3M Science. Applied to Life.™

3M Advanced Materials Division

3M™ Bornitrid Cooling Fillers

The next level of thermal management

For thermally conductive and electrically insulating plastics and adhesives.

Designing polymers to manage heat better

Manufacturers of consumer and automotive electronics, high capacity batteries, LED lighting and other electrical and electronic devices are increasingly utilizing high-performance polymers to reduce component size and weight while simplifying assembly. Most polymers, however, have inherent limitations in their ability to conduct heat, which can greatly affect a device's long-term reliability and performance.

3M™ Boron Nitride Cooling Fillers offer a unique opportunity for designers, compounders and molders to improve both thermal conductivity and electrical insulation in a wide range of plastics, elastomers, adhesives and more. Thanks to their enhanced thermal management capabilities, these materials are enabling a new generation of electrical and electronic components that offer improved performance, reliability and energy savings.

Meeting the need for *smart* materials

3M™ Boron Nitride Cooling Fillers are a family of advanced ceramic materials used to improve thermal conductivity in polymers while maintaining or improving electrical insulation. They are also ideal for developing lightweight parts with complex geometries.

Using 3M™ Boron Nitride Cooling Fillers, thermal conductivity can be tailored to meet the thermal requirements in your system – harmonized with performance criteria such as target electric insulation, flame retardancy, mechanical properties and compound/system cost requirements.

For example, many modern electrical and electronics applications require materials that can effectively spread heat within a small space and transfer it to the surrounding air. Plastics are the material of choice in these kinds of applications – but plastics are generally not thermally conductive. Adding 3M™ Boron Nitride Cooling Fillers to the compound is an effective way to resolve this issue.

„We work with customers to troubleshoot their processes in order to optimize performance and achieve their thermal management requirements.“

→ **DR. STEFANIE WILDHACK**

Potential Applications

- Thermal interface materials (TIMs) and heat sinks for laptops, smart phones, televisions and other consumer and automotive electronics
- Thermally-conductive adhesives and greases as well as potting resins
- Automotive electrification, including housings for high-capacity batteries and electric motors in electric and hybrid vehicles
- LEDs for street and interior lighting

With 3M™ Boron Nitride Cooling Fillers, you can achieve polymers with excellent thermal conductivity.

To see how it works, visit **3M.com/thermalmanagement**

Inside the Technology

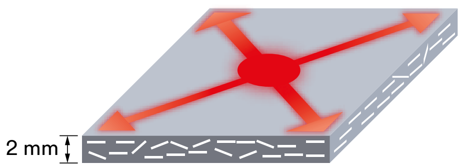
Boron nitride: the *white graphite*

Hexagonal boron nitride (hBN) is a synthetic material with a high aspect ratio (ranging from 2:1 to 30:1) and a structure similar to graphite. Unlike graphite, 3M™ Boron Nitride has a pure white color and is not electrically conductive.

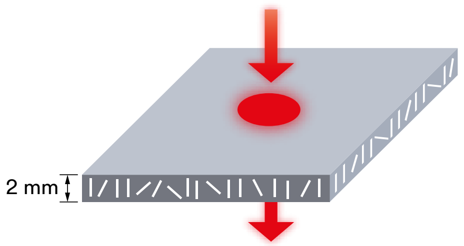
The particle geometry and composition of 3M™ Boron Nitride cooling fillers have been specially engineered for better heat transfer and dissipation – both of which are affected by the orientation of the material grades (platelets, flakes, agglomerates) as shown in the illustrations below.

The 3M™ Boron Nitride Cooling Fillers are engineered to line up easily and to form *bridges* that conduct heat in the direction of their orientation, which can be made either generally horizontal or generally vertical. This orientation is accomplished by employing various formulating and processing techniques.

PIC. 1 › Heat Spreading/Dissipation In-Plane x-y Direction



PIC. 2 › Heat Transfer Through-Plane z Direction



Features and Benefits

- High thermal conductivity – improve thermal dissipation and heat transfer.
- Electrical insulation – high dielectric strength and breakthrough voltages in insulation.
- Low density – for lighter weight final parts.
- Very good processing properties – non-abrasive, lubricating; typically minimal viscosity increase.
- Optical properties – easy to color, excellent optical surface quality and >95 % reflectivity.

„3M's application engineering team has the experience and technical expertise to help customers optimize their formulations to take advantage of the unique properties of 3M™ Boron Nitride Cooling Fillers.“

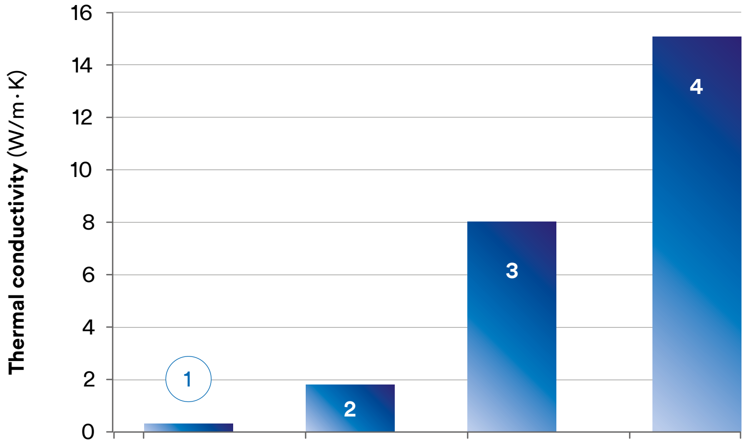
→ **KAZUOMI MOTODAV**

Thermal Conductivity

Thermal conductivity in plastics is limited by the amount of fillers and the natural conductivity of the base polymer matrix. For example, with spherical alumina, thermal conductivity can be increased up to 3.5 or 4 W/m·K* Compounds filled with 3M™ Boron Nitride Cooling Fillers, however, can reach conductivity levels up to 15 W/m·K* while maintaining good processing properties.

* Flash measurement according to ASTM E 1461/DIN EN 821 on 2 mm samples.

Comparing In-Plane Thermal Conductivity of Thermally Conductive Plastics



1. Engineering plastics
2. PA compounds with ~60 wt.% of oxide-ceramic fillers
3. PA compounds with ~60 wt.% 3M™ Boron Nitride Cooling Fillers Platelets
4. TPE compounds with ~75 wt.% 3M™ Boron Nitride Cooling Fillers Platelets

Electrical Insulation

When using electrically conductive additives, such as graphite, additional insulation layers are typically required. These layers not only add to the size and cost of the component, but also form an added barrier to efficient heat transfer. 3M™ Boron Nitride Cooling Fillers can maintain or even improve the electrical insulation values of the filled compound while achieving high thermal conductivity.

Typical Electrical Properties

Electrical Resistance	> 10^{15} Ohm·cm
Dielectric Constant	3.9

Low Density

For equivalent thermal conductivity levels, a much lower weight percentage of boron nitride is necessary, compared to mineral or oxide-based fillers. Consequently, a boron nitride-filled compound at the same level has lower density. For example, an Al_2O_3-PA66 compound (2.3 kg/L) is 1.6 × heavier than a BN-PA66 compound (1.4 kg/L).

The lower density of 3M™ Boron Nitride Cooling Fillers can help improve processing and reduce final part weight.

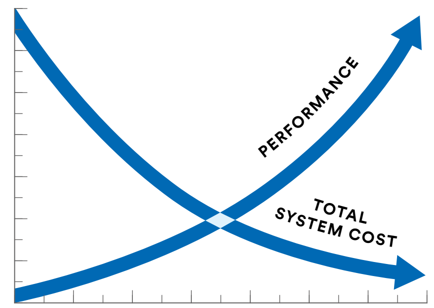
Density of Thermally Conductive Fillers

Fillers	Density (g/cm³)
Al_2O_3	3.99
AlN	3.26
Al_2SiO_5	3.60
BN	**2.25**

System Cost Reduction

Boron nitride-filled compounds can achieve thermally conductive properties that are not possible with conventional plastics. By integrating thermal management with electrical insulation, you may eliminate the need for metal heat sinks or heat-dissipating TIM foils in many applications.

In addition, boron nitride-filled compounds are suitable for thin-walling and complex geometries, while being easy to process using standard techniques and equipment. For all these reasons, plastics filled with 3M™ Boron Nitride Cooling Fillers enable lighter, simpler component designs, which can result in more cost-effective system solutions.



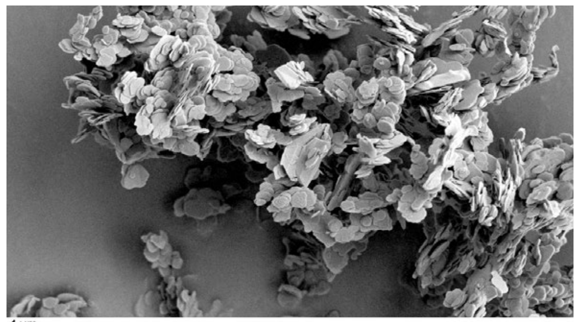
3M™ Boron Nitride Cooling Fillers can offer significant savings in total system cost by simplifying component design and improving performance.

3M™ Boron Nitride Cooling Fillers vs. Aluminum Oxide

	3M™ Bornitrid Cooling Fillers	Aluminum Oxide (Al_2O_3)
Raw Materials	• Lower loading level • Lower material consumption for thin-walled parts	• Requires higher filler loading to generate desired thermal conductivity
Processing	• Faster cycle times and line speeds • Easier to process thin-walled and complex shapes • No increase in wear on process tooling • No dust build-up during processing	• Hard to process complex or thin-walled shapes • Hard, abrasive particles cause wear on process tooling
Final Article	• Lighter weight, thinner parts • High heat removal capability • Simpler, more compact designs • High reflectivity	• Higher density • Heavier parts • Low reflectivity for LED applications

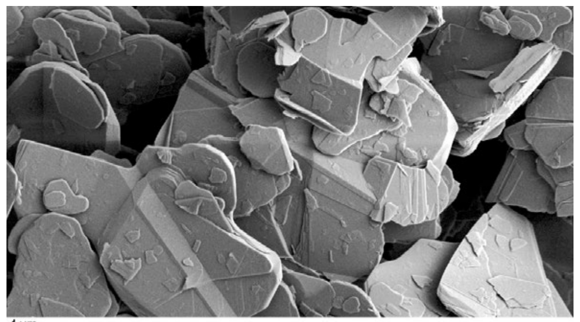
3M™ Bornitrid Cooling Fillers: Grade Profiles

3M™ Bornitrid Cooling Fillers Platelets
CFP 001 und 003SF
Preferred for thin films <25 µm and fibers, fine channels and windings.
CFP 003SF has a controlled top size.



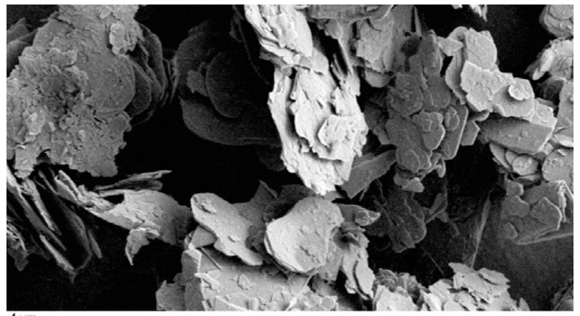
1 µm SEM micrograph: CFP 003SF

3M™ Bornitrid Cooling Fillers Platelets
CFP 003E, 003, 006, 0075, 009 and 012
Optimal all-purpose grades for pads and injection molded parts.



1 µm SEM micrograph: CFP 0075

3M™ Bornitrid Cooling Fillers Platelets
CFP 007HS
Ideal for thin films <50 µm due to its controlled top size. Highest reflectivity and increased in-plane thermal conductivity in pads.



1 µm SEM micrograph: CFP 007HS

3M™ Bornitrid Cooling Fillers Granulated Platelets
CFP 012P
Spray-dried boron nitride platelets for excellent processability, flowability and high dosing velocities for extruded and injection molded parts.

20 µm SEM micrograph: CFP 012P

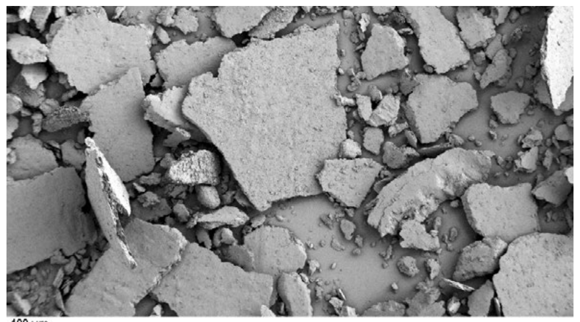
3M™ Bornitrid Cooling Fillers Agglomerates
CFA 250S
Soft agglomerates for high filler loadings. Excellent processability, flowability and high dosing velocities. Best fit for silicone TIMs.

20 µm SEM micrograph: CFA 250S

3M™ Bornitrid Cooling Fillers Agglomerates
CFA 50M
Mix of agglomerates, platelets and boron nitride clusters. Excellent for potting resins.

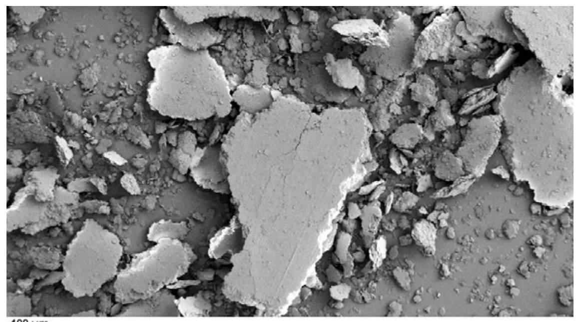
20 µm SEM micrograph: CFA 50M

3M™ Bornitrid Cooling Fillers Flakes
CFF 500-3 and 200-3
Highest through-plane thermal conductivity. Boosts thermal conductivity of compounds as secondary filler.



100 µm SEM micrograph: CFF 500-3

3M™ Bornitrid Cooling Fillers Flakes
CFF 500-15 and 200-15
Preferred for lowest viscosity in epoxies and silicones. High thermal conductivity.



100 µm SEM micrograph: CFF 500-15

3M™ Bornitrid Cooling Fillers Powder Characteristics

Particle Size Distribution				Bulk Density. Scott (g/cm³)	Bulk Density. DIN (g/cm³)	Surface Area (m²/g)	Grade
d(0.1) µm	d(0.5) µm	d(0.9) µm	d(0.97) µm				
n. a.	0.5[b]	0.8[b]	–	< 0.14	–	< 30	Platelets CFP 001
1.5	5	n.a.[c]	–	–	< 0.3	< 15	Platelets CFP 003E
1 – 2	2 – 6	8.5 – 22.5	–	< 0.15	–	< 20	Platelets CFP 003
0.5 – 2	2 – 6	6 – 14	–	–	< 0.15	< 20	Platelets CFP 003SF
1.5 – 3	4.5 – 8	10 – 20	–	< 0.2	–	< 10	Platelets CFP 006
1.5 – 3	5 – 8	10 – 20	–	< 0.22	–	< 15	Platelets CFP 007HS
2 – 3.5	6 – 9.5	12 – 25	–	< 0.22	–	< 7	Platelets CFP 0075
2 – 3.5	6 – 12	14 – 32	–	< 0.22	–	< 6	Platelets CFP 009
2 – 4.5	8 – 14	20 – 40	–	< 0.25	–	< 5	Platelets CFP 012
65 – 120	125 – 190	200 – 300	–	–	0.3 – 0.55	< 3.5	Platelets CFP 012P[a]
5 – 10	15 – 30	35 – 70	–	–	0.1 – 0.4	< 3.5	Agglomerates CFA 50M[a]
8 – 20	40 – 100	120 – 210	–	–	0.3 – 0.6	< 5	Agglomerates CFA 250S[a]
140 – 260	300 – 530	–	–	–	0.25 – 0.5	< 7.5	Flakes CFF 500-3[a]
5 – 120	140 – 240	–	< 450	–	0.3 – 0.6	< 10	Flakes CFF 200-3[a]
20 – 150	160 – 400	–	–	–	0.5 – 0.7	< 3.0	Flakes CFF 500-15[a]
5 – 55	65 – 210	–	< 450	–	0.5 – 0.75	< 3.0	Flakes CFF 200-15*

Typical Physical Properties	
O	< 0.7 %[d]
C	< 0.2 %[e]
B_2O_3	< 0.1 %[f]
BN	< 98.5 %[g]

Bulk density determined according to ASTM B329/ISO 3923-2 (Scott density) and according to ISO 23145-2 (DIN density)Particle size distribution measured by laser light scattering (Mastersizer 2000, dispersion in ethanol)

a) Particle size distribution measured by laser light scattering (Mastersizer 2000, dry, 0.1 bar)
b) Data determined by means of SEM pictures
c) Can include soft agglomerates with 50 – 100 µm
d) Platelets CFP 003, 003E and 003SF: O ≤ 1.1 %, Platelets CFP 001: O ≤ 1.2 %, Agglomerates CFA 250S: O ≤ 10.0 %
e) Platelets CFP 012P: C ≤ 2.0%
f) Platelets CFP 001 ana 003SF: B_2O_3 ≤ 0.2 %
g) BN content is calculated as (100 % – B_2O_3, O, C, Si, Al, Fe, Ca, without loss on drying), Platelets CFP 001, 003, 003E and 003SF: BN ≥ 98.0 %, Platelets CFP 012P: BN ≥ 97.0 %, Agglomerates CFA 250S: BN ≥ 80.0 %, contains an organic binder

For calculation purpose: Density of bulk hBN 2.25 g/cm³

Not for specification purposes.

Expert application support

That's the 3M difference

3M is known throughout the world as a pioneer in advanced ceramics, and has provided industry with innovative boron nitride cooling fillers for over 10 years. But when it comes to making finished parts, the quality of your raw material is just one piece of the puzzle.

Factors such as melt temperature, screw speed, injection rate and more can have a significant effect on the thermal and electrical insulative properties of parts made with boron nitride cooling fillers. That's why our experienced team of materials engineers, product specialists and field application engineers will work closely with you to develop formulations and processes that can help you achieve optimal thermal conductivity and desired performance levels.

Our mission is to help you be successful in the implementation of new product ideas or in the optimization of existing designs using 3M™ Boron Nitride Cooling Fillers. By taking advantage of our expertise and insights, you can realize the full potential of these materials.

Product is manufactured and sold by 3M Technical Ceramics, Zweigniederlassung der 3M Deutschland GmbH.

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The management system has been certified according to DIN EN ISO 9001, DIN EN ISO 50001, DIN EN ISO 14001.