Self-healing composites for high voltage electrical insulation

Cédric **LESAINT**, Vetle **RISINGGÅRD**, Øystein **HESTAD**, Sverre **HVIDSTEN;** SINTEF Energy Research, Trondheim, Norway, cedric.lesaint@sintef.no, oystein.hestad@sintef.no, sverre.hvidsten@sintef.no

Wilhelm R. **GLOMM**; SINTEF Materials and Chemistry, Trondheim, Norway, wilhelm.glomm@sintef.no

ABSTRACT

A self-healing electrical insulation material for high voltage apparatuses has yet not been developed. Such a material would have been very attractive for electrical components installed in conditions were service failures cause time consuming and very expensive replacements. This paper reports results from electrical characterization of a candidate self-healing high voltage composite. The composite includes a bisphenol A epoxy resin filled with microcapsules with a monomer (healing agent).The results show e.g. that microcapsules rupture when reached by an electrical tree, likely preventing further tree propagation.

KEYWORDS

Self healing, electrical treeing, epoxy insulation

INTRODUCTION

Self-healing materials have the structurally incorporated ability to repair damage. For a material to be defined as self-healing, it is necessary that the healing process occurs without human intervention [1]. The technology is inspired by biological systems, which have the ability to heal after being wounded. For composites, micro cracking can be the precursor to catastrophic failure. Considering that damage inside the composites is usually difficult to detect and particularly to repair, the ability to self-heal is very attractive. The main purpose of this paper is to present results from electrical testing of a self-healing composite. Such a composite could e.g. be used as the solid electrical insulation in subsea power cable connectors for deep water oil exploitation where repair is very time consuming and costly.

Electrical treeing can be a precursor to catastrophic failure in electrical insulation materials, and hence significantly shorten their service lifetime. Electrical trees can be initiated at regions with high local electrical fields, typically at contaminations in the insulation or from conducting irregularities/protrusions or voids [2]. These can either occur at the interface between insulation and conductor or within the insulation system. The insulation material must therefore be clean to prevent or delay inception of electrical trees. Irrespective of where the contamination occurs, the insulation system will never be perfect, and cumulative long term degradation of the insulation may cause inception of electrical trees, *i.e.;* hollow tubules or channels that are developing in the polymer matrix. Multiple channels are typically formed, and they branch out into an interconnected structure that resembles a tree or a bush as depicted Fig. 1, depending on several factors such as the electrical field strength, frequency and voltage waveform. Subsequently, local partial discharges will cause chemical degradation and disintegration of the polymer, thus further extending the tree channels until final electrical breakdown occurs. These electrical degradation phenomena have many similarities with mechanical cracking of the material of the material, but differ in the chemical degradation and carbonization.

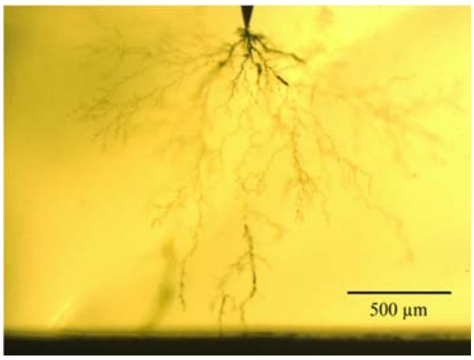

Fig. 1: Optical micrograph of a typical electrical tree captured about halfway to breakdown. The tree is grown in an unfilled epoxy.

As detection and repair of electrical trees are very difficult under service conditions, a self-healing mechanism that is triggered by the electrical tree itself is very attractive. In particular, self-healing electrically insulating materials may be used as electrical insulation in high voltage apparatuses for applications such as offshore wind farms and subsea grid where maintenance and repair is extremely time-consuming and expensive.
The approach used herein for development of self-healing thermoset electrical insulation materials is adapted from a technology developed by White et al. in 2001 [3], intended to halt mechanical degradation of the material. In mechanically triggered self-healing, microcapsules filled with a monomer (healing agent) are added to the epoxy prior to casting. When cracks propagate in the matrix the microcapsules will rapture, releasing liquid monomer (healing agent) into the crack. The final step of the self-healing process is the polymerization of the monomer, which occurs upon contact with a catalyst added to the epoxy resin, Fig. 2. This principle has been further developed over the last decade, and has been shown to significantly improve the resistance of the materials to mechanical cracking [4]. To the best of our knowledge, self-healing composites have never been studied or used as electrical insulation for high voltage electric components; where it is the electrical failure mechanism itself triggers the self-healing process of the insulation [5].