TCLAD’s Dielectric Materials for IMS Applications Provide Durable Thermal Management Solutions for High Power Electronics

Introduction

The use of high dielectric strength materials in high power devices for power conversion applications offers several advantages. These materials are specifically designed to provide excellent electrical insulation. This allows them to withstand high voltages and electric fields without breaking down due to partial discharge, and makes them ideal for use in high voltage applications such as:

- Electric vehicle (EV) power modules such as On-Board Chargers (OBC), DC fast charging (DCFC) systems, battery management and traction inverters,
- Industrial power conversion,
- Automation controls.

In addition, materials with high dielectric strength are generally more resistant to breakdown caused by moisture, contaminants, and temperature fluctuations, enhancing the performance and extending the operational lifespan of high-power devices. Moreover, high dielectric strength materials also improve efficiency, as they help to minimize losses.

Overall, the use of high dielectric strength materials in power devices can improve equipment reliability, reduce maintenance costs, and enhance system efficiency.

Insulated Metal Substrates (IMS)

Insulated Metal Substrates (IMS) are composite assemblies that can be used as a base substrate for electronic circuits and are especially advantageous for high-power electronics. They consist of a metal heat spreader, typically aluminum or copper, which is bonded to the circuit layer using a thin layer of thermally conductive dielectric insulation material such as TCLAD’s high performance polymer-ceramic matrix. Shown in Figure-1, the dielectric layer serves to electrically isolate the metal base layer from the circuitry and provides thermal management by helping to spread and dissipate heat generated by the electronic components.

IMS offers several advantages over traditional circuit board materials, including improved thermal and electrical performance, increased reliability, and reduced size. These materials are widely used in applications such as automotive and industrial electronics, power converters, inverters, and motor controls, where high power densities and thermal management are critical to performance and reliability.

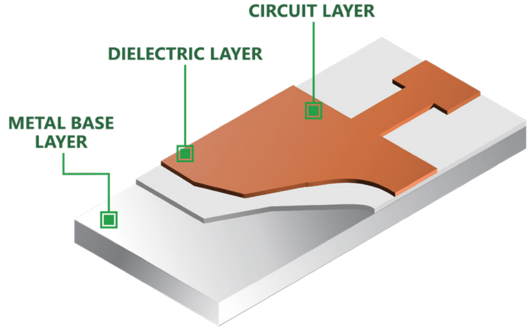

Figure-1 Structure of an IMS Substrate

Partial Discharge Inception Voltage (PDIV) Testing of IMS Dielectric Insulating Materials

Partial Discharge Inception Voltage (PDIV) is the voltage level at which a small spark discharges through or across the surface of an insulation system. These partial discharges, over time, can cause significant damage to dielectric insulation material and electronic components, leading to equipment failures. Therefore, PDIV testing of dielectric insulating materials is critical to assessing the reliability and lifespan of electronic equipment.

High dielectric strength materials designed to insulate electronics that operate at high temperatures must undergo high temperature PDIV testing. This helps designers select the right material for high temperature applications. It is important to note that PDIV values are expected to decrease as temperature increases, as there is a reduction in the insulation’s ability to withstand electrical stress at higher temperatures.

PDIV Test Setup

TCLAD, a leading provider of dielectric materials for IMS applications, provided twelve test coupons each of the following dielectric materials:

- TCLAD 3 mil HT
- TCLAD 6 mil HT
- TCLAD 6 mil HPL
- TCLAD 9 mil HT
- TCLAD 12 mil HT
- TCLAD 15 mil HT

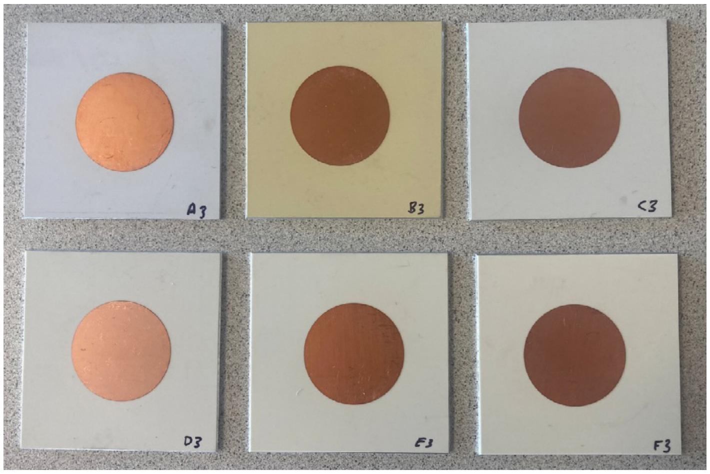

Figure-2 Six Types of Test Coupons

Technical data on the above materials is available at https://www.tclad.com/page/technical-download

An Omicron MPD 600 partial discharge measurement analysis system and a 1NF coupling capacitor were used to obtain the PDIV measurements. The test coupons were placed in an oven on a grounded copper pad. A 1-inch brass weight was used as the high voltage electrode, and a 120/7200 V transformer was used as the 60 Hz voltage source.

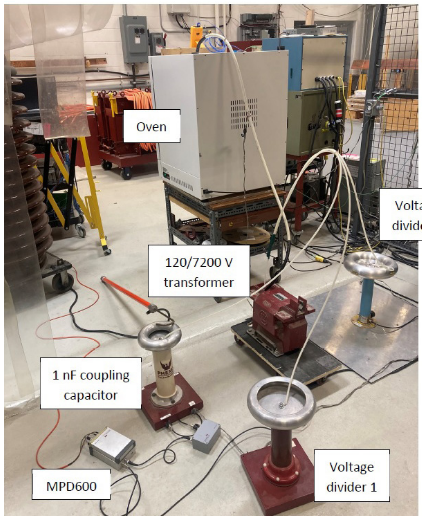

Figure-3 PDIV Test Setup

Figure-4 Test Setup Inside Oven

PDIV Test Procedure in Accordance with IEC 602700 Standard

PDIV testing was performed in air at three different temperature settings: 25°C, 50°C and 100°C. At each temperature, each type of dielectric material was represented by three replicate coupons. The coupons were preconditioned at the test temperature prior to taking PDIV measurements.

The background partial discharge (PD) level was recorded at 0.2 – 0.3 V. The voltage was then raised gradually until a PDIV greater than 2pC was detected. The voltage at which the inception occurred was recorded. Three PDIV measurements were obtained for each test coupon.

PDIV Test Results

Mean PDIV values were calculated at each temperature for each type of dielectric material. Mean PDIV values are shown in Table-1 and plotted graphically in Figure-5.

Table-1 Mean PDIV Values

TCLAD Dielectric	25°C	50°C	100°C
3 mil HT	764.6	697.7	670.3
6 mil HT	822.2	833.3	826.9
6 mil HPL	974.0	949.2	929.4
9 mil HT	1180.2	1084.0	1108.1
12 mil HT	1189.1	1186.2	1136.1
15 mil HT	1371.2	1370.0	1192.0

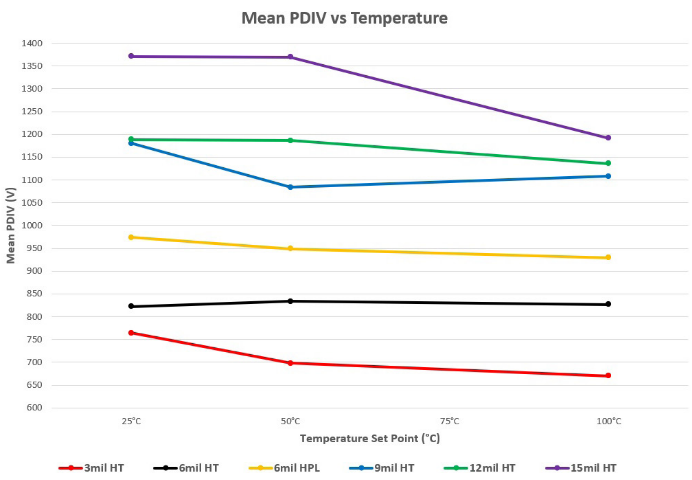

Figure-5 Mean PDIV as Function of Temperature Set Point

Interpretation of Test Results

Thicker dielectric materials exhibit higher PDIV values, indicating that thicker material options may be more appropriate for higher power applications.

As temperature increases, PDIV values typically decrease, indicating there is a reduction in the insulation's ability to withstand electrical stress at higher temperatures. The amount of decrease depends on many factors including the material chemistry and other environmental conditions.

Conclusions

TCLAD's HT and HPL dielectric materials maintained impressive mean PDIV values (670 V to 1192), depending on thickness, at high temperature (100°C) performing well in a range generally associated with high power applications such as automotive and industrial electronics, power converters, inverters, and motor controls.

TCLAD dielectric materials provide excellent thermal management due to it homogenous isotropic nature and reliable, long-lasting electrical insulation. In addition, they are resistant to breakdown caused by moisture, contaminants, and temperature fluctuations. Incorporating TCLAD high dielectric insulating materials into high power devices improves reliability, reduces maintenance costs, and enhances system efficiency.

Note: All testing was done third party at
Manitoba Hydro international Ltd.
High Voltage Test Facility,
Winnipeg, Manitoba, Canada.

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