COVALENT METROLOGY

eBook

Printed Circuit Board Assembly (PCBA) Characterization by Destructive Physical Analysis

Comprehensive Quality Assessment for PCBAs and Components

Covalent Metrology, Failure Analysis

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Printed circuit boards (PCBs) and assemblies (PCBAs) are the foundational backbone in the vast majority of modern electronic devices.

They are used in products ranging from high-density, ultrafast processors in laboratory super computers to everyday home appliances, such as coffee makers or microwaves. In these systems, PCBs and PCBAs provide the infrastructure that connects all other electrical components.

When this infrastructure is damaged, or when it is not manufactured correctly, critical device failure can result.

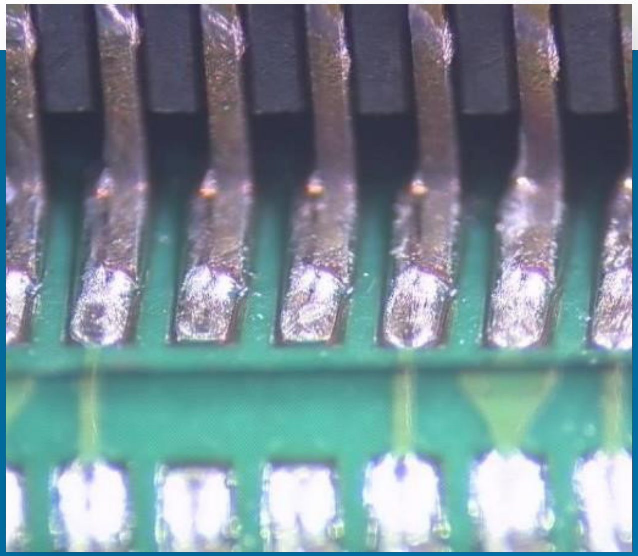
The best-known method to test the quality of printed circuit boards and their components is **Destructive Physical Analysis (DPA)**. This process yields a comprehensive quality assessment for workmanship on PCBAs, and involves both non-destructive and destructive inspections using high resolution microscopy.

These inspections are typically performed in alignment to protocols outlined by the IPC: an international association that supports the PCB industry with a globally recognized certification process for validating the quality and reliability of printed circuit boards.

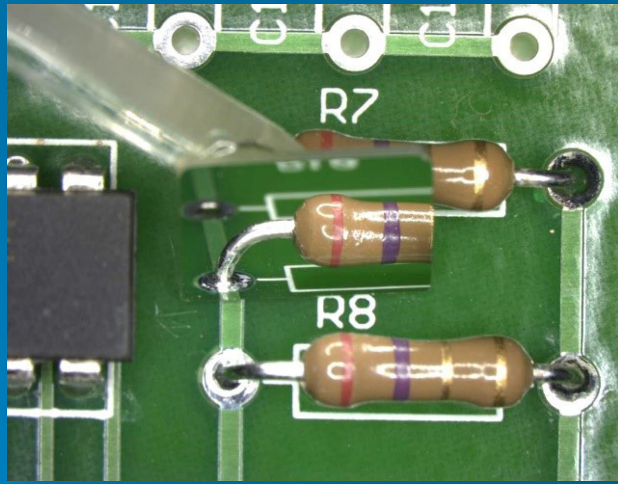
Phase 1: External Inspection

Destructive Physical Analysis (DPA) for IPC Compliance Testing involves multiple inspections of a sample circuit board. Initial inspection is nondestructive and requires an expert's visual inspection of the exterior of the board. This is often supplemented with optical microscopy, and sometimes X-ray imaging techniques.

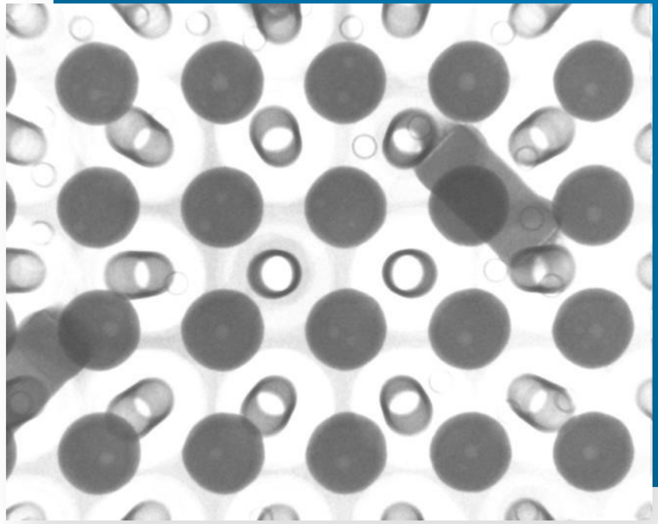
1. A stereo-zoom optical microscope is used with a small handheld mirror to examine solder fillets, pin alignment, BGA solder balls (particularly the outer rows), as well as any visible contamination areas.
2. X-ray imaging provides non-destructive visualization of internal defects (such as voids, pin misalignment, or Plated Through Hole (PTH) issues) and features (including: press-fit connections and solder-fill).
3. External inspection methods are used to identify areas of interest where there may be potential workmanship issues. Once identified, mechanical cross sectioning techniques reveal the PCB interior at each area, allowing for accurate dimensional measurements and clearer visualization of defects.



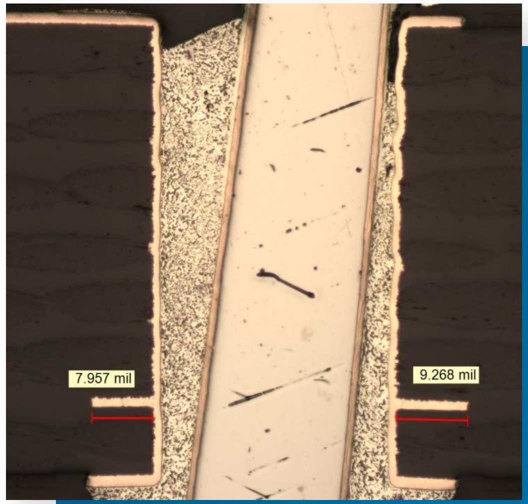
A magnified view of a surface-mounted integrated circuit (IC) captured with Covalent's high-resolution digital optical microscope. Its motorized stage and rotating camera enable image capture from flexible viewpoints.



A small handheld mirror augments inspection with the optical microscope, enabling experts to maneuver their view even further to evaluate fine structural details from every angle.

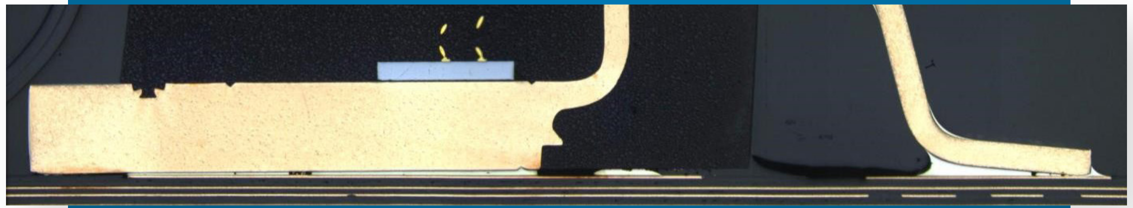


X-ray images show projections of the different types of materials in PCBA components. Covalent's 2D x-ray inspection tool is equipped with an industry-leading detector which captures 6.7 MP images with sub-micron-scale resolution.



The use of a digital optical microscope enables critical dimensions to be measured directly within images after length scale has been calibrated.

High-resolutions made possible with advanced optical microscopes enable clear visualization of tiny defects; such as the fractured solder connection shown on this capacitor pin tip.



Optical microscope image of an end-overhang defect in the power relay. In this example, the issues is with the PCB layout and not with the soldering or assembly; the copper pads beneath the relay are not properly spaced.

Phase 2: Internal Inspection

Subsequent evaluations are performed by mechanically cross-sectioning the board at sites of interest, to expose and examine the internal connections. Inspection at this stage can then be completed using high-resolution microscopy tools.

1. Cross-sectioning is an inherently destructive technique, which physically slices into components or regions in the PCB itself that are targeted during the first phase of analysis. It yields extracted segments that enclose the areas of interest, and these must then be ground and polished to show the details of their internal structure. To preserve the internal features, the slices are mounted in epoxy prior to grinding.
2. High resolution microscopy tools are used to carefully examine the fine details of each extracted slice. The appropriate instrument is selected to visualize each piece. For most macroscopic segments, digital optical microscopes work well; in the case of microscopic components, electron microscopy is sometimes better suited to achieve the necessary magnification.
3. Common features assessed using this technique include: fillet height, percent hole-fill, press-fit pin alignment, solder-cracking, areas with wetting issues, solder balls, plated through holes, delamination areas, etc. If whole electrical devices are attached to the PCB, it is often beneficial to cross-section and inspect these as well: especially if a device shows signs of questionable workmanship. Representative devices include: connectors, BGAs, capacitors, and PLCCs.
4. At each phase of this visual analysis, the board and its parts are determined to meet “Target” (ideal), “Acceptable,” “Process-Indicator” (feature suggests issue with processing procedure), or “Defect” conditions as outlined in IPC-A-610G for the applicable product class.

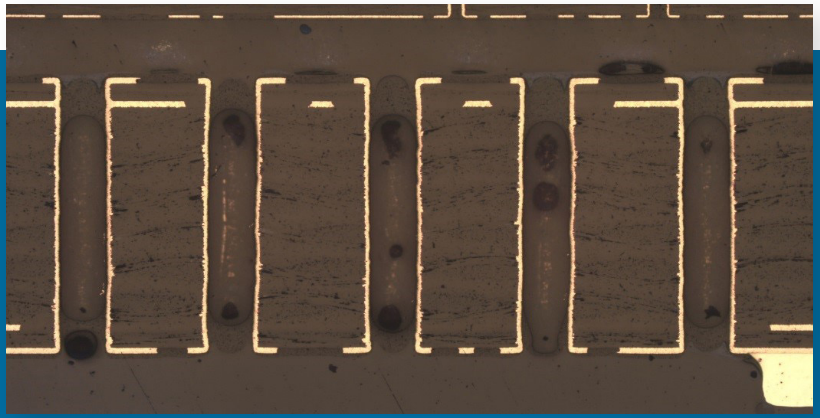
Phase 3: Plated Through Hole Evaluation

Plated through holes are used in some boards to enable electrical components to be joined by leads fed through holes one side of the board and soldered on the opposite side. When included, these are determined to be “Target” (ideal), “Acceptable,” or “Non-conforming” based on IPC-A-600H.

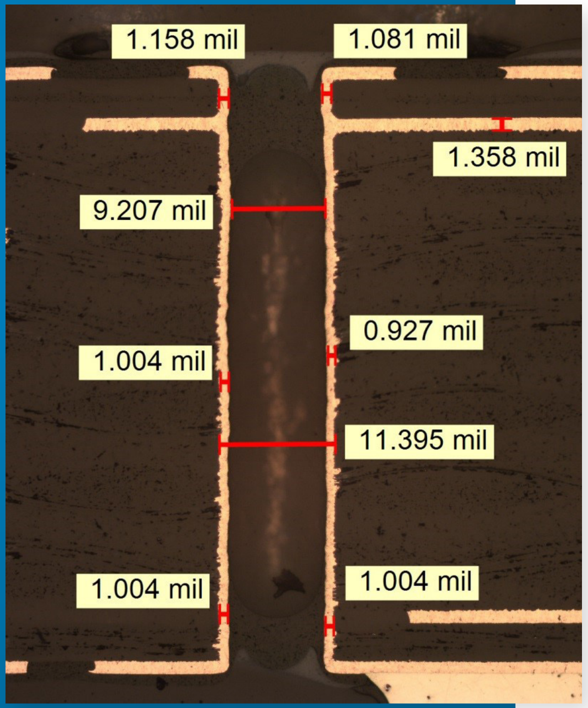
Phase 4: Ionic Cleanliness Testing

Ionic Cleanliness Testing is an efficient way of evaluating whether damaging ion species may be present on the sample. These compounds may cause degradation on the board over time, through corrosion, dendrite formation, parasitic leakage, or other mechanisms if their source is not identified and treated. Identifying the ion species present allows analysts to anticipate process vulnerabilities and preempt more serious issues.

1. Ion Chromatography is performed on rinse fluid flushed from the sample board to identify and quantify extracted ion species.
2. The results of this test are validated against standard IPC-A-610G.



Optical microscope image showing a cross-section of plated through-holes. Conductive hole plating is shown in the cream- colored features.



Using the digital measurement capabilities on an advanced optical microscope, precise measurements of the plating thickness and hole diameter can be made to evaluate the through-hole’s conformity with IPC standards.

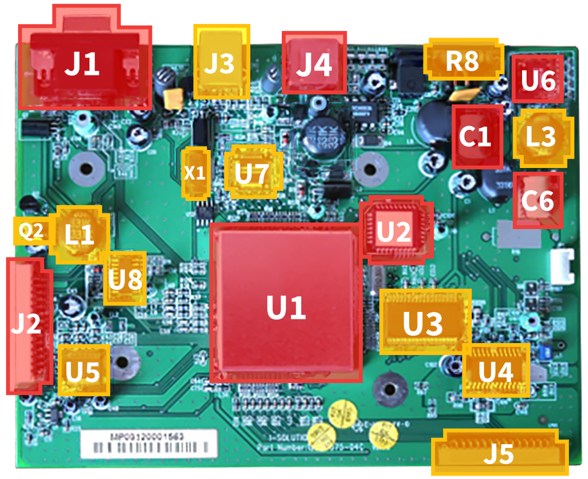


Photo taken of the front-side of sample XYZ. Component locations labelled with a reference designator for identification during destructive and nondestructive inspection phases. Components highlighted in red were mechanically cross-sectioned.

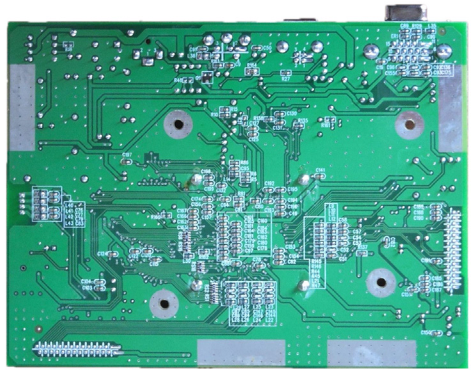


Photo taken of the back (solder-source) side of sample XYZ. This side of the board is analyzed for fillets and pad coverage, as well as through-pin devices, lead protrusion, exposed base metal, and solder-joint quality for chip components and larger devices.

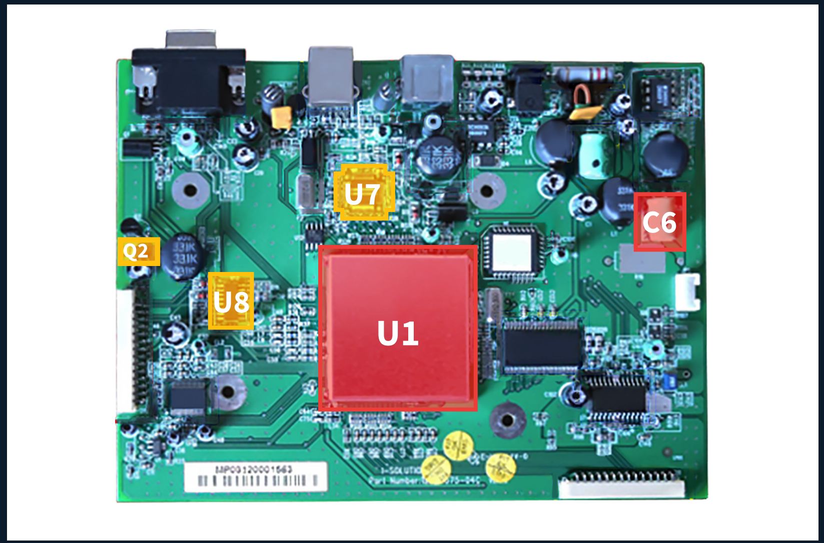
Sample Analysis of a PCBA

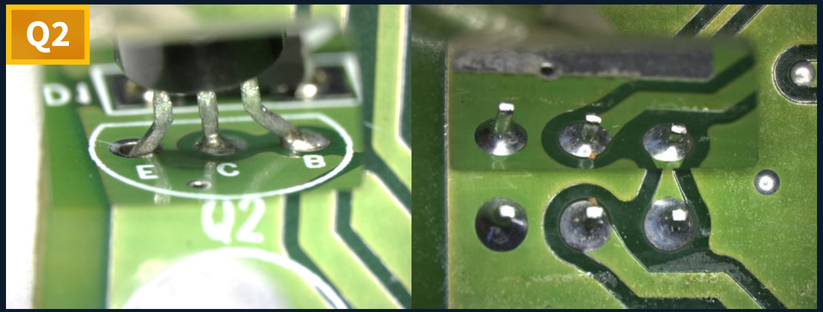
The following pages provide a sampling of the destructive physical analysis (DPA) performed on a single PCBA (anonymized as "sample XYZ"). This sample underwent both external and internal analysis, as well as a plated through hole evaluation (phases 1-3 described previously).

Ionic cleanliness testing (phase 4) was not performed on this sample, as no chemical contamination of the board was suspected. After initial visual inspection of the board, no visible chemical degredation was found.

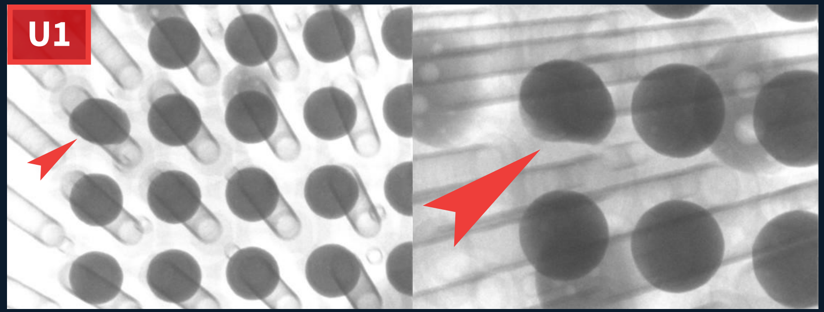
Nonetheless, sample XYZ had several irregularities that were identified through the DPA procedure. These included some defective features - which can lead to performance deficits and device failure - and some acceptable deformations - which are non-ideal, but unlikely to cause significant issues.

Identifying these irregularities and their morphologies enables manufacturers to better understand processing issues, prevent serious malfunctions, and optimize PCBA quality.

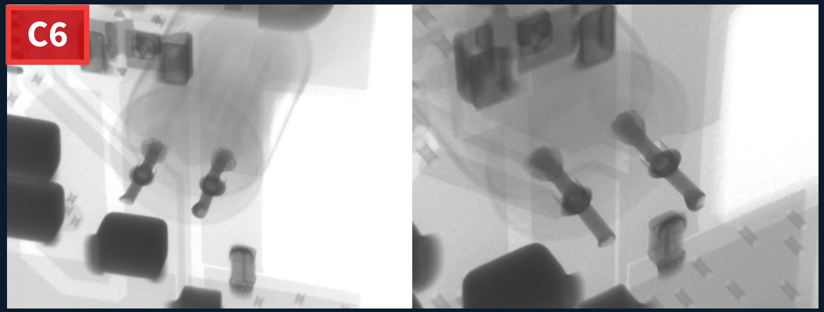




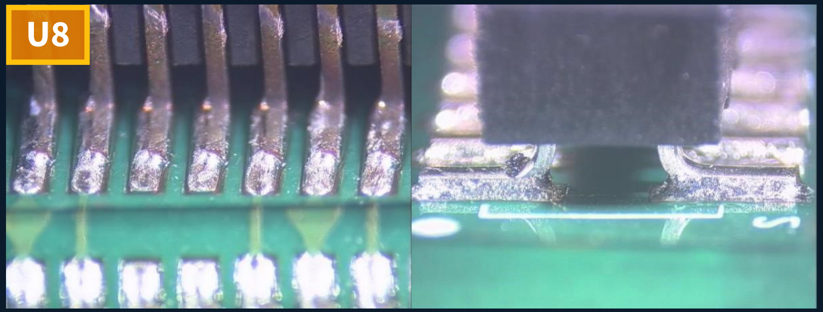
Q2 through-pin transistor has primary (left) and secondary-side (right) fillets. One pin (E) shows incomplete hole-fill per IPC-A-610G §7.3.5. Whether or not it still meets an "acceptable" degree of fill will be determined by cross-sectioning. All 3 pins (E, C, and B) show "target" quality fillets at the solder-source side per IPC-A-610G §7.3.5 for all 3 classes of product.



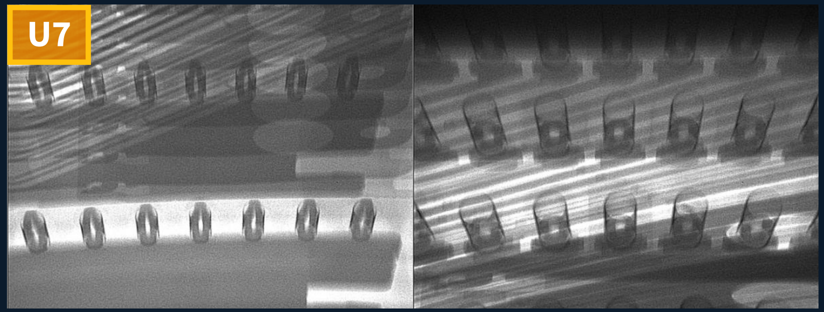
X-ray images at two magnifications showing the irregularly shaped BGA solder ball (which should be spherical). In this case, the overall BGA was deemed to be acceptable, as this irregularity should not interfere significantly with function.



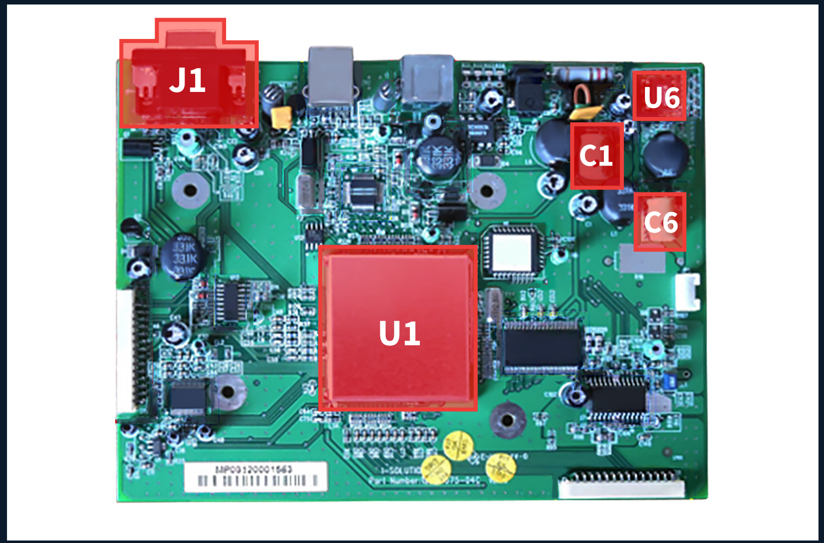
2D X-ray images of the C6 capacitor captured from near orthogonal angles. From these images, one can see the unfilled areas around the pins within the hole. Confirmation of this defect is achieved with cross-sectioning.



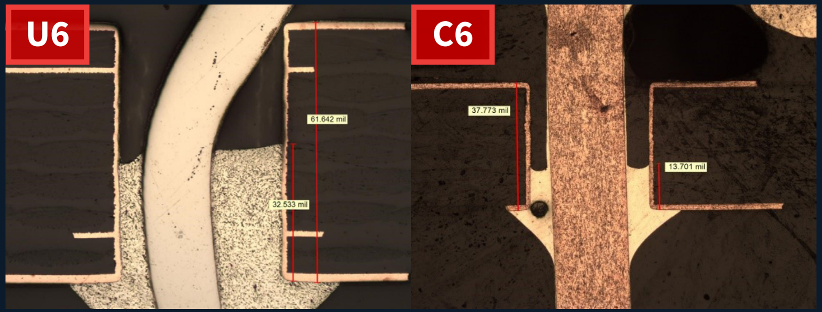
Optical microscope image capturing two different views of the SMT connector device: one from a single side (left), and the other from the front of the device (right). Jointly, these portray the near-parallel alignment of the heel fillets: while not quite ideal, their slight angling is not likely to cause significant defect in quality.



2D X-ray images from 2 angles (top-down on the left and at an incline on the right) capturing the internal structures of the board and a joined press-fit connector. All pins appear nearly parallel, and there are no indications of damage or significant defect.

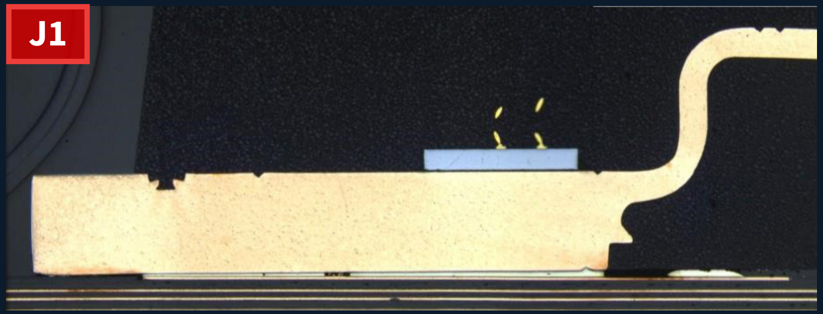


At left is an optical microscope image of the cross-sectioned segment of the C1 capacitor. The left-hand pin had a fracture through the solder connection, which is magnified in the optical image at right.

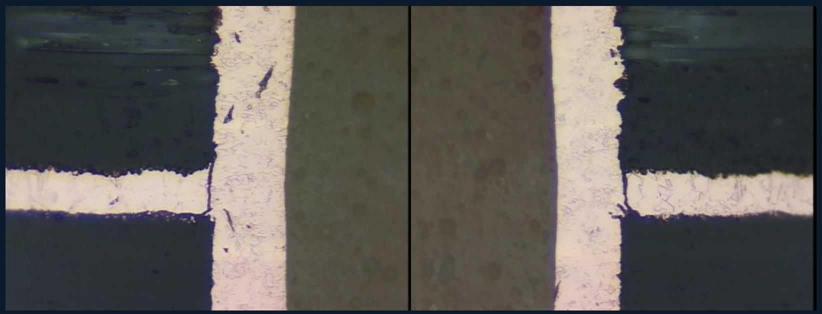


At left is an optical microscope image showing a transistor through-pin of with inadequate solder fill (approximately 58%) of the pin hole. Unfilled regions are shown with dark-contrast around the pin (light cream). At right, C6 Capacitor pin (shown with copper-colored contrast) demonstrates defect-level of incomplete hole fill (solder is shown in light cream).

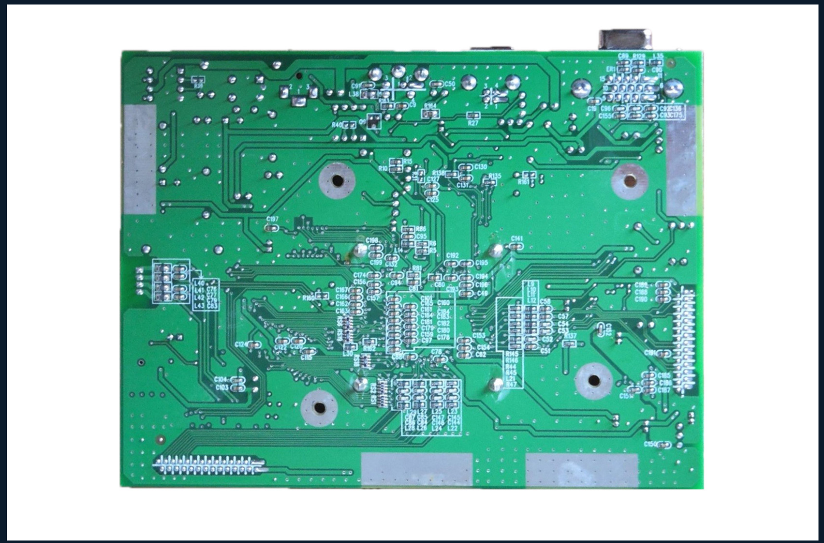
Optical microscope images of cross-sectioned BGA solder balls, showing one with a head-in-pillow defect, where the ball is not flush with the base of the connector.

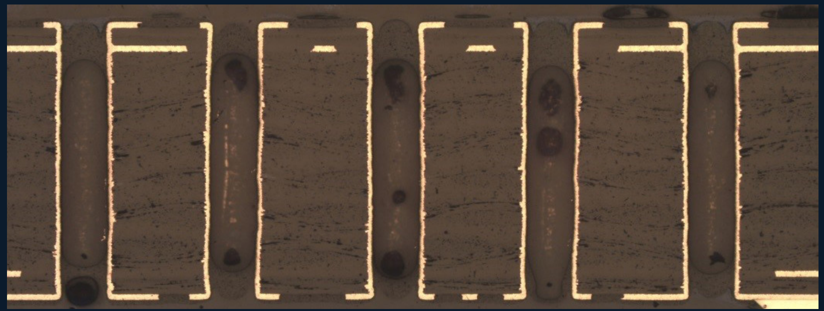


Optical microscope image of the end-overhang defect in the power relay. In this example, the issues is with the PCB layout. If you moved the unit to the right, centering the heatsink over the pad, the lead would no longer be centered over its own pad.

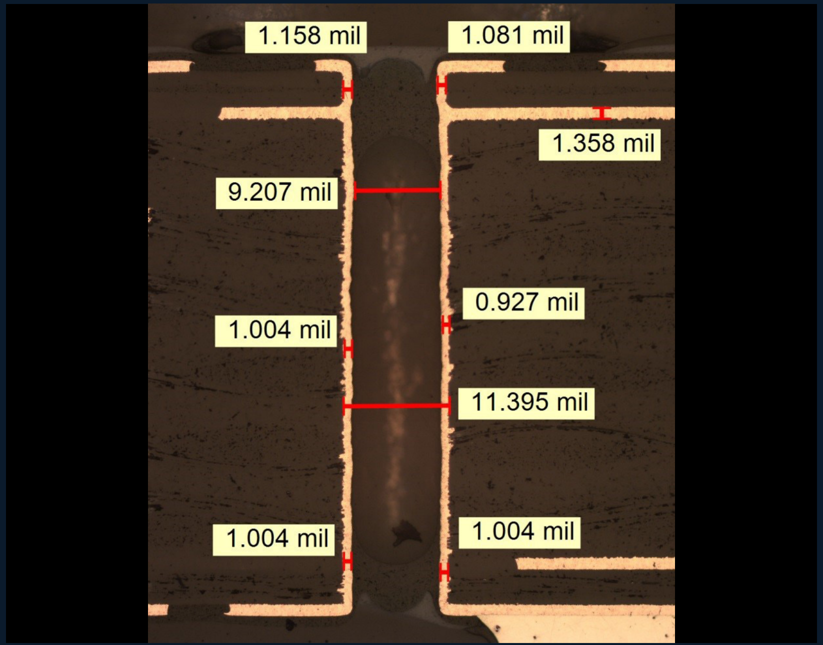


Optical microscope image showing complete layer separation in the inner conductive layers of the circuit board. Note: these images correspond to analysis done to the board itself and are not associated with a specific component.





Optical microscope image showing the plated through-holes. Medium-brown regions reflect the PCB, and the tan-colored rectangles show the copper plating around each hole. Note: this image corresponds to analysis done to the board itself and is not associated with a specific component.



Optical microscope image of a single through-hole showing sample measurements of the copper plating thickness on either side. Note: this image corresponds to analysis done to the board itself and is not associated with a specific component.

Thorough inspection of Printed Circuit Boards (PCBs) is necessary to ensure optimum performance, reliability, and consistency.

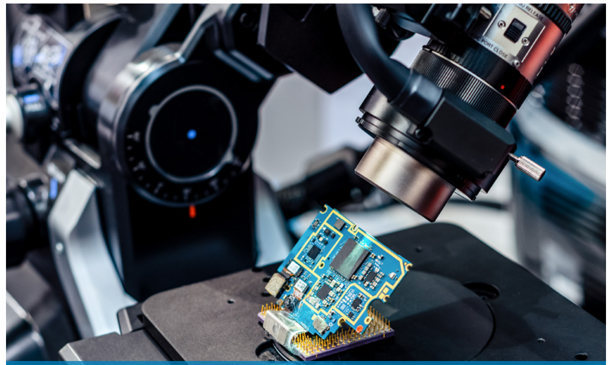
Globally standardized quality assessments, set forth by the Institute of Printed Circuits (now known as the IPC), outline the exacting expectations of the modern electronics industry. These provide a benchmark for evaluating the intricate structures in PCB assemblies. The IPC has more than 300 active industry standards addressing nearly every stage of development for electronic products. To achieve the most thorough characterization of a sample PCB, experts deconstruct the board, exposing each component for rigorous inspection.

This method, Destructive Physical Analysis (DPA), is widely regarded as the best and most complete means of IPC Compliance testing.

Whether used to investigate device failure, as a means of quality or process control, or in development of new electronics assemblies, these techniques are paramount to driving superior quality in electronics.

What to Look For in a Failure Analysis Partner

In the world of Failure Analysis, it can be a challenge to find the right expertise and hands-on experience, making it difficult to find the right partner. But, when it comes right down to it, some service labs can be slow, expensive or rigid in their approach and often fall flat when it comes to providing adequate data insights. There are a few questions that should be considered if you want a long-term, reliable and strategic partner for your R&D efforts. Do they offer:



A Comprehensive Solutions Stack

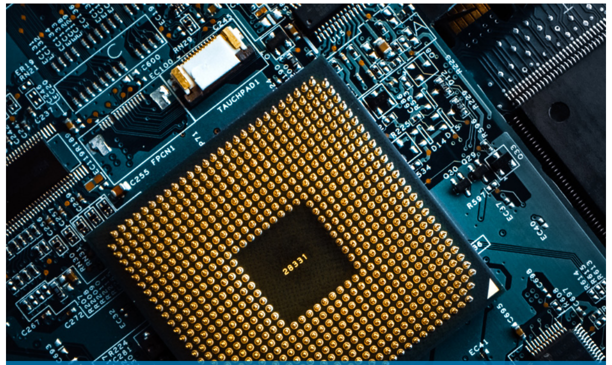
With diverse offering of techniques, instruments and expertise in advanced modeling, method development and analytical services.

A Flexible Business Model

With the ability to offer custom consulting and onsite support when needed, training and certification on instrumentation, and tool-share capabilities.

A Network of Partnerships

With expanded access to specialty labs, instrumentation and community learning.



Speed and Access to Data

With fast turn-around times and secure portal for uploading, downloading and viewing data.

About Covalent Metrology

Covalent Metrology is ready to serve you with our comprehensive platform of techniques and services, even during COVID 19. Reach out to our friendly team of experts to receive our answers to the above questions and to start a conversation about how we can help your team achieve your materials characterization goals.

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