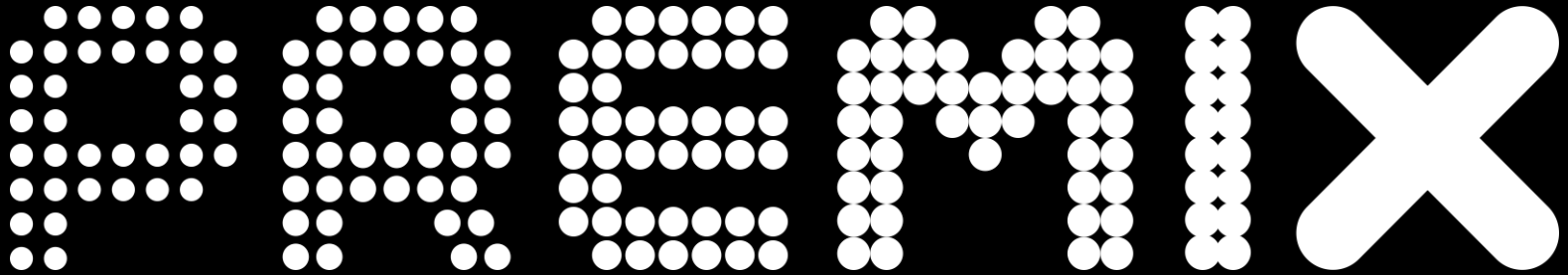

Processing PRE-ELEC®

Guidelines for extrusion and injection moulding of carbon black filled electrically conductive compounds and concentrates

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Introduction

Processing PRE-ELEC®

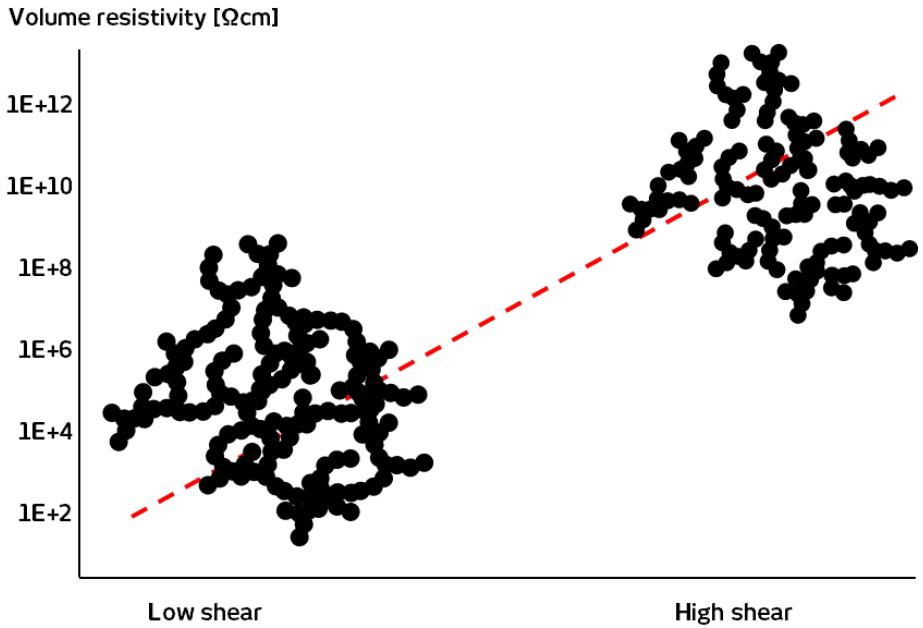
- Conductive and dissipative products can be manufactured in standard plastic production lines without major investments
- However, the procedures in materials handling, process optimization and production scheduling may require changes
- Concentrates are worth of considering as an alternative for straight compounds in larger volume production.

Characteristics of carbon black compounds

Special features related to carbon black filled compounds

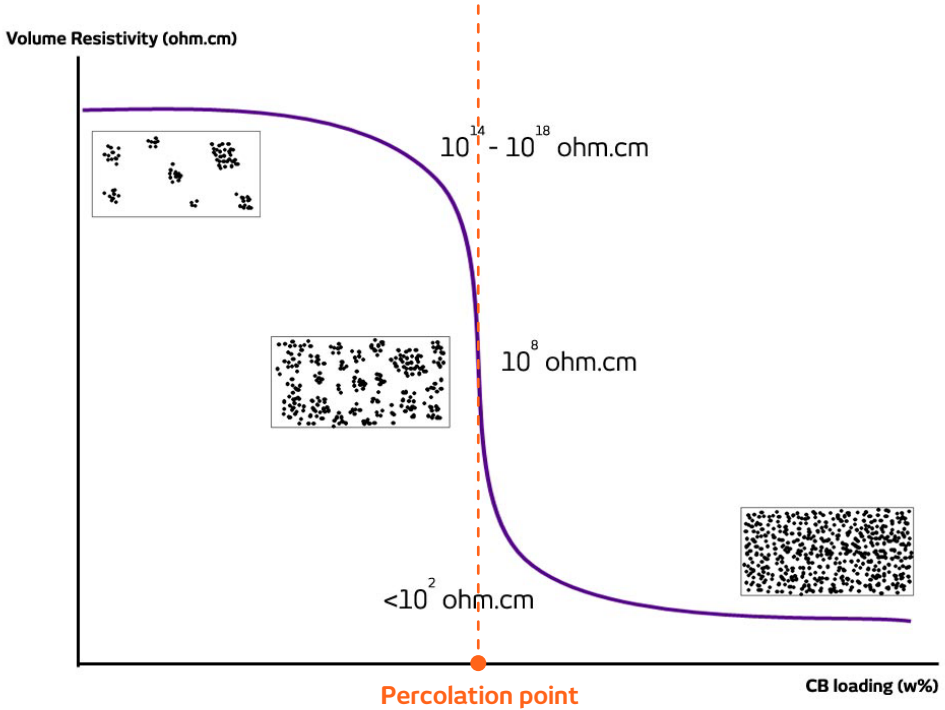
- Shear sensitivity
- Percolation
- Moisture sensitivity
- Impact on mechanical properties
- Impact on processing viscosity

High shear leads to lower conductivity



High shear forces often lead to breakage in carbon black network. This results in higher resistance of the moulded parts.

Carbon black's percolation behaviour



Percolation describes the contact between carbon black particles. At certain carbon black loading level the carbon black particles loose the direct contact between each other and the resistance increases dramatically. This point is called percolation point. Over the percolation point, the change in conductivity is very fast.

Moisture sensitivity

- All carbon blacks are moisture sensitive; some more, some less
- Moisture is one of the most typical problems faced by converters
- Trouble-free processing depends on:
  - initial moisture in compound (as delivered)
  - polymer type
  - packaging type
  - method of processing
  - thickness of extrudate
  - exposure to ambient moisture

Drying recommendations for carbon black compounds

Base polymer	Temperature [°C]	Time [h]	Note
ABS	80	2-3	
PA	75	4-5	
PC	120	2-3	
EVA	Check product data sheet, no universal recommendations available		
PE-LD / LLD	85	1-2	
PE-HD	90	2-3	
PP	90	1-2	
PS	80	1-2	
TPU	70	4	for PRE-ELEC® grades

Values are given for desiccant drying.
Hot air drying requires 1 hour longer or more (depends on % RH). Hot air dryer is usually for adequate for polyolefins and polystyrene. Premix compounds which are delivered in aluminum package do not need pre-drying.

Impact on mechanical properties

- Impact on mechanical properties is highly dependent on type of the polymer and amount of carbon black used
- The more crystalline polymer, the more pronounced difference
- Impact properties are worse than with non-filled compounds
- Supplier has means to reduce the difference, if desired
- Some polymers, like rubbers, do benefit from the presence of carbon black
- It is advisable to consult the supplier for optimal combination of needed properties prior final design product

Properties		PP homopolymer	PRE-ELEC® PP compound
MFR 230 °C / 2.16kg	g / 10min	35	1
Density	g / cc	0,905	1,06
Tensile strength	MPa	32	30
Elongation	%	9	4
Flexural modulus	MPa	1500	2000
Charpy notched	J / cm^2	0,3	0,3
HDT 0.45 Mpa	°C	100	109
Volumetric resistivity	Ωcm	1,00E+13	4

Carbon black's impact on processing viscosity

- Filling decreases the melt viscosity of polymers
- Effect depends on filler loading, surface chemistry and specific surface area of the used carbon black
- Carbon black structure breakup during processing can be prevented to some degree by increasing melt temperature and eliminating other sources of high shearing
- Carbon black absorbs moisture, which often acts as a unwanted lubricant, and may lead to viscosity problems such as pulsating extrusion flow

Other factors influencing conductive carbon black filled compounds

- Food contact approvals; carbon black content of packaging is limited to < 2.5 wt.-%
- UV stability; carbon black gives adequate UV stability
- Electrical "hysteresis"; thermal cycling may alter the electrical properties irreversibly
- Conductivity is temperature and humidity dependent, high humidity increases the conductivity
- Carbon black improves slightly flame retardancy by reducing polymer content
- Carbon black has a minor impact on surface energy; minor change in adhesion against other substrates
- Staining (scuffing); rubbing with carbon black containing compound leaves a black stain on other material

Extrusion of PRE-ELEC® compounds and concentrates

PREMIX

Extrusion of conductive carbon black compounds (1/2)

Optimal parameters are close to the same as with non-filled polymers*:

- Cold hopper zone
- Feed zone below melting (or glass transition)
- Compression zone slightly (5-15 C) above melting point
- Metering zone adiabatic or close to adiabatic
- Adapter and tooling slightly above melt temperature. 10-20 °C higher processing temperatures is recommended compared to natural polymers

*This does not apply for POK and PC. Chek the processing instructions from the product data sheet.

Extrusion of conductive carbon black compounds (1/2)

- Screw cooling is needed very seldom. General purpose screw with L/D ratio of 20-30 is recommended
- Compression ratio requirement is not impacted. Low compression ratio is preferred in compression zone
- Venting is definetely a good asset
- Remember the shear factor. Lower extrusion speeds are preferred compared to natural grades. Avoid stretching the melt. Extrusion and haul of speeds should be equal. Calendar rolls should not have beads, upper roll should have slightly higher temperature than lower roll. Higher chill roll pressure reduces the conductivity
- We recommend drying the material before processing. (See the slide "Drying recommendations for carbon black compounds")

Extrusion of conductive carbon black concentrates (1/2)

Conductive concentrates provide cost improvement for large scale converters. Available dilution rates exceed 50%

Design and mechanical condition of the extruder are important factors for succesful usage of conductive concentrate:

- L/D ratio should be preferably higher than 20
- Appropriate melt homogenization should be ensured, but addition of high shear mixing elements is not recommended

Extrusion of conductive carbon black concentrates (2/2)

Critical factors:

- MFR and granulate size of dilution polymer should be as close to concentrate as viable
- Melting point of dilution polymer should not be lower than that of concentrate
- Correct settings for compression zone are critical
- Moisture is even bigger threat than in straight compounds
- Quality of granulates including regrind
- Avoiding segregation of components prior feeding
- Avoid stretching the melt
- It's important to measure conductivity after extrusion. Complete material change takes time, be patient

Post processing

- Some conductive extrudates are streched in post processing: thermoforming, foaming & fiber production etc.
- Stretching may impact the conductivity and therefore it is important to measure the conductivity from final product
- Thermoplastic compounds allow the production scrap to be recycled back into the process. However, attention is needed to avoid moisture problems and some loss in conductivity will be experienced when incorporating the recycled material

Troubleshooting

Processing PRE-ELEC® | Extrusion of PRE-ELEC® compounds and concentrates

Problem	Cause	Corrective action
Die drool	Excessive moisture	Dry the compound. Coat the die with smooth coating,
Temperature fluctuations	Moisture Too flat extrusion profile	Dry the compound. Make the extrusion profile sharper.
Sharp protrusions	Bad dispersion of carbon black	Increase mixing of melt, increase temperature
Shark skin	Melt fracture	Decrease line speed, increase temperature, use lubricants., coat the die, round die edges.
Lumps in flow direction	Material sticking to die	Clean the die. Coat the die. Use lubricants.
Lumps at random	Contamination or scorch before the die	Lower the temperature if scorch, clean the die
Voids in extrudate	Moisture Trapped air	Dry the compound Increase pressure
Unmolten pellets in extrudate	Wrong compression ratio Contamination Unsuitable lubricants	Change extrusion parameters to have more mixing and pressure. Increase temperature.
Scratched surface	Die moisture, Thermal breakdown of compound	Polish the die, dry the compound, decrease extrusion temperature
Warpage	Too flat temperatureprofile along die	Increase melt temperature on the sides, reduce line speed

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Injection molding of PRE-ELEC® compounds and concentrates

Injection molding of carbon black compounds (1/2)

- Injection moulding does not require special equipment, but careful design of mould and optimization of cycle
- Injection moulding has typically far higher shear stresses than extrusion. Same material can give ten fold resistivity as injection moulded compared to the extruded

Injection molding of carbon black compounds (2/2)

Technically optimal moulding cycle has:

- High melt temperature (barrel temperature)
- Slightly higher back pressure than similar non-conductive material
- Lower injection speed
- Optimized switch-over point
- Possibly higher mould temperature
- Consistent cooling

Mold design tips

- Flow conditions are crucial for electrical conductivity of finished part
- Avoid excessive shear in sprues, runners and gates
- Prefer streamlined channels and part shapes, flanges etc.
- Hard and sharp shapes create more shear than gentle ones
- Shrinkage is less than with non-filled compounds

Possible problems in injection molding

- Excessive moisture will give surface imperfections, voids and even brittleness. Moisture can even impact adhesion in overmoulding
- Low conductivity may be caused by too high shear, too high holding pressure, too much regrind or wrong dilution rate
- Uneven surface resistivity can be caused by excessive gate pressure, uneven cooling or improper mould design
- In the vicinity of mould gates, resistivity is typically higher

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