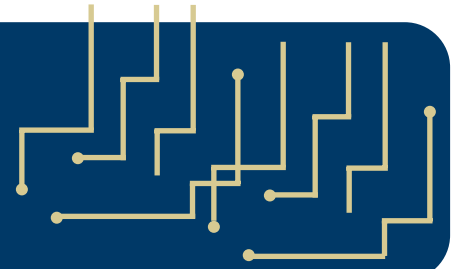


# empfasis



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The EMPF is a U.S. Navy-sponsored National 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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## MicroElectro Mechanical Systems Packaging

MicroElectro Mechanical Systems (MEMS) and the processes for their fabrication represent an ingenious extension of the technologies that were first developed to create microchips and integrated circuits. At their core is an adaptation of materials and techniques that were developed for miniature electronic circuits to the design and fabrication of miniature machines. In the process, it has been possible to do many things more economically than had been possible with "macro-scale" devices. More importantly, many MEMS devices exhibit capabilities and performance that surpass anything that can be achieved in larger scale devices, where inertia and scale may limit response time and accuracy.

These advantages and advances do not come easily, however. The magnitude of the change in scale introduces new barriers and opportunities that must be discovered and understood before they can be utilized to maximum advantage. For these reasons, each new MEMS device and MEMS application is unique, and can be anticipated to require significant development effort to perfect a fully-functioning, reliable product.

#### MEMS Production

There are two basic approaches to MEMS production, both utilizing silicon wafers as the starting point. The approaches are characterized as an additive process and a subtractive process. The additive processes (surface micromachining) deposit alternating layers of structural material and a temporary oxide (sacrificial layers) that will subsequently

be removed to "free" the free-standing or moveable MEMS structures.

Alternatively, the so-called subtractive processes approach (bulk micromachining) involve only processes that etch away material from the silicon wafer. To provide space for the movement of these MEMS components, silicon layers are first patterned and etched, then brought

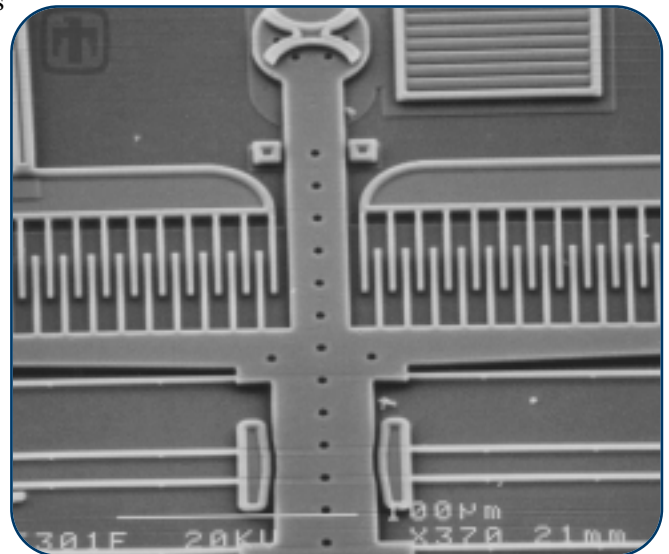


Figure 1. Scanning electron micrograph of a MEMS electrostatic comb-drive mechanism. Courtesy of the Intelligent Micromachine Initiative, Sandia National Laboratories, <http://www.mdl.sandia.gov/Micromachine>

together using a glass frame or border to provide the correct spacing of the layers. The silicone layers are customarily joined to the glass frames by anodic bonding to create a secure, hermetic seal.

Additive processes have been highly developed by Sandia Laboratories among others, to create micro motors and systems of gears and levers. Subtractive processes have been used as a key route to accelerometers and similar devices.

*continued on p. 4*

# Reliability Testing of BGA Solder Joints

Attaching Integrated Circuits (IC) chips to printed circuit boards (PCBs) using the attachment method of Ball Grid Arrays (BGAs) can result in improved electrical performance, higher I/O counts, and reduced board real estate, compared to more traditional approaches. However, the advantages offered by these attachment methods will be unrealized if the interconnections are unreliable. As a result, it is important to have an appreciation for some of the potential failure mechanisms that exist with BGAs as well as some of the environmental tests used to study their reliability. This article describes the stress experienced by the BGA solder connections, as well as the typical environmental test, thermal cycling, used to assess the reliability of these attachments.

BGAs make use of solder ball arrays at the PCB board attachment level. These arrays may be full, staggered, or peripheral. A common BGA design (see Figure 1) consists of the silicon die wire bonded to points on a substrate, such as BT glass/epoxy. A BGA of this type is considered a plastic ball grid array (PBGA). This substrate electrically connects the wire bonds to the solder balls of the array on the underside of the substrate, typically using either plated through holes (PTHs) or internal vias connecting multiple substrate layers. The IC is encapsulated by a plastic molding compound.

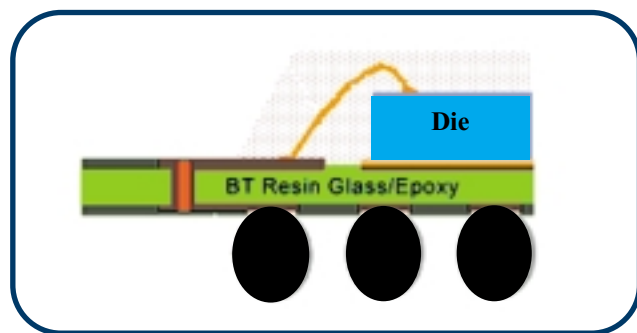


Figure 1. Typical structure of a plastic ball grid array (PBGA)

One of the main reliability concerns with BGAs results from Coefficient of Thermal Expansion (CTE) mismatches of the materials involved (see Table 1). Materials expand and contract to different extents upon heating and cooling, depending on their CTE value. As seen in Table 1, the greatest difference in CTE of some common BGA materials is due to the low CTE of the silicon die. The unequal expansion and/or contraction results in mechanical stress. This phenomenon can cause cracking with solder ball attachments either at the solder ball/PCB pad interface, or more commonly, at the solder ball/package interface.

Thermal cycling is used to test the reliability of the processed BGA solder connections. The thermal cycles subject the solder joints of the BGA to repeated expansions and contractions, creating stress at the joints. Failures are typically manifested as cracks in the solder connection. The thermal cycle parameters vary according to the potential use conditions of the final electronic assembly. Accelerated testing is intended to test with conditions beyond those expected in the actual use environment. A common temperature range for commercial electronics cycles from 0<sup>o</sup> to 100<sup>o</sup>C. Expanded temperature ranges, with lower limits of -40<sup>o</sup> or even -55<sup>o</sup>C and upper limits of 125<sup>o</sup>C at rates varying from a couple degrees per minute up to an extreme of 20<sup>o</sup>C per minute, are typical for automotive or military applications.

BGAs are often analyzed on test boards. It is helpful to have a sample size of at least 30 BGAs for statistical reasons. In order to pinpoint failures, the test BGAs are commonly daisy-chained, which involves shorting adjacent solder balls on the package substrate. This creates connected patterns such as rows, or inner or outer areas of the array that can be electrically monitored. The monitoring is preferred to be in situ versus intermittently after a certain number of cycles. A failure at the solder joint will cause a detectable change in resistance. Thermal cycling is typically conducted until a certain number of failures occur (i.e., 50% or 75% of the samples). Statistical data analysis can

*continued on p. 10*

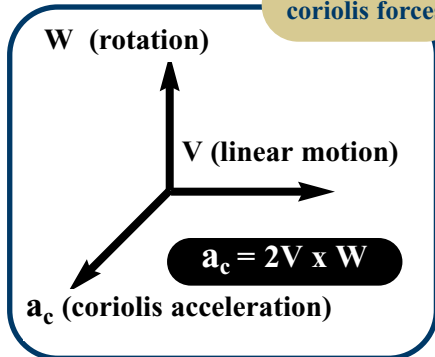
Table 1. CTE of common materials used in electronics assemblies.

Material	Temperature Range <sup>o</sup> C	CTE (ppm/ <sup>o</sup> C)
ABS Epoxy	0-100	45-65
E-glass	(-30) - 250	5.4
FR4(Composite)	0-100	18
Polyimide E-glass	20	14
Copper	0-100	18
Tin	0-100	23.5
Lead	0-100	29
63Sn37Pb	0-100	24.5
Cu <sub>3</sub> Sn	25-100	18.4
Cu <sub>6</sub> Sn <sub>3</sub>	25-100	20.0
CLCC	20	6
PLCC	20	19
Silicon Die	0-100	2-5

# NAVY MEMS IMU Applications

Microelectro mechanical systems (MEMS) are the next generation of electronic devices, promising major advances in performance as well as miniaturization and cost effectiveness (see page 1). The most prolific application of MEMS is for micro-sensors. These sensors are uniquely qualified to exploit the combination of mechanical and electrical systems on a micro scale. MEMS sensors have been fabricated or proposed to perform a variety of tasks, such as detecting chemical/biological agents, pressure, temperature, light, stress, strain, acceleration, motion/rotation, etc. Many of these applications are being pursued by various commercial and government entities. One application that will be implemented in the near future is a MEMS based inertial measurement unit.

**Figure 1  
coriolis forces**



An inertial measurement unit, or IMU, is a device that can measure both acceleration and rotation in all three axes (x, y, and z). The most common configuration would be three accelerometers and three gyros each having the ability to sense in a single axis. MEMS based accelerometers are currently available for commercial systems and are employed in applications such as air bag sensors. MEMS based accelerometers that can meet the Navy's need are not difficult to obtain. The more difficult technical challenge to date is in generating a viable MEMS based gyroscope to meet the needs of military devices in terms of precision and robustness.

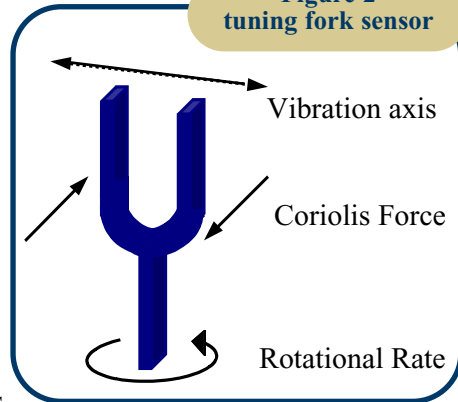
The most well known example of a gyroscope is a spinning-mass gyro. This is what most people remember as a spinning toy. Gyros of this type work based on the fact that angular momentum is conserved. As the gyro is sent spinning, it will always have a net momentum in a single direction. When this object is inside an aircraft or missile that turns, electronic systems within the vehicle can sense the current heading using the gyro as a "true" reference. These gyros are bulky and require large amounts of power. Newer systems employ a sensing system based on light systems, either a fiber optic based gyro (FOG) or a ring-laser gyro (RLG). These systems are very precise, but they are costly and require significant amounts of power.

Costly and precise FOG and RLG systems are applicable for aircraft, but for munitions these systems are not ideal due to their high cost. For most missile platforms, the guidance and navigation systems are the largest portion of the cost, using current technology. A MEMS based IMU would be smaller and require less power than the current technologies, if they can be fabricated cost effectively then these would be the ideal system for guidance of munitions.

MEMS gyros are usually designed as an electrostatic drive resonator fabricated from a single piece of quartz or silicon. These gyros operate on the principle that when an angle rate is applied to a translating body, a Coriolis force is generated (see Figure 1). For example, when this angle rate is applied to the axis of a resonating tuning fork, its prongs receive a Coriolis force, which then produces torsional

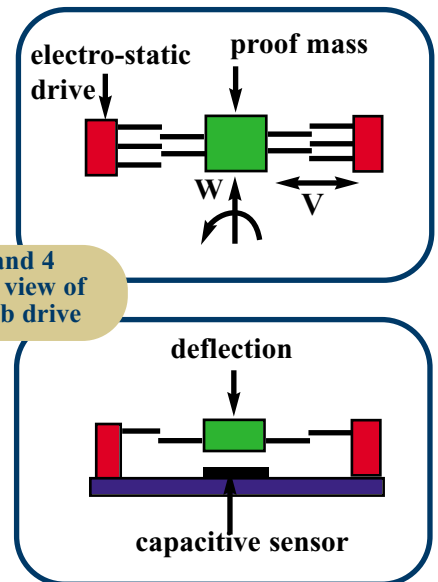
forces about the sensor axis (see Figure 2). These forces are proportional to the applied angular rate, which can be measured capacitively (silicon based) or piezoelectricity (quartz based). The output is then demodulated, amplified, and digitized to form the device output. There are prototype MEMS devices being fabricated today based on these principles that can sense in one, two, or all three dimensions (see Figures 3 and 4).

**Figure 2  
tuning fork sensor**



Resonant beam accelerometers operate on the same principle as a violin. When the violin string is tightened, its frequency of operation goes up. Similarly, when the accelerometer is loaded, one tine is put into tension and the other into compression. These tines can be electrostatically excited at frequencies in the hundreds of kilohertz range

**Figure 3 and 4  
top and side view of  
MEMS comb drive**



*continued on p. 10*

# MicroElectro Mechanical Systems Packaging (continued from page 1)

## Packaging MEMS

Once the silicon processing of the MEMS is complete, the challenges have just begun. The chip must be usefully integrated with other components to create a functioning device. Many self-contained MEMS sensors such as accelerators and gyros require only electrical connections. Optical MEMS (M O E M S) require a light path to the outside world.

Other types of MEMS require mechanical, gas or fluid access to the environment. Connections and intercon-

nections become integrated into the packaging and become part of the process of making the MEMS package itself. Multi-disciplinary design approaches are frequently required to supply electrical, fluid, motion, optical or thermal communication.

A general statement can be made that at this point in time there is no existing infrastructure within the United States for MEMS packaging capability to produce a microsystem. There are few developed metrics, specifications, experience base, depository for knowledge and infrastructure from which to select microfabrication and microassembly packaging and connection schemes. Each product is distinct, conceived from ground zero in the development of its packaging and interconnection systems.

Fortunately, several companies are now working on MEMS mathematical modeling tools to serve the MEMS designer. Among these companies are Microcosm's MEMCAD [www.memcad.com], IntelliSense's IntelliCAD [www.intellisense.com], Coyote Systems [pbljung@coyotesystems.com], Tanner Research [www.tanner.com] and MEMsCAP [http://memscap.e-sip.com]. Thus, design tools are increasingly available as the field matures.

Compounding the difficulty of packaging MEMS, the problems of positioning micron-scale parts with respect to one

another and securing them into position within acceptable micron tolerances have not yet been solved by equipment suppliers. Motion systems are capable

of achieving 0.1 $\mu$ , but the reliable observation of fiducials on two parts to be assembled at high magnification in the same field of view remains difficult to

Subtractive Processes	Additive Processes
W etching	P lasm a vapor deposition
D ry etching	C hem ical vapor deposition
P lasm a etching	L I G A electroform ing
I on beam etching	M icrom olding
L aser ablation	S intering
E D M	

Table 1. Common Microfabrication Processes

achieve. The difficulty of accurately dispensing adhesive, placing parts onto the adhesive, and maintaining the positioning during curing of the adhesive all add to the tolerance stack ups that are encountered. Common microfabrication processes and packaging systems are presented in Table 1.

MEMS packages tend to be individually tailored for each unique MEMS device. Therefore, a large number of processes are used, each with their own distinct advantages and disadvantages for specific applications. Some of the more common techniques include anodic bonding to join silicon to glass (~450°C and ~1000volts), fusion bonding of silicon to silicon, glass or oxide (~1000°C), and eutectic bonding of silicon to metal (silicon-to-gold at ~363°C).

The generalized construction of a silicon nitride shell to package and protect a surface micromachined MEMS device by encapsulation can be illustrated in Figures 2 through 5.

ACI is actively engaged in expanding its expertise to include the new micro-scale

of MEMS requirements. ACI has expertise with the full range of polymers and ceramic packaging. The environmental test and failure analysis facilities at ACI can be used to verify the suitability of MEMS packaging systems for their specific applications. These tools are vital in assuring the successful implementation of the following MEMS design and production processes:

- Die attachment
- Encapsulation
- Packaging system
- Package integrity and hermeticity
- Reliability under use conditions

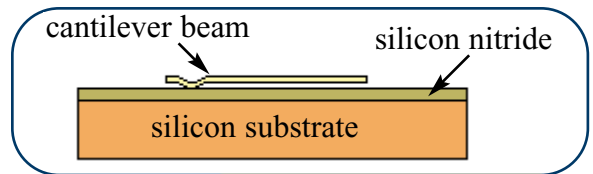


Figure 2: a generalized MEMS resonator

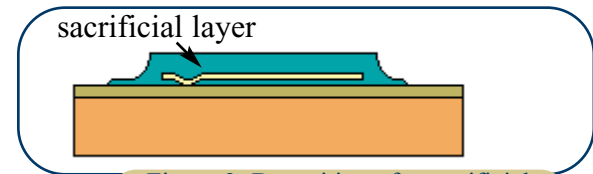


Figure 3: Deposition of a sacrificial layer to define the package

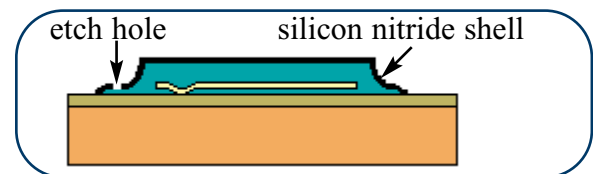


Figure 4: Silicon nitride deposition followed by patterning of an etch hole

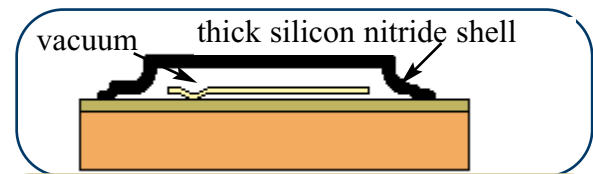


Figure 5: Removal of all sacrificial layer, followed by supercritical CO<sub>2</sub> drying and sealing by global low pressure chemical vapor deposition of silicon nitride.

# Lab Services - Chemical Testing and Analysis

## Ion Chromatography

ACI performs ion chromatography (IC) analysis on electronic assemblies. This technique is used to measure cleanliness of assemblies, components, and bare board with precision. IC can determine the precise amount of F, Cl, Br, NO<sub>2</sub>, NO<sub>3</sub>, PO<sub>4</sub>, and SO<sub>4</sub>, down to 0.5 mg/cm<sup>2</sup>. A common test method employed by ACI is the IPC TM-650 2.3.28. ACI has analyzed thousands of assemblies, components, and bare boards using this technique.

## Resistivity of Solvent Extract (ROSE)

ACI performs Resistivity of Solvent Extract (ROSE) analysis on electronics assemblies. This technique is used to measure the cleanliness of assemblies, components, and bare boards. Bulk ionics are measured according to their conductivity in solution and referenced to a sodium chloride standard. A common test method employed by ACI is the IPC TM-650 2.3.25. ACI has analyzed thousand of assemblies, components and bare boards using this technique.

## Fourier-Transform Infrared (FT-IR) Spectroscopy

ACI performs FT-IR spectroscopy on a variety of sample types using both transmission and reflective modes as well as FT-IR microscopy on a routine basis. This technique is an excellent tool for examining organic materials such as adhesives, polymers, plastics, etc. ACI can obtain FT-IR spectra on surfaces, powders, liquids, and semi-solids. Common test methods include IPC TM-650 2.3.39B and ASTM methods. The spectra that are generated can then be analyzed against thousands of compounds in our spectral database and commercial spectral databases. This library search can be used to identify the compound being sampled.

## Ultraviolet-Visible (UV-Vis) Spectroscopy

ACI performs both transmission as well as reflective UV-Vis spectroscopy on liquids and surfaces. UV-Vis spectroscopy is a technique that measures the amount of UV-Vis light absorbed by the sample of interest. Our spectrometer can operate from 230 - 1100 nm and is calibrated against a NIST traceable white reference standard. ACI has developed UV-Vis chemometric techniques that are applicable to the electronics and aerospace industries.

## Sequential Electrochemical Reduction Analysis (SERA)

ACI has the equipment to analyze the surface oxides and sulfides on metals using sequential electrochemical reduction analysis (SERA). Any metal oxides or sulfides that are present on the surface can be identified and a thickness determined (within 50 angstroms). This technique can be used to identify and differentiate between SnO, SnO<sub>2</sub>, Cu<sub>2</sub>O, CuO<sub>2</sub>, Cu<sub>x</sub>Sn<sub>y</sub>O<sub>z</sub>, Ag<sub>2</sub>S, etc. ACI participated in the development of this technology and continues to employ this technology in failure analysis and surface analysis.

## Reduced Oxide Solderability Activation (ROSA)

ACI has a process available that removes any metal oxides that may be contaminating a surface, Reduced Oxide Solderability Activation (ROSA). This technique was developed to remove the oxides and sulfides that inhibit solderability such as, tin (II), tin (IV), copper (I), copper (IV), and silver oxides and sulfides. The process is electrochemical and takes place in an aqueous solution. The process is rapid, a typical treatment takes less than one minute. The samples are rinsed in deionized water and are immediately available for processing. ACI has reconditioned thousands of components and printed wire boards that have been used in assembly of various military and commercial systems.

## Wetting Balance Testing

Solderability is vital to producing quality electronic assemblies. ACI performs quantitative solderability testing as well as qualitative dip-and-look tests. The tests can be performed on leaded components, chip components, wires, and coupons, with the results compared to established evaluation standards such as the J-STD 002 and 003, as well as IEC-68-2-69 among others.

## Optical Microscopy

Optical microscopy at ACI is often coupled with digital imaging and analysis. ACI performs such tasks as dimensioning, annotation, archiving, and standardized inspections (e.g. IPC, MIL spec, and JEDEC). ACI specializes in bright field illumination and metallic contrast imaging using an inverted stage metallograph. Using various forms of optical microscopy, ACI examines components, circuit boards, solder, material microstructure, contamination, defects and anomalies, and other electronic materials at 2 to 1500 times magnification.

## Metallurgy

Using SEM, EDS, optical microscopy, and SERA, ACI engineers investigate many of the metallurgical issues involved in electronics packaging. Metallurgy is used to study diffusion, intermetallic formation and growth, contamination, morphology, thermodynamics, and kinetics involving a number of electronics related metals, ceramics, composites, and semiconductors. This information can be used to study failure modes.

## What's New for 2002 in the Learning Center?

**E**mpf's Learning Center (EMLC) is continually updating courses to meet customer needs and to help maintain a competitive edge. Combining classroom training with hands-on experience allows students to maximize their learning and comprehension. Technical excellence is provided by each instructor as well as the state-of-the-art training/demonstration center. Certification and skill based training will bring your company up to speed on the latest technologies and manufacturing specifications. Following are some brief explanations of courses available.

### **J-STD-001 Recertification**

Approximately three years ago, IPC-J-STD-001 changed to Revision C, and for many instructors and operators, it is now time to be recertified. If you were certified prior to 1999, your certification will expire very soon, so please take a minute to verify when you are due for recertification.

The IPC Committee is in the process of revising the recertification material for J-STD-001 from Revision B to Revision C, and will be ready for release to the public in October 2001. ACI will be ready to begin recertifications as early as November 2001.

The course duration for instructors is one and a half days long. During this time, instructors will review the material, demonstrate proficiency of hand soldering techniques, and complete a written test. Upon completion, instructors will receive IPC certification, along with a full training materials kit to perform operator recertification at your facility.

In-house operator recertification will be available for companies sending four or more students per class. ACI also offers on-site recertification for operators. A master certified instructor will come to your facility with all of the necessary equipment, including soldering irons, lamps, hand tools and microscopes. This is ideal for companies that need to recertify operators, but do not have a registered instructor or curriculum in place. The duration for operator recertification is two days. This will include a review of the material, demonstration of hand

soldering techniques and a written test. Upon completion, operators will receive IPC operator certification. Worker proficiency classes will be held upon request only. Please contact the EMLC Registrar for complete details at (610) 362-1295.

### **Design for Manufacturability**

Are you continually redesigning your Printed Wiring Boards? Have you lost countless hours and untold amounts of money trying to perfect Printed Wiring Assembly (PWA) methods and processes? Mastery of the training program on perfecting Printed Wiring Board/Assembly designs and manufacturing processes prior to production has a great impact on overall manufacturability, testability and cost.

ACI developed a program, based on the IPC-2220 Series of Design Documents. The Design for Manufacturability (DFM) course takes a look at J-STD-001 end item requirements and relates them to the IPC-2220 Series. This two day course is intended to provide engineers and design personnel with the basic guidelines for Printed Circuit Board fabrication (both rigid and flexible) and Printed Wiring Assemblies. It goes on to provide guidance on how to set up a producibility checklist for designs. These guidelines may directly impact assembly manufacturability, circuit performance, testability and maintainability. Students will learn critical design considerations for Printed Wiring Board and panelization, component selection and packaging, through-hole and surface mount clearance, land design, fiducial and registration marking, as well as solder masking and conformal coating. Engineers and Designers will complete the course with a strong knowledge base of design principles and considerations which will help in greatly reducing the amount of time and effort needed to correctly design PWB's and Assemblies.

### **Additional Courses**

In addition to IPC J-STD-001 and DFM, ACI has additional courses for effective training including Boot Camp, SMT Manufacturing, Advanced Packaging Techniques, Failure Analysis, and Characteristic Properties of Materials.

Boot Camp is an intense two-week hands-on course. Students will learn screen printer set up, programming and placing components using automated equipment, profiling reflow ovens and wave soldering machines using the latest technological profiling systems, set up of various types of cleaning processes and more. The Cadets will also be exposed to decision-making exercises regarding process options such as flux considerations, which covers process control tools, troubleshooting, and cause and effect.

SMT Manufacturing focuses on the in-depth technical basics of SMT assemblies, including a detailed look at key process parameters. Students will be capable of successfully planning, setting up and operating a complete SMT assembly line, including everything from initial design considerations through final assembly and inspection.

Advanced Packaging Techniques (APT) was developed to meet the demand for smaller footprints, improved electrical performance and/or higher input/output in a given space, and manufacturers investigating advanced packaging technologies. This course will allow students to make informed decisions about advanced packaging technologies (flip chips, chip scale packages, wire bonding, micro BGAs and BGAs) based upon your company's needs.

The Failure Analysis course objective is to prepare the participant to make informed decisions when troubleshooting a manufacturing problem or collaborating with an analytical laboratory. The course is designed so that case studies will provide a forum for problem formulation, investigation and resolution.

The Characteristic Properties of Materials course relates material properties to product and process quality. The lectures focus on the fundamentals of material properties and selection. The laboratory exercises explore measurement techniques and Material Selection Behavior, with testing at ACI's on-site analytical facility.

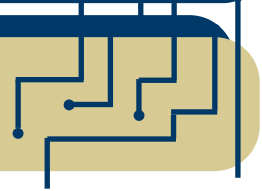
**If you would like more information on Learning Center courses, please contact our registrar at 610-362-1295.**



Electronics Manufacturing  
Productivity Facility

TECH TIPS...

Wave Soldering - Part II



Cut here and save!!

In this month's issue of Tech Tips, we continue to look at wave soldering and some of the new processes that are being used today.

**1) Improving Yields With Selective Debridging**

Selective debridging occurs when a tuned gas flow (air or nitrogen) is applied to a specific area where solder bridging may occur. This is performed while the solder is still in molten form, immediately after the assembly exits the last solder wave. The process parameters are programmed and controlled by the wave soldering system's computer. The keys to selective debridging is tuning the gas flow specifically and bringing the nozzles into close proximity to the PCB (Printed Circuit Board) without actually contacting it. Other significant factors include board design, optimization of parameters, and tooling design. Studies have shown that selective

debridging has improved yields up to 80 percent where traditional air knife configurations (as shown in Table 1) prove to be a less effective method.

**2) Lead-Free Wave Soldering**

When choosing to use a lead-free alloy for wave soldering, there are a few parameters that differ from the use of a tin/lead alloy. They include the pre-heat temperatures, the pot temperatures, the use of nitrogen, and the distance of the exit from the pot.

The pre-heat temperatures are profiled to the type of flux used. (See Table 2 ). This is typically 50<sup>o</sup>-750<sup>o</sup> C higher than that of tin/lead.

*continued on p.8*

Parameter	Selective Air Knife	Traditional Air Knife
Estimated Basic Unit Cost	Lower	Higher
Disturbance Of Normal Solder Joints	No	Yes
Programmable (reduce thermal stress)	Yes	No
Gas Flow	Selective	Continuous
Gas Consumption (cfm)	Lower	Higher

Table 1  
Circuits Assembly: July 2000 Improving Wave Soldering Yields with Selective Debridging

Application	Product	Solids % W/W	Type	Spec	Cleaning
Spray	NR330	4%	VOC-Free	J-Std, Bellcore	No-Clean
Foam	NR300FPM	4%	VOC-Free	J-Std, 004	No-Clean
Dip/Foam/Spray	RF800	4.1%	Rosin	J-Std, Bellcore	No Clean (Solvent/Semi-Aqueous as required)

Table 2  
Alpha Metals Chart: Lead -Free Compatible Fluxes

## Wave Soldering Part II (Continued from p. 7)

The pot temperature is set according to the melting point of the lead-free alloys used and according to the type of flux. The chart in Table 3 shows the recommended pot temperature range of typical lead-free alloys as well as the primary application for which they are used. To pin point exactly what temperature required would be determined by the flux used.

Nitrogen is used due to the excessive dross build up that the wave produces. It also improves the wetting

characteristics of the solder joints much like it would for a typical tin/lead process.

The distance from the pot to the exit of the wave solder machine must be long enough to fully expose the board to ambient air. This is for cooling purposes due to the fact that it takes lead free alloys longer to solidify.

**Table 3  
Alpha Metals Chart: Lead Free Application**

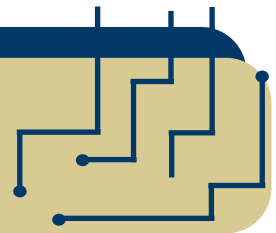
Alloy	Composition	Liquidus	Primary Application	Wetting Balance Data at 271 <sup>0</sup> C for Reference <sup>1</sup>		Suggested Solder Pot Temperature Range
				Wetting Time (Sec) <sup>2</sup>	Max. Wetting Force (mN/mm) <sup>3</sup>	Suggested Solder Pot Temperature Range
Sn/Pb for Ref.	63Sn/37Pb	183 <sup>0</sup> C/361 <sup>0</sup> F		1.76	184	232-271 <sup>0</sup> C/ 450-520 <sup>0</sup> F
Sn/Ag	96.5Sn/3.5Ag	221 <sup>0</sup> C/430 <sup>0</sup> F	SMT/Wave	.69	312	260-276 <sup>0</sup> C/500-530 <sup>0</sup> F
Sn/Cu	99.3Sn/.7Cu	227 <sup>0</sup> C/441 <sup>0</sup> F	Wave/Semiconductor	.96	299	265-276 <sup>0</sup> C/510-530 <sup>0</sup> F
Sn/Ag/Cu Family	95.5Sn/4.0Ag/.5Cu	215-218 <sup>0</sup> C/419-424 <sup>0</sup> F	SMT/Wave/Semiconductor	.75	317	271-276 <sup>0</sup> C/520-530 <sup>0</sup> F
	96.5Sn/3.0Ag/.5Cu	215-218 <sup>0</sup> C/419-424 <sup>0</sup> F	SMT/Wave/Semiconductor	-	-	271-276 <sup>0</sup> C/520-530 <sup>0</sup> F
	96.3Sn/3.0Ag/.7Cu	215-218 <sup>0</sup> C/419-424 <sup>0</sup> F	SMT/Wave/Semiconductor	-	-	271-276 <sup>0</sup> C/520-530 <sup>0</sup> F
Safe-Flo <sup>R</sup>	96.0Sn/2.5Ag/1.0Bi/.5Cu <sup>4</sup>	215 <sup>0</sup> C <sup>**</sup> /419 <sup>0</sup> F <sup>5</sup>	SMT/Wave	1.36	230	271-276 <sup>0</sup> C/520-530 <sup>0</sup> F
CASTIN <sup>TM6</sup>	96.25Sn/2.5Ag/.75Cu/.5Sb	214-217 <sup>0</sup> C/417-423 <sup>0</sup> F	SMT/Wave	1.53	216	271-276 <sup>0</sup> C/520-530 <sup>0</sup> F

1. Data based on 15 replicates of clean copper coupons and RF800 (JSTD ROL1).  
Note that the standard deviations were very low for each test condition.
2. Lower wetting time is desired.
3. Higher maximum wetting force is desired.
4. Most popular alloy in the Safe-Flo patented range.
5. Actual liquidus determined by Bi content.
6. Products made with the CASTIN alloy made upon request.

**For more information  
on wave soldering, please call the  
EMPF Helpline at (610) 362-1320.**

# Manufacturer's Corner

MRSI



ACI is currently engaged in the study and planning of manufacturing Micro Electro Mechanical Systems (MEMS) device assemblies. MEMS are silicon devices ranging in size from a micron to a few centimeters, which combine mechanical and electrical structures that use fabrication technologies developed for manufacturing integrated circuits (IC). MEMS are fabricated from equipment or technology that can be found in the integrated circuit manufacturing arena; however most of this equipment is expensive to own and operate.

MEMS are miniaturized devices, gears, movable mirrors, and high-speed motors and MEMS technology can combine, motors, motion translators, sensors, gyros, gears and computers onto one single chip. The accelerometer in your vehicle's air bag that triggers a signal when a specified acceleration or deceleration profile is experienced is one of the earliest and most common examples of a MEMS device that consumers may come in contact. A second example is the ink jet cartridge that uses a MEMS chip to propel droplets of ink when an electrical impulse is received. The chip consists of microscopic jet nozzles that discharge the droplets of ink using piezoelectric or thermo-mechanical pumps inside the chip.

ACI is currently enhancing its capability to serve the commercial electronic and military communities by studying and developing inexpensive assembly methods of MEMS devices.

The complicated processes used to assemble a MEMS device may utilize the following automatic equipment:

- Precision placement - pick and place equipment with five microns for enhanced accuracy, vision system for substrate and die alignment
- Die bonding - attaching a bare die to a substrate or other material

- Wire bonding - welded electrical connections from the die to the lead or post.
- Wafer dicing - a high speed, precision cutting saw with a diamond blade and automatic vision system, or the precision breaking of a perforated or scribed wafer.
- Encapsulation - dispensing a sealant to surround and protect the assembly
- Vacuum sealing, injection molding and welding - final packaging and protection



The MRSI - Model 505 Advanced Packaging and Ultra-precision Work Cell

A recent addition to the ACI Electronic Manufacturing Learning Center and Demo Factory that enhances its MEMS development capability, is the MRSI - Model 505 Advanced Packaging and Ultra-Precision Work Cell. This work cell is a multi tasking system, which can be configured to perform specific ultra precision and critical microelectronic applications. Offering advanced vision and fully automatic operation, the system is specifically designed and configured for advanced packaging applications required for MEMS, medical, military, automotive, and computer applications.

The MRSI 505 system capabilities are as follows:

- Automatic material handling system (magazine to magazine, mechanical /vacuum fixturing etc.)
- Automatic vision system
- Wafer handling
- Waffle Pack and Gelpak
- Positive displacement pump dispensing
- Epoxy stamping
- Cassette- to-cassette part handling systems
- Flip chip operation with upwards looking camera
- Eutectic hot plate
- Programmable amplitude and frequency scrubbing

This unit gives ACI the ability to train and conduct research in the latest electronic technologies, such as photonics, high frequency, flip chip, MEMS, eutectic attachment applications and advanced packaging. Typical assembly applications include: Analog to Digital (AtoD) converters, hearing aids, disk drive controllers, microprocessors, MEMS, super conductors, guidance systems, RF modules and microwave modules. In addition to the specific packaging options listed previously, MRSI Model 505 provides ACI the precision placement accuracy required for complex assembly operations.

If you would like to arrange a demo on this piece of equipment, please contact Jeff Stong at 610-362-1200 x224 or via E-mail at [Jstong@aciusa.org](mailto:Jstong@aciusa.org).

## Reliability Testing of BGA Solder Joints (continued from page 2)

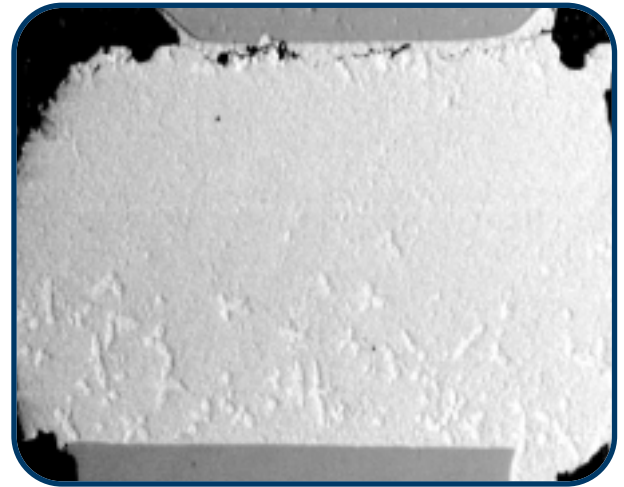
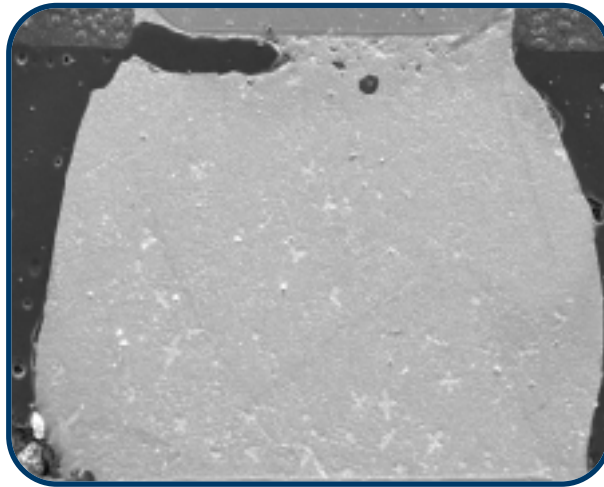
result in a failure distribution as well as extrapolate the data to actual application conditions. Ideally, the daisy-chaining will allow one to pinpoint the area of the failed solder joint. Cross-sectioning the area can potentially reveal the location of the induced cracks (see Figures 2 and 3).

Thermal cycling can provide valuable information as to the reliability of the solder joints on BGAs. This information is helpful in evaluating one's soldering process as well as understanding the expected lifetime of the BGAs in actual field use.

With this information in hand, the advantages provided by BGAs can be realized and relied upon. ACI's laboratory possesses the capability to perform thermal cycling, electrical monitoring, and any subsequent failure analysis involving cross-sectioning and optical inspection using scanning electron microscopy (SEM). This is

one of many technical areas where ACI can provide direct support to the electronics manufacturing industry.

Figures 2 and 3:  
Examples of cracks BGA solder balls



## NAVY MEMS IMU Applications (continued from p. 3)

when unloaded. Therefore, when loaded due to G forces from an acceleration one time's oscillation frequency increases and the other decreases. The difference in frequency is a measure of the acceleration the device is observing. Due to the infinitesimal inertial mass of MEMS structures and the semiconductor nature of silicon these devices can be fabricated at a low cost, with the precision necessary for military applications.

The major roadblocks for the implementation of these devices into weapon platforms are related to the fact that MEMS is still a cutting edge technology. Manufacturing costs for

many of the different MEMS gyros available is high because some of the processes are still manual in nature and the processes used to fabricate the devices still need to be optimized. Packaging of MEMS devices continues to be an issue with MEMS devices in all areas, and IMU devices are no exception. Some gyro or accelerometer devices need to be packaged in a buffer gas or vacuum environment, necessitating hermetic packaging. Another complicating factor is that this packaging also cannot deform or stress the MEMS device. If these delicate structures are stressed, bent, or deformed in any way then their measurements will not be accurate.

There are a number of different Department of Defense weapon platforms that can benefit from a low-cost precise MEMS IMU, such as WCMD, JDAM, JASSM, JSOW, ERGM, XM982, and Standard Missile. In order for these devices to be inserted into a munitions platform, they will have to be able to withstand greater than 10,000 G shock, vibration, long-term storage, and have drift rates no more than ten degrees per hour. Several IMU fabricators intend to have MEMS devices available that meet this criteria by the end of 2003.

## Ask the EMPF Helpline!

**CUSTOMER ISSUE:** The EMPF Helpline received a call from a customer concerned with the IPC-A-610C requirements on the vertical fill of solder in plated through-holes with leads. The customer's issue was that they were getting "weak knees," which describes the poor wetting of the plated through-hole on the primary side of the Printed Wire Assembly (PWA).

### HELPLINE RESPONSE:

The technical advisor, who is an IPC Master Certified Instructor, requested more details about the problem. After a phone discussion, the advisor was e-mailed a description on the "weak knees" and some images of what the customer had seen through cross sections. As the technical advisor explained the images, the advisor prepared for his reply. First, he defined the knee to be "the plated portion of the through-hole that connects to the copper foil on the primary or secondary surface planes of the printed wire board." Second, he pointed out IPC's ruling on the matter. These rulings are as follows:

- The IPC-A-600F discusses weakness in this feature of the plated through-hole in Section 3.3.4, which can apply to cracks found on plated through-holes.

- Under IPC-A-610C Section 1.2: the visual standards in this document reflect the requirements of existing IPC and other applicable specifications... such as IPC-SM-782, IPC-2221, IPC-6011 and IPC-A-600.

- Section 1.4.3.2: Acceptable Condition is a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment. Acceptable can be slightly better than the minimum end product requirements to allow for shifts in the process.

- Section 1.4.3.4 Process Indicator Condition: Process control methodologies are to be used in the planning, implementation, and evaluation of the manufacturing processes used to produce soldered electrical and electronic assemblies.

In accordance with these standards, there would be assumptions that the design and materials conform to standards that would enable the performance requirements to be satisfied given good process controls and appropriate conditions.

With the given highlights of IPC standards on the issue, the advisor then commented on the images as follows:



**Image 1**

There appears to be no weakness of the knee. The solder fillet did not wet onto the surface of the

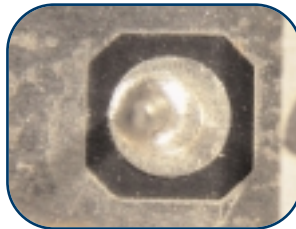
plated through-hole. The condition is 100% vertical fill. This would be acceptable to IPC-A-610C.



**Image 2**

Again the image does not show a weak knee and is acceptable to IPC-A-610C. Careful evaluation of the solder fillet at the barrel interface

reveals a low contact angle. This suggests good wetting. An additional point of discussion is the variation in solder plate thickness observable on the primary side land.



**Image 3**

As one can see, this image was taken from a different view, where the lead of the component is directed at the

viewer. To the advisor, the image shows acceptability to the IPC-A-610C. One may take the position that it is not possible to know how far the barrel "non-wetting" condition extends. Further examination of the image shows a very mottled appearance on the solder coating. This appearance is often associated with problems in process at the board fabrication level.

### Conclusion

The advisor concluded that the boards satisfy IPC-A-600F acceptability requirements, J-STD-003 solderability requirements; and that the assembly was manufactured in accordance with process requirements outlined in J-STD-001C. The conditions presented in the images, while disconcerting in the context of IPC-A-600F, would not require disposition when evaluated as an end item per the requirements IPC-A-610C. He also directs attention to J-STD-001C section 1.4.2 about conformity. IPC-6012 Section 3.6.2.1 and Table 3-7 is another document that relates to the requirements described in the article.

### Recommendations

The customer was asked to evaluate unpopulated PWBs. The advisor then stated that it is possible that the boards do not conform to industry consensus standards including: IPC-A-600F Section 3.3.11, and Section 5.1.1 which is fully defined in J-STD-003. The advisor suggested that the customer might look into the J-STD-001C Section 5.4 on solderability maintenance. However, caution must be taken because cracks in the knee can create solder process results that appear identical to those presented in the third image. Ignoring this may increase the passing of unacceptable products.

The IPC position on this matter is that the risk is reasonable, if you have methods in place verifying that the materials and components are acceptable. The goal of every solder process is to achieve target conditions. The advisor recommended that the disposition of the product associated with conditions identified in the images provided should be used as is. Attempts to rework these assemblies will create additional cost and unnecessary risk.

**If you have an electronics manufacturing problem, call the EMPF Helpline at (610) 362-1320.**

# American Competitiveness Institute - 2001 EMLC COURSES

## September

10th-11th	EMPF J-STD-001 Instructor Recertification
12th	IPC Challenge
13th-14th	IPC-A-610 Instructor Recertification
17th-21st	IPC J-STD-001 Instructor Certification
24th-28th	IPC-A-610 Instructor Certification
24th-28th	Electronics Manufacturing Boot Camp A

## October

1st-5th	Electronics Manufacturing Boot Camp B
8th-10th	Advanced Packaging Technique <span style="color: red; font-weight: bold;">New</span>
9th-11th	IPC-A-600 Instructor Certification
11th-12th	BGA: Manufacturing, Inspection & Rework <span style="color: red; font-weight: bold;">New</span>
15th-19th	IPC J-STD-001 Instructor Certification
22nd-26th	IPC-A-610 Instructor Certification
22nd-26th	SMT Manufacturing <span style="color: red; font-weight: bold;">New</span>
29th-Nov. 2nd	Surface Mount Soldering/Rework <span style="color: red; font-weight: bold;">New</span>

## November

5th-6th	EMPF J-STD-001 Instructor Recertification
7th	IPC Challenge
8th-9th	IPC-A-610 Instructor Recertification
15th-16th	BGA: Manufacturing, Inspection & Rework <span style="color: red; font-weight: bold;">New</span>

## December

3rd-7th	IPC J-STD-001 Instructor Certification
10th-14th	IPC-A-610 Instructor Certification

New = new dates added to the schedule

**For more information,  
please call the  
EMPF registrar at  
(610) 362-1295 or  
e-mail: registrar@empf.org**



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 increasing domestic productivity in electronics manufacturing.



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