

Effect of carbon black selection on semiconductive compound water content and uptake

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ABSTRACT

Water uptake of three different carbon blacks produced by different manufacturing processes (Ensaco, acetylene and furnace), commonly used in the power cable industry, has been studied revealing consistent differences. Surface chemical composition can be responsible for the higher water uptake found in one of them. The different moisture level in the carbon blacks determines the different water content of the respective EBA semiconductive formulations that cannot be removed by drying procedures.

KEYWORDS

Water uptake, moisture, carbon black, semiconductor.

INTRODUCTION

Water molecules entrapped in High Voltage (HV) and Extra High Voltage (EHV) cable insulation are known to promote electrical treeing [1-2]. As HV and EHV cables are usually protected from external water penetration, the main source of water molecules inside a cable is certainly the insulation compound used during cable manufacturing but also the water contained in both conductor and insulation shields are important. Water contained in semiconductive compound can migrate into the insulation layer during cable operation and contribute to electrical degradation. It should be noted that water has a solvation effect on the ionic species such as transition metal ions present in the carbon black and these species, once solvated, can migrate into the insulation layer and catalyze polymer degradation [3-4]. Conductive carbon black is one of the main constituents of semiconductive formulations and has its own moisture content, normally specified in the carbon black technical data sheet. Surface area is one of the main reasons for carbon black water content but other factors are known to play an important role. Carbon blacks with similar surface area can differ in water content and uptake behavior, this difference is linked to the production process. Surface chemistry certainly plays a role in the water uptake mechanism, for example the presence of oxygen groups promotes water uptake but also the porosity (microporosity and mesoporosity) of the material can influence moisture adsorption. In this article we will compare the moisture uptake behavior and the ionic content of three different carbon blacks with similar surface area but produced with different production processes: IMERYS Graphite & Carbon (Ensaco), acetylene and furnace processes. The moisture uptake behavior in different conditions will be analyzed (as packed, in ambient condition) and correlated to specific characteristics of the carbon black (for example surface chemistry and porosity). Finally, the moisture content of compounds made with the three different conductive carbon blacks will be analyzed and discussed in relation to cable manufacturing.

MOISTURE UPTAKE

Conductive carbon blacks are known to have a hydrophobic surface that explains the increase of the tensile strength in their compounds with non-polar matrices such as polyolefins. Despite carbon black general hydrophobicity, that would suggest low moisture uptake behavior, their high surface area determines a tendency to adsorb moisture. Figure 1 shows the dynamic water uptake behavior at 25 °C of two furnace blacks with different surface area measured with dynamic water sorption instrument. The effect of the surface area on the water uptake is evident: by decreasing the surface area of the carbon black less water is sorbed. It must be remarked that although the surface area is the main parameter influencing the water uptake mechanism other factors are known to be determinant.

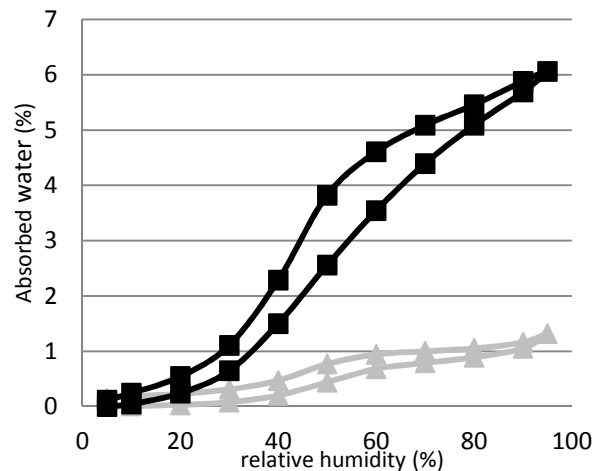


Fig. 1: A dynamic water sorption of two furnace carbon blacks with different BET nitrogen surface area: BET-NSA=246 m²/g (squares) and BET-NSA=58m²/g (triangles)

In this article we used three carbon blacks of similar surface area, commonly used in the power cable industry: IMERYS Graphite & Carbon (or Ensaco) carbon black Ensaco 250G, acetylene black from Denka and clean furnace black Vulcan XC500 from Cabot. Some characteristics are presented in table 1.

Water uptake mechanism by dynamic water sorption at 25 °C is reported in figure 2. The measurement consists of a precise weighing of a certain amount of carbon black, a drying cycle (flow of dry nitrogen, for approx. 12 hours, at 75 °C) and progressive exposure of the sample to a controlled humidity environment for a determined amount of time sufficient for stabilization with consequent weight measurement from which is calculated the amount of sorbed water.