Space charge properties of EPDM under different electric field and thermal ageing

Rujia **MEN**, Zhipeng **LEI**, Pulong **GENG**, Jiancheng **SONG**, Yuanyuan **LI**, Muqin **TIAN**; Taiyuan University of Technology, (China), 414980960@qq.com, leizhipeng@163.com, gpl_1016@163.com, sjc6018@163.com, liyuanyuan2005_2008@126.com, tianmuqin@163.com

Tao **HAN**; Tianjin University, (China), hant@tju.edu.cn

Chuanyang **LI**, Davide **FABIANI**; University of Bologna, (Italy), lichuanyangsuper@163.com, davide.fabiani@unibo.it

ABSTRACT

Ethylene Propylene Diene Monomer (EPDM) has been widely used as the insulating material of power cables and accessories. Due to the formation and injection of space charge under DC electric field, the distortion of electric field strength will influence the dielectric properties of EPDM. In the paper, the space charge profiles at different electric field and ageing temperature were carried out. The total charge quantity and trap distribution of aged EPDM were analysed. The results show that the charge injection from electrodes was intensified with the increase of electric field. The behaviour characteristics of the space charge in EPDM during polarization can be divided into four stages: (I) no charge injection, (II) bipolar injection, (III) charge transformation and recombination, and (IV) anode injection. Space charge properties of EPDM aged at different temperature are also different. With the ageing time increasing, homocharge injected from anode increases, and heterocharge accumulates in the vicinity of cathode. When EPDM is aged at 120 °C, the total charge quantity at the initial ageing stage increases with ageing time. Then it decreases. However, the total charge quantity of EPDM aged 2 days at 160 °C reaches to a higher value. The space charge properties of aged EPDM can be explained by degassing process and the theory of trap filling.

KEYWORDS

Ethylene Propylene Diene Monomer, space charge, dielectric strength, thermal ageing

AUTHOR NAMES & AFFILIATIONS

Ethylene Propylene Diene Monomer (EPDM), being of excellent moisture resistance, thermal resistance, corona resistance and high tensile strength, has been widely used as the insulating material of MV/HV power cables and accessories. Both physical and chemical defects from production process or operating ageing would introduce traps into the material. Under DC electric field, the internal trap of EPDM can capture carriers from electrode injection or impurity dissociation, which will form the space charge, and cause local electric field distortion in the insulation. Moreover, space charge accumulation will accelerate the insulation ageing, reduce the insulation life and even cause breakdown [2].

Therefore, after the technique of space charge measurement was developed in 1980s [2], many researchers focused on space charge properties of insulation under thermal and electrical stress. The space charge distribution in EPR and XLPE were measured under thermal gradient, which reveals the field distortion were enhanced with the thermal gradient [3]. The effect of electrical stress on the space charge characteristics of EPDM was studied by measuring and analyzing the space charge distribution and conductive current, which reveals the energy loss dynamics caused by space charge [4].

For understanding the long-term ageing properties of EPDM and the effects on the space charge characteristics, EPDM specimens were thermally aged at different temperature in the paper. The space charge properties of aged EPDM were analyzed. The total charge quantity during depolarization and the trap energy distribution was calculation for explaining the charge transportation in aged EPDM.

EXPERIMENTAL ARRANGEMENT

Sample preparation

The DCJ30M type EPDM, mixed and filtered in the manufactory, was vulcanized for 15 min under 160 °C and 14 MPa in laboratory. Cured specimens were naturally cooled down to room temperature. After taken off from mould, the specimens were put into the vacuum oven with 80 °C and 50 Pa for 24 hours in order to eliminate the by-product and mechanical stress during vulcanization. The thickness of specimen was 390 μm. Specimens were cut into discs with a diameter of 60 mm. Before the test, all specimens' surface was cleared by absolute alcohol.

Space charge measurement

Space charge was measured by the PEA device, produced by Peanuts Five Lab. The measurement sensitivity of PEA device is about 0.2 C/m^3. The upper and lower electrode of the test device is semiconductor layer (SC) and aluminium (Al) respectively. During the PEA test, negative DC voltage was applied to specimen, so Al was anode and SC was cathode. The amplitude of pulse voltage was 400 V. Firstly, the space charge profiles of EPDM at different electric field, including 5, 10, 20, and 40 kV/mm were test. The polarization time was 2 hours, and the depolarization time was 1 hour. Then, for different thermal ageing specimens, the space charge profiles at each ageing stage were measured under 20 kV/mm within 30 min. After that, the voltage was removed, and the depolarization characteristics within 60 min were measured.

Thermal ageing

For analysing the long-term effect of temperature on EPDM, the thermal ageing tests were conducted in an electro-thermostatic blast oven. The ageing temperature were 120 °C, 140 °C and 160 °C. Before space charge test, the specimens were taken off the oven and cooled down to room temperature. After space charge test, the specimens were wrapped with aluminium foil, shorted with ground and placed back to the oven.