Specialty carbon black for polymers

Industry Information 0403

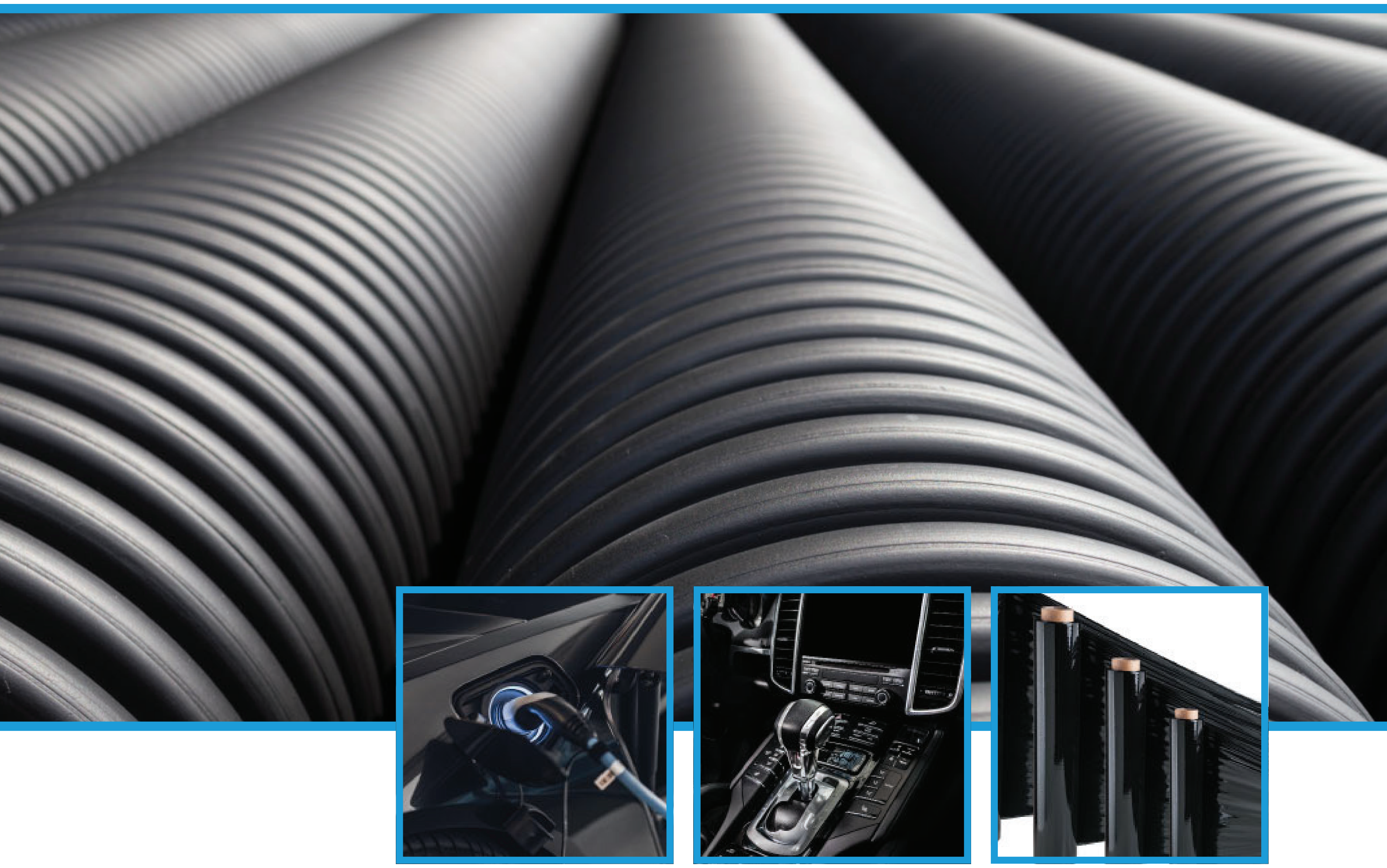


Table of contents

1 Introduction

Orion Engineered Carbons is one of the world's leading manufacturers of carbon black. Following our claim "WE KNOW BLACK", our passion is dedicated to the color black in all its shades and elegant appearance. With our expertise in carbon black we continuously strive to push the customer product to the top of its performance.

We are the only supplier, who possesses five different production processes. Our furnace-, lamp-, gas-, Acetylene- and thermal blacks enable us to offer our customers the broadest range of products and find the perfect match for their requirements. Thanks to our 14 plants worldwide we are globally present and able to react as fast as possible to our customers' needs. Our four technical centers focus continuously on searching for new innovations and carrying our product quality to the next level. More than 1400 employees work passionately every day to offer our customers the highest quality and the best service.

Carbon black boosts the chemical and physical properties of batteries, coatings, paints, polymers, rubber, and many other applications. They also enhance its electrical conductivity, UV-protection and infrared absorption. We constantly stay tuned to the customers' needs to provide them with a solution that matches perfectly their requirements following our core value of collaborative partnerships for any business action.

Carbon black is of highest importance in the polymer industry and suitable for the following applications:

- Pipes for gas, drinking and waste water
- Synthetic fibers for textiles and industrial applications
- Adhesives and sealants
- Semiconductive compounds for high voltage cables
- Cablejacketing
- Engineered polymers for automotive parts
- Films for food packaging and agricultural applications
- Conductivity

These are just some examples for the usage of carbon black in the polymer industry, should your application be missing, please do not hesitate to contact the address on the backside of the brochure.

2 Why carbon black in polymers?

Carbon black is used in polymers for various reasons. Its most important effects are recorded in its coloristic properties, UV-protection and electrical conductivity in polymers. Also, the reinforcing power and the ability to change the rheological properties of the final product are advantages of carbon black in elastomers and adhesive & sealants.

Due to carbon black's excellent UV protection, the lifetime of products exposed to environmental effects can be extended and resource consumption is effectively reduced. UV-resistant polymer pipes used for water and gas transportation have a calculated longer life span of up to 100 years.

In many ways, carbon black contributes to sustainable business approaches.

Conductive polymers can be coated antistatically, this makes them very suitable to replace heavy car body parts with lightweight plastic materials. Such a replacement leads to a lighter vehicle and thereby fosters the reduction of energy consumption, CO_2 emissions and production costs. Power cables benefit from very clean conductive carbon black. Semi conductive layers smoothen the electrical field stress, avoiding local heat overexposure which could cause a premature cable failure. An additional benefit is an increased energy transmission performance. Consequentially, a power cable's lifetime and performance are extended with carbon black.

Rheological and mechanical properties of adhesives and sealants are modified by carbon black. Flexible bonds of various materials are now possible, automotive and building constructions are optimized, weight is reduced, resources are conserved and improved processes lead to possible cost reduction. The excellent tinting strength and jetness of carbon black gives polymers an intense color and prevents color fading. These properties are requested in almost all industry fields, especially the automotive, electronic consumer goods and textile industry.

3 Carbon black basics – structure, particle size, aggregates

Carbon black is a commercial form of solid carbon that is manufactured in highly controlled processes to produce specifically engineered aggregates of carbon particles that vary in particle size, aggregate size, porosity and surface chemistry. The smaller the primary particle size, the bigger the surface. The surface is measured with nitrogen following a method by Brunauner, Emmett und Teller (BET). The specific surface area correlates indirectly with the primary particle size. The smaller the primary particles are, the higher the specific surface area is.

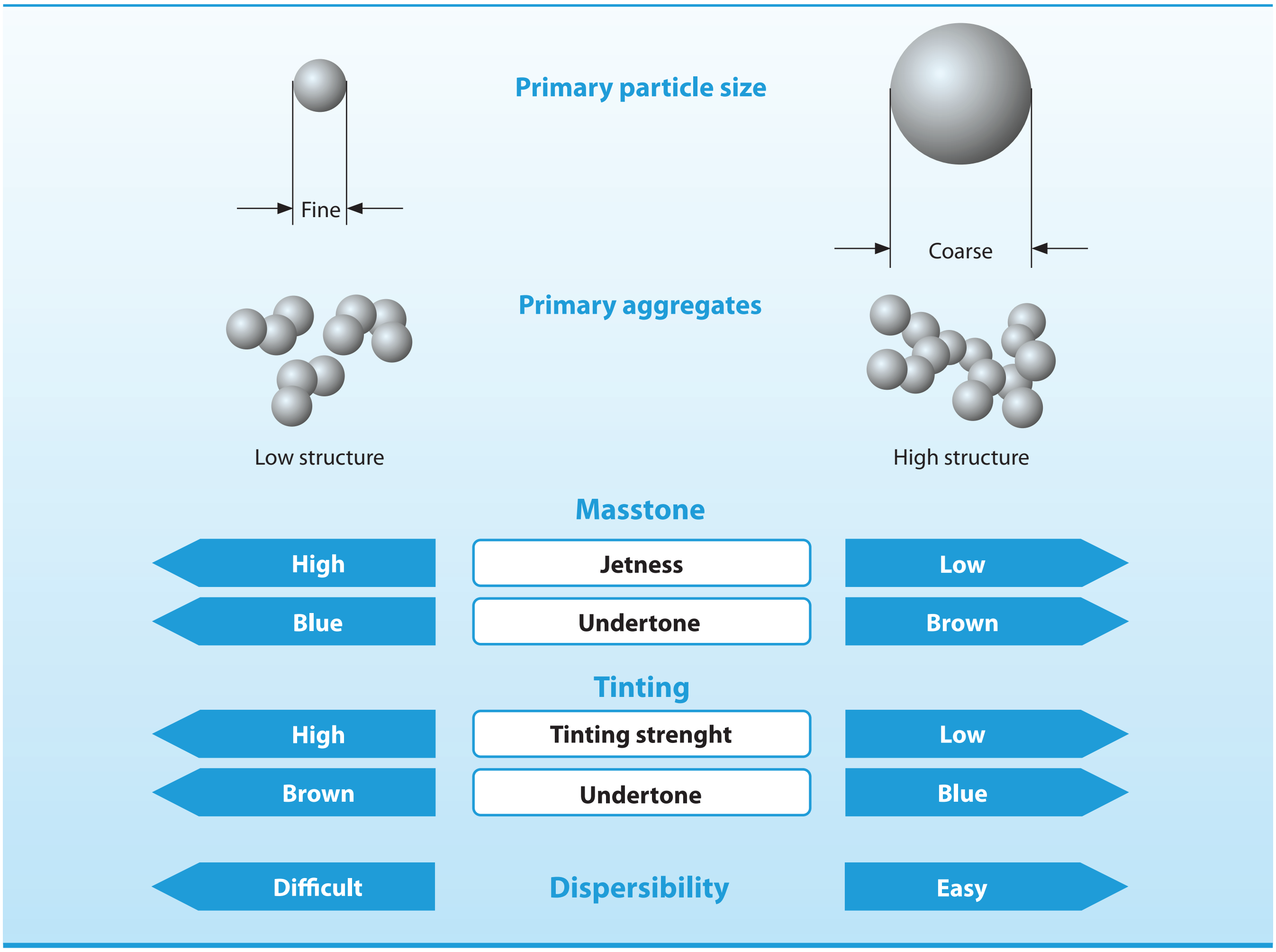
The structure of carbon black can be determined by the oil absorption number (OAN). Carbon black is put into the kneading chamber of a measuring kneader and oil is added. The endpoint has been reached when all the voids have been filled. This point of the measurement indicates the maximum of the wetting and if the structure is of low, medium or high character.

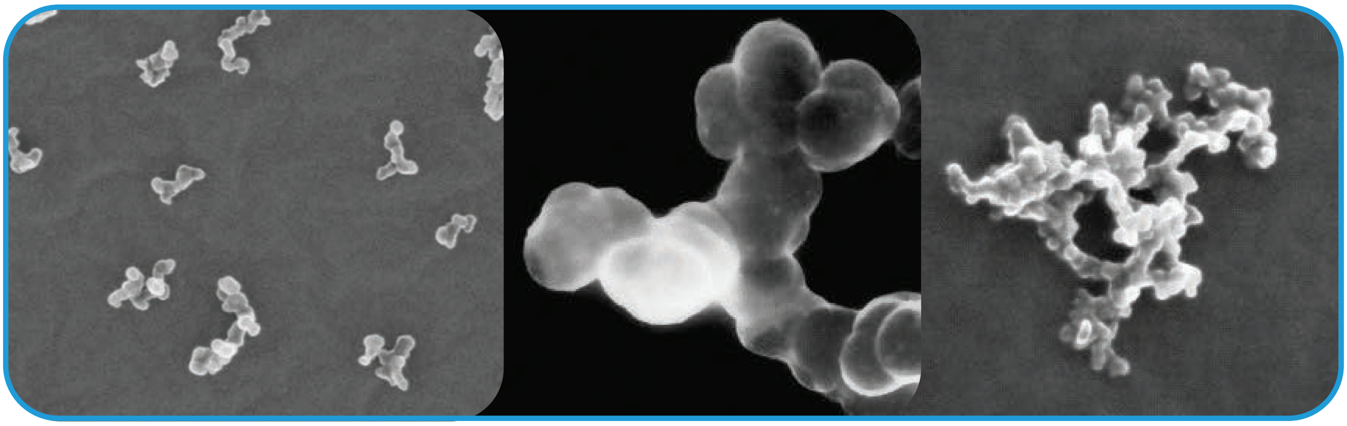
Surface and structure are independent of each other. While the surface can be defined within the production process, the structure is only adjustable in the furnace black process by using additional additives. The nature of the surface derives from the type of production process and the resulting degree of oxidation. Volatile components on the surface of the carbon black determine whether it is acidic or basic. The functional groups on the surface increase the polarity and improve the wetting properties in polar binding systems, which then has a positive effect on the dispersibility in those systems. Carbon blacks gain the best polarity characteristics when produced in the gas black process, but with possible after treatments every carbon black surface can be adapted to the customer's needs.

Figure 1 summarizes the effects of primary particle size and structure on carbon black's jetness, tinting strength, undertone and dispersibility.

Figure 1

The effects of the primary particle size and structure of specialty carbon black on jetness, tinting strength and undertone in polymers





4 Dispersion of carbon black in polymer

As all small particle size products, carbon black requires an excellent dispersion in its respective binder system to develop its fully desired and reproducible effect.

There are numerous dispersing devices, continuous and discontinuous kneaders for compounding used and available on the market today. The viscosity of the complete system and the type of polymer determine which fits best. In general, beaded carbon blacks are commonly used to produce masterbatch, as they have good flowability and can be continually dosed without interruption during processing.

During the direct compounding process of carbon black in PVC, the material usually gets pre-dispersed in heat-cool mixing combinations. As the polymer is very sensitive to shearing and only limited shear forces can be applied in the compounding process, a good pre-dispersion is important to achieve a satisfying coloring result. In this process mainly powder carbon black is used but also beaded carbon black becomes more and more popular.

For incorporating carbon black in liquid systems, such as color concentrates in form of pastes and adhesives, beading mills, 3 roller mills, rotor-stator systems, planetary dissolvers and horizontal mixers are used. Disc dissolvers are often used for prewetting the product but are rarely enough as solely used dispersing machine. In high viscose systems an additional stabilization of the carbon black dispersion is usually not necessary, while low viscose systems need to be stabilized with additional dispersing agents. Both carbon black powder and beads are used depending mainly on the dispersion equipment.

5 Carbon black performance

5.1 Coloring

Carbon black is the most commonly used pigment to provide dashboards, films, electronic devices and many other plastic articles with intense black color. The addition of 0.3 % - 1 % is usually sufficient for achieving an opaque black color. However, higher concentrations may be required for those polymer materials possessing their own inherit color, which needs to be covered.

Technical terms, such as jetness, tinting strength and undertone are frequently used when describing the coloring of polymers with carbon black. The dispersibility represents an additional key factor for getting the best color performance. The parameters are briefly defined as follows:

Jetness is the intensity of the black color achieved by the carbon black grade. The lower the light reflection from the colored material the higher is the jetness level.

Tinting strength describes carbon black's ability to color other coloring components or mask them with black coloring. If a given color shade (e.g. white or colored) is darkened by adding carbon black it is called tinting. Tinting strength indicates how much carbon black loading is necessary to cover the inherit color of the component.

Carbon blacks which have a high specific surface area and low structure have a higher tinting strength than those with lower specific surface area and higher structure. Usually those carbon blacks with a lower tinting strength and very good dispersion properties fits best for the use in a tinting application.

During the pigmenting of polymers, a definite undertone develops in addition to the black color. It can either be brownish or bluish depending on the applied type of carbon black. One must distinguish between the visual assessments of a black pigmentation in masstone when seen from above or when viewed through a transparent section or in opaque tinting applications for example grey colors.

To get the most out of carbon black, good dispersion is essential. This is achieved by wetting the carbon black surface, breaking beads and agglomerates by shear forces and distributing these fine aggregates evenly into the polymer matrix. Higher structure and coarse particles sized carbon black are easier to disperse than small and low structured carbon black.

5.2 UV Stabilization

The excellent light absorption properties of carbon black effectively protect polymers, which are exposed to sunlight, from photo-oxidative degradation.

Carbon black has several functions in regards of UV stabilization:

- It shields the polymer surface form radiation of a multitude of various wavelengths
- It converts light energy into thermal energy
- It acts as stabilizer by trapping free radicals

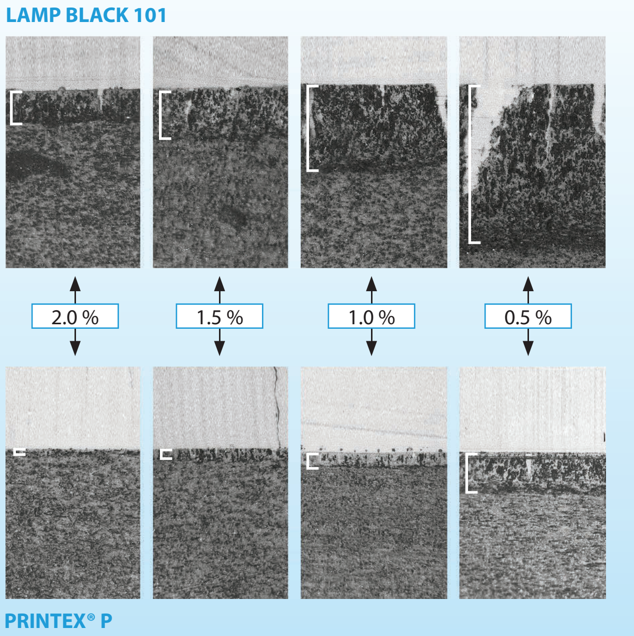
The influence of the carbon black concentration on UV stability of Polypropylene becomes visible in figure 2. Here, the depth of damage was measured in vertical cross-sections taken from the surface exposed to radiation.

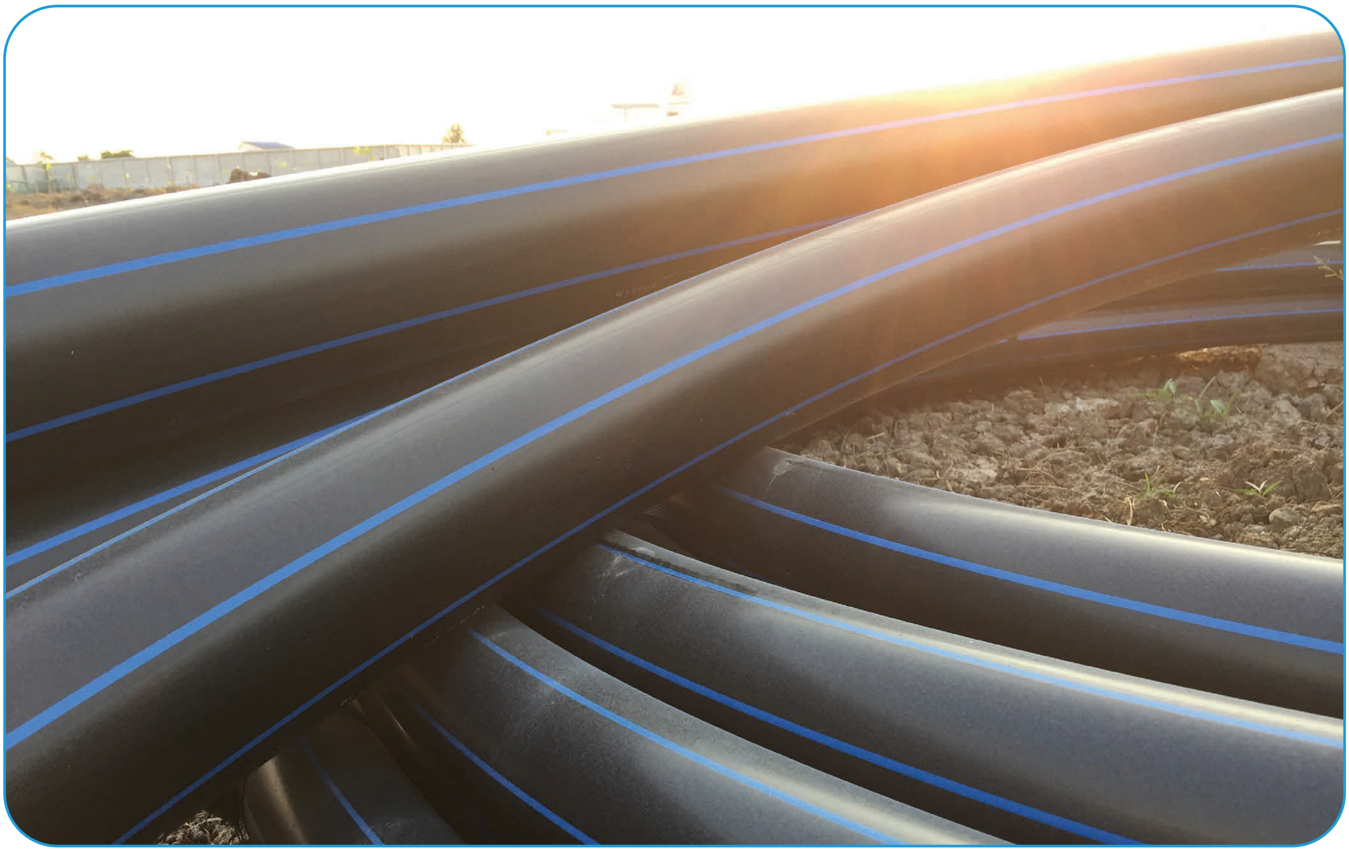
Polyolefins, in particular, are damaged by UV radiation. To protect Polyolefins a carbon black loading of ~2.0 - 2.5 wt% is recommended. This limited addition of specialty carbon black meets the various European regulations governing the use of the material in food contact applications and does not significantly affect other polymer properties, e.g. mechanical properties.

Carbon black with a primary particle size <25 nm and high structure are the most suitable UV stabilizers.

Figure 2

UV protection of Polypropylene with specialty carbon black (microtome section after 3,500 h in the Xenon test)





5.3 Electrical conductivity and insulation

Carbon black can impart conductivity and anti-static properties to polymers. Conductive polymers are used for transport packaging of sensitive electronic components, semi conductive cable compounds for conductor shielding, in floor coverings, carpet belts and conveyor belts as well as in air conduits and blasting hoses for explosives in the mining industry, just to name a few examples.

Polymers generally possess good insulation properties. Their electrical characteristics remain unchanged at carbon black loadings required for pigmentation or UV protection. Once a certain concentration of conductive carbon black is exceeded, the electrical resistivity strongly drops by several units to the power of 10 (Percolation threshold). After percolation the resistance continues to decline more slowly at increasing carbon black concentration.

The required loading level of carbon black depends on the applied type of conductive carbon black, the processing method, the requirements, which must be met and the polymer system. Typical carbon black parameters such as structure, specific surface area, porosity define the conductivity performance. In general, a higher structured carbon black is more suitable for conductive applications. For the polymer system parameters like the density, rheology, crystallinity and morphology have a high impact on the loading level.

Different processing methods can lead to substantial variations in the electrical resistance of the finished products (table 1). The reasons for this are orientation caused by different shear stress coming from the processing.

Table 1

Influence of processing methods on the electrical resistance

Process	Specific resitivity [Ω • cm]
Sheet pressing	$< 10^2$
Extrusion	$10^3 – 10^6$
Injection moulding	$10^3 – 10^{12}$
Film blowing	$10^3 – 10^8$

Figure 3

The Influence of the specialty carbon black content on the electrical resistivity of polymers

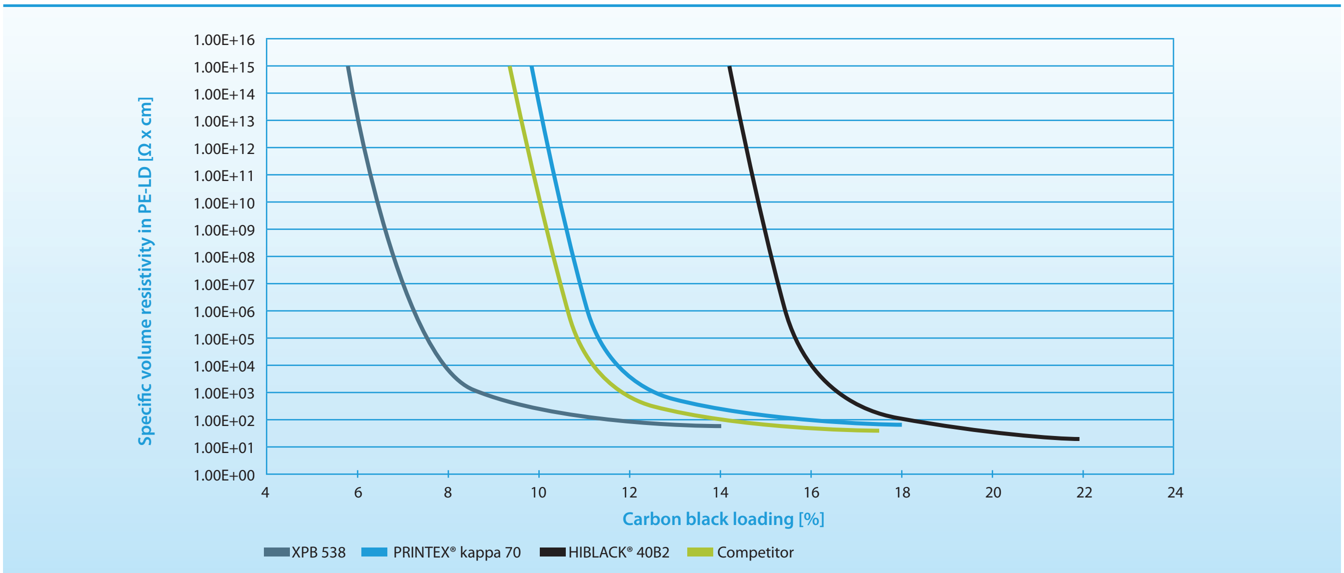
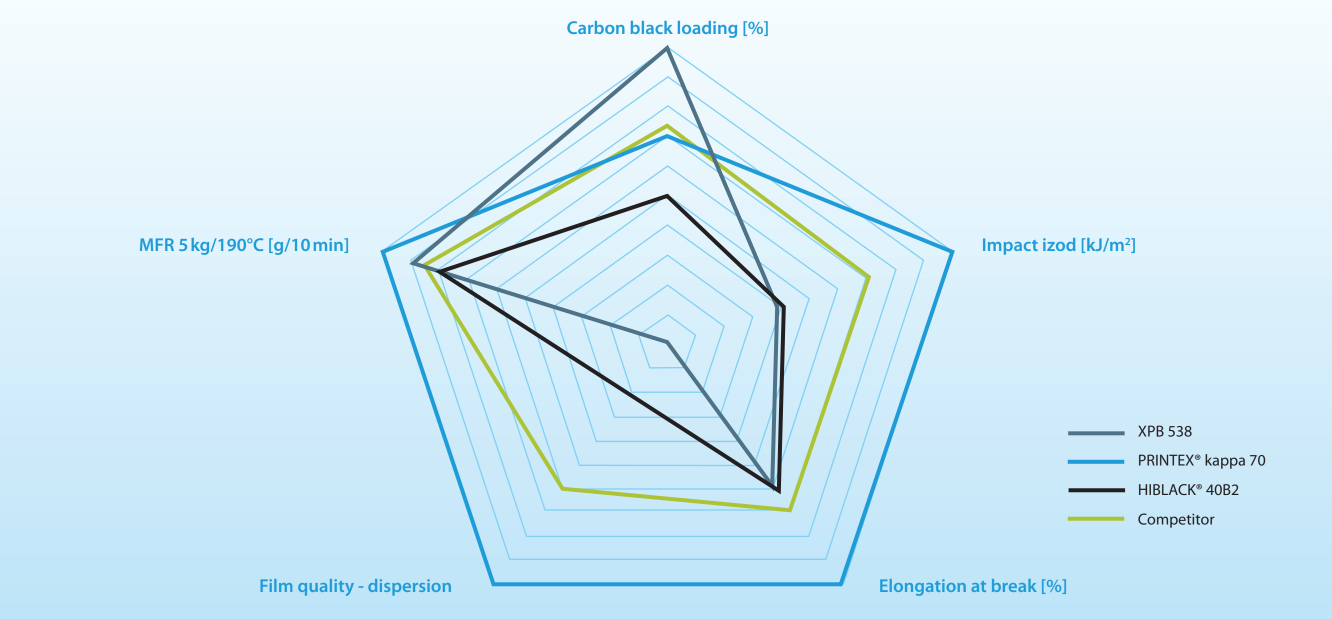


Figure 4

Product perfomance at an electrical volume resitivity of 10^4 Ω*cm



5.4 Reinforcement and rheological control

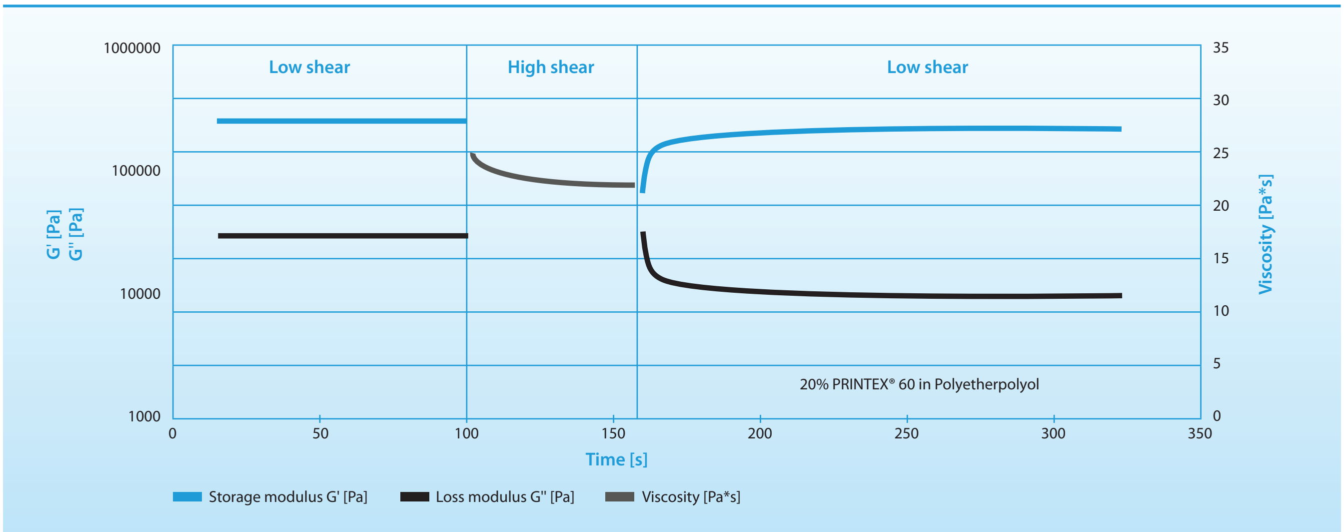
Carbon black are particularly used in the automotive industry in high-tech windshield polyurethane-based adhesives. It gets also applied in silicon rubber, silyl modified polymer, thermoplastic elastomers and butyl rubber. Carbon black provide an excellent sag resistance, improve the mechanical properties and make the adhesive stable facilitating its application. With carbon black it is possible to formulate high end structural adhesives for the use in several industries like automotive, electronics, construction and aerospace.

The following performance parameters make carbon black beneficial for adhesives and sealants:

- Excellent thixotropy
- High and quick viscosity decrease at higher shear rates
- Fast and perfect viscosity recovery after strain reinforcing

Figure 5

Thixotropy performance of specialty carbon black



6 Product recommendations

Adhesives & Sealants

Our product recommendations

PRINTEX® 60
PRINTEX® 60A
PRINTEX® 30
Y50A
SPECIAL BLACK 100
AROSPERSE® 11
PRINTEX® 3
PRINTEX® V
PRINTEX® U

The effect

Rheological control
Electrical conductivity
UV stabilization
Coloring
Reinforcement

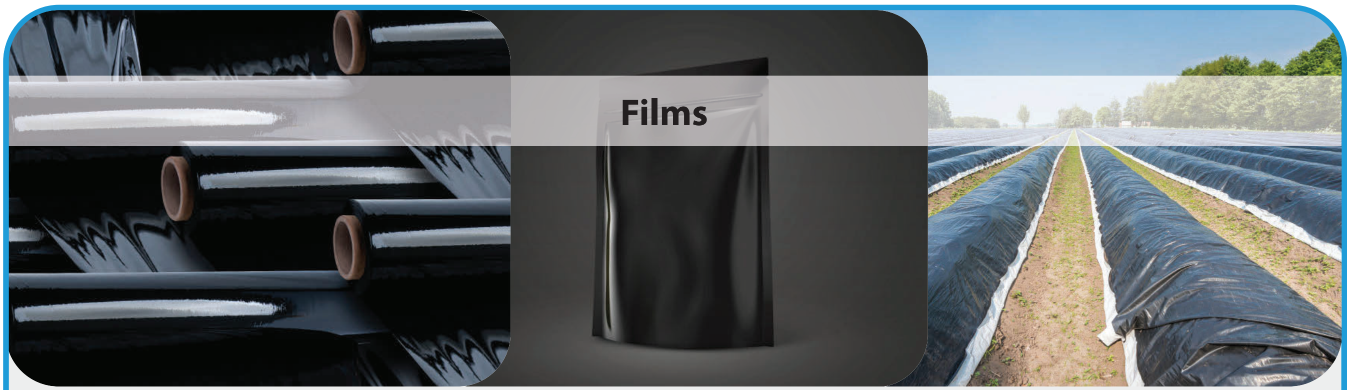
Synthetic fibers

Our product recommendations

PRINTEX® alpha SQ
AROSPERSE® 138
PRINTEX® 300
AROSPERSE® 26
PRINTEX® L6 SQ
AROSPERSE® 11
PRINTEX® U

The effect

UV protection
Coloring



Our Product Recommendations

PRINTEX® 60A
PRINTEX® zeta A
PRINTEX® alpha SQ
PRINTEX® alpha A
PRINTEX® kappa 70

The Effect

Coloring
UV stabilization
Conductivity

Our product recommendations

PRINTEX® zeta A
PRINTEX® U
PRINTEX® P
PRINTEX® alpha A
PRINTEX® kappa 70

The effect

UV protection
Electrical conductivity

Wire & Cable

Our product recommendations

HIBLACK® 420B

HIBLACK® 150B

PRINTEX® HV

PRINTEX® MV

PRINTEX® kappa 10

AROSPERSE® 5-183A

The effect

Electrical conductivity

UV stabilization

Engineered plastics

Our product recommendations

SPECIAL BLACK 4

PRINTEX® 80

PRINTEX® 85

NEROX® 555

NEROX® 3500

HIBLACK® 600LB

PRINTEX® 90

HIBLACK® 890

The effect

Coloring

UV stabilization

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OEC-II 0403-09/2023