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Implementing Warpage Management: A Five-Step Process for EMS Providers

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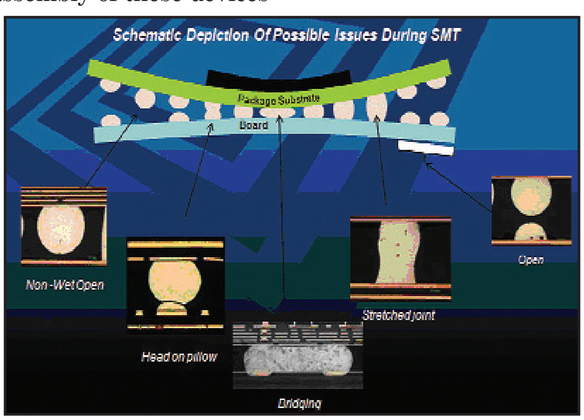
Warpage management consists of planning, measuring, analyzing, sharing, and reacting to data related to the surface shapes of electronics components as they change throughout the reflow assembly process. Leading semiconductor manufacturers have had warpage management systems in place for ten years or more, mainly because microchip package warpage must be understood and compensated for in order to attain high assembly yields. Similarly, newer device architectures such as package-on-package and system-on-a-chip are sensitive to warpage-related assembly issues, and companies involved in the manufacture and assembly of these devices tend to have the most advanced warpage management programs.

Managing warpage is important not only for those who manufacture components, but also for those manufacturing products by means of a reflow assembly process. Some electronics manufacturing services (EMS) providers involved with the most complex, thinnest, most mission-critical electronics products have already implemented warpage management systems out of necessity. Akrometrix (www.akrometrix.com) has advised and assisted several of these companies, in creating protocols that help them understand, monitor, compensate for, and correct warpage-related issues and provide high-quality, high-reliability products to their customers. Creating a warpage management program for EMS providers can be summarized as a five-step process:

- Understand the relevant standards.
- Plan to share data with customers and supply-chain partners.
- Choose the required equipment and personnel to be trained.
- Implement best practices.
- Learn from ongoing data collection and analysis.



Warped boards or packages can lead to a number of problems during circuit assembly, including stretched joints and opens.

Akrometrix is in a good position to advise on managing warpage. The original technology for measuring electronics components in a simulated reflow environment was invented in the early 1990s by a team at Georgia Institute of Technology led by Dr. Charles Ume. That team became a company called Electronics Packaging Services (EPS), focused on meeting urgent semiconductor industry requests for component warpage measurements. In 1994, EPS became Akrometrix LLC. The high volume of testing services needed by cutting-edge electronics innovators led to the development and release of the firm's first TherMoiré equipment products for warpage testing. The testers use patented shadow moiré and phase-stepping technologies to provide three-dimensional (3D) full-field, high-resolution information about the shape of electronics components as they progress through a reflow cycle.

The first TherMoiré measurement system was installed in Berlin, Germany in 1998. Hundreds of systems are now in use throughout the global electronics supply-chain network. In addition to shadow moiré technology, a TherMoiré system features "modular metrology" capabilities, allowing other technologies, such as digital image correlation (DIC) for surface strain, and digital fringe projection (DFP), to be used interchangeably inside a common TherMoiré hardware and software platform.

Still, the system's shadow moiré technology still provides the best combination of high-speed, high-resolution measurement capabilities at elevated temperatures, and delivers accurate full-field 3D warpage results for any measured area. The five key steps in the warpage management process provide an outline for companies wanting or needing to implement any program involving warpage data. And Akrometrix engineers are in a unique position to help companies implement such programs in as basic or advanced forms as needed.

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The first step in developing a warpage management program involves understanding appropriate standards and, currently, no international standard directly addresses stacked package or package-to-board assembly related to collecting warpage data or how to use that data from more than one surface. Some companies may have proprietary standards related to warpage. But, for now, all relevant public standards address warpage of packages and their corresponding land areas separately.

Addressing Warpage Standards

Traditionally, warpage standards have addressed only the "package side" of a design, typically setting limits on the maximum coplanarity of a package at a peak reflow temperature. But standards bodies have more recently begun to address how warpage of package land areas on printed-circuit boards (PCBs) can affect assembly yield and reliability.

The most relevant current public standards include IPC-9641, JESD22-B112A, and ED-7306 from the Japan Electronics and Information Technology Industries (JEITA).

The IPC-9641 standard, "High Temperature Printed Board Flatness Guideline," from the IPC (www.ipc.org), provides explanations about why measuring PCB land areas is important, guidelines for selecting measurement equipment, and an introduction to collecting warpage data so it can be correlated with other companies' results.

The JESD22-B112A standard from JEDEC (www.jedec.org), "Package Warpage Measurement of Surface-Mount Integrated Circuits at Elevated Temperature," released in 2009, is the electronic industry's main reference for package warpage measurements. It defines warpage and how to measure it, introduces relevant measurement technologies such as shadow moiré, DIC, and fringe projection, and provides example measurement processes and results. It is a good starting point for understanding the warpage performance of electronic components.

JEITA's (www.jeita.or.jp) ED-7306 standard, "Measurement Methods of Package Warpage at Elevated Temperature and the Maximum Permissible Warpage," was published in 2007. Although this document is often used, the warpage limits presented in ED-7306 are best considered guidelines rather than absolute "pass/fail" specifications.

Customer Requirements

In addition to these public standards, EMS companies are often guided by customer requirements for warpage-related issues. Custom-provided guidelines and design-specific requirements should be considered in any efforts to establish a warpage management program.

Sharing data is an important part of any warpage management program. By sharing data, supply-chain partners can improve their designs and develop products that can be assembled with fewer defects and perform more reliably for customers. Any EMS company considering a warpage management program or upgrading their existing surface measurement data collection and analysis system should consult with supply-chain partners on which data is useful and should be shared. They must also learn how to best share the appropriate data, upstream and downstream, with their partners. Such sharing can help improve product designs, enhance assembly planning, and lead to continuous process improvements.

In establishing warpage management capabilities, an EMS provider will need people and equipment to perform these measurements in-house. While it is possible to outsource warpage measurements and reporting, by means of outside test laboratories, it is typically not done due to confidentiality require-

Phase image from PCB, shadow moiré acquisition.

ments. As a result, it is essential to install the needed measurement equipment at the location where components are received and assembly is being performed, and to have the right people trained and ready to perform the warpage measurements.

A number of measurement technologies are available for obtaining surface warpage data. Selecting the appropriate tools should take into account factors such as the measurement volume (how many samples per day), the measurement resolution required, which people will be using the equipment (for ease-of-use requirements), and which types of tools are already in use by supply-chain partners (for compatibility).

Warpage Measurement Systems

Warpage measurement systems can be added to different locations within an EMS facility. For example, they can usually fit within existing incoming quality control (QC) or outgoing quality assurance (QA) departments. They also make sense within a manufacturing engineering department. A new warpage measurement system and personnel training for it usually requires about two or three days. Maintenance and upkeep are simple, usually only requiring only about one-half day of preventative maintenance each year.

Once warpage measurement equipment is in place, and an EMS organization has a plan for using and sharing data that is collected, it is a good idea to test, analyze, and report results according to industry "best practices," so that collected data will correlate with warpage management data from other companies, including original equipment manufacturers (OEMs), partner companies, and even competitors.

Data Correlation

Data correlation is critical, especially for OEMs partnered with a large network of suppliers and EMS providers. For example, Akrometrix assists OEMs and EMS companies in correlating their data, especially in cases where the validity of collected data may be in doubt. Testing at Akrometrix is performed according to "best practices" that are published and available to all TherMoiré users. These guides offer "how to" explanations of setting up and performing measurements, with clear instructions on operating the equipment that will lead to accurate results that can be correlated with results achieved by any other TherMoiré user who is also producing accurate results.

The last step in a warpage management program is more of a continuous process than a step. With a well-running warpage management system in place, EMS providers can be prepared for any warpage-related customer request as well as any reflow assembly process problems involving shape mismatches within the process temperature profile (defects such as head-on-pillow, non-wet opens, or shorts). Tools such as the Akrometrix Interface Analysis system enable simple but powerful visualization and evaluation of interconnect gaps between top and bottom assembly surfaces at any temperature during the process. This system can help determine problem locations where defects are likely to form. Understanding how components fit within interfaces at each stage of reflow assembly can help in the adjustment of process parameters, such as solder print sizes for critical locations, and provide better yields and higher product reliability.

Ongoing data collection and analysis makes it possible to perform statistical process control (SPC) of the warpage characteristics of all components involved in reflow assembly. Knowing when data is indicating a statistically "out of control" situation can provide a warning that assembly process parameters may need to be adjusted to ensure consistent output quality.

As components become thinner, with more interconnections that must be properly soldered, warpage management increases in importance. Companies with warpage management systems in place benefit from improvements in end-product yield and reliability, and EMS providers without warpage management programs are more and more considering the value of implementing such a system in their own facilities.

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