THE EFFECT OF MECHANICAL PRESSURE ON THE ELECTRICAL RESISTIVITY AND WATER TRANSPORT CAPABILITIES OF A SEMI-CONDUCTIVE SUPERABSORBENT TAPE

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ABSTRACT

Semi-conductive superabsorbent tapes used to prevent axial water ingress near the conductor in a high voltage cable will be subjected to high mechanical pressures after manufacturing and during service. Measurement of the electrical resistivity showed that while the axial resistivity was almost unaffected by pressure, the radial resistivity was found to depend on both applied pressure and relative humidity. The axial water transport of the tape was also found to depend on plateau pressure, with more water being able to pass through the fibre tape backing when pressure was applied.

KEYWORDS

Superabsorbent tape; swelling; water absorption; diffusion; semi-conductive; electrical resistivity

INTRODUCTION

Superabsorbent tapes are used in submarine high voltage cables to prevent axial water ingress after a cable failure or mechanical damage. These tapes can be placed both directly underneath the outer metallic water barrier, and between the conductor and conductor screen. For tapes placed close to the metallic conductor, it is important to have a low and uniform electrical resistivity. The extruded layers of the insulation system and cable sheath that enclose the tape will exert a radial mechanical pressure on the tape and thereby the superabsorbent particles after production due to shrinkage. This will likely limit the free swelling of the superabsorbents and may also change the water blocking properties and the electrical resistivity of the tape.

In this paper, the influence of water content and applied mechanical plateau pressure on the electrical resistivity of an electrically semi-conductive superabsorbent tape was investigated at ambient temperature conditions. In addition, experiments on the effect of mechanical pressure on the water transport features of the superabsorbent tape were performed.

THEORY

Superabsorbent polymers

Superabsorbent polymers (SAP) are cross-linked polymers with hydrophilic groups, capable of absorbing water up to many times their own weight. As water is absorbed, the SAPs expand to form an insoluble hydrogel, with the cross-links preventing the polymer from dissolving completely. The superabsorbent tape used in this paper contains the most commonly used SAP: poly(sodium acrylate). It consists of carbon chains with sodium neutralized polyacrylic acid side groups, with water affinity being obtained through ion-dipole interactions. In the tape, SAP particles are glued to one side of a carbon black-coated textile backing, as illustrated in Figure 1. The axial and radial direction terms shown in the figure are references to how the superabsorbent tape will be aligned in a cable. The axial direction is *along* the longitudinal axis of the cable, while the radial direction is *perpendicular* to the longitudinal axis of the cable.

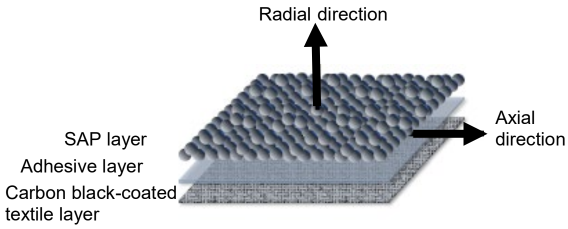

Figure 1: Representation of superabsorbent tape structure, with indications of the direction terms

Water absorption and diffusion

Water transport in non-porous polymers can be divided into two processes: sorption and diffusion. The sorption process governs how easily water is dissolved in a sample, with the solubility coefficient as the main parameter. Diffusion governs how fast water moves through the sample, with the diffusion coefficient as the main parameter. It is assumed that water uptake in superabsorbent tape is dominated by water absorption in the SAP particles, due to their hygroscopic nature. In this paper, the absorptive and diffusive properties of the complete superabsorbent tape will be characterised.

Water absorption in polymers is governed by the partial pressure of water. The concentration of water molecules just inside the polymer surface will be proportional to the partial pressure just outside [1]:

$$C = Sp \tag{1}$$

where *C* is the concentration of water, *p* is the partial pressure, and *S* is a proportionality coefficient called the solubility coefficient. If *S* is independent of concentration, Equation (1) is called Henry's law. For superabsorbent tapes, *S* has been found to be concentration dependent [2]. *S* can be found by measuring the equilibrium water concentration at a given partial pressure.

Fick's law of diffusion states that the steady-state flux of water, *J*, is proportional with the concentration gradient [3]:

$$J = -D\nabla C \tag{2}$$

where *C* is the concentration of water, and *D* is a proportionality coefficient called the diffusion coefficient. The diffusion coefficient of superabsorbent tapes has also been found to be concentration dependent [2], likely an