MATERIAL FAILURE ANALYSIS

Qualification Testing
Visual Inspection to IPC Compliance
SEM/EDS
Ion Chromatography
Transmission X-Ray
Microsectional Analysis
XRF/Plating Thickness Analysis
Wetting Balance Testing

FTIR/Organic Contamination Testing
Dye and Pry Testing
Environmental Testing
Strain Gage Testing
Experimental Design and Processing (Electronics DOE)
Expert Witness/Arbitration
Supply Chain Validation

(256) 705-5531
www.stielectronicsinc.com
STI’s Analytical Laboratory’s enhanced capabilities are the result of the recent addition of several new analytical tools and equipment. The analytical equipment includes some of the industry’s newest and most advanced tools.

Qualification Testing

Qualification testing can be performed on bare boards (PCB) as well as electronic assemblies (PCBA). Testing on bare boards would be performed to ensure incoming bare board quality and conformance to any built specifications (e.g. IPC-A-600, IPC-6012 or customer specific test criteria). Such an investigation could include (but is not limited to) the following analytical methods:

- Visual Inspection
- Plating Surface Evaluation (SEM/EDS)
- Plating Thickness Evaluation (XRF)
- Plating Adhesion Testing
- Ionic Cleanliness Testing (IC)
- X-Ray Inspection
- SIR Testing
- Environmental Testing
- Micro-Sectional SEM Evaluation

These analytical methods would provide information on overall fabrication, plating adhesion quality and thickness, conductor and laminate dimensions, conductor solderability and through-hole integrity. Testing on electronic assemblies would be performed to ensure overall process quality and conformance to any built specifications (e.g. IPC-A-610, J-STD-001 or customer specific test criteria). Such an investigation could include (but is not limited to) the following analytical methods:

- Visual Inspection
- Surface Evaluation (SEM/EDS)
- X-Ray Inspection
- Ionic Cleanliness Testing (IC)
- Environmental Testing
- Micro-Sectional SEM Evaluation

These analytical methods would provide information on specification compliance, assembly cleanliness, overall solder joint integrity and long-term reliability of the hardware.
Visual Inspection/IPC-Compliance testing can be performed on bare boards (PCB) as well as electronic assemblies (PCBA). Such an investigation on bare boards (PCB) would consist of the visual interpretation of conformance/compliance to minimum requirements set forth in various printed board specifications, e.g., customer specific criteria, IPC-600 or J-STD-003. Such an investigation on assemblies (PCBA) would consist of the visual interpretation of conformance/compliance to minimum requirements set forth in various electronic assemblies specifications, e.g., customer specific criteria or IPC-610, J-STD-001.

**Scanning Electron Microscope (SEM)/Energy Dispersive Spectroscopy (EDS)**

Scanning Electron Microscopy (SEM) is ideal for inspection of PCBAs, bare PCBs, electronic components or any other materials used in the industry. It enables visual inspection and both linear and geometric dimensional measurement at very high magnifications. This equipment has the capability of providing digital imaging of specimens with magnification in the thousands, or simple exploratory analysis at low magnification for gross failure analysis and identification. Along with very high magnification capability from that of a traditional optical microscope is the very high depth of field, which allows for very detailed and easily interpretable images. This aids in the process of root cause failure analysis and subsequent reporting of failures. Finally, the oversized specimen chamber allows for large samples on the order of 6” x 6” to be analyzed without destructive sample preparation, important for expensive hardware.

Secondary Electron imaging allows for surface topography mapping. Applications include fracture surface analysis, integrated circuit surface mapping, Micro Electro-Mechanical (MEM’s) inspection and analysis, surface residue analysis and external plating analysis.

Backscattered Electron imaging allows for atomic number contrasting and imaging. Applications include contamination analysis, elemental phase mapping and identification and surface quality evaluations.

Energy Dispersive Spectroscopy (EDS) allows for characteristic x-rays emitted from a sample to be identified, allowing qualitative and quantitative elemental identification on a microscopic scale. In addition, elemental “mapping” can be utilized to produce an image detailing both the composition and structure of the different phases of materials present. Used in conjunction with SEM imaging, elemental identification provides a very powerful tool in evaluating manufacturing processes, materials selection, residue and corrosion identification and quantification, as well as other failure analysis efforts.
Ion Chromatography

Ion Chromatography (IC) or Ionic Cleanliness testing is performed in compliance with IPC-TM-650, Method 2.3.28, “Ionic Analysis of Circuit Boards, Ion Chromatography Method”, on either bare boards (PCB) or electronic assemblies (PCBA). A conductivity detector measures the ionic activity, separated in anions, cations and weak organic acids, of the solvent extract from each individual sample presented in µg/in².

Along with subject matter experts in the field of cleanliness and cleanliness testing, we offer real world experience and consultation for all your manufacturing cleanliness problems.

Transmission X-Ray Evaluation

Real time transmission x-ray analysis allows for immediate non-destructive imaging of specimens. The extra large chamber permits specimens ranging from small micro ball grid arrays (BGA) to large circuit board assemblies (18” x 21”). Interior defect characterization is possible using the digitally projected x-ray image. As with the Scanning Electron Microscope (SEM), high-resolution images can be digitally captured or photo quality images can be printed depending on the requirements of the analysis. X-Ray inspection can be utilized for examination of the following examples to the right:

- Ball Collapse in Ball Grid Arrays (BGA)
- Obvious Open Solder Connections
- Void Inspection
- Solder Bridges Between Adjacent Conductors
- Gold Wire-Bond Evaluation
- Through-Hole Barrel Fractures
- Internal Annular Ring Registration
- PCB Trace Inspection

Magnification up to 125 times can be accomplished allowing for inspection of features on the scale of individual wire bonds and flip chip ball interfaces.

Micro-Sectional Analysis

Full micro-sectioning and sample preparation services are performed on-site for expediting failure analysis efforts. Once a failure site is located, micro-sectioning is performed and the subsequent analysis will identify the exact failure mechanism and root cause.
XRF – Plating Thickness Evaluation

X-Ray Fluorescence Spectroscopy (XRF) allows for accurate quality control of printed circuit boards and electronics, by measuring plating thickness non-destructively. It can measure the plating thickness on large and fine-pitch conductors of a variety of plating finishes: tin-lead (Sn-Pb), immersion silver (ImAg), immersion tin (ImSn), electroless nickel immersion gold (ENIG) and thick gold (Au).

Wetting Balance Testing

The solderability of a surface is defined by its solder wetting characteristics. Solder wetting pertains to the formation of a relatively uniform, smooth, and unbroken film of solder that exhibits excellent adherence on the soldered surface. Non-wetting, on the other hand, is the condition wherein the solder coating has contacted the surface but did not adhere completely to it, causing the surface or a part thereof to be exposed. Dewetting is the condition wherein the solder recedes after coating a surface, creating irregular mounds of solder, but leaving behind no exposed areas.

Wetting balance testing is a quantitative solderability test that measures the wetting forces between molten solder and the test surface as a function of time. The plot starts with the wetting force being negative (non-wet condition), which rises until it crosses the zero axis of wetting force, indicating that wetting has occurred. The time it takes for wetting to occur is one parameter used to assess solderability. It is utilized to measure the willingness to take solder on both lead or lead-free surface mount (SMT) and thru-hole (PTH) components, with either lead or lead-free solder. Testing is performed per IPC J-STD-002, IPC J-STD-003 or Mil-Std-883 specifications.

FTIR – Organic Contamination Testing

Fourier Transform InfraRed Spectroscopy (FTIR) is most useful for identifying chemicals that are either organic or inorganic in nature. It relies on the identification of the types of chemical bonds (functional groups). The wavelength of light absorbed is characteristic of the chemical bond. FTIR spectra of pure compounds are generally so unique that they are like a molecular “fingerprint”. It can be utilized to quantitate some components of an unknown mixture. It can be applied to identify chemicals (e.g., fluxes, cleaners, coatings and contaminants). The spectrum of an unknown can be identified by comparison to STI’s library of known materials used within the industry.
Dye and Pry Testing

The dye and pry technique relies on the ability of a very low viscosity dye to penetrate a fracture while under a high vacuum. Generally a vacuum is applied for several hours, followed by a high temperature bake to cure the dye. Next, the BGA component or QFN is mechanically removed and the interfaces inspected for any traces of the dye on the surface of the pads. If the bonds are intact, dye will not penetrate and stain the pads. However, if there is a complete or partial fracture, the dye will coat the fractured surface and subsequent inspection will identify the fractured solder joints.

Environmental Testing

All electronic hardware is susceptible to the damaging effects of moisture, temperature, and contaminants. STI understands the criticality of reliability testing and test-to-failure. Improper selection of assembly materials and manufacturing processes can result in field failure returns which can lead to high warranty reserves thus affecting long-term profitability. STI’s environmental testing capabilities include replicating environments such as Humidity/Moisture Resistance, Thermal Shock/Thermal Cycle, Steam Aging and Vibration/Shock testing. Coupled with the ability to perform in-situ electrical testing as well as a full range of post-test analysis of samples, these tools allow for rapid “aging” of components and prediction of operational life of hardware.

- Thermal Shock
- Temperature Cycling
- Moisture Resistance
- Humidity Cycling
- Shelf Life
- Accelerated Aging
- Vibration Testing
- Mechanical Shock Testing
Strain Gage Testing

Strain gage testing is utilized to evaluate materials and processes effect on PWB and component-level stress due to static and dynamic loads. These stresses can originate from sources such as thermal, mechanical, and/or a combination of the two. STI offers strain gage testing and analysis services to characterize these stresses as a result of design, assembly materials, and/or assembly and test processes. If not addressed, these stresses can lead to microfractures and ultimately field returns due to failure. Identification and elimination of these stresses can greatly improve assembly yield and long term reliability of your electronics assembly.

Experimental Design and Processing (Electronics DOE)

STI helps customers understand their layout parameters, processing challenges, component selections, laminate materials, and enclosure materials. These decisions, in some cases, can be quite detailed and considered a multi-variable analysis. To this end, STI provides evaluation services combined with custom design of experiments (DOE) to help guide engineers to sound design and processing choices. STI creates a custom DOE that is co-developed with the customer’s design engineers to gather the data necessary to understand those multi-variable issues. STI’s approach is to create a DOE that gathers data to develop a full understanding of the interrelationship of the variables as well as the ability to replicate the variable sets. This ensures a full understanding of the impacts of a multi-variable problem. The DOE is a custom designed test protocol to gather and quantify the data into a format that enables a decision to be reached on the problem at hand. STI utilizes the assets of its multi-disciplined departments to develop these unique DOE that aid in defining and understanding the complex relationship between material choices, component selections, board design layout, processing materials (i.e. flux selection, alloy composition, etc), as well as their impact on the assembly process and reliability of the final product. These variables all play a role in the product’s performance and its ability to meet the design objective and warranty expectations. Examples of variables to be considered in a customized DOE are as follows:

- Strain Gage Rosette Selection
- Rosette Attachment and Wiring
- Data Acquisition with Thermal Correlation
- Stress/Strain Analysis
- Flux Type and Alloy Composition for Solder Interconnects
- Processing Requirements
- Cleaning Requirements
- Processing Aids
- Component Selection
- Enclosure Requirements
- Layout Requirements
- Harsh Environment Design Guidelines
- Laminate Choice and PCB Layout Design
- Reliability and Warranty Expectation
STI's Analytical Lab has added some exciting new technology: the Keyence VHX digital microscope.

This free-angle observation Keyence high-resolution digital microscope is able to achieve a 20x greater depth of field when compared to a typical optical microscope. This allows objects with large variations in surface topography to be focused and accurately observed in a single image. Even at higher magnifications you can obtain a fully-focused image. Our system has a wide range of 20x-2500x magnification.

Images can be generated in either 2D or 3D display. After collection of either a 2D or 3D image, we can perform real-time measurements of distance, angle, radius, areas, etc. and three-dimensional measurements such as profile and volume.

The variable angle option allows observation of a sample from all directions. By adjusting the viewing angle of the camera and lens, no detail is ever missed.
Keyence VHX-2000 Digital Microscope

This allows objects with large variations in surface topography to be focused and accurately observed in a single image.

Even at higher magnifications you can obtain a fully-focused image. Images can be generated in either 2D or 3D display. Once a 3D image has been created, data can be easily collected to calculate the profile, height and volume for any area within the field of view.
Arbitration/Expert Witness

STI offers two services in the conflict resolution arena when differences of opinion arise between a client and its electronic manufacturing partner. The first is an arbitration service whereby STI provides in-depth expertise in a specific subject matter, i.e. Subject Matter Experts, to help arbitrate a conflict between a customer and its electronic manufacturing supplier on a specific problem which has lead to an impasse. This service provides a third party engineering review and analytical lab review of the problem at hand. This allows for equitable resolution and true third party assessment to eliminate opinions and any personal bias which often causes a conflict between partners in the electronic assembly relationship. The second service STI offers is an expert legal witness service on a specific subject matter to help facilitate an understanding of the issue at hand. Problems often arise between two companies in relation to electronic manufacturing or a product’s long term reliability. This service takes the form of an analytical lab assessment of the issue and then provides the technical support and review necessary to render an opinion on the subject matter. STI’s expert legal witness service helps define the true root cause of an issue, the interrelationship of an issue on the reliability of the electronic assembly, and the relationship of how the electronics assembly was manufactured.

Supply Chain Validation

STI Electronics is facilitated with the equipment set and personnel to complete a variety of tests and analysis on electronic assemblies as well as electromechanical assemblies to determine the integrity of the supply chain. Our methods can determine the origin of the components and materials in order to identify counterfeit components and/or those which have been altered. We also work closely with software and firmware partners to identify and resolve malicious intent at the system level.

From operating in a detection mode to identify gaps to developing a trusted supply chain, STI can also establish a project plan that will include a phased approach that is designed to optimize defining lessons learned which can be shared with the broader Trusted Systems and Networks community (DoD and Commercial). Our team composition is designed to include representatives from each stakeholder in the acquisition process.

Phase I - defines the prototype scenario, developing an overall requirements specification and documenting the project plan to include deliverables.

Phase II - implements the prototype project plan, mitigates the design manufacturing and packaging risks, and captures the lessons learned to repeat this process on a wider scale.

Phase III - expands the prototype to other areas within these commercial and government communities to create a model for compliance for the supply chain associated with electronics and electromechanical assemblies at the hardware and system (software and firmware) level.
For more information contact:

Mark McMeen  
mmcmeen@stielectronicsinc.com  
(256) 705-5515

Marietta Lemieux  
mlemieux@stielectronicsinc.com  
(256) 705-5531

261 Palmer Road • Madison, AL 35758

www.stielectronicsinc.com