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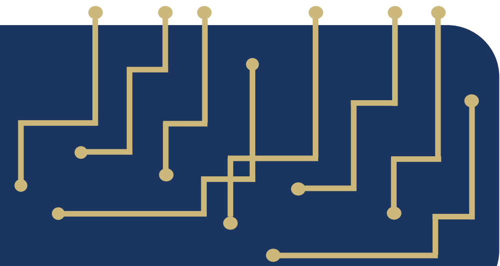

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The EMPF is a U. S. Navy-sponsored National Electronics Manufacturing Center of Excellence focused on the development, application, and transfer of new electronics manufacturing technology by partnering with industry, academia and government centers and laboratories in the U.S.

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Heat Transfer Fluids for Power Electronics

Solid state power electronics systems that do not exceed recommended operational temperature limits will regulate the flow of electricity in an efficient and reliable manner. Insulated Gate Bipolar Transistor modules (IGBT modules) are an integral part of modern shipboard power systems. For high voltage applications, 1700V IGBTs are ganged into a Power Electronics Module (PEM); and the PEMs are integrated into a Line Replaceable Unit (LRU). The LRU is a self-contained system containing drivers, control circuits, monitor circuits, and a coldplate typically made from copper or aluminum, which serves as the heat sink for the IGBT system. The coldplate is ground extremely smooth and flat to ensure complete contact between the IGBT modules and heat sink. A thermal grease or Thermal Interface Material (TIM) is placed between the heat sink and the IGBT module to promote heat transfer through conduction. Cooling the heat sink can be accomplished by many means including recirculation of a fluid. In a recirculation system, the fluid passes through channels inside the heat sink and heat is transferred into the fluid. The heat is removed from the fluid using an external heat exchanger that transfers the heat to cold sea water as showin in Figure 1-3.

Figure 1-1: Fairchild Semiconductor IGBT Module. Part # FMG2G400LS60

One of the biggest challenges for cooling PEMs, lies in the way an IGBT is designed. The IGBT channels current from the back of the silicon device through its face. As a result, the IGBT must be electrically isolated from the heat sink. This adds an additional thermal barrier between the IGBT and the base plate of the IGBT module. Studies indicate that 75% of the thermal bottleneck in PEMs comes from the IGBT module package itself. If a method could be devised to immerse the IGBT into a cooling liquid, the largest thermal barrier would be removed, resulting in an efficient system that would reduce the overall number of IGBTs required onboard a ship. This has the twofold effect of reducing weight and space on a ship.

In 2002, the 3M™ Corporation introduced a new hydrofluoroether (HFE) heat transfer fluid that is environmentally friendlier that perfluorocarbons (PFCs) and 3M™ can tailor this material for specific applications. Moreover, the fluid has a very high electrical resistivity and dielectric strength, making it suitable for use in immersion cooling of high voltage IGBT based systems. Figure 1-2 shows selected material properties of Novec™ 7500 HFE liquid.

continued on page 3

NAVY MANTECH manufacturing technology program

Ask the EMPF Helpline!

A customer called into the EMPF Helpline to request root cause failure analysis of functionality issues with their life critical electronic devices…

An original equipment manufacturer (OEM) contacted the EMPF Helpline and requested guidance and direction to obtain root-cause failure analysis services for an electronic assembly classified as life critical. A teleconference was conducted with the client to discuss various investigative processes to achieve their requirements. Based on the agreements from the teleconference, a summary of investigative methodology was issued for review and acceptance. The OEM selected the following technologies: electrical testing, chemical analysis, visual inspection, X-ray inspection, and temperature testing. The OEM submitted multiple samples of materials and assemblies, applicable drawings, bill-of-materials and copies of recent field failure reports and a summary statement of known product failures. The client confirmed functionality failures occurred when temperatures went below 40 degrees C.

Test Methods:
Visual and X-ray inspection were performed to determine any obvious defects or anomalies. The technical data sheets were examined and evaluated for Design for Manufacturability and process design and a number of experiments were performed to evaluate the comparative insulation resistance and dielectric properties of different revisions. Ionic cleanliness testing was performed to assess the overall relative cleanliness of the assemblies. Samples were immersed in a 75 percent alcohol, 25 percent deionized water solution heated to 35ºC. Ionic contaminants were extracted from the assemblies and measured using a conductivity meter.

Results:
Visual Inspection:
The surface-mount and through hole soldering process used for the assembly produced acceptable solder joints. However on some samples, debris and solder balls were found on component bodies. Microscopy used to inspect the assemblies revealed the quality of the printed circuit board etching differs between revision assemblies. When compared with the source Gerber files, poorer trace etch resulted in some reduction in trace spacing (Figure 2-1).

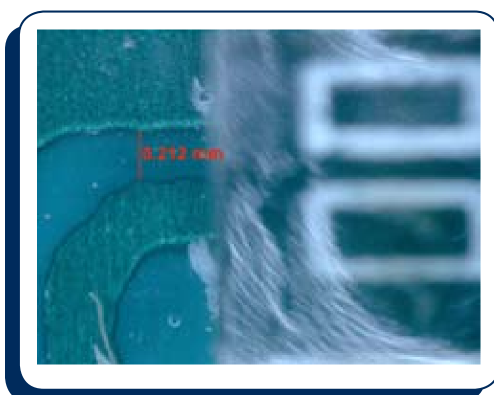


Figure 2-1: Poor etching reduced trace spacing on assemblies

X-ray inspection:
X-ray inspection was also performed on one revision assemby and solder was found under several component bodies (Figure 2-2.) The contamination was a point of interest and was a process indicator even though the assemblies passed functional testing at room temperature.

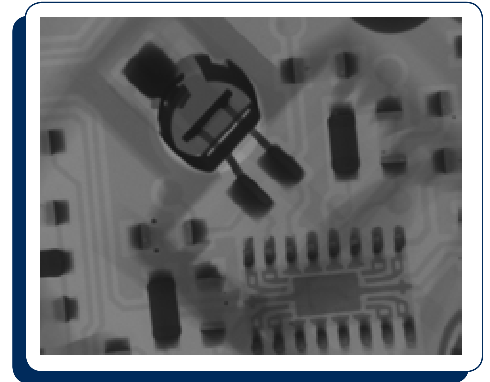


Figure 2-2: Solder present on assemblies

Gerber file comparison:
A comparison of the Gerber data did reveal some minor differences between the board revisions including the increase in the clearance from some traces to the ground fill.

Design of Experiments:
A series of experiments was performed with the different revision assemblies. Units were tested over temperature per customer's procedure. The performance of each sample was monitored using the client supplied data logger and a digital storage oscilloscope. Tests included procedures to:

- Baseline the performance of each unit before making any changes to the assemblies;
- Establish the effect of the solder contamination on performance of the revision assembly with functionality issue;
- Determine the effect of contamination on the performance of an assembly;
- Determine the effect of component tolerance on inputs with different assemblies, e.g. differential amplifier inputs.

Dielectric Withstanding Voltage and Insulation Resistance Testing were performed and revealed that they are not likely to affect the circuit performance. In addition, bulk ionic test results from the Ionograph indicated the ionic residue level observed on the different revision assemblies exceeded IPC standards specifications.

Conclusions and Recommendations:
The tests and circuit analysis performed on each revision of the PCB revealed several critical issues such as the presence of solder balls and solder contamination under component packages; higher ionic residue level on the suspect boards

continued on page 9

Heat Transfer Fluids for Power Electronics
(continued from page 1)

Properties	Novec 7500
Boiling Point @ 1 atm	128°C (262°F)
Pour Point	-100°C (-1477°F)
Molecular Weight	414
Liquid Density	1614 kg/m3
Coefficient of Expansion	0.00129 K-1
Latent Heat of Vaporization	88.5 kJ/kg
Surface Tension	16.2 mN/m
Viscosity	0.77 cSt
Critical Temperature	261°C (502°F)
Critical Pressure	1.55 Mpa
Solubility of Fluid in Water	<3 ppb by weight
Dielectric Strength	35 kV, 0.1" gap
Electrical Resistivity	2.2 x 108 ohm-cm

Table 1-2 Properties of Novec™ 7500 fluid

There are some considerations that must be taken into account when developing immersion cooling systems. Hydrocarbons are soluble in HFEs. If an immersion cooling system uses hydrocarbon based plastics or plastics with hydrocarbon plasticizers, the HFEs can slowly leach away the plasticizer or decompose the plastic. These contaminants can redeposit onto other surfaces, clogging pumps or generating static charges. However, by carefully selecting the materials used in the immersion cooling system, this issue can be mitigated.

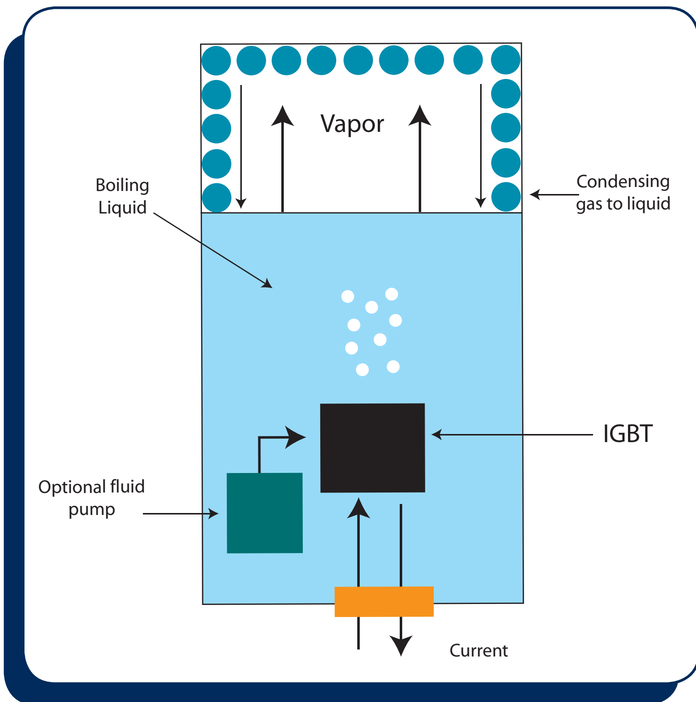


Figure 1-3 Immersion cooling basics

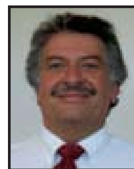
Recently, 3M™ began development of a proprietary coating technique for immersion boiling systems that has the potential to increase the heat removal to 250 W/cm². Developmental research using the coating system in immersion cooling systems is ongoing. Reports can be found on the 3M™ website which provide in-depth analysis of immersion cooling techniques using HFEs. If 3M™ achieves its goal of reaching 250 W/cm² for heat removal, the door will be opened for very efficient IGBT-based PEMs for all electric busses, trains and automobiles.

Immersion cooling system design is dramatically different from the transfer molded IGBT module shown in Figure 1-1. In an immersion cooling set up, the bare IGBT module is immersed into a liquid as shown in the Figure 1-3 illustration.

Conclusion

Immersion cooling has a history of successful use. Raytheon used passive two-phase immersion cooling on transformers manufactured in the late 1950's. Siemens used passive two-phase cooling on locomotive train traction converters designed in the 1990s. The Cray Corporation's X-1 supercomputer released to the market in 2002 used spray-impingement cooling. What these methods had in common was that they all used either a PFC or an HFE based fluid.

The migration of conventionally packaged high voltage IGBT devices from the technology base used in Figure 1-1 to an immersion cooled system will occur when there is an application for the immersion cooled systems to provide an advantage over the current methods. Hybrid vehicles may prove to be the area where a higher efficiency electrical conversion system will provide a market differentiator that attracts automotive designers to adopt and utilize advanced cooling techniques.



Dean Kossives - Lead Package Engineer

Profiling for the Attachment of Large Ball Grid Array Packages

Thermal profiling is an essential and powerful tool that is commonly used to ensure electronic circuits are properly manufactured. The profiling basics for the attachement of large ball grid array packages using industry specific precision systems consist of bottom heaters commonly referred to as preheaters, and a top heater also referred to as a nozzle heater. The convection settings of temperature and air flow rate are controlled by profiles within system specific software. When processing on a rework system, profiles are also created. The process is similar to that of a reflow oven, however, the board is not conveyed through the temperature zones, but remains in place and the system heaters are ramped instead.

From a system viewpoint, the process attaches a large ballgrid array (BGA) component to a printed circuit board composed of epoxy, fiberglass, and many layers of copper metal. The substrate will also have various components already attached. Each of these materials has specific thermal properties. Some components are large, some are small.

As the heated air is applied onto the bottom of the board by the preheaters, conduction takes place within the materials. Copper is an extraordinary conductor of heat with a thermal conductivity of 401 $W \cdot m^{-1} \cdot K^{-1}$ (at 25°C). With large boards and high thermal mass, the input heat must be significant in order to heat the localized area of interest. For a lead-free solder attach profile, a typical preheat will target 150°C-180°C at the end-of-zone temperature. This temperature is read at the component/substrate interface, T_{CS}. A consistent preheat is important because temperature variations in environment will be present, and elimination of this uncontrolled factor is best kept in check.

For large substrates, the preheater will apply most of the heat in order to minimize the temperature difference across a component. This is accomplished by having the preheater temperature higher than the nozzle temperature. This will be the case for the first two or three zones. This practice also prevents the drying or early activation of flux materials. Figure 3-1 shows an example of a four-zone ramp. Zone two should have a target end-of-zone temperature of 190°C. This is where the flux is activated and specifications require a defined amount of time within this range. The flux materials used for lead-free rework conditions are typically referred to as gel flux or tacky flux. These materials are stable to higher temperatures than those of traditional solvent based flux materials.

Lead-free tin/silver/copper solder (SAC 305 - Sn 96.5%, Ag 3.0%, Cu 0.5%) has a liquidus temperature of 217°C and is reflowed at peak temperatures of 235°C. Zones three and four are where the nozzle temperature is raised in conjunction with an increased air flow rate. For ball grid array components that are relatively large, 35-50 mm on a side, air flows will generally be high for zones three and four.

To summarize, the sequence of events are:

- the substrate is preheated to 150°C using primarily bottom heat
- the substrate is heated to within twenty degrees of the liquidus
- the component is directly heated using a higher nozzle temperature and air flow rates
- the attachment material reaches liquid temperature at the reflow zone
- the solder densifies to a stand off height

There are two values to consider for temperature differences. The first is across the component, ΔT_{XY}, and is measured from the center of the component to a corner. Faster profiles will generally create a larger temperature difference across the component. This is important because when the grid begins to reflow, the center may liquefy first and then the edges. For lead-free components, a differential of as low as 5-10 °C is required. The second temperature gradient that exists is ΔT_Z and is measured from the top of the component to the bottom of the substrate. A value for this is directly measured from the placement of monitoring thermocouples on the top of the lid and at a secure attachment on the bottom of the board, centered below the component. A value of 10°C is generally required and is important for fine pitch components.

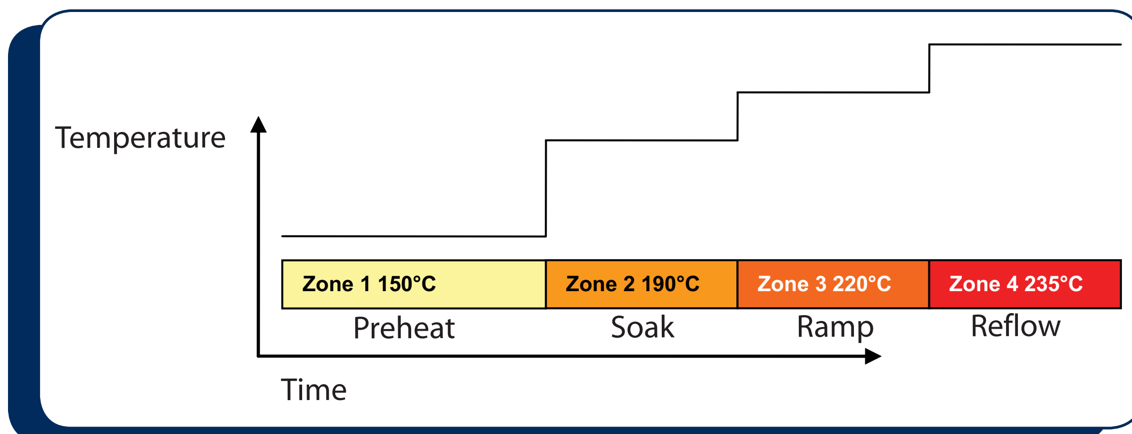


Figure 3-1: Target end-of-zone temperatures for thermocouple reading at component

The justification for using process parameters with a higher

continued on page 9

Customized Training

For many companies, finding suitable training for their specific manufacturing needs is a difficult chore, akin to fitting a square peg into a round hole. Eventually, the company winds up shaving corners and settles for a partial solution, that often leaves training gaps for employees required to learn the needed manufacturing skills. The necessary skill sets and experience required for qualified instructors often make the implementation of a comprehensive training curriculum very costly, forcing many training centers to narrow the scope of their class offerings. The boiler plate approach used in the many areas of electronic assembly training is often driven by necessity, and may not meet the specific need to focus on the relevant areas pertinent to a customer's particular manufacturing operation.

One of the core competencies of the EMPF is that it leverages the ability and flexibility to offer a modular approach to training, allowing for modifications and revisions of the course curriculum as new technologies emerge. EMPF employees are often engaged in the development of new electronic and material packaging technologies with the goal of re-educating ourselves on the importance of maintaining flexibility, quality, and cost for our valued partners and customers. Each course is maintained and scrutinized for content, and all our instructors are cross-trained in several relevant technological areas.

For Our engineering and skill related courses, the EMPF's customized approach is being adopted both in house and on site at customer facilities. The BOOT CAMP program is a good example of adopting a modularized approach to allow selective portions of the course curriculum to be extracted according to the needs and skill set of the student. Our world Class IPC certification courses offer onsite training that include Master Certified CIT and Module specific CIS training in IPC 610, J-STD-001, IPC 7711/7721, IPC 600, and CIS 620.

The EMPF's Electronic Manufacturing training courses are structured to include students from a wide range of disciplines, such as Program Managers, R&D, Engineering, Quality, and Operations personnel. The course content is geared specifically to meet the many challenges of the ever-changing world of electronics technology. The modular system offers course content on the basis of the need and skill set of the students. The customized courses offered at ACI or off-site are taught by top level personnel with extensive experience in their fields, knowledgeable in both the theoretical and practical applications of their trade. Additionally, those who choose training at ACI will benefit from the hands-on experience of working in the state-of-the-art EMPF facility.

For more information on the benefits and of customized training, or to inquire about any of the EMPF course offerings, please contact the Training Center Registrar at (610) 362-1289, or call our Helpline.

Carmine Meola- Manager, Commercial Services

New Lead-Free Regulatory Standards

Effective March 1, 2007
Be Prepared!

ACI, globally recognized by the electronics manufacturing industry as an independent lead-free authority, offers a new, comprehensive lead-free training program for 2007/2008.

Lead Free Manufacturing

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• Related Courses •

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IPC-7711/7721
CIT Certification

November 26-30 • January 28-February 1

Rework, Repair & Modification of Electronic Assemblies
IPC-7711/7722
CIT Recertification

November 15-16 • December 3-4
February 18-19

Manufacturer's Corner: Oxford XRF

The X-Strata 960+ is an XRF (X-Ray Fluorescence) analyzer from Oxford Instruments that the EMPF has in the demonstration factory. The primary use of this instrument is to measure the thickness and/or composition of plating, coatings, and films containing elements from Titanium through Uranium.

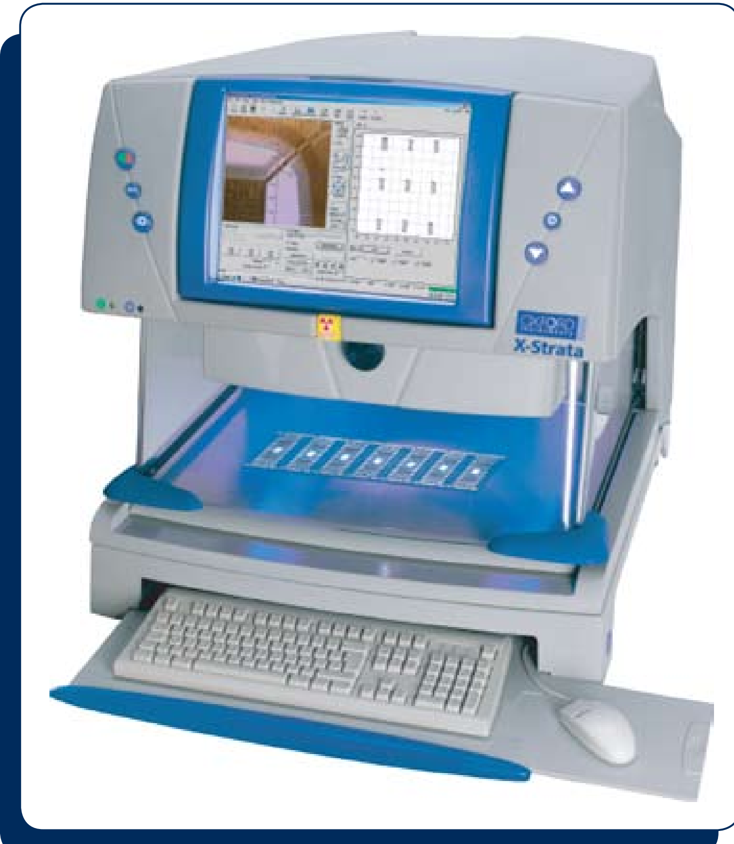

Figure 5-1: X-Strata 960 +

The Oxford XRF is an invaluable tool for providing a quick and thorough composition analysis of up to 15 elements simultaneously. It can be used to confirm the absence or presence of lead in "lead free" parts. This is an indispensable feature considering all the counterfeit electronic components finding their way into the US supply chain*. Often, XRF instruments have the capability to scan entire PC boards and generate an elemental composition map of all components present, while at the same time, measure coating thickness, plating, and film.

The material analysis it performs is non-destructive and provides results in a matter of seconds or minutes. This is another important factor for quality assurance and in-coming inspection and can save time and money when component defects and material inconsistencies are present in a single tray or tube.

The X-Strata is very easy to operate with minimal set up calibrations. It features automatic spectrum calibrations, a small spot size with a very large sample tray area. This sample area features a unique one-click laser alignment system which automatically finds the correct focal distance. This feature improves the focusing process for the DIM (Distance Independent Measurement), improves system reproducibility, and gains clarity and accuracy for the overall X-ray image.

Some optional capabilities of the Oxford X-Strata 960+ are automated laser focusing, advanced data export and integrated computer and monitor for improved user interface.

For more information related to this article, or to schedule a demonstration of the Oxford X-Strata 960 located at the EMPF, contact Ken Friedman, 610-362-1200 x 279 or via email at kfriedman@aciusa.org

* The EMPF performs a full analysis of suspected counterfeit components. Please see the website www.aciusa.org for details.

Ken Friedman - EAB Coordinator

2008

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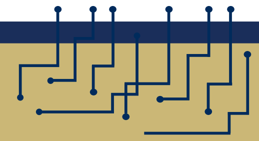

Tech Tips...

Identifying Counterfeit Components

The number of counterfeit semiconductors being introduced into the supply chain is on the increase, and as the numbers increase, so does the sophistication of the counterfeiters themselves. Military and space OEMs and small volume manufacturers, faced with procuring obsolete or allocated devices via the open market, are now challenged with the problem of how to effectively detect counterfeit semiconductors. These companies are now compelled to put processes in place to ensure counterfeit devices do not make it to their production line. The processes defined must ensure detection, but also balance the cost and lead-time issues associated with destruction of precious components and non-recurring engineering (NRE) cost and testing. Devices can be either factory sealed, or repackaged. Generally, the inspection processes are not intended to inspect used parts. Used parts, sometimes known as "board-pulls", are automatically suspect and will be rejected according to accepted inspection practices. Sophisticated counterfeits or OEM rejects cannot be detected by an external, physical inspection process. Advanced testing methods such as AC/DC electrical tests, or de-capsulation and die inspection are required to identify sophisticated counterfeits.

A first-line suite of tests has been identified by the EMPF which can be used to identify counterfeit integrated circuits for quick turn requirements. Using this procedure, limited qualification testing can be performed on suspected counterfeit ICs. The testing methods and inspection methodology that are currently being used for counterfeit detection are in part derived from the following documents:

- IDEA-STD-1010-A "Acceptability of Electronic Components Distributed in the Open Market", The Independent Distributors of Electronics Association (IDEA)
- JESD22-B107C Marking Permanency Test, JEDEC Solid State Technology Association
- MIL-STD-883E Department of Defense Test Method Standard Microcircuits

Additionally, the EMPF provides more in-depth analysis of more sophisticated counterfeits including de-capsulation, die inspection by SEM/EDS, and electrical testing through industry partners. The following testing and inspection methods have been selected for the quick-turn counterfeit detection process.

VISUAL INSPECTION

A visual inspection is performed on a sampling of devices from a given lot. The magnification is adjusted as required to inspect certain features of the part. Device markings and dimensions are compared with the manufacturer's datasheet for authenticity. The lead finish is examined for evidence of previous use or refinishing. The body of the device is examined for evidence of improper handling or previous use. With more sophisticated counterfeits, a visual inspection is often insufficient. Being able to look inside the package is often required. De-capsulation is destructive, but X-Ray inspection is non-destructive and can reveal many hidden features.

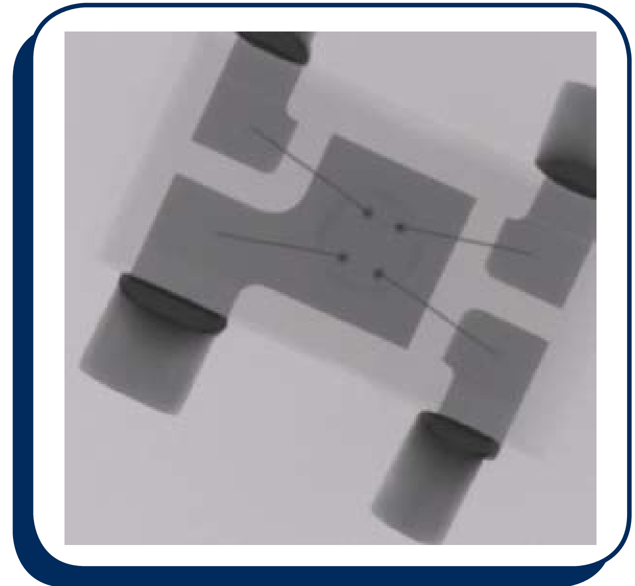

Figure 6-1 No Die in Package

X-RAY INSPECTION

X-Ray inspection is performed on each device to confirm the presence of a die. Counterfeits are sometimes packaged without a die (Figure 6-1) or with a different die. Finding a different die does not necessarily indicate a counterfeit since manufacturers sometimes will institute a process change on a particular product, but the parts would not have the same date code. Note that the resolution of X-Ray imaging is not yet sufficient to resolve markings on the die surfaces to authenticate the device (Figure 6-2).

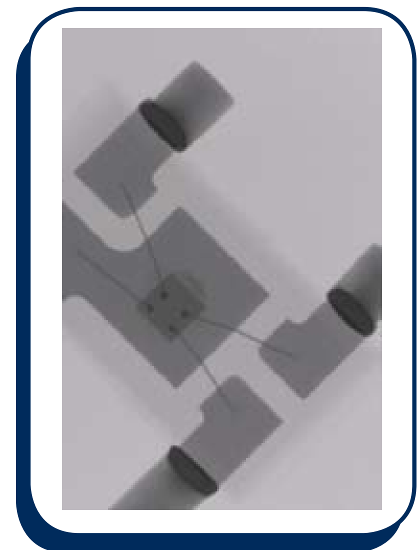

Figure 6-2 Die in Package

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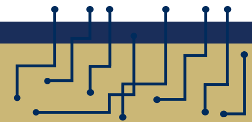

Tech Tips...

Identifying Counterfeit Components (cont. from page 7)

XRF INSPECTION
X-ray fluorescence inspection (XRF) is performed on the leads to confirm whether the material composition of the finish on the leads has lead or is lead-free. This technique is useful for determining if a counterfeit component has been marked ROHS compliant when it actually contains lead.

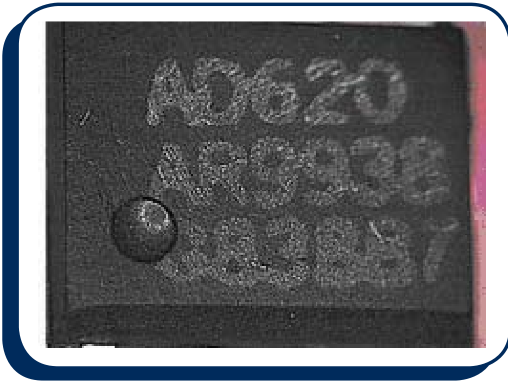

Figure 6-3 Suspect Marking

Figure 6-4 Good Marking

RESURFACING TEST
The purpose of this inspection is to find evidence that the devices have been remarked. Remarked parts sometimes make use of ink that does not withstand the solvents used in board assembly manufacturing processes (Figure 6-3 compared to Figure 6-4). The marking permanency test is used to determine if the IC ink marking is resistant to solvents. Remarking, using either laser marking or ink marking, requires resurfacing of the component to remove evidence of the original mark. The resurfacing test inspects for evidence of alterations to the component body. Evidence of sanding is often hidden by resurfacing. This test chemically cleans the body of the part and removes the resurfacing material. The part is visually inspected after cleaning for evidence of sanding. This is a destructive test.

RESOURCES
Information from component vendors is required to perform the visual inspections of this process. Access to this information for an obsolete part is sometimes limited. A few on-line resources are available to help bridge this information gap.

- http://www.aciusa.org/Cart/counter_analysis.html
- www.icphotos.org Free data base that has photos of many integrated circuits
- www.chipdocs.com Subscription service to a datasheet database
- www.datasheetcatalog.com Free datasheet database
- www.jedec.org JEDEC Solid State Technology Association
- www.gidep.org Government-Industry Data Exchange Program (GIDEP)
- www.erai.com Electronic Resellers Association International Inc., (ERAI)
- http://www.idofea.org The Independent Distributors of Electronics Association (IDEA)

The first-line suite of testing and inspection methods described above has been useful for a quick-turn counterfeit detection process. Using these procedures, limited qualification testing can be performed on suspected counterfeit ICs. The EMPF also provides more in depth analysis of more sophisticated counterfeits including de-capsulation, die inspection by SEM/EDS, and electrical testing through industry partners. If you are currently buying electronic components from independent brokers or from a new source, consider qualifying your orders to assure that you are not receiving counterfeit parts.

Michael Barger - Senior Materials Engineer

Have a question concerning electronics manufacturing and don't know where to go?

Call the HELPLINE
(610) 362-1320

Your Direct Connection to the Experienced Engineers on our staff.

cut here and save!

Profiling for the Attachment of Large Ball Grid Array Packages (continued from page 4)

bottom heat relative to the nozzle temperature, is to prevent component warping. Component packaging is considered safe below 250°C. However, with the application of higher preheat, the board T_g is another limiting factor. Too much heat will cause board warpage. In addition, components that are localized to the area that is directly heated by a chimney heater on the bottom side may also attain liquidus temperatures.

The EMPF has conducted profile experiments that varied the top and bottom heaters and measured temperatures at the top of the chip, bottom of the board, and target (internal thermocouple at solder ball area). The goal of the profile was to attain the liquidus temperature of the SAC 305 alloy (217°C) and then attain a peak that is 20°C higher. From the data, several conclusions can be made to fine tune the profile. The most interesting and useful observation was that the average temperature (between the top and bottom heaters) approximated the target temperature at the interface.

For example, when the top heat was at 280°C and the bottom heat is 200°C, the target thermocouple (T/C) measurement at the BGA interface was 238°C, and the T/C measurement at the top of the component was safe at 248°C. There were also many small empirical observations that were useful. For instance, the bottom board T/C was on average 15°C lower than the average heat input. Based on these observations and the desire to not reflow the bottom of the board, the target temperatures were determined as well as the average heat inputs.

The time and duration of each stage is another consideration. The preheat stage depends on both the mass of the substrate being worked, the preheat temperature, and airflow rates. When the T/C response becomes asymptotic (the temperature is no longer increasing rapidly and has flattened off), the zone duration may be decreased.

Using thermocouples to monitor the temperature response of the electronics that are being reworked, observations can be made such as end-of-zone temperatures and peak temperatures. Using these observations, modifications to the system heaters can be adjusted incrementally to improve the attachment process. These are elements that are key to proper temperature profiling. The EMPF has the experience and equipment to develop or fine tune industry rework processes and procedures. For more information, please contact us.

Anthony Vigliotti - Senior Materials Engineer

Ask the EMPF Helpline! (continued from page 2)

assemblies, and component tolerance test value discrepancies.

These issues collectively contributed to the intermittent functionality and in some cases performance degradation. A sampling test program to screen for these characteristics could provide some control on the quality of the printed circuit boards.

To address these problems, the EMPF recommended updating the PCB artwork to incorporate coupons that allow for calibrated resistance measurements. Also, the EMPF recommended screening of circuit assemblies for contamination on a lot sampling basis and also running a selected list of acceptance tests based on IPC-6012: Dielectric Withstanding Voltage, Electrical Continuity and Insulation Resistance Testing, Moisture and Insulation Resistance Testing.

Using experienced electrical, materials, process and manufacturing engineers and scientists, the EMPF performs detailed investigations in the areas of materials analysis, electrical characterization, and device integrity. For more information, please contact the EMPF helpline at (610)362-1200 or via email at helpline@empf.org.

YinHao Wu - Design Engineer

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National Electronics Manufacturing Technology Center of Excellence
Monthly Class Schedule for the Calendar Year 2007

Contact the Registrar for course information and pricing:
610-362-1295
FAX: 610-362-1289
registrar@empf.org

NEW COURSE!

CIT/Instructor Certification

Rework, Repair, & Modification of Electronic Assemblies

2007 IPC-7711/7721 CIT Certification

January 29-February 2
March 5-9
May 7-11
July 9-13
September 24-28
November 26-30

2007 IPC-7711/7721 CIT Recertification

February 20-21
April 4-5
June 25-26
September 4-5
November 15-16
December 3-4

Call the EMPF Helpline for Free Electronics Manufacturing Assistance
610-362-1320
helpline@empf.org

Electronics Manufacturing

Boot Camp A
January 29-February 2
April 16-20
June 4-8
September 10-14
November 5-9

Boot Camp B
February 5-9
April 23-27
June 11-15
September 17-21
November 12-16

IPC Certifications CIT/Instructor

IPC J-STD-001
January 8-12
February 12-16
March 12-16
April 9-13
May 21-25
June 18-22
July 16-20
August 20-24
September 24-28
October 22-26
December 10-14

IPC-A-610
January 22-26
February 26-March 2
April 16-20
May 14-18
June 11-15
July 23-27
August 13-17
September 17-21
October 15-19
November 5-9
December 3-7

IPC-A-600 PWB Acceptability
January 3-5
February 27-March 1
April 9-11
May 29-31
July 31-August 2
August 27-29
October 10-12
November 19-21

IPC-A-610 Recertification
January 16-17
February 20-21
March 19-20
April 23-24
May 14-15
June 4-5
July 16-17
August 20-21
September 10-11
October 29-30
December 10-11

IPC J-STD-001 Recertification
January 17-18
February 21-22
March 21-22
April 25-26
May 16-17
June 6-7
July 18-19
August 22-23
September 12-13
October 31-November1
December 5-6

CIS/Operator

IPC/WHMA-A-620 Wire Harness Manufacturing
March 13-15
June 26-28
October 2-4
December 17-19

SMT Rework & Circuit Repair IPC-7711/7721 (Modules 1 &4-7)
February 12-15
May 7-10
August 13-16
October 29-Nov. 1

SMT Rework/ IPC-7711 (Modules 1, 4-6)
February 12-14
May 7-9
August 13-15
October 29-31

Surface Mount & Thru-Hole Rework of Electronic Assemblies IPC-7711 (Modules 1 & 3-6)
March 19-22
July 30-August 2
October 8-11

Repair & Modifications of PCB's IPC-7721 (Modules 1 &7-9)
February 5-8
April 30-May 3
August 6-9
November 12-15

Circuit Repair IPC-7721 (Modules 1 & 7)
February 5-6
April 30-May 1
August 6-7
November 12-13

IPC Challenge
January 19
February 23
March 23
April 27
May 18
June 8
July 20
August 24
September 14
November 2
December 7

Skills

Chip Scale Manufacturing
March 28-30
June 20-22
October 22-24

BGA Manufacturing Inspection & Rework
January 18-19
April 3-4
June 18-19
July 23-24
August 29-30
October 15-16
November 26-27

Continuing Professional Advancement in Electronics Manufacturing

Lead Free Manufacturing
January 16-17
February 26-27
March 26-27
April 30-May 1
May 30-31
June 27-28
July 25-26
August 27-28
October 17-18
November 19-20
December 12-13

Design for Manufacturability
February 22-23
April 11-12
May 24-25
August 6-7
October 8-9

Failure Analysis and Reliability Testing
January 3-5
March 6-8
May 21-23
July 9-11
September 5-7
November 28-30

Custom Courses and On-Site Training Available

Conveniently Located Next to the Philadelphia International Airport

All courses & dates subject to change without notice
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