particles are combined in one plastic matrix, the alignment of flaky BNF with the flow direction will be suspended. The through-plane conductivity is significantly enhanced.

KEY FEATURES

- Quasi-isotropic thermal conductivity
- Easy dosing and compounding due to high flowability
- Easy blending with other fillers in the plastic system, perfect ensemble acting with flaky BNF
- High filling ability and less interfacial resistance with the polymer matrix lead to excellent overall thermal conductivity in the system
- Standard and customized surface treatments are available

MAJOR APPLICATIONS

- Silicone thermal interface materials
- Potting compounds with high filler loads, requiring highest thermal conductivity performance



Hi-Cool TCF BNS 120

DID YOU KNOW ...?

Flame retardant magnesium hydroxide HIDROMAG additionally equalizes directional differences and provides a synergistic effect on thermal conductivity.

HI-COOL TCF FILLER COMBINATIONS WITH HIDROMAG

Thermal Management is one aspect to be observed in designing plastic composites. Flame retardancy in many cases has to be regarded equally. Having in view a lower impact on human health and environment FR-additives should be halogen-free. Magnesium hydroxide is one of the proven and most efficient mineral fillers providing a halogen-free solution.

In a bench study Hi-Cool TCF products on alumina or boron nitride base have been utilized in combination with a specific grade of Hidromag (LY1, aminosilane-coated) in a PA 6.6 matrix. In the composition an appropriate portion of the thermal conductive filler has been replaced with the intention not to impair the thermal, but to improve the flame retardant properties.

HI-COOL TCF, ALUMINA BASED

In case of alumina based Hi-Cool TCF AR and AS fillers 10 wt.% of the 70 wt.% total filler load have been substituted. Surprisingly, the tests did not show any disruption of the thermal conductivity, on the contrary a further improving and equalizing effect on the thermal conductivity could be observed.

Flame retardant properties could be lifted according to UL94 vertical test from V2 classification to V1 and glow wire ignitability test (IEC 60695-2-13) GWIT for a 1mm specimen from 700°C to 750°C. Considering the small portion of flame retardant filler in the system, it is conceivable to increase the share up to 20 – 25 wt.% without disturbing the thermal conductivity and simultaneously achieving good flame retardant properties. Furthermore, the introduction of Hidromag magnesium hydroxide in the plastic system offers the opportunity to reduce the overall costs of the compound formulation.

HI-COOL TCF, BORON NITRIDE BASED

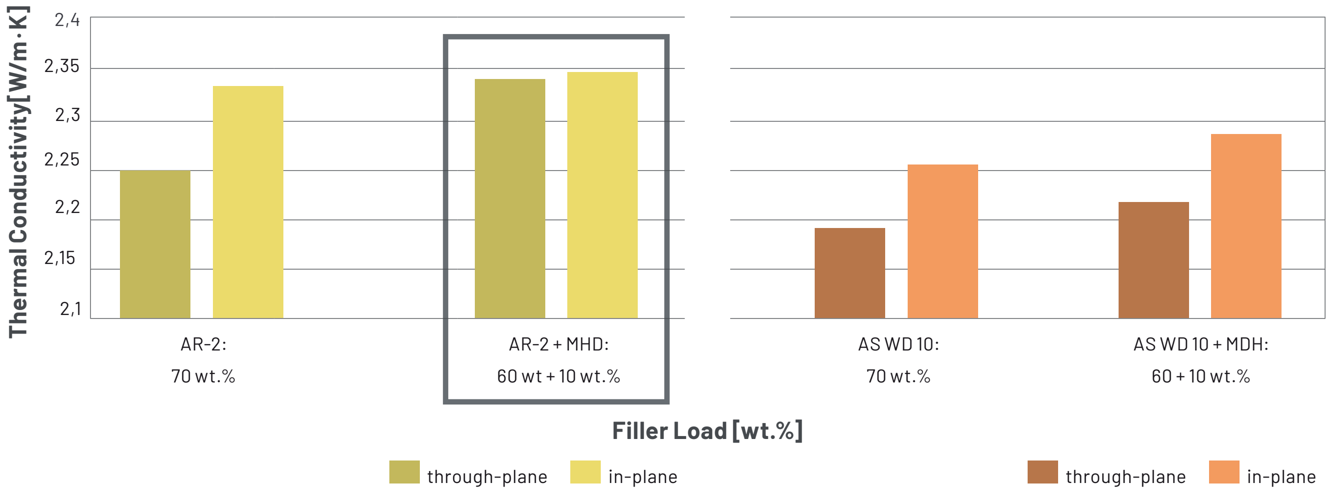
The impact of magnesium hydroxide on thermal conductive and flame retardant properties has been examined in a composite containing 35 wt.% Hi-Cool BNF and 30 wt.% Hidromag LY1 in a PA 6.6 matrix. The filler volume has been kept similar to the blend of 50 wt.% boron nitride flakes in the polyamide 6.6.

The introduction of magnesium hydroxide into the formulation led to a significant increase of thermal conductivity in the through-plane direction, while only a minor impact could be observed for in-plane flow direction. The application of Hidromag magnesium hydroxide enhances remarkably the already strong thermal conductive capabilities of Hi-Cool BNF.

The flame retardant effect of magnesium hydroxide in the composition lifts the UL 94 vertical test classification from failure to a V2 passing. The glow wire ignitability test (IEC 60695-2-13) GWIT for a 1mm specimen increased from 725°C to 775°C.

Apart from technical aspects the partial replacement of boron nitride in the overall composition by magnesium hydroxide initiates considerable cost cutting options in thermal conductive formulations.

Thermal Conductivity of Aluminas in PA 6.6 Matrix combined with MDH HIDROMAG



Thermal Conductivity of BNF in PA 6.6 Matrix combined with MDH HIDROMAG