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Biography:
Dr. Bixenman is a co-founder and CTO of Kyzen Corporation. An active researcher and innovator in the field of precision cleaning, he chaired the committee that developed IPC Cleaning & Alternatives Handbook and IPC Stencil Cleaning Handbook as well as two IPC/SMTA Cleaning and Conformal Coating Conferences. Dr. Bixenman holds four degrees, including a doctorate in business administration.

Title:
Cleaning Challenges in an HDI World - Phase 3

Executive Summary:
Electronic assembly innovations drive more performance using highly dense interconnects. Assembly residues may increase the risk of premature failure or improper functionality. The challenge for OEMs is to quantify safe residue levels and gain insight into how residues impact long term reliability and functionality of hardware. To compound this problem, the question of "how clean is clean enough" is more challenging as conductors and circuit traces are increasingly narrower. Highly dense bottom termination components decrease conductor pitch, spacing and standoff heights. The problem is that current spacing trends can yield spacing between printed circuit traces as small as 2 mils. As electrical fields rise, contamination at these narrower traces becomes more problematic due to voltage swings, high frequencies, leakage currents, and high impedance. The objective of this research is to advance the understanding of chemical and electrical effects on reliability of high dense interconnects Phase 1 of the research focused on designing a new test vehicle to measure electrical responses to high voltage, rate of current change and frequency. Phase 2 studied the effects of high voltage effects on leakage currents in the presence of flux residue and environmental conditions under bottom termination components. Phase 3 will study the effects of frequency on leakage currents in the presence of flux residue and environmental conditions under bottom termination components.

Cleaning in an HDI World

IPC Midwest Conference

August 21, 2012

Mark Northrup, IEC Electronics

Joe Russeau, Precision Analytical Labs

Mike Bixenman, Kyzen Corporation

Agenda

- Introduction
- HDI Electronics
- Methodology
- Data Findings

Circuit Designers

- The challenge for assemblers and OEMs is to
  - Design reliable electronic hardware
  - Performs consistently in the field
- Smart devices require
  - Increased functionality
  - Small form factor
  - Fast data transfer

Information on Demand

- Trends lead to
  - Electronic component complexity
  - Switches that require faster signal flow rates
  - Higher transmission frequencies
- The concern is that hardware failures will become more prevalent

Reliability

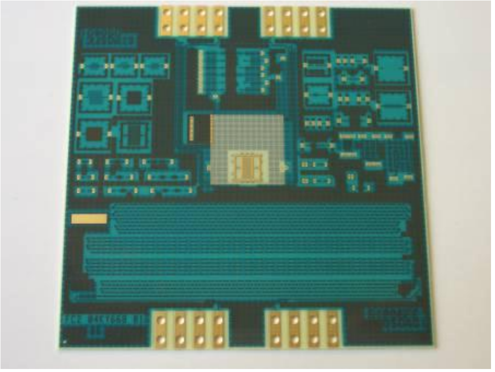
- Reliability challenge forces
  - Industry to look outside the existing design rules
  - Toward application specific field simulations
  - Better understanding of reliability risks

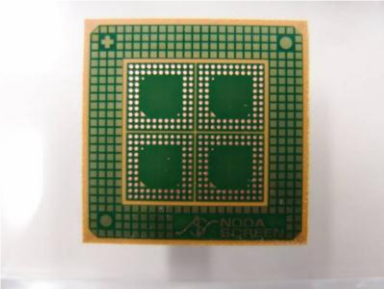
HDI Electronics

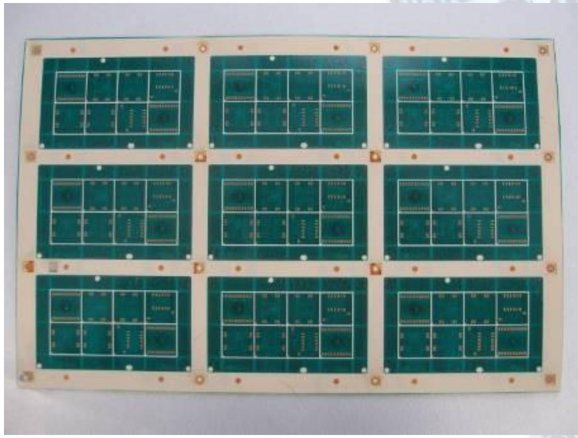
- Optics
- High Frequency RF Electronics
- Memory

HF Circuit Boards Materials

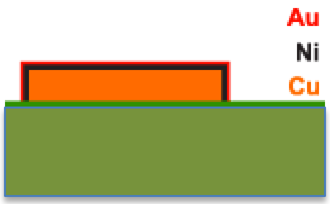
Material	Resin / Reinforcement	εr	Data sheet
Isola Duraver (FR4)	Epoxy	4,75@1MHz	Isola E-Cu 104i
Isola IS620	Epoxy		Isola IS620
Taconic TLX	PTFE	2,5@10GHz	Taconic TLX
Taconic TLC	PTFE	3,2@10GHz	Taconic TLC
Rogers 4350B	Polymer / ceramic	3,7@10GHz	Rogers 4350B



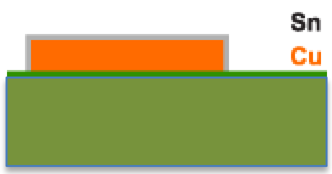




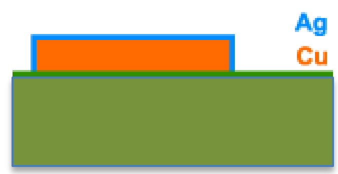
PCB Surface Finish for HF Circuit Boards



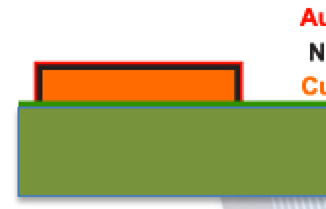
Immersion gold



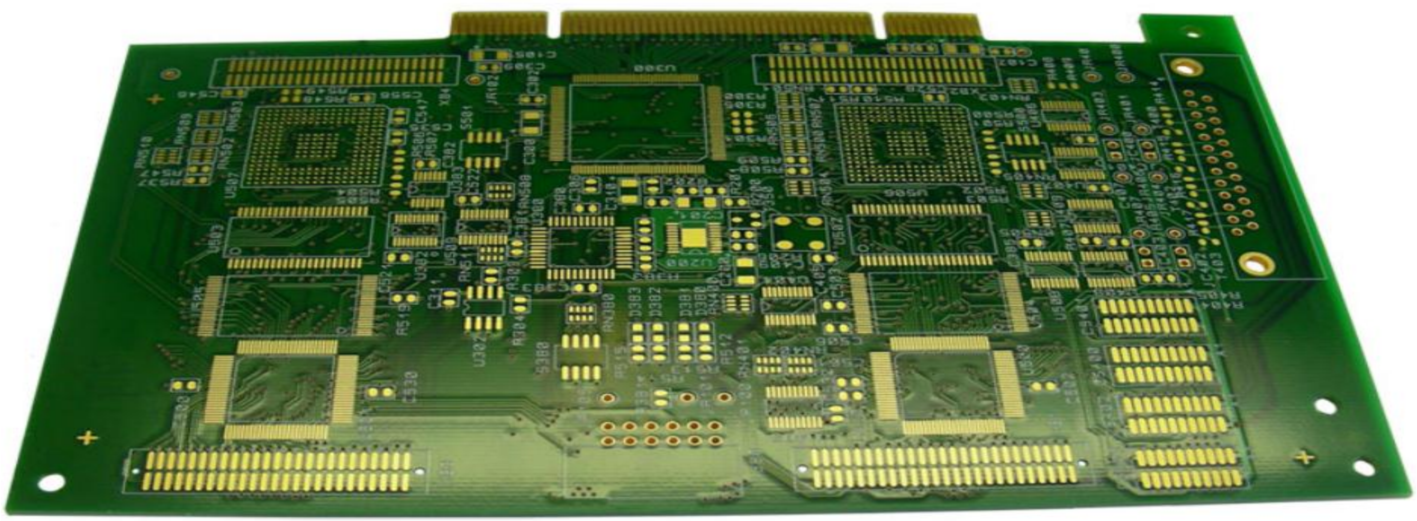
Immersion tin



Immersion silver



ENEPIG



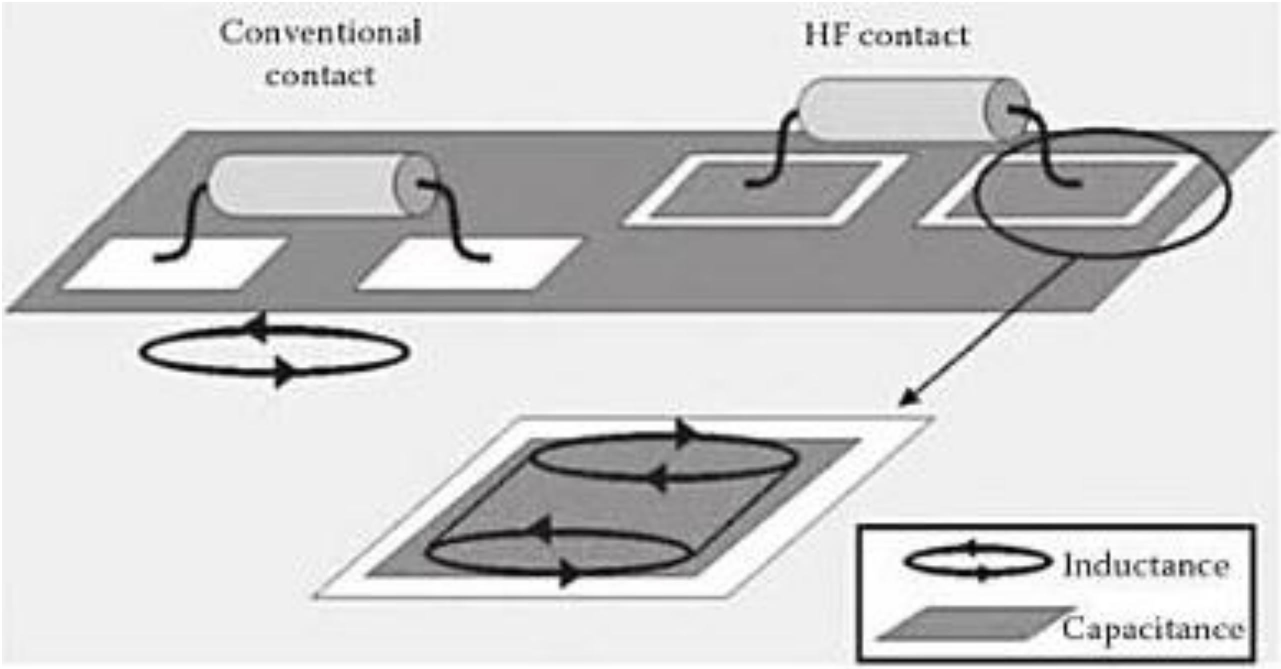
IPC MIDWEST CONFERENCE & EXHIBITION

www.IPCMidwestShow.org

High Frequency Characteristics

- High-frequency electrical losses are disconcerting
- Microwave community accustomed to loss issues
- Outgoing quality control required to mitigate these via
  - Controlled loss testing
  - Controlled impedance testing

Inductance, Capacitance , or Impedance



Handbook for Critical Cleaning: Applications, processes, and controls
By Barbara Kanegsberg

Wireless Devices

- Wireless high frequency transmission
  - Devices and their interactions behave differently
  - The sinusoidal voltage source with its associated impedance can affect current that flows into and out of the circuit
  - Factors than can distort the wavelengths at the frequency of interest may affect the expected performance of the device

Transmission Lines

- RF/microwave circuits
  - Transmission lines
  - Structures
- PCB characteristics relate to
  - Electrical performance at higher frequencies
- The PCB alone involves four components of insertion loss which include
    - Dielectric
    - Conductor
    - Leakage and
    - Radiation

Electrical Effects

- Traditional low frequency hardware
  - Wires connect devices
  - Little to no resistance

Signal Interruption

- Electrical losses
  - Become important when the circuit is no longer acting like a simple interconnect, but is actually a transmission line
- For most high-frequency applications laminates with moisture absorption values of less than 0.25% are considered acceptable

Chemical Effects

- Flux residues are identified by
  - Flux activity
  - Potential for the residue to ionize
- Flux activity is needed for
  - Removing metal oxides from alloys and surface finishes
  - Halide activators perform well but have been discouraged due to environmental concerns and the corrosive nature of the residue
  - Halogen free no-clean solder paste innovations are hitting the market from solder paste manufactures at a high rate
  - The goal is to design flux compositions that improve solderability and leave a benign residue that may or may not need to be cleaned, dependent on the end use environment

Contamination

- Process and service related contaminations may accelerate reliability issues due to a range of different failure mechanisms
- Three common failure mechanisms that may come into play on RF high frequency circuits
    1. Electrochemical migration (ECM)
    2. Electromigration (EM)
    3. Parasitic capacitance(xtalk)

HIGH FREQUENCY RELIABILITY TESTING

Impedance Testing

- Controlled impedance testing variables involve
  - Dielectric constant (Dk) of the PCB material
  - PCB Thickness of electrically critical layers
  - Uniformity of the PCB conductor-etched features

Controlled Loss Testing

- Controlled loss testing involves more variables
  - Dissipation factor (Df) of the PCB material
  - Copper surface roughness
  - Uniformity of the PCB conductor etched features
  - Conductor length and impedance mismatches
  - PCB surface finish, solder mask , etc .

Insertion Loss

- The PCB alone involves four components of insertion loss which include
  - Dielectric
  - Conductor
  - Leakage and
  - Radiation

Current Cleanliness Testing Protocol

- IPC-TM-650 Method 2.3.28 - Ion Chromatography
  - 75% IPA / 25% DI water
  - 60 minute extraction period
  - Ineffective for High Frequency
- Foresite C3 Localized extraction
  - Steam extraction using DI water
  - 3 minute extraction period
  - Limited application

Progression of Methods

IPC 2.3.28 (Global)

↓

Foresite C3 (Isolated)

↓

? New Method (Tighter isolation)

Table 8-1 Accelerated Testing for End Use Environments

Worst-case use environment								Accelerated testing			
Use category	Tmin °C	Tmax °C	$\Delta T^{(1)}$ °C	t_D hrs	Cycles/ year	Typical years of service	Approx. accept. failure risk %	Tmin °C	Tmax °C	$\Delta T^{(2)}$ °C	t_D min
1) Consumer	0	+60	35	12	365	1–3	1	+25	+100	75	15
2) Computers	+15	+60	20	2	1 460	5	0.1	+25	+100	75	15
3) Telecom	-40	+85	35	12	365	7–20	0.01	0	+100	100	15
4) Commercial aircraft	-55	+95	20	12	365	20	0,001	0	+100	100	15
5) Industrial & automotive Passenger Compartment	-55	+95	20 &40 &60 &80	12 12 12 12	185 100 60 20	10	0.1	0	+100	100 & COLD[3]	15
6) Military Ground & ship	-55	+95	40 &60	12 12	100 265	10	0.1	0	+100	100 & COLD[3]	15
7) Space Leo Geo	-55	+95	3 to 100	1 12	8 760 365	5–30	0.001	0	+100	100 & COLD[3]	15
8) Military avionics a b c	-55	+95	40 60 80 &20	2 2 2 1	365 365 365 365	10	0.01	0	+100	100 & COLD[3]	15
9) Automotive under hood	-55	+125	60 &100 &140	1 1 2	1 000 300 40	5	0.1	0	+100	100 & COLD[3] & LARGE $\Delta T^{(4)}$	15

METHODOLOGY

Research Objective

- Research electrical versus chemical effects on determining reliability of High Frequency HDI Interconnects

Research Approach

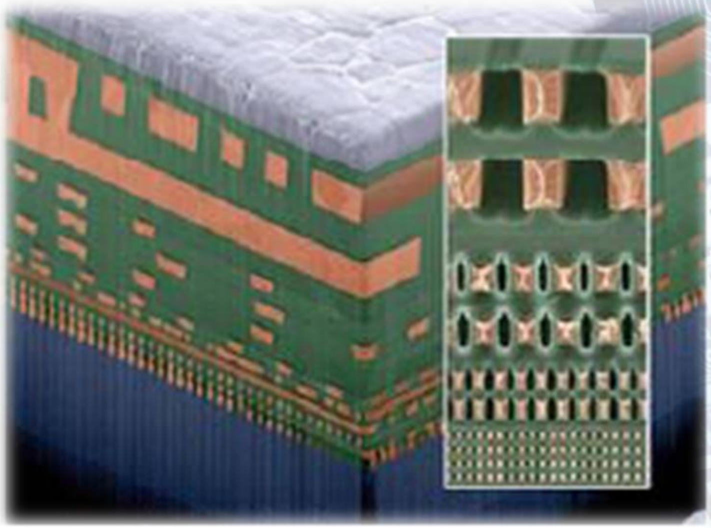
- Study and quantify
  - Electrical versus Chemical Effects
  - At what point does frequency and pitch meet a dimension where interactions create potential failures
    - Parallel traces
    - Dampen signal
    - Pulse between the two closest points (xtalk)
  - Parameters we are trying to measure
    - Bare board extractions
    - Localized a gap <.40mm, .40 - .60mm, and > .60 mm to isolate

Correlational Study

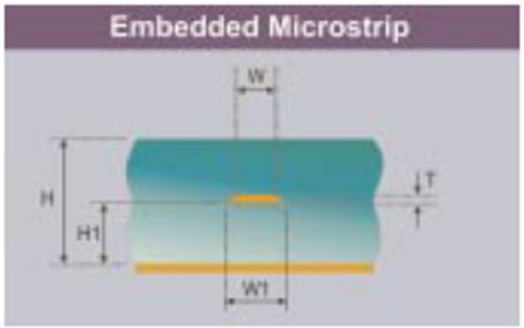
- Correlate to a level of Ionics and effects
  - Extraction techniques we are developing is a challenge
  - Correlate Ionics on a test board to failure with different frequency levels
    - 1 GHz
    - 10 GHz
    - 20 GHz
    - 40 GHz
  - Set limits that an engineer can use to predict failure and control a process

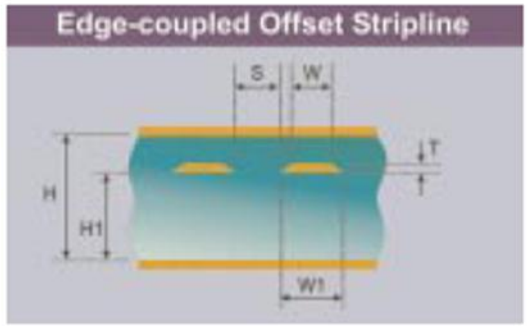
Test Vehicle

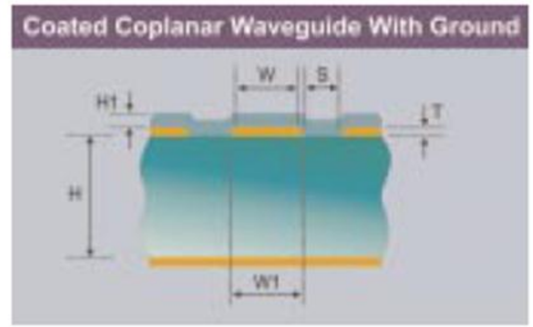
- Test from 1, 10, 20, 40 Giga Hertz
  - Measure interactions
  - What do we measure
    - Parasitic Capacitance
    - Controlled Impedance
    - Controlled Inductance
    - Frequency Shift
    - Gain or Loss
    - Phase Shift or Change
    - Scattering(S) Parameters

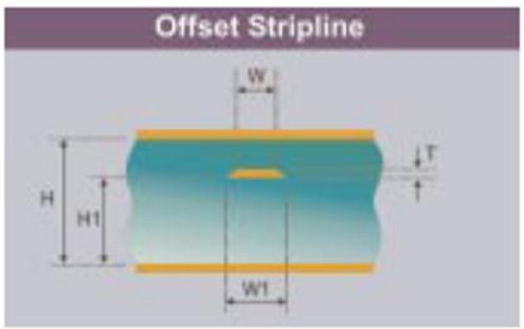


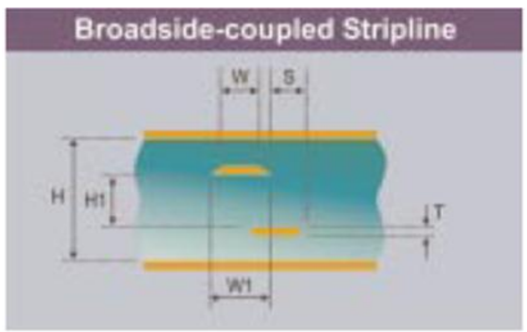
Proposed Test Vehicle Structures

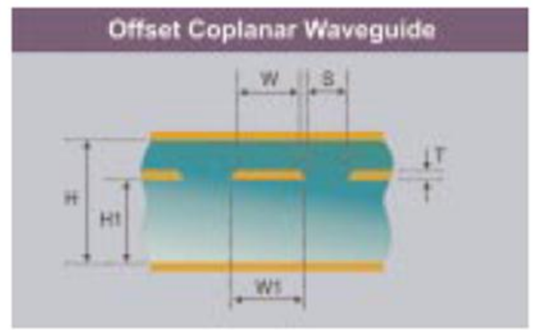


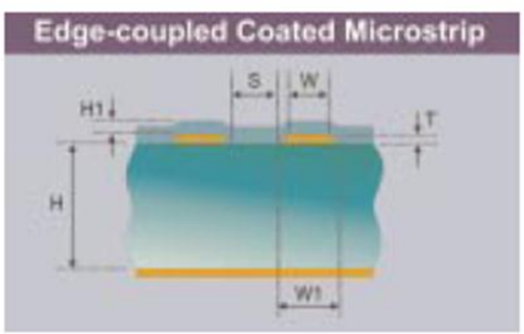


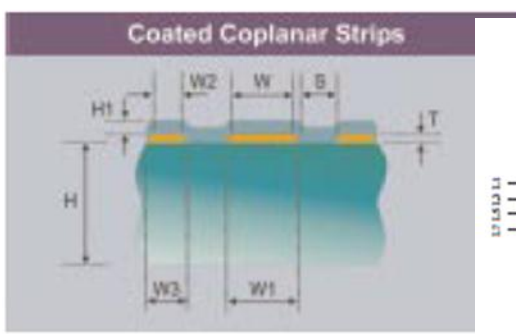


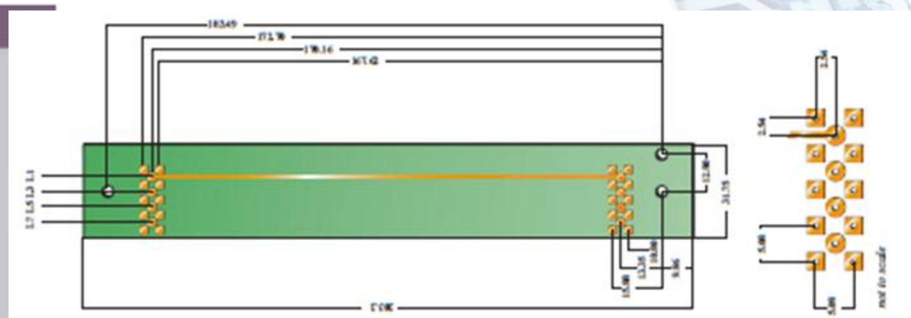




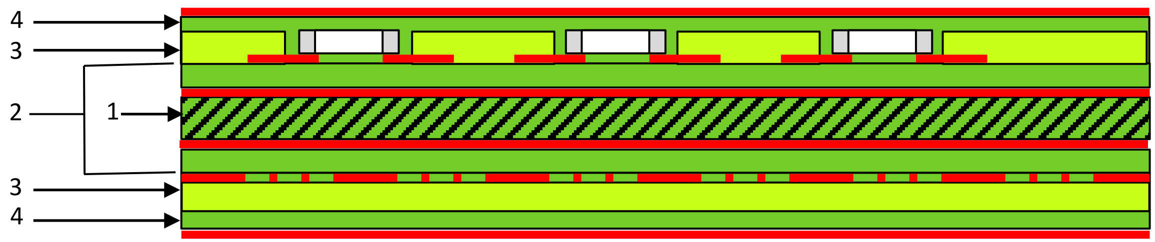




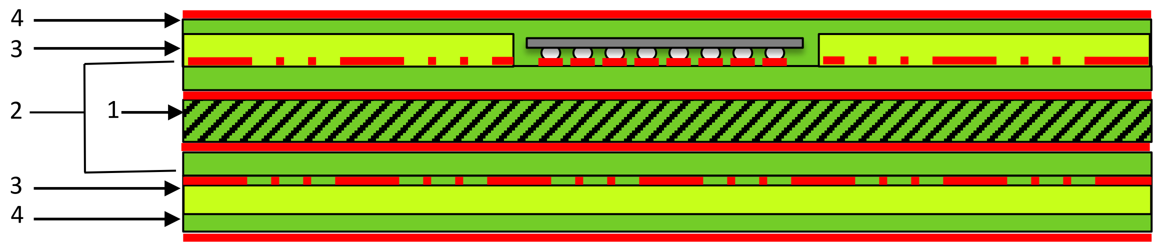




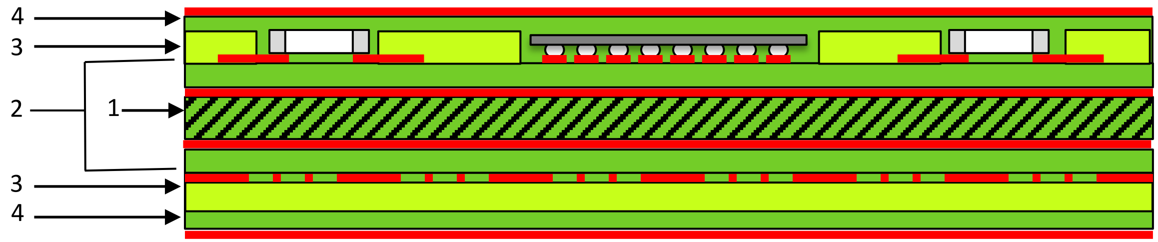
EPCB Test Vehicle Structures



A1(EPCB Passive)

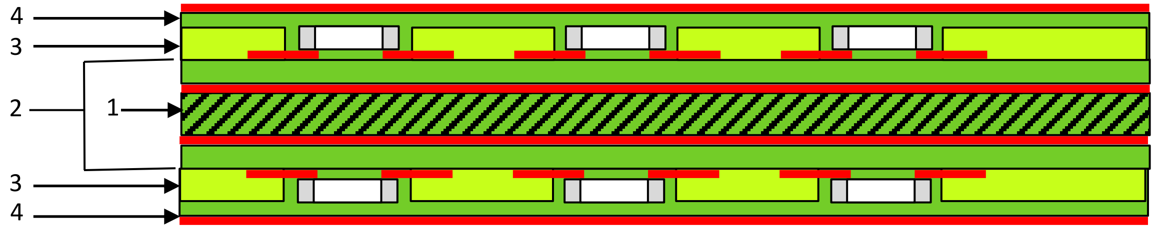


A2(EPCB Active)

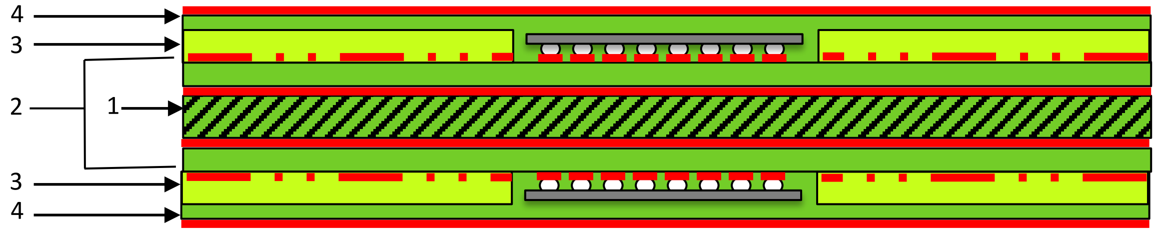


A3(EPCB Base Core)

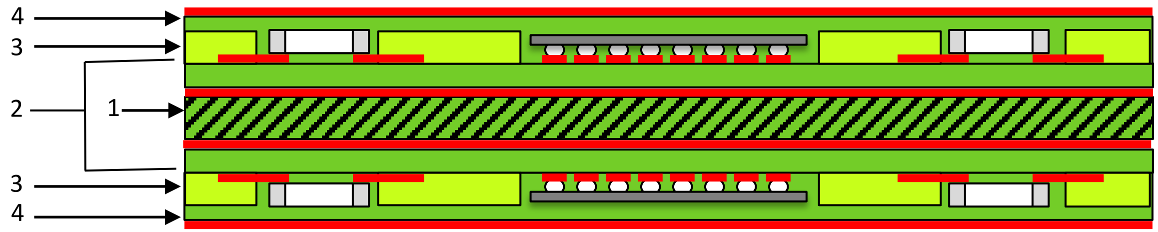
EPCB Test Vehicle Structures



B1(Base Core Passives)

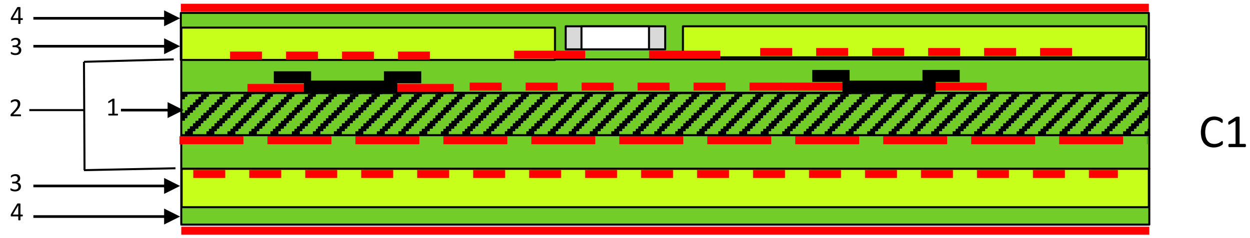


B2(Base Core Actives)

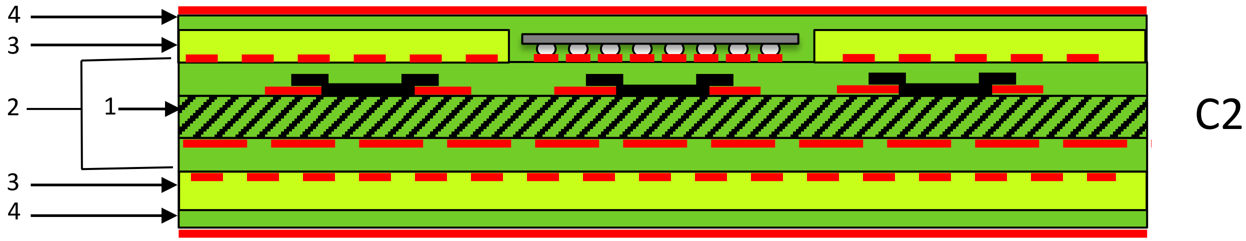


B3(Base Core Pass/Act.)

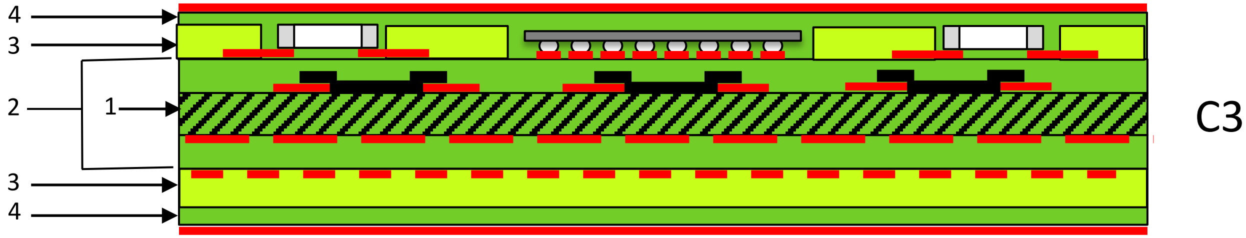
EPCB Test Vehicle Structures



Base-core example with formed passive components in the mounting base and inserted passive components on one side

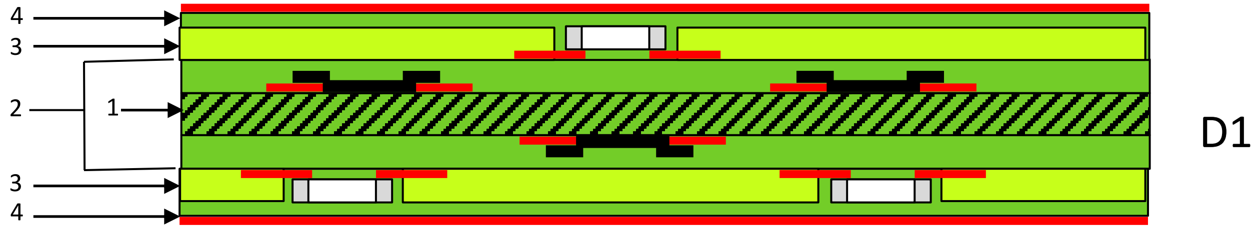


Base-core example with formed passive components in the mounting base and inserted active components on one side

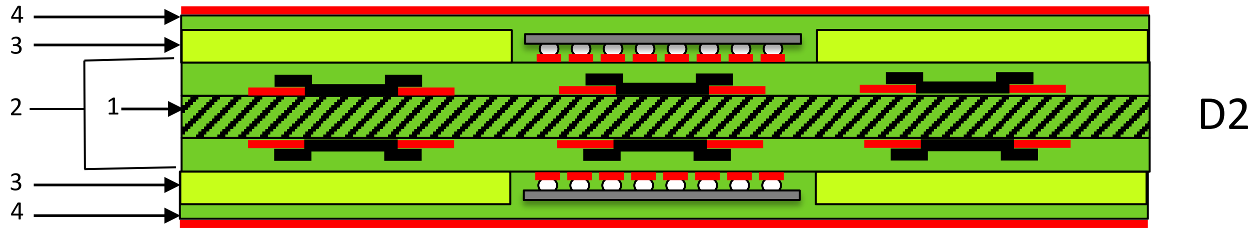


Base-core example with formed passive components in the mounting base and inserted passive and active components on one side

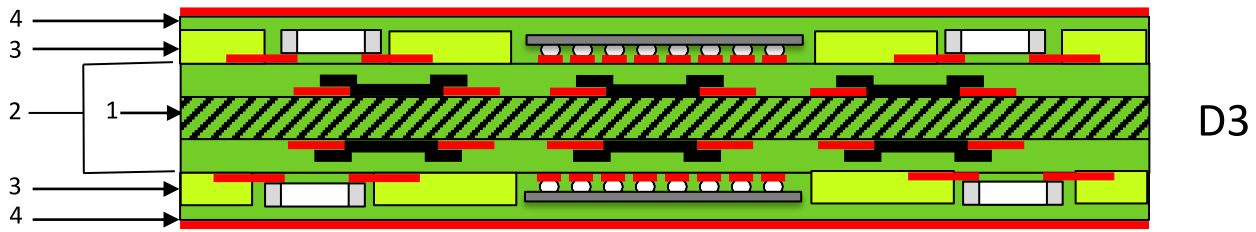
EPCB Test Vehicle Structures



Base-core example with formed passive components in the mounting base and inserted passive components on both sides

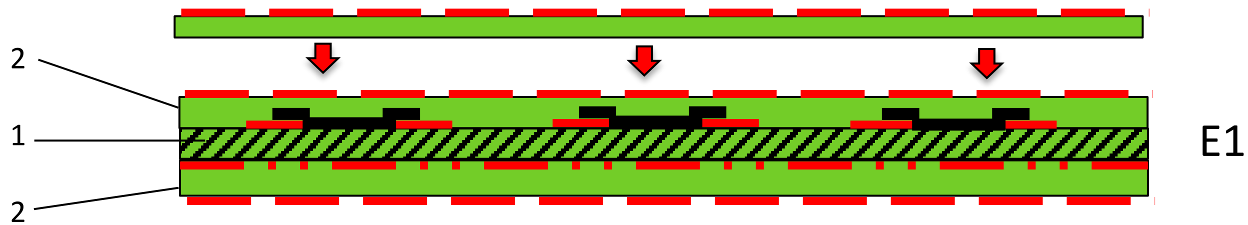


Base-core example with formed passive components in the mounting base and inserted active components on both sides

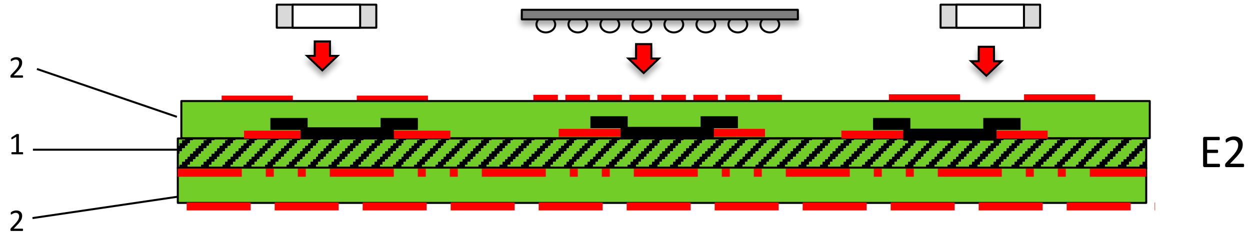


Base-core example with formed passive components in the mounting base and inserted passive and active components on both sides

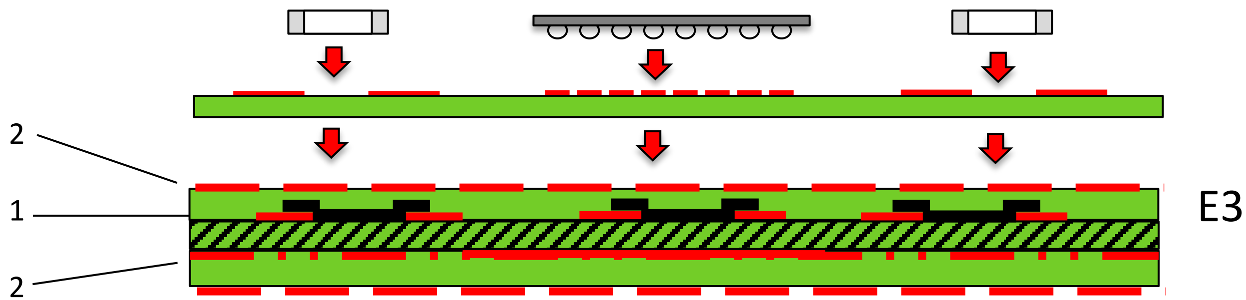
EPCB Test Vehicle Structures



Mounting base example with formed passive components inside the mounting base plus additional layering added to one or both sides to complete the Embedded Component Printed Board



Mounting base example with formed passive components inside the mounting base turning the product into an base-core ready for component mounting to complete an Embedded Component Board Assembly



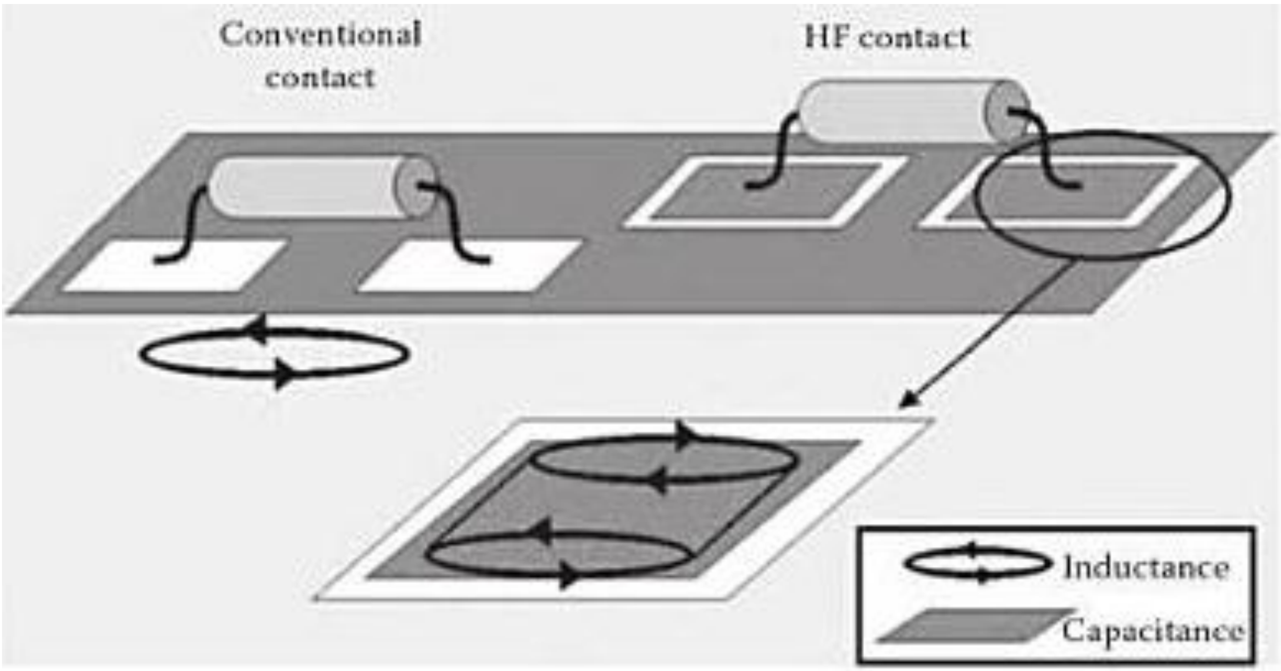
Mounting base example with formed passive components inside the mounting base plus additional layering added to one or both sides to complete the Embedded Component Printed Board ready for component mounting to complete an Embedded Component Board Assembly

High Frequency Packaging Designs

Pkg. Type	Lp	Cp	Rs	θj	Cost	Max Freq.	Hermetic	Comments
Ceramic	Excellent	Excellent	Excellent	Excellent	High	18 GHz	Yes	All products available
MELF	Good	Fair	Excellent	Very Good	Moderate	2 GHz	Yes	Only select PIN diodes available
MMSM	Very Good	Very Good	Good	Very Good	Low	8 GHz	No	Only select PINs and varactors
EPSM	Good	Good	Good	Good	Moderate	6 GHz	No	All products available
Glass Axial	Fair	Good	Good	Poor	Moderate	1.5 GHz	Yes	Many products available
Plastic	Poor	Fair	Fair	Poor	Low	2 GHz	No	Only select PINs, varactors & Schottkys
Stripline	Good	Good	Good	Fair	Moderate	8 GHz	Yes or No	All products available

- Microwave Diode Package types have various combinations of parasitics, which limit circuit performance in different ways.
- Ceramic packages are the best performing microwave package available. They are hermetic and the type of choice for military and space applications.
  - Metal Electrode Leadless Faced (MELF)
  - Microwave Monolithic Surface Mount (MMSM™)
  - Enhanced Performance Surface Mount (EPSM™)
  - *Series Inductance (Lp)*
  - *Shunt Capacitance (Cp)*
  - *Series Resistance (Rs)*
  - *Thermal Resistance (ϑ j)*

Inductance, Capacitance , or Impedance



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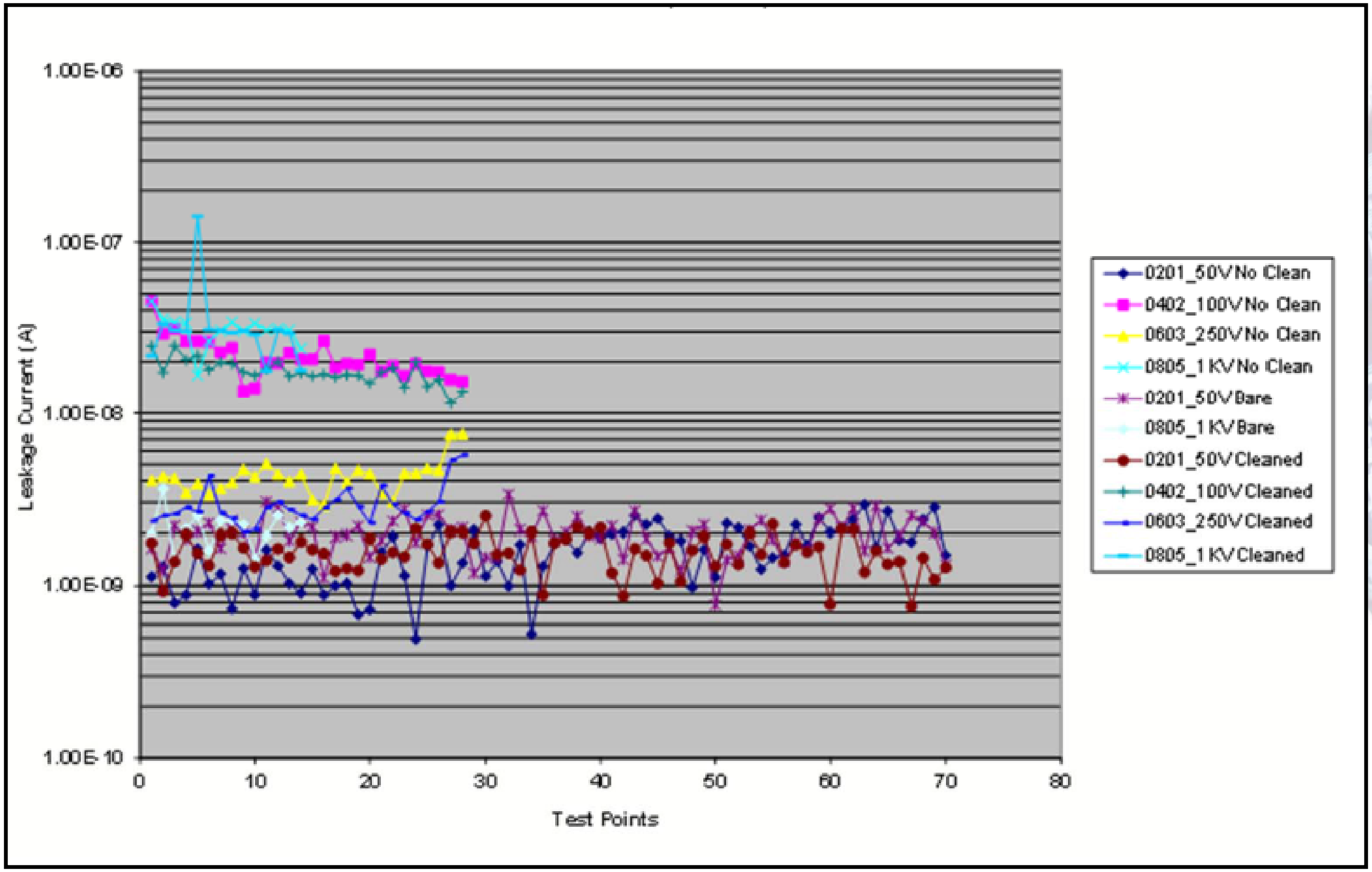
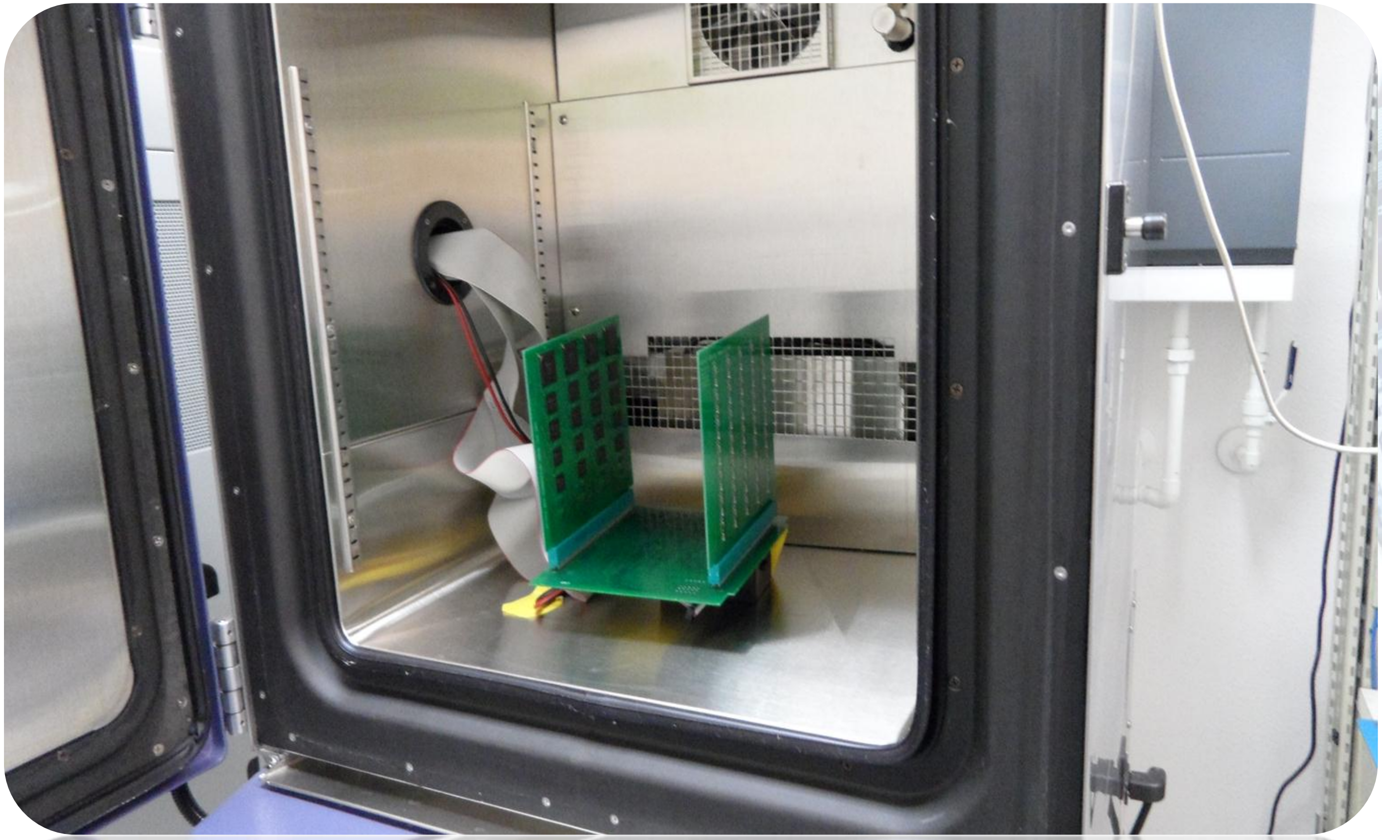
High Voltage Electrical Leakage Data



High Voltage Electrical Leakage Data



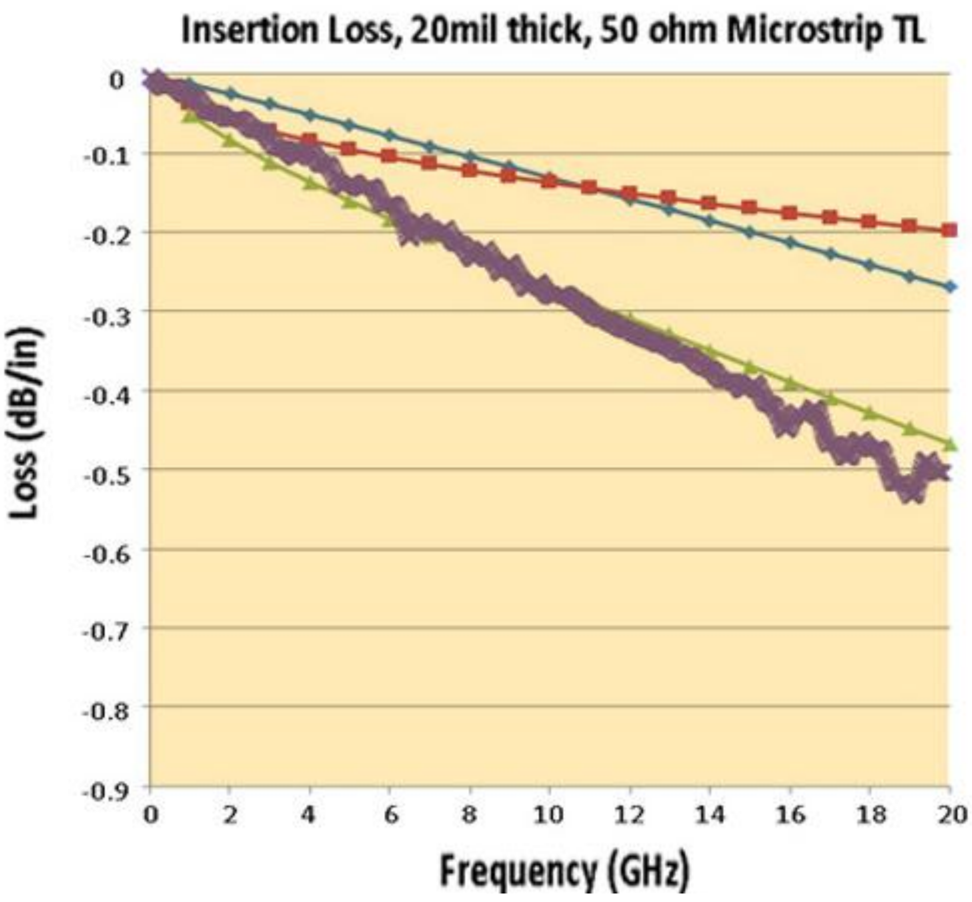
RF Loss IC Test Data Example

Company: Precision Analytical Lab

Date: January 31, 2012

ION NAME	CHEM ID	Bare Board (BB)	Reticle 0201 Bare Boards									
			BB 1	BB 2	BB 3	BB 4	BB 5	BB 6	BB 7	BB 8	BB 9	BB 10
Sodium	Na++	1.00	0.73	0.50	0.56	0.56	0.49	0.55	0.54	0.50	0.57	0.52
Potassium	K+	1.00	0.34	0.33	0.34	0.43	0.41	0.40	0.34	0.38	0.33	0.32
Calcium	Ca++	1.00	0.09	0.05	0.05	0.08	0.09	0.10	0.10	0.15	0.20	0.09
Lithium	Li+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magnesium	Mg++	1.00	0.41	0.38	0.38	0.56	0.45	0.38	0.42	0.43	0.41	0.39
Ammonium	NH4+	2.50	1.57	1.47	1.37	1.62	1.48	1.46	1.39	1.34	1.28	1.25
Acetate	CCOO-	0.00	5.24	4.45	4.04	5.16	4.65	4.68	3.70	5.61	4.76	4.73
Formate	COO-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromide	Br-	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloride	Cl-	2.00	0.34	0.24	0.29	0.30	0.22	0.26	0.32	0.25	0.25	0.23
Fluoride	F-	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitrate	NO3--	0.00	0.08	0.07	0.07	0.09	0.10	0.11	0.13	0.06	0.09	0.12
Nitrite	NO2-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate	SO4--	1.00										
Phosphate	PO3--	0.00	0.53	0.75	0.75	0.62	1.38	0.59	0.62	0.69	0.72	0.60
Citrate	Citrate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weak Org. Acid (VOA	VOA-SMT	25.00	18.69	23.69	16.97	17.40	16.81	17.33	17.23	15.65	17.52	15.01
Weak Org. Acid (VOA	VOA-PTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSA	MSA	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Loss Test Data Example



Test Vehicle Properties

- New test vehicle
  - Electrical measures as the control for cleanliness in a production line
  - Electrical measures correlate to cleanliness issue
  - Quantifying electrical measurements to ionic levels to set limits
  - Guideline for engineers to know limits for specific voltage, frequency and currents

Why is it Important?

- Technology Evolution
  - Miniaturized technology with glass interposers
  - Interposers very close together
  - Complex high frequency devices
- Reliability could cause
  - Life threatening
  - Loss of information
  - Disruptive

Questions

- Does anyone have a industry acceptable localized ionic extraction method?
- What is the preferred parameter (i.e. inductance, capacitance or impedance)?
- What test pattern should we agree upon to use?
- What device(s) (i.e. microwave diodes) should we use?

Thank You