Electrical tests on PCB insulation materials and investigation of influence of solder fillets geometry on partial discharge

A. Bulletti, L. Capineri

B. Dunn

ESTEC – Material and Process Division

EMPS-3 in Genoa, Italy, 21 March 2012

Research activities at Ultrasound and Non Destructive Testing Laboratory

• Design and fabrication of innovative or customized transducers
• Design of advanced ultrasonic electronic systems for “real time” signal and image processing
• Developments of diagnostic methods for medical and non destructive testing ultrasound
• Subsurface soil investigations with georadar, holographic radar and acousto-seismic methods
• Methods and instruments for the characterization of material properties
• Design of electronic equipments for industrial processes control
Sensors and instruments for NDT and industrial applications

Lamb wave inspection on metal and composite laminate (ESA/ITI 2004)

(Sx) Pyroelectric matrix sensor 8x8 elements
For IR laser beam monitoring

(Dx) Front end electronics with microcontroller programming

Array of airborne ultrasound transducers at 120 kHz with real-time electronics
(National Semiconductor Corporation, 2011)

Scope

- Partial discharge testing of solder fillets on PCB in partial vacuum: experimental results
- Characterization of electrical properties of printed circuit boards base laminates
Partial Discharge Testing of Solder Fillets on PCB in Partial Vacuum: Experimental Results

- This work investigates the influence on the partial discharge (PD) onset due to the geometry of solder fillets of aerospace and spacecraft component assemblies operating in vacuum and at high voltages.
- An automatic measuring system has been developed and calibrated to detect PD signals in vacuum.
- Two types of solder fillet geometries have been realized for each electrode configuration: round joints and sharp pointed joints.
- Corona Inception Voltage (CIV) and Corona Extinction Voltage (CEV) were recorded at different values of pressure x distance.

PD detector and processing system

- Vacuum chamber: Diameter 45 cm, Height 50 cm
- PD passive detector
- Turbo-molecular vacuum pump, controllable pressure range: $10^{-2}$ mbar - 10 mbar
- High Voltage (0-20kV) programmable DC Power Supply
- PD calibration and signal conditioning instrument
- Software for PD acquisition/processing in real-time (LabView) 12bit / 1.25 MHz
Examples of test objects

SOLDER FILLETS
- Sharp
- Round

PADS GEOMETRY
- 5 mm

RESIN CALIBRATION BLOCK

Real-time signal processing and analysis

Example of real-time data output for the evaluation of the partial discharge activity before the inception of the glow discharge (CIV) on pairs of round shaped soldered fillet terminals on PCB at distance 6 mm.

- Round shaped soldered fillet
- Testing voltage: 530 Volt
- CIV: 545 V
- Pressure: 2 mbar
- Measurement time interval: 5 minutes

Temporal events histogram

Typical discharge pulse

Amplitude histogram

Graphs and images depicting real-time signal processing and analysis.
Concluding remarks

The improved sensitivity of the present laboratory set-up has confirmed that the corona inception voltage (CIV) of the solder joint configurations having sharp solder fillets have a Paschen curve minimum value of 550 V. This is only 50 V lower than the 600 V minimum determined for round, smooth solder joints.

Concluding remarks cont’ed

- Two electrode geometries with parallel copper lines and facing sharp corner electrodes, with solder terminals at a distance greater than 5 mm, have not revealed substantial differences in terms of PD activity (amplitude and temporal histograms) between the two types of solder fillets. This confirms the theoretical assumptions which predict that it is the minimum distance between electrodes which influences the CIV value and hence the PD activity.
- Deliberately contaminated joints (flux residue left without cleaning) confirmed that the very active RA flux (i.e. Alpha 850-33) gave a far worse CIV than the residues from pure rosin (type R) when tested under vacuum between two adjacent solder joints.

References:
Characterization of electrical properties of printed circuit boards base laminates

• New dielectric materials have been introduced for printed circuit board applications, such as Thermount (85NT) and Polyimide (N7001-1) with the aim to match the requirements for high speed and high density of electronic devices that are planned for new spacecraft electronic boards.

• The scope of this study is to report quantitative characterization of the surface and volume resistivity for the different material samples under various testing conditions that include relative humidity, electron beam irradiation, and UV exposure.
Characterization of “as received” samples: Surface and Volume Resistivity ($R_S$ and $R_V$)

**EPOXY FR4**

- $R_S = 1.02E+16 \ \Omega$
- $\sigma = 4.72E+15 \ \Omega$
- $R_V = 2.57E+16 \ \Omega cm$
- $\sigma = 6.09E+15 \ \Omega cm$

**POLYIMIDE**

- $R_S = 1.77E+17 \ \Omega$
- $\sigma = 5.05E+16 \ \Omega$
- $R_V = 3.34E+16 \ \Omega cm$
- $\sigma = 2.96E+15 \ \Omega cm$

**THERMOUNT**

- $R_S = 6.66E+16 \ \Omega$
- $\sigma = 3.46E+16 \ \Omega$
- $R_V = 1.29E+16 \ \Omega cm$
- $\sigma = 2.03E+15 \ \Omega cm$

Each set counts 30 samples (thickness 1.6mm ±10%)

---

**Experimental set-up for UV exposure ($\lambda = 365nm$)**

Top view

- Intensity of illumination $2mW/cm^2$ for 10 minutes ($1.2J/cm^2$)
- Inclination of 30° to guarantee a uniform intensity on each sample
Summary of data of UV exposure tests

- Epoxy FR4: $R_S$ decreases of 28%
- Polyimide: $R_S$ decreases of 14%
- Thermount: $R_S$ decreases of 62%

- The surface resistivity variations remain within the standard deviation. However Thermount shows largest variation.

Summary of data of E-beam irradiation tests

Electron beam irradiation (50kGy @ $10^{-3}$mbar (297keV, 10mA for 7 minutes)

- Epoxy FR4: $R_V$ decreases of 93% (~1 order of magnitude)
- Polyimide: $R_V$ decreases of 99.5% (>2 order of magnitude)
- Thermount: $R_V$ decreases of 96% (>1 order of magnitude)

- The volume resistivity of base laminate materials decreases up to 2 order of magnitude when measured after 10 minutes from the end of the irradiation and recovers almost completely after 24 hours and completely after 15 days.
Set-up for relative humidity conditioning procedure

Testing chamber conditions:
T = 22°C±2°C
RH = (90±1)%
Exposure time: 20 days

Summary of results for RH exposure tests

90% RH exposure (20 days @ T = (22±2)°C)

- Epoxy - $R_s$ decreases of 70%
- Polyimide - $R_s$ decreases of 98% (>1 order of magnitude)
- Thermount - $R_s$ decreases of 96.5% (>1 order of magnitude)
- Epoxy - $R_v$ decreases of 82.5%
- Polyimide - $R_v$ decreases of 77%
- Thermount - $R_v$ decreases of 87%
Observations on RH exposure tests

• With 90% relative humidity tests at room temperature for 20 days the surface resistivity present a more evident decrease except for Epoxy samples. The recover effect after one month has been partially verified for Polyimide and Thermount.

Further tests with relative humidity with higher temperature (90% RH @ 70°C for 96 hours) to accomplish to ASTM standards

Observations on results (90% RH @ 70°C for 96 hours)

Comparing the 90% RH @ 22°C for 20 days exposure test with 90% RH @ 70°C for 96 hours exposure test, we can observe that:

Relative humidity tests with high temperature accelerate the process of variation of surface and volume resistivity.
Final Remarks

- Thermount showed a greater sensitivity to environmental conditions respect to a standard Epoxy and this lead to a larger variation of its electrical parameters.
- For both Polyimide and Thermount the larger decrease observed from their initial values are within two orders of magnitude but always greater than the minimum values declared by the manufacturer (E-24/125 and IPC-TM-650).

References:

Electrical tests on PCB insulation materials and investigation of influence of solder fillets geometry on partial discharge

A. Bulletti, L. Capineri
B. Dunn

EMPS-3 in Genoa, Italy, 21 March 2012