Epoxy Parameters for High Partial Discharge Inspection Voltages

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Introduction

Partial discharge occurs in a void between two metal plates when the applied voltage exceeds the partial discharge inception voltage (PDIV). A small spark bridges the void and causes an emission of radio frequency noise. An MRI scanner detects the noise burst producing artifacts in the MRI image, called "white pixels". A MRI gradient coil consists of several layers of copper boards interspersed with insulation layers consisting of epoxy, glass tape and FR4 sheets. The epoxy is an integral component for both mechanical support and electrical performance. Epoxy manufactures typically specify parameters describing the viscosity, glass transition temperature (T_g), thermal expansion (CTE), tensile, modulus, elongation, dielectric constant and dissipation factor. As a PDIV performance parameter is not specified by the manufactures of epoxy systems, a method must be developed to use the epoxy manufacture's properties to ensure high PDIV for an MRI gradient coil.

Experimental PDIV Test Method

An MRI gradient coil is impregnated with epoxy resin during a vacuum pressure impregnation (VPI) process. The resin is injected into a mold while the mold is under vacuum and the epoxy forms the shape of the gradient coil. To simulate a gradient coil, flat transverse gradient boards, each press-laminated with one-millimeter of FR4, are stacked on top of each other with a one-millimeter layer of dry glass tape between boards inside the aluminum mold. Each gradient coil board is approximately 30 inches by 40 inches with three-millimeter thick copper. The cross section is shown in Figure 1, and each test was conducted with an identical vertical layout and glass tape. The aluminum mold, see Figure 2, was then filled with one of eight different VPI resins suggested by various manufactures for good PDIV performance. After the VPI process is complete, a PDIV test is conducted with one voltage lead attached to each board and the voltage is recorded when the partial discharge exceeds 20 picocoulombs.

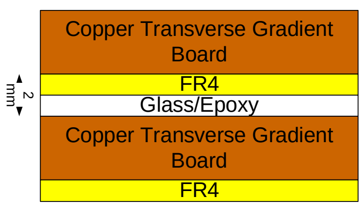

Figure 1. The experiment layout for the PDIV test consists of a controlled 2 mm gap. There is one millimeter of epoxy/glass layer impregnated in each experiment with the epoxy encasing the entire structure.

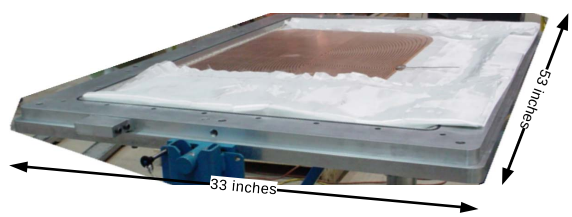

Figure 2. The aluminum mold is shown with the top transverse gradient board visible along with the dry glass tape separating the bottom board. The mold is then sealed and impregnated with an epoxy resin per the guidelines of the individual manufacturer and tested for PDIV between the two vertically adjacent copper boards.

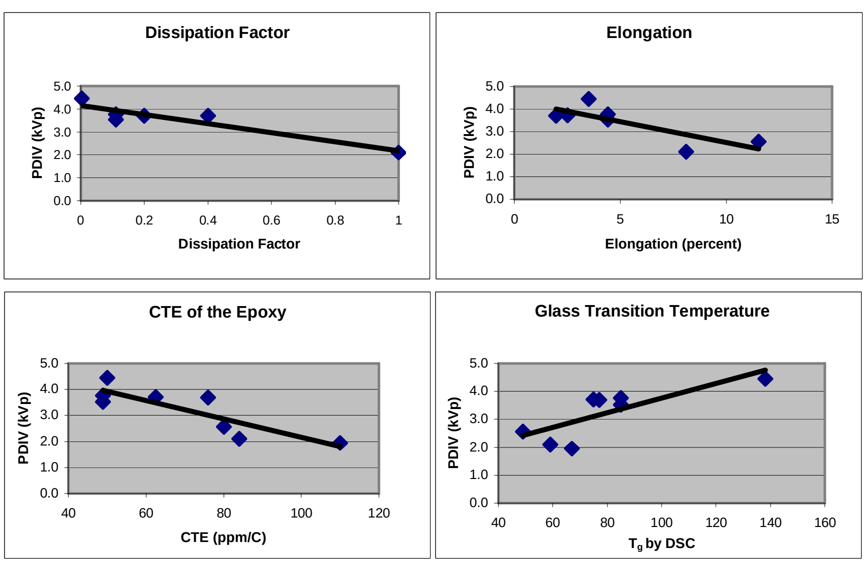

Figure 3. The PDIV optimized epoxy will have a low dissipation factor, low elongation, low CTE, high glass transition temperature and high tensile strength (not shown).

Results of PDIV Experiments

From the experiments, several epoxy parameters correlate with the PDIV performance. The parameters important to PDIV are the tensile strength at yield, elongation at yield, dissipation factor, glass transition temperature and the CTE of the epoxy below T_g. While the previous parameters did correlate with PDIV there appears to be little correlation with the modulus, dielectric constant, dielectric strength, and viscosity at 50 degrees Celsius (typical impregnation temperature). The correlation between epoxy parameters and PDIV are shown in Figure 3. Of course, optimizing for maximum PDIV needs to be balanced with the mechanical strength requirements of the coil that appear to oppose increasing the PDIV without limit. From the experimental results, it is possible to specify an epoxy for high PDIV in terms of parameters manufactures specify.