High quality carbon black to surpass traditional solution for HV semicons?

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ABSTRACT

The quality of carbon black in semicon compound is essential for long life power cables manufacture. Carbon black dispersion, purity, electrical conductivity and rheological properties are the main parameters when evaluating semiconductive materials. In this article we will show how new carbon black selection allows reduction of the carbon black loading with resulting improved viscosity and scorch time, retaining perfect dispersion and electrical properties.

KEYWORDS

Carbon black, moisture uptake, semicon, dispersion, scorch time, purity, smoothness.

INTRODUCTION

The efficiency of the semiconductive layer depends on the electrical conductivity that is guaranteed by the presence of conductive carbon black in the semicon formulation. It has been proven that electrical aging mechanisms are directly linked to semicon protrusion as they locally increase the electrical field [1-2]
As an essential constituent of semicon compound, carbon black strongly contributes to the semicon performance and hence the final cable lifetime. Any impurities present in the raw material such as grit (e.g. large amorphous carbon particles remaining from production) or carbon black agglomerates not to mention ionic content and metallic impurities are detrimental in the final application [2]. While the level of grit is an intrinsic characteristic of the carbon black used and will remain in the final compound, the carbon black agglomerates must be dispersed and distributed by proper compounding although only specifically designed carbon blacks can achieve high level of dispersion [1]. For example low surface area is linked to large primary particles and is known to favor dispersion thanks to the better wetting of the aggregates by the molten polymer. Also the high carbon black structure (e.g. a high degree of branching of the carbon black aggregates) is known to ease dispersion and distribution thanks to the lower inter-aggregate interactions and that is why low surface area high structure carbon black is the only choice for High Voltage (HV) and Extra High Voltage (EHV) semicon compounds [2-3]. Although surface smoothness is the primary requisite for a good semiconductive compound, other characteristics are essential for a good quality HV cable. A moderate volume resistivity at the operating cable temperature and its stability after thermal cycling is also crucial for good cable lifetime. An acceptable conductivity is achieved only at a specific carbon black loading that is in turn dependent mainly on the level of branching or "structure" of the carbon black aggregates and the intrinsic carbon black conductivity.
In this article we will show that an easy-dispersible, clean carbon black, with higher intrinsic conductivity can be used at lower loadings than the most commonly used carbon black in HV semicons. By direct comparison we will show the benefits of using a lower amount of the new carbon black, especially the lower viscosity and the longer scorch time of the compound while keeping excellent surface smoothness and stable conductivity. Carbon black ionic impurities and moisture uptake that are transmitted to the final compound and can initiate electrical vented treeing will also be discussed in detail.

CARBON BLACK PROPERTIES

In this article we analyze two grades of carbon blacks used in high voltage and extra-high voltage semicon compounds that are produced by different processes: Ensaco carbon black and acetylene carbon black. Ensaco carbon blacks are produced by a partial combustion process of a hydrocarbon feedstock with unique reactor design and production set-up while acetylene carbon black is produced by thermal decomposition of an acetylene precursor in controlled conditions [4]. The two carbon blacks, as can be seen in table 1, have very similar level of high structure (OAN) and low surface area (BET); these values are necessary to obtain excellent dispersion during the compounding operation. Beside these two parameters a number of other analyses are normally performed by carbon black producers or semicon compounders to verify the quality of carbon black for semicon formulation.

Property test method	Unit	Ensaco Carbon Black	Acetylene Carbon Black
BET Nitrogen Surface Area	m^2/g	66	74
Oil Absorption Number (Structure)	ml/100g	194	207
Sieve Residue 325 Mesh (2.5 kg of carbon black)	ppm	0.6	4
Water Conductivity 1 h, 25 °C	µS/cm	1.0	2.3
Water Conductivity 264 h, 80 °C	µS/cm	3.1	4.7

Table 1: Selected properties of carbon blacks

For example during carbon black manufacturing, a small number of amorphous carbon particles are produced that are named grit. This small amount of impurities is measured according to a specific norm (ASTM D1514) that consists of sieving 0.5 kg of carbon black powder under a water jet though a 45 micron filter (325 Mesh), the grit being the residue left on the filter. These particles are normally sieved during compounding by a melt filter but