Syntactic foam as an alternative electrical insulation material for superconducting cable systems

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ABSTRACT

Insulation systems for superconducting power cables consisting of polypropylene laminated paper which is impregnated with liquid nitrogen are state of the art. One disadvantage of these insulation systems is the significantly reduced dielectric strength if gas bubbles occur due to heat losses. Syntactic foam as a solid insulation system consisting of a polymer matrix and embedded hollow microspheres is investigated regarding its dielectric and mechanical strengths at ambient and within the liquid nitrogen temperature range. Due to the investigation results syntactic foam is a promising alternative insulation system for superconducting power cables and their accessories.

KEYWORDS

Syntactic foam, superconducting cable, dielectric strength, mechanical strength, thermal contraction.

INTRODUCTION

Superconducting power components especially superconducting power cables are a promising approach for a reliable and sustainable power delivery in urban areas with increasing power demand. The insulation system of these cables is commonly composed of polypropylene laminated paper (PPLP) which is impregnated with liquid nitrogen (LN_2). Hence, LN_2 serves as cooling medium for the current carrying superconductor and as part of the electrical insulation of the cable system simultaneously [1, 2]. Disadvantageously, the dielectric strength of LN_2 based insulation systems will be significantly reduced, if bubbling occurs due to heat losses within the conductors during operation of the cable [3]. Since superconducting power components are always delivered at ambient conditions, LN_2 which cools the power cable during routine tests immediately after the cable production has to be removed for delivery. Thus, the routine tests performed lose their significance. Additionally, impurities conceivably contained in LN_2 could get into the electrical insulation system while refilling the cable system on-site. These impurities will have an impact on the dielectric properties of the insulation system [4].

The application of solid insulation systems enables to overcome these drawbacks, since then LN_2 has only a cooling but no more an insulating function. Pure polymers which are commonly used as electrical insulation in conventional power cables show relatively high thermal contractions (> 1 %) compared to superconducting or metallic materials (0.2 – 0.4. %) when being cooled from ambient temperature to liquid nitrogen temperature (LNT) [5, 6]. Due to strongly different contractions, the cooling process would most probably lead to delaminations between solid insulation system and conductor. Therefore, polymers need to be filled to reduce the thermal contraction.

This paper deals with syntactic foam as an alternative solid insulation system for superconducting cables and their accessories as syntactic foam features good electrical and mechanical properties at ambient temperature [7, 8] and significantly reduced thermal contractions due to cooling to LNT [9]. Syntactic foam consists of a polymeric matrix with embedded hollow microspheres (HMS). HMS typically have diameters of several 10 µm and can be made of glass, ceramics, plastics or metals. Their kind of filling gas depends on their production procedure. A scanning electron micrograph of syntactic foam is shown in Fig. 1.

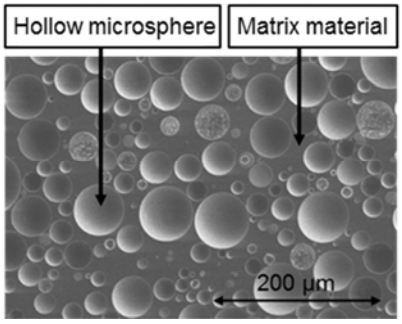

Fig. 1: Scanning electron micrograph of syntactic foam

In this paper the capability of syntactic foam for application in superonducting power cables and their accessories is estimated as promissig. In particular, the dielectric AC strength and the mechanical strength both at LNT and ambient temperature are demonstrated. Furthermore, the impact of the HMS on the thermal contraction of syntactic foam is shown.

SYNTACTIC FOAM

Syntactic foam is a compound of a polymer and hollow microspheres. Here, epoxy resin (ER) and unsaturated polyester resin (UPR) serve as polymeric matrix material. The HMS filled into the matrix are made of glass and have a mean diameter of 45 µm and a wall thickness of about 1 µm. Due to the spheres' production process they are filled with gaseous sulphur dioxide (SO_2). To determine the impact of the bonding quality between matrix material and HMS on the properties of syntactic foam some glass HMS are silanized, which features a stronger chemical bonding between organic matrix and inorganic HMS. By variation of the degree of HMS filling the impact of the HMS on syntactic foam can be ascertained. Thus, measurements are performed on unfilled i.e. pure matrix material and on syntactic foam filled with 30 percent by volume (vol.%) and 50 vol.% of HMS. The glossary of the hollow microspheres used is given in Tab. 1.