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ANNEALING EFFECT ON THE CONDUCTIVITY OF XLPE INSULATION IN POWER CABLE

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ABSTRACT

Conductivity of XLPE insulation of power cables annealed at 90ºC at temperatures between 50 and 97ºC has been measured. In all cases there is an initial increase in conductivity, associated with the presence of crosslinking by products that are volatile and disappear after 20 days annealing approximately. At low temperatures (50ºC), the conductivity decreases after long annealing times and its value stabilize approximately after 45 days annealing. This behavior can be associated with current limited by space charge. At high temperatures, conductivity after long annealing times is higher than the initial value. Obtained results are in good agreement with a hopping controlled mechanism. Infrared spectroscopy indicate that, during annealing, defects diffuse from the semiconducting shields into the XLPE. At lower field, ohmic conductivity is observed, associated with thermally generated carriers. Thermally stimulated depolarization technique (TSDC) is used to corroborate data obtained by conductivity measurements.

KEYWORDS

XLPE, conductivity, ARC, TSDC, FTIR, cable, insulation.

INTRODUCTION

Polyethylene (PE) is a non-polar polymer. It is found in semi-crystalline state at room temperature. In industrial applications, crosslinked PE (XLPE) is commonly used as an electrical insulator due to its outstanding insulating characteristics and its low price. It is well known that PE conductive properties are conditioned by its morphology [13] and that insulation degradation can be related to volume space charges [4]. Particularly, conduction and space charge formation in low-density PE were studied including the interval of temperatures of interest for cable diagnostics [5].

Current versus voltage (I-V) characteristics studied in LDPE by Stetter [6] at 42, 82 and 110ºC, indicate that for low electric fields (*E*) an ohmic behaviour is observed; for higher electric fields, conduction can be interpreted on the basis of a quadratic law in *E* which depends on temperature and reveals the existence of traps. More recently, several authors have also observed that current-voltage characteristics in PE can be explained by the theory of space-charge-limited currents model (SCLC) [7]. Nath et al. [8] apply the band theory to LDPE by developing a mathematical model based on the hopping of carriers which are injected into amorphous regions. They consider a SCLC and a process of charge-trapping at amorphous-crystalline boundaries. In addition, they suppose that the density of trapping centres is high enough so that the interaction between them results in an effective lowering of trap depth (PooleFrenkel effect). In this latter model, the “distance between traps” parameter is introduced and it has a constant value. Even more recently, following the same research theme, it is concluded that electronic transport is bound to thermally activated hopping, which is assisted by electric field with a very low activation energy [9]. Recent studies of our research group have deal with conductivity in XLPE cable samples measured by the absorption resorption current method (ARC) [10]. This studies revealed that conductivity is highly influenced by the thermal treatment of the samples in the presence of the cable semiconducting shields (SC), and it is based on a hopping process.

Thermally stimulated depolarization current technique (TSDC) has been applied to XLPE cable electrets [11,12]. A broad current peak can be observed at 105ºC, which has been associated with charge in the crystalline volume [11]. The combination of TSDC and infrared spectroscopy (IR) studies [12] proved that annealing procedures in MV cables lead to the diffusion of components from the SC screens into the XLPE insulation bulk. Moreover, the defects associated with diffused particles act as trapping centres of charge injected from the electrodes. This process is clearly promoted at temperatures above a critical temperature approximately equal to 80ºC. Annealing at these temperatures reverses the polarity of TSDC spectra (from heteropolar to homopolar). Further annealing results in new current polarity inversion, and the current regains its heteropolar character [11].

The aim of the present work is to obtain further experimental results concerning conductivity in XLPE in order to better understand conductivity processes in this material. Following this purpose, several samples were annealed at T_a=90ºC for different times t_a between 0 and 90 days and conductivity (σ), TSDC spectra and infrared spectroscopy (IR) was measured.