WhitePaper

Shielded from Electromagnetic Waves

Lightweight Conductive Plastics

Bekaert

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Less is more

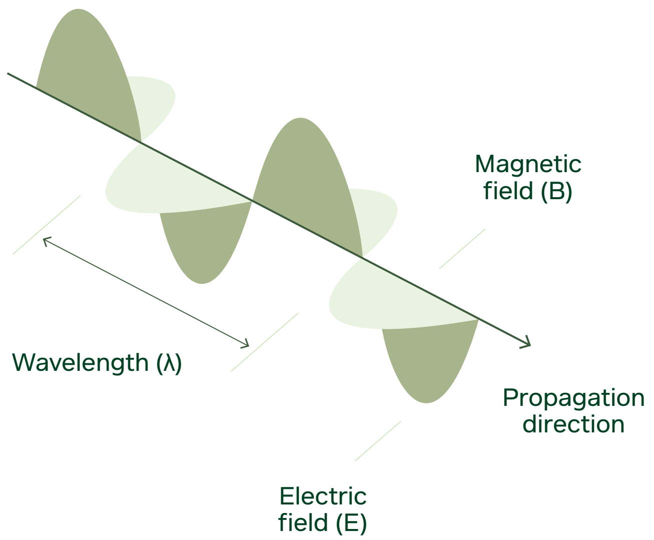
Recent studies show vehicles could be up to 35% lighter. Such dramatic weight loss could reduce fuel consumption by 12-20%. All without sacrificing safety features. To produce energy efficient vehicles, OEMs are gearing toward lightweight designs. Think bold, electrically complex designs capable of maintaining strength and integrity. To achieve their goals, manufacturers have taken bold steps toward innovative technologies and materials.

The automotive industry is evolving more and more to a self-driving computer (e.g.: electrification of cars, self-driving cars). In the pursuit of lightweight vehicles and solving EMC problems (e.g.: influence of high voltage lines and sensing electronics), lightweight technology such as EMI shielding play a crucial role. The demand for effective shielding increases alongside the number of internal components. When it comes to conductive plastics, it's all about the filler. From carbon black to stainless steel, fillers have a unique impact on the final result.

Putting metal fibers to use

Creating a Faraday cage

Electromagnetic waves are a combination of an electrical field and a magnetic field. These fields can create unwanted noise or interaction with other signals. To avoid disturbing properly functioning critical equipment, it is necessary to shield devices from electric discharges or radiation. Emission is accomplished by a Faraday cage.



By attenuating the effects of static discharges or radiation within the cage's interior (or vice-versa), a Faraday cage shields its contents from external influences like electromagnetic fields. Metal fibers can be used to create a Faraday cage, simply by incorporating metal fibers into a plastic item surrounding critical equipment.

Conductive fiber fillers

There are a wide variety of conductive fillers used in EMI shielding, many of which are both electrically and thermally conductive. Today we are going to focus on the most suitable options on the market:

- Carbon fibers (CF)
- Carbon black (CB)
- Stainless steel fibers (SSF)

Carbon fibers[1] (CF) are known for their low weight, strength, and overall stiffness. They are ideal for applications within the range of 20-40 decibel (dB). It does require a higher number of fibers to reach desired shielding effectiveness.

Carbon black[2] (CB) is comprised of carbonized fuel (acetylene) and features a high aspect ratio/conductivity. While they are used in many environments, they are well suited to a 20 dB range. However, carbon black tends to change the mechanical parameters of the plastic completely, due to high loading content.

Stainless steel fibers (SSF) are resistant to high temperatures, chemicals, and more. These fibers are also very conductive. As such, SSF easily achieve a higher shielding effectiveness within the range of 20 to 60 dB, In some cases SSF can shield at 80 dB or higher. This level of shielding is achieved with fewer fibers compared to carbon-based alternatives, resulting in low density conductive plastic.

[1] Carbon fibers are typically made from a PAN or PITCH base, succeeded by a carbonization/graphitization process.
[2] Carbon black can be made through several processes: furnace black, thermal black process, channel black process, lamp black process, acetylene black process, and so on. In most cases, an acetylene black process is used for conductive plastics.

Understanding EMI

Electromagnetic interference (EMI) is a common phenomenon found in day-to-day life. For example, EMI causes the annoying buzzing noise heard through old TV speakers while using a cell phone. While instances such as this serve as one seemingly harmless example, it does not mean EMI should be ignored. More serious consequences of EMI include life-threatening accidents and the malfunctioning of sensitive, important equipment (i.e., aviation (EMI), secure transaction servers (EMI), electric vehicles (EMI), fuel vapors at fuel stations (ESD)).

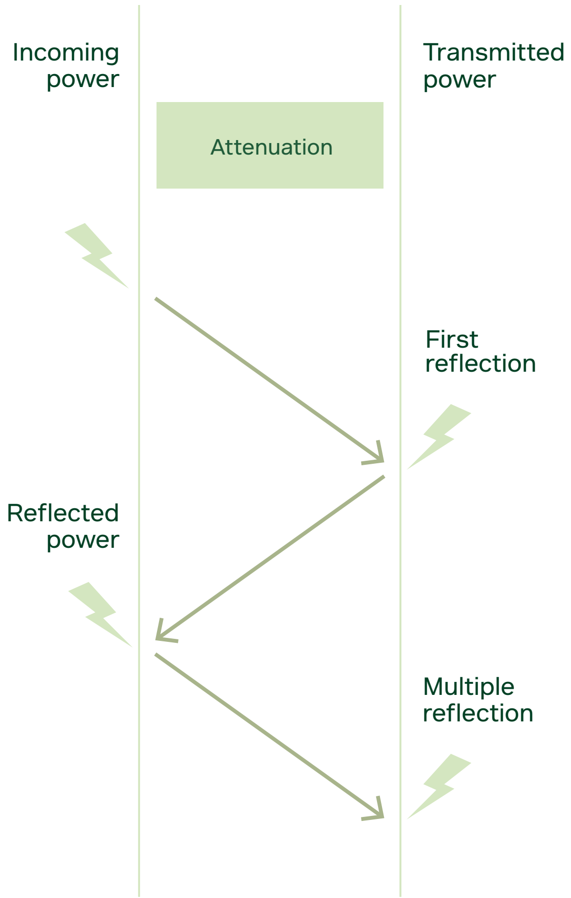
Near and far electromagnetic fields

An electromagnetic field can be described as either near or far. Whether an object is in a near or far electromagnetic field depends on its distance from the source of the electromagnetic wave, and the wavelength of said electromagnetic wave. The boundary between the near field and the far field is defined by the following equation:

- **Distance from source/(λ/2π)>1 = far field:** shielding is driven by the conductivity of Faraday cage
- **Distance from source/(λ/2π)<1 = near field:** shielding is driven by magnetic permeability

Depending on the distance from one object to source, the importance of electric and magnetic fields differs. In a near field, magnetic characteristics become more important. In a far field, electrical characteristics become stronger. The following table displays some near/far field boundaries for certain objects.

Some material properties will become more important, depending on whether the object is in a near or far field. In electrical fields, high conductivity material enables induced currents to generate an opposing electromagnetic wave that cancels incoming waves. The higher the conductivity, the more the wave cancels the incoming wave for improved shielding. In magnetic fields, the magnetic permeability and conductivity of enclosures captures the magnetic field lines of incoming waves. The housing provides a path leading away from protected objects to redirect any damaging effects. Different alloys with magnetic permeability provide better shielding in the magnetic field.



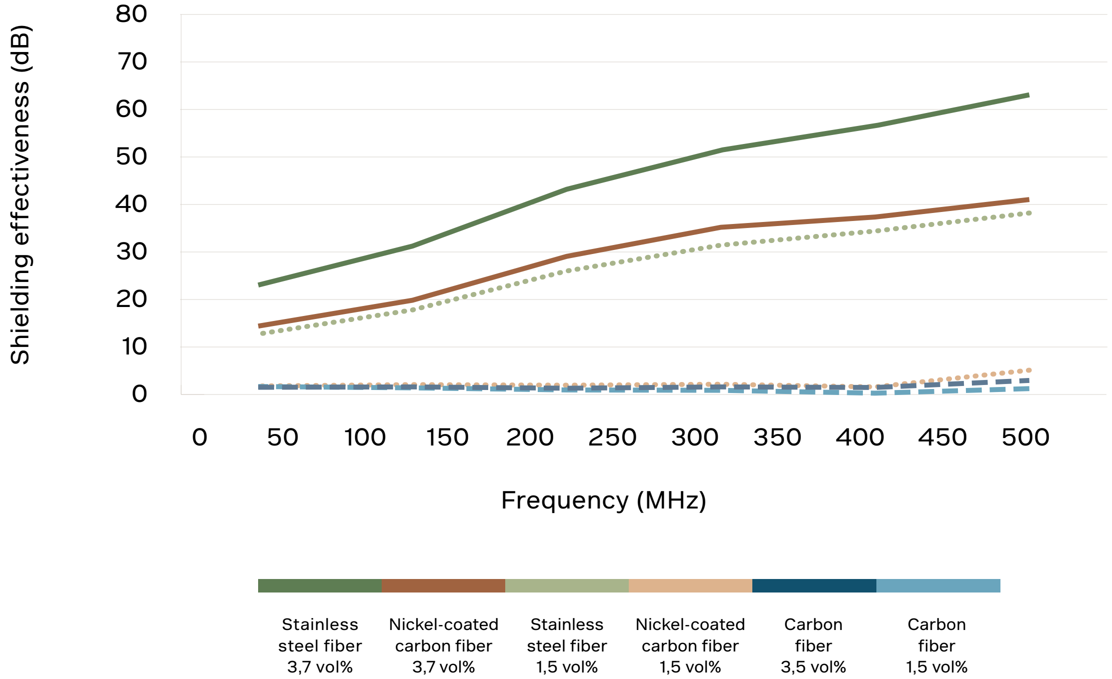
See image on page 4.

In far fields, metal fiber conductive plastics display strong shielding effectiveness at low load levels. The following figures show how the amount of filler material required with metal fibers is much lower than that of carbon fiber.

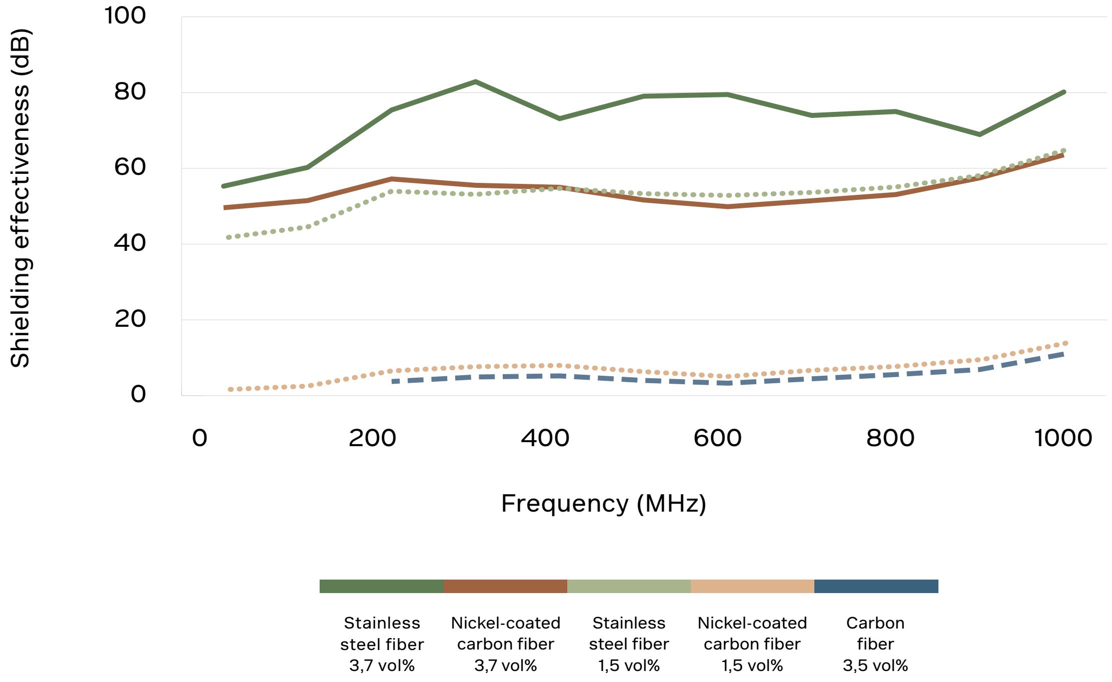
Volume % fibers	Weight % fibers (*)	Volume resistivity (Ohm. cm)	Performance (**)
0,25 - 0,5	4	< 10^2	ESD protection
1	8	0,5 - 2	30 - 50 dB EMI shielding
1,5	11	0,1 - 0,5	50 - 60 dB EMI schielding
> 1,5	> 11	< 0,1	> 60 dB EMI schielding

(*) resin density: ± 1 g/cm³ - stainless steel fiber density: ± 8 g/cm³
(**) 30-1000 MHz range of shielding

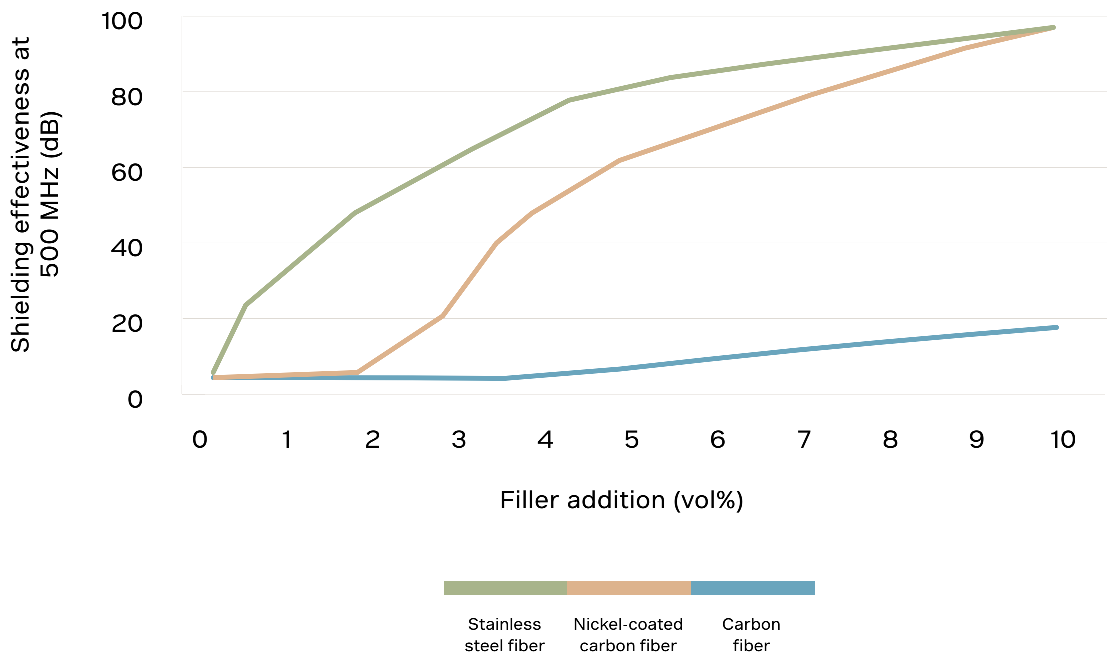
Magnetic near field



Electric far field

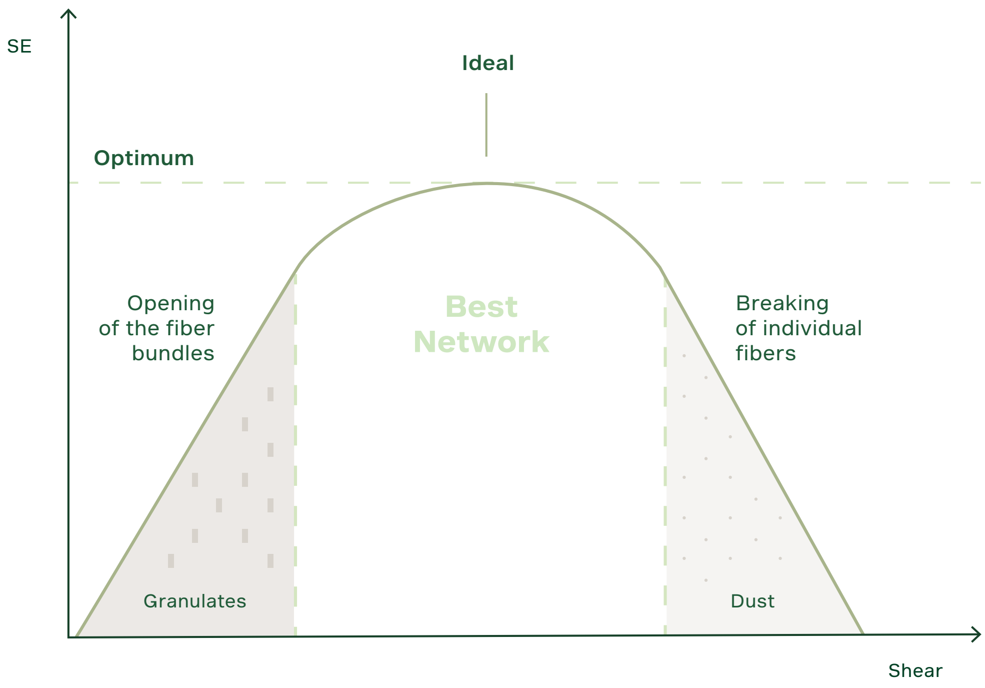


Effect of filler addition (electric far field)



The figure shown here displays the importance of maintaining shielding effectiveness by limiting the exposure to shear forces. Metal fibers will fail to disperse into a fiber network through insufficient shear forces. However, under extreme shear forces, fibers will begin to break into dust, preventing the creation of a fiber network.

Relation of SE (= Shielding Effectiveness) VS SHEAR FORCES



Metal fibers for conductive plastics

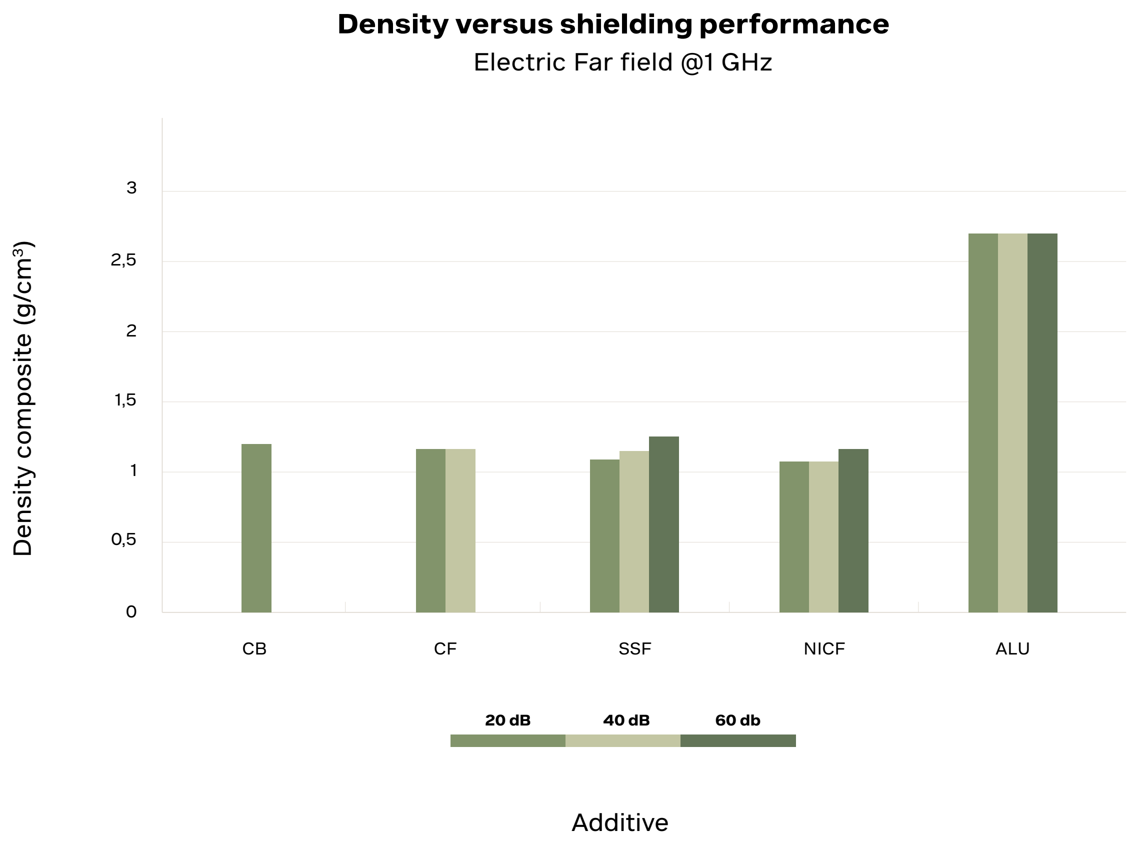
One way of preventing EMI is by adding metal fibers to a plastic component to create a conductive matrix. In such applications, metal fibers perform an additional role by replacing metal parts with lightweight plastic parts, while maintaining the required electrical conductivity.

Other advantages of metal fibers for conductive plastics include:

- High electric conductivity at low volume % of metal fiber
- Low impact on physical plastic properties (IZOD impact strength, part shrinkage)
- Durable long-lasting conductivity, non-marking, and non-sloughing characteristics
- Easy and safe handling of the material
- Processing in compounding and injection molding
- Limited influence on final color – no post processing needed
- Low volume fraction of material fibers in the end-product
- Large freedom of design – a variety of color possibilities without influencing end result

Low-density metallic fibers

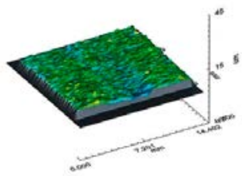
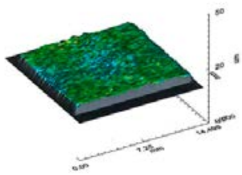
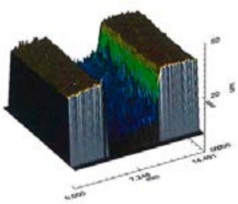
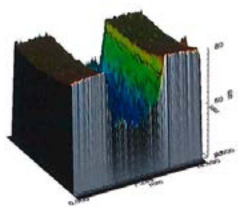
Gram for gram, stainless steel fibers have an inherently higher density than carbon-based fillers. The overall compound density, however, is much lower with stainless steel. This is because a lower volume percentage is needed to achieve quality shielding capabilities compared to alternative fillers. With good shielding performance, stainless steel fiber based compounds achieve a density of 1,15.



Metal fibers in production processing equipment

Metal fibers also play a role in shielding of equipment from EMI, such as projector devices, ECU enclosures, sensing devices, and more. Not only do metal fibers achieve a high level of EMI shielding performance but they also lead to minimal wear and tear of processing machines, like injection molding machines, extruders, and more.

Production processing equipment, such as injection molding machines, experience wear and tear during their normal lifetime. The impact of metal fibers on normal depreciation is found to be significantly less than the impact of carbon fibers. The research institute Fraunhofer LBF investigated wear testing through standardized testing. Through the DKI platelet wear testing method, researchers compared a pure PA66 sample with platelets of polyamide 66 base resins impregnated with 10% stainless steel fiber, 20% carbon fiber, and 30% fiber.

	PA66	PA66 **+ 10% stainless steel fiber (GR75)**	PA66 **+ 20% carbon fiber**	PA66 **+ 30% glass fiber**
Weight difference*	1 mg	1 mg	13 mg	20 mg
Visual inspection*				

* DKI platelet wear testing method
Metal fibers cause less wear and tear on injection molding equipment because of low required volumetric fiber content.

Testing concluded that, from an EMI shielding perspective, 10% stainless steel fiber resulted in approximately the same shielding capabilities of 20% carbon fiber. The addition of stainless steel fiber caused minimal wear and tear compared to the significant impact of carbon fiber. The key difference here being the low volumetric addition of steel fibers versus the carbon equivalent. The table shown here illustrates the weight and volume percentages required to achieve a certain level of performance of EMI shielding with metal fibers. It's possible to achieve a high degree of conductivity using low percentage volumes and weight of metal fibers.

EMI shielding plastic parts in e-mobility

- EMI functionality needed
- Low load level for high conductivity
- Limited impact on physical properties
- Sensors, battery casing, dashboards
- Lightweight design for material replacements
- Low impact on wear of processing equipment
- Colors possible for aesthetics
- Freedom of design

Endless shapes and colors

Depending on the application, stainless steel fibers offer more shape and color options than other conductive fillers. These metal fibers blend seamlessly with polymers, resins, and other materials. Although uncoated SSFs are typically silver or gray, the inherent color of the metal fibers has limited influence over the final product color, due to the low concentration of stainless steel fibers. In other words, Henry Ford's famous policy of 1914, "Any color, as long as its black," no longer apply.

Fewer fibers for low density shielding. That's the fuel efficiency of tomorrow.

Contributors

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Anthony Passchyn is the Global Head of Strategy and Product for Innovative Fiber Solutions at Bekaert. He is responsible for the long-term growth strategy and product portfolio development conductive plastics, conductive and heatresistant textiles and microcables. Anthony has a Master of Science in Electrical Engineering. He has more than 20 years of experience in B2B strategic marketing in automotive, industrial and telecom applications focusing on strategy development, global market management, international business and product development.

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Rik is an Application Manager in conductive solutions at Bekaert Fiber Technologies. Functioning in a global capacity, Rik contributes to the strategic development of new markets. While his primary focus is on anti-static and shielded plastics, Rik also works in anti-static and conductive fibers and yarns. He currently holds degrees in Electrical Engineering with a concentration in Electronics and EMC. Over the last 16 years, he has worked as an R&D Engineer at BFT for both conductive plastics and filtration. His prior experience includes EMC design, shielded materials, and more.

Modifications reserved

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