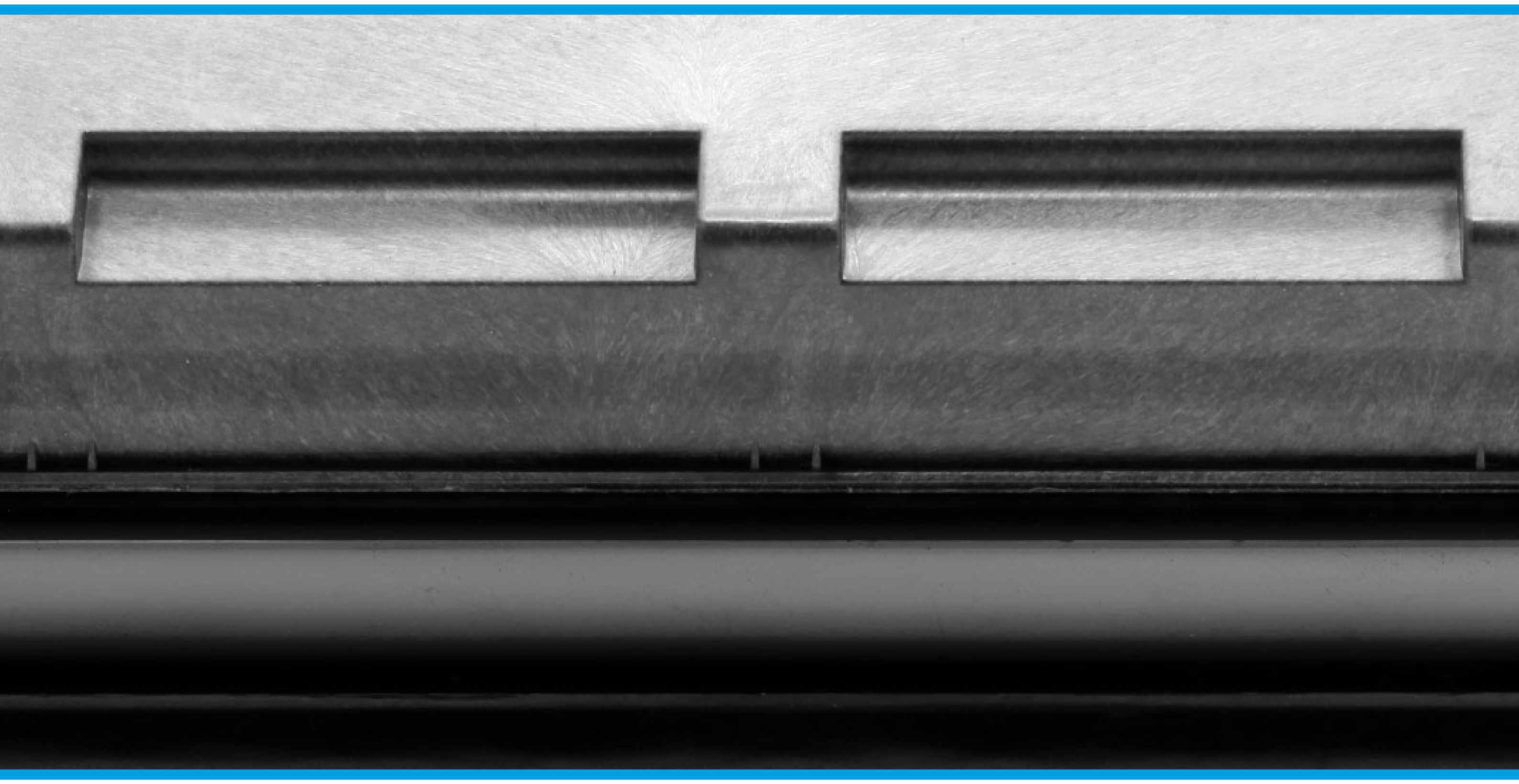
# Specialty carbon blacks for toner

Technical Information 1025



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# Contents

# 1 Introduction

Toner technology is a wide-ranging application area which covers, for instance, one and two component positive and negative toners, magnetic and non-magnetic conductive toners as well as chemically prepared toners. The variety of the different toner systems requires tailored ingredients such as carbon black pigments, fumed silica and fumed metal oxides.

Specialty carbon blacks are mainly used as colorants; however, they can also be used to control toner tribo-charge and binder resin elasticity. Therefore, Orion Engineered Carbons developed a portfolio of furnace and gas blacks specifically for the non-impact printing industry addressing today's performance as well as safety requirements.

## 1.1 Overview

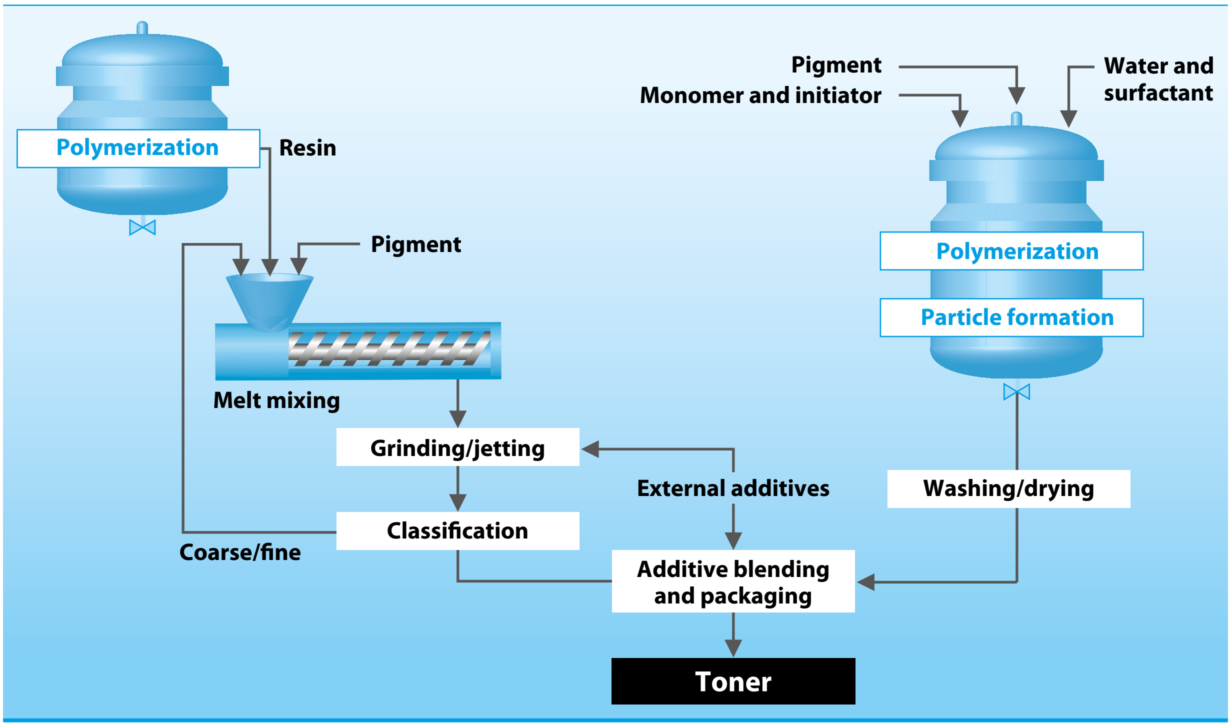
The electro-photographic process, also referred to as xerography, was invented by Chester Carlson in 1938. It involves the creation of a visible image from an electrostatic latent image. The electrostatic image in the form of surface charge patterns on a photoconductive surface – the so called photoreceptor – is developed using charged toner particles which are transferred and fused to the paper surface. The first commercial xerographic copier, the Xerox 914, made seven 9"x14" copies per minute in black. Current copiers, high speed color laser printers, and digital presses print more than 100 pages per minute in full color.

Conventional mechanical toners are produced by mixing and extruding a pigment/thermoplastic resin mixture. The extrudates are then pulverized (crushed/milled) and the desired particle size fraction is blended with external additives particularly to adjust flow and tribo-charge. Chemically produced toners (CPT) are manufactured from water-and/or solvent based emulsions or suspensions of monomers which are polymerized in the presence of a colorant. Like mechanical toners, they are subsequently blended with external additives (**figure 1**).

The basics of toner formulation consist of: pigment, such as carbon black, binder resin, wax, and, most often, charge control agent(s). Of course, the proper choice of pigment is an essential first step. However, each of the other ingredients plays a critical supporting role. The polymer of the toner particle is chosen so that the toner will tribo-electrically charge to the preferred polarity and melt at the desired fusing temperature. Internal waxes are added to lower toner adhesion to the fuser roll and improve toner fixation to the paper, and charge control agents (CCA) are added to control the sign, level, and rate of tribo-charging.

**Figure 1**

**Schematic depiction of mechanical (left) versus chemical toner processing (right).**

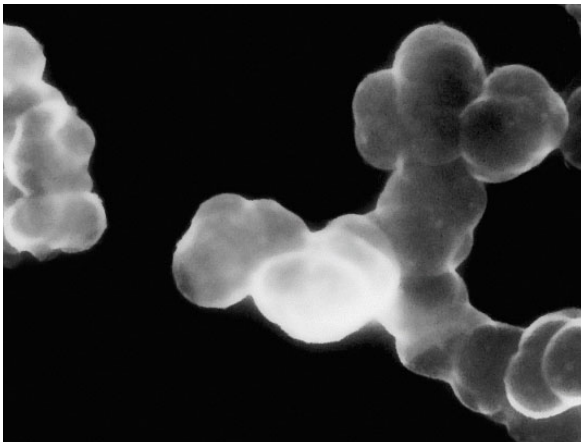


# 2 Specialty carbon blacks manufacturing processes

Specialty carbon blacks are manufactured by the partial combustion of hydrocarbons forming individual carbon black particles. The conditions in the process are such that the newly created particles collide and fuse together within fractions of a second. This results in branched chain-like aggregates with a length above 100 nm. The aggregates are the smallest dispersable unit of a specialty carbon black (**figure 2**).

### Figure 2

**Scanning electron microscopic image of carbon black aggregate (120,000 fold magnification)**



The aggregates, via mechanical entanglement, form loose collections of larger structures commonly referred to as agglomerates. In contrast to the sub-micron size of the aggregates, the more friable agglomerates can range in size from one to several hundred microns. Since agglomerates are only bound through weak forces, they are easily broken down by shear forces during processing, so that the aggregates are the dominant particle species in a toner formulation.

## 2.1 The furnace black process

The furnace black process **(figure 3)** uses liquid hydrocarbons as feedstock. They are sprayed into a refractory-lined furnace, hence the name, which is heated by the combustion of natural gas and pre-heated air. After the specialty carbon black is formed, it is quenched by water, cooled down and separated from the gas stream. The main advantage of the furnace black process is its flexibility to tailor specialty carbon black properties such as average primary particle size (between 10 and 80 nm), degree of aggregation, aggregate size distribution, and porosity. Furnace blacks usually carry only a small amount of, mainly, basic functional groups on their surface and therefore exhibit a hydrophobic, non-polar character and a pH value above 7. Post-oxidation processes allow modification of these surface characteristics.

## 2.2 The gas black process

The gas black process **(figure 4)** derives its name from the fact that the feedstock is vaporized and fed to the combustion chamber by means of a carrier gas. This vaporization step prevents the contamination of the specialty carbon black with feedstock residues and results in a low-ash product. During the burning phase, the presence of oxygen ensures a high degree of oxygen-functional groups on the pigment surface. These polar groups account for the acidic pH value of all gas blacks. Some of the important properties of gas blacks are:

- Primary particle size between 10 and 30 nm with a narrow distribution
- Narrow aggregate size distribution
- High purity
- Very high but loose structure

## 3 Properties of specialty carbon blacks in toner

Although toner performance depends on many factors, choosing the right pigment is very critical to achieve the desired application properties. Selection of the specialty carbon black does not only allow controlling the toner tribo-charge but also modifying the elasticity of the binder resin. Through adjustment of the binder elasticity both grindability and fixing behavior of the toner can be fine-tuned. This results in a higher throughput rate in the milling process as well as a broader window for the fusing process.

**Figure 3**

**Schematic depiction of the furnace black process.**

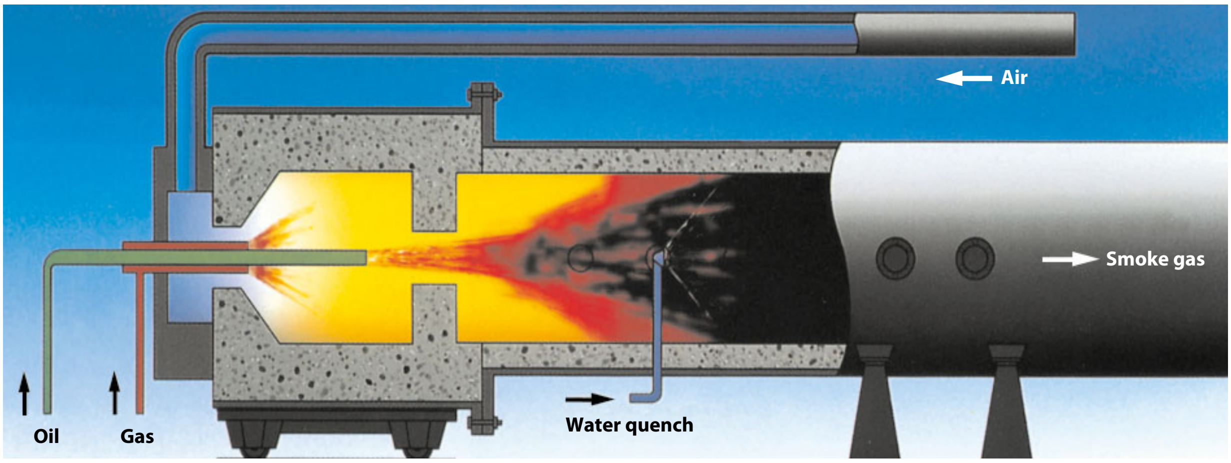
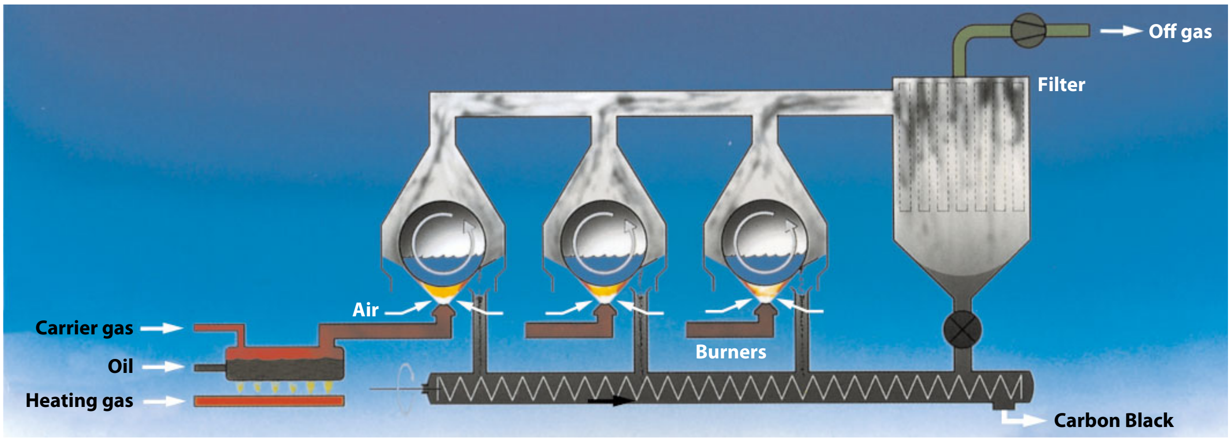



**Figure 4**

**Schematic depiction of the gas black process.**



Test series with various specialty carbon blacks in toner formulations showed two important correlations between specialty carbon black and toner properties:

- The tribo-charge distribution of a toner is mainly determined by the dispersibility of a specialty carbon black.
- The elasticity of the binder resin is particularly impacted by the particle size of the specialty carbon black.

The amount of volatiles influences both tribo-charge and elasticity. The correlations between carbon black properties and toner performance are summarized in **table 1**.

### Table 1

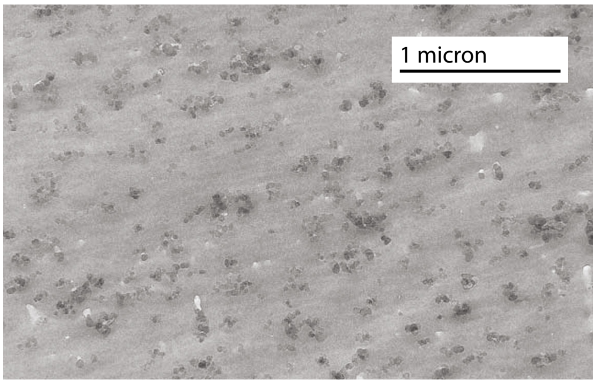
**Correlation between specialty carbon black properties and toner performance**

| Toner properties | Specialty Carbon Black properties | Effect on toner performance |
|---|---|---|
| Tribo-charge | Dispersibility | Narrow charge distribution |
| | Volatile content | |
| Grindability | Particle size | High throughput rate of milling process |
| | Volatile content | |
| Fixing behavior | Particle size | Broad fusing window |
| | Volatile content | |

Dispersibilty of a carbon black pigment in a toner formulation can be evaluated by transmission electron microscopy (**figure 5**).

### Figure 5

**Transmission electron microscopic image (cross-section) of a toner containing NIPex® 150**




## 4 Specialty carbon black product range

The following specialty carbon black grades are recommended as a first choice when developing a new toner formulation. Orion Engineered Carbon's product portfolio comprises, however, many more grades. Please contact our technical experts around the globe at any time for a more detailed discussion of your product needs.

- **NIPex® 35**
  NIPex 35® is a non-oxidized, low structure furnace black recommended for toner qualities which require a high electrical resistivity. Processed into toner, NIPex® 35 has a neutral to blue undertone. Besides mechanical toner, NIPex® 35 has excellent properties in chemically prepared toners because of its ease of dispersion.

- **NIPex® 60**
  NIPex® 60 is a non-oxidized, high structure furnace black with universal applicability in dual component positive and negative toner. This specialty carbon black is easy to disperse in styrene/acrylate- and polyester resins and provides excellent charge characteristics.

- **PRINTEX® 26**
  NIPex® 70 is a non-oxidized, high structure furnace black specially designed for excellent electrostatic properties. It helps to reduce production cost due to improved throughput rates in jet mills. By using PRINTEX® 26, the elasticity of the binder increases and a positive effect on the fusing properties can be achieved.

- **NIPex® 90**
  NIPex® 90 is a highly dispersed, non-oxidized, high structure furnace black with superior dispersion properties. This specialty carbon black is useful in styrene/acrylate and polyester resins. The recommended application is for dual-component positive and negative toners. NIPex® 90 increases the elasticity of the binder resin, which significantly improves the fixing behavior.

- **NIPex® 150**
  NIPex® 150 is a high structure, oxidized gas black which is easy to disperse. The acidic functional groups on the pigment surface improve the negative tribo-charge of a toner. NIPex® 150 can also be used in one component conductive toners.

# 5 Product safety

Our specialty carbon blacks are used in a wide range of applications. It is therefore important to characterize the toxicological profile of specialty carbon black and evaluate its safety with respect to human health and the environment.

Data generated for specialty carbon black with regard to acute toxicity, eye and skin irritation, skin sensitization, genotoxicity, reproduction toxicity and specific target organ toxicity (STOT) do not provide cause for concern.

With regard to the carcinogenicity endpoint, specialty carbon black has been classified by IARC as a category 2B carcinogen. This means that it is regarded as "possibly carcinogenic to humans". In its conclusions, IARC determined that there was "sufficient evidence" from animal studies to conclude that specialty carbon black is "possibly carcinogenic to humans" but that "there is inadequate evidence in humans for the carcinogenicity of specialty carbon black". This means that IARC's classification is founded solely on experimental animal data. Indeed, the overall conclusion by IARC that specialty carbon blacks is possibly carcinogenic to humans is predicated upon the observation that rats under extreme conditions developed lung tumors following repeated long-term exposure to specialty carbon black. These tumors in rats develop under a condition termed by scientists as "lung overload". Mice and hamsters subjected to equivalent treatment conditions as rats did not develop lung tumors in these experiments.

The scientific basis and relevance of data generated in rats for use in human risk assessment is therefore being challenged by many scientists. One important reason why effects seen in rats are considered not relevant for humans is because data obtained from human epidemiological studies do not show any evidence of a causal link between exposure to specialty carbon black or similar dusts (like coal dust, toner and titanium dioxide) and lung cancer. It has been shown for example, that coal miners, known to have traditionally high coal dust exposures, do to not develop "lung overload" and also do not have a higher lung cancer risk than the general population. More importantly, long-term investigations on large groups of workers in specialty carbon black facilities in Germany, the UK and the USA show no evidence of a link between exposure to specialty carbon black and higher lung cancer mortality rates. This evidence is in line with IARC's determination that "there is inadequate evidence in humans for the carcinogenicity of specialty carbon black".

In conclusion, when handled in accordance with good housekeeping and safe workplace practices as outlined in our safety data sheet, we believe that specialty carbon black does not present a health hazard.

All our grades for toner applications have been tested for their mutagenicity potential in the Ames test. These grades have all produced a negative response in the Ames test and are therefore specified as "Ames test negative".

The Ames tests are GLP (Good Laboratory Practice) standard and follow the methodology described in OECD Test Guideline 471 with bacteria strains Salmonella typhimurium TA 100, TA 1535, TA 1537, TA 98 and Escherichia coli WP2 uvrA . Ames tests are carried out following a Soxhlet extraction of the specialty carbon black grade in toluene. Post extraction and prior Ames testing, the extract is taken up in dimethylsulfoxide (DMSO).

All our grades for toner application constitutionally contain very low amount of polycyclic aromatic hydrocarbons (PAH). These grades are screened routinely for the 15 PAHs identified as potential human carcinogens (IARC rating 2A and 2B) on the Report on Carcinogens (RoC) issued by the U.S. Department of Health and Human Services (DHHS) – Public Health Service–National Toxicology Program (**table 2**).

## Table 2

**Polycyclic aromatic hydrocarbons commonly tested for specialty carbon black grades used in the toner industry**

| | |
|---|---|
| Benz(a)anthracene, | Dibenz(aj)acridin |
| Benzo(b)fluoranthene, | 7H-Dibenzo(cg)carbazol |
| Benzo(j)fluoranthene, | Dibenzo(ae)pyren |
| Benzo(k)fluoranthene, | Dibenzo(ah)pyren |
| Benzo(a)pyrene | Dibenzo(ai)pyren |
| Dibenz(a,h/a,c)anthracene | Dibenzo(al)pyren |
| Indeno(1,2,3-cd)pyrene | 5-Methylchrysen |
| Dibenz(ah)acridin | |

For further and detailed information relating to product safety, please refer to the respective safety data sheet and our product safety information (PSI) which are downloadable from our website (http://www.orioncarbons.com/product_safety_datasheets). Please note that downloading of the PSIs requires prior registration. Downloading of SDSs does not require registration.

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