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3M Advanced Materials Division

Boron nitride: Why it's more effective vs. other thermally conductive filler materials

As technology rapidly advances in fields such as electronics, automotive, 5G and more, thermal management has never been more important. Components like EV battery and LED housings, adhesives, potting resins, thermal pads and heat spreaders must manage heat much more effectively to help keep vital systems operating smoothly. Manufacturers in search of lighter weight and lower production costs increasingly choose polymer-based materials in place of metal – but the thermal conductivity of these polymers is typically very low. Adding thermal fillers to thermoplastic, elastomer and thermoset resin compounds is a common solution.

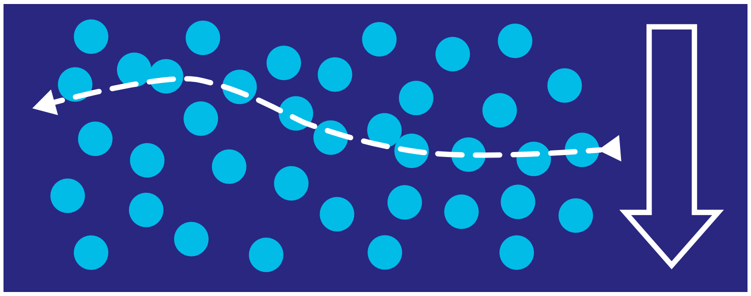
Thermally conductive filler materials include silica, alumina, minerals and magnesium oxide. Among competing priorities for powerful functionality, smaller space and lighter weight, which filler can provide the highest performance?

What makes 3M™ Boron Nitride Cooling Fillers more thermally conductive?

The key to thermal conductivity is the shape of the filler particles. Common oxide- and mineral-based cooling fillers typically contain round particles that do not readily interact with each other in the compound. 3M Boron Nitride Cooling Fillers (3M BN cooling fillers) are comprised of hexagonal or randomly-shaped particles with high aspect ratios. Even in isotropic grades (3M™ Boron Nitride Cooling Filler Platelets, 3M™ Boron Nitride Cooling Filler Flakes), these high aspect-ratio particles contact and align with each other during compounding to form multiple heat paths through the polymer. This increases the thermal conductivity of both the compound and the finished part.

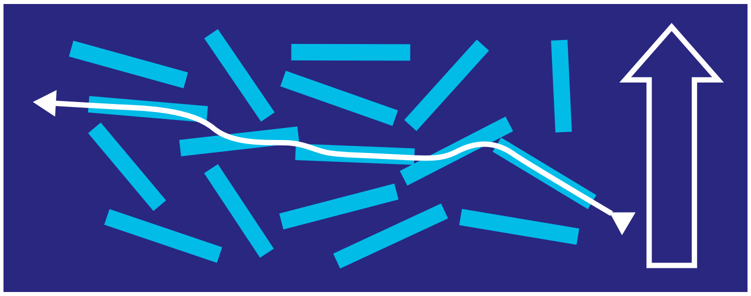
Low aspect-ratio fillers

- Particles are round, often very close to spherical
- Little or no contact with each other
- Very limited direct heat paths within polymers
- Low aspect-ratio fillers include: alumina, aluminosilicate, mineral



High aspect-ratio fillers

- Align randomly within polymer
- Multiple contact points and heat paths
- Higher thermal conductivity without altering filler loadings
- High aspect ratio fillers include: graphite, hexagonal boron nitride



For example, boron nitride is 8–20x more thermally conductive than alumina fillers and 2–8x more thermally conductive when mixed in polymers. When used in a compound with 40% vol of thermal filler, 3M BN cooling filler flakes have 3.9x higher W/m•k vs. aluminosilicate.

Thermal conductivity is just the start.

Intrinsic thermal conductivity is the most basic property of thermal cooling fillers. However, beside the thermal conductivity, other important characteristics of the filled material, such as electrical insulation, density, viscosity and more, are modified by the fillers. The properties of the cooling filler must therefore maintain – or improve – the compound, the processing and the properties of the finished part.

The chart at right shows typical performance among a range of properties and filler materials.

Along with thermal conductivity, boron nitride excels at nearly every relevant property for all thermoplastics, thermosets and elastomers. 3M Boron Nitride Cooling Fillers help manufacturers to preserve and prolong their equipment life, and are excellent for use in parts for 5G applications thanks to their low loss factor and dielectric constant.

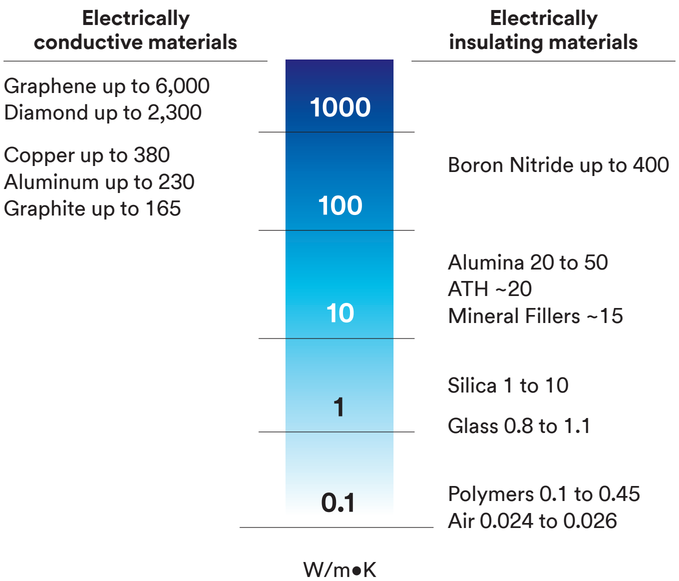
	Silica	Minerals	Alumina	Boron Nitride
Thermal conductivity	Poor	Fair	Acceptable	Good
Electrical insulation	Fair	Poor	Acceptable	Good
Abrasiveness	Fair	Acceptable	Poor	Good
Low frequency loss	Acceptable	Poor	Fair	Good
Compound density @ 2 W / m•K	–	Poor	Fair	Good
Compound tensile strength @ 2 W / m•K	–	Good	Good	Acceptable
Compound elongation at break @ 2 W / m•K	–	Acceptable	Acceptable	Good
Compound viscosity @ 2 W / m•K	–	–	Acceptable	Good

Poor Fair Acceptable Good

Electrical insulation

Boron nitride is one of the few filler materials that is both thermally conductive and electrically insulating – often critical for components used in dense electronic designs and EV batteries such as potting resins, TIM pads, housings and as direct injection overmolds to electronic components.

This graph shows the approximate electrically insulating performance of various cooling filler materials.



Boron nitride far outperforms other common thermal filler types for electrical insulation, making it a better choice for components used in automotive, electronics, 5G and more.

Density

Low-density conductive fillers are preferred for increasing the thermal conductivity of a compound without significantly altering its weight. This can help control viscosity, preserve the performance attributes of the compound, improve processing and reduce final part weight.

This chart shows approximate densities of common thermally conductive filler materials.

Filler	Density (g/cm³)
Al_2O_3	3.99
AIN	3.26
minerals (e.g. Al_2SiO_2)	3.6
BN	2.25

Boron nitride is less dense than mineral- or oxide-based fillers, so it achieves equivalent thermal conductivity at much lower percent weights. Certain grades can also be used for boosting, or reducing the amount of secondary fillers and replacing it with boron nitride for higher thermal conductivity at the same or less total percent weight.

Compounding

3M Boron Nitride Cooling Fillers are easy to process and to compound. Limiting shear stresses enables 3M BN cooling filler agglomerates and flakes to deliver better performances in many thermoplastics, thermosets and elastomers. When used with other fillers, 3M BN cooling filler agglomerates and flakes may be compounded as the very last component.

3M BN cooling fillers are excellent for use as a secondary filler in compounds that otherwise would require high volume loadings to boost thermal conductivity.

For additional information, visit www.3m.com/thermalmanagement

Safety

3M BN cooling filler platelet grades 001 and 003 SF contain diboron trioxide (CASRN 1303-86-2) as an impurity at levels which may exceed 0.1 % by weight. Diboron trioxide is listed as a Substance of Very High Concern (SVHC) identified according to Article 59 of REACH. All other 3M BN cooling filler products contain less than 0.1 wt% diboron trioxide. See product SDS for information about exposure controls and personal protective equipment.

Refer to the 3M Boron Nitride Cooling Filler Safety Data Sheet **for safety information.**

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