empfasis

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American Competitiveness Institute

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American Competitiveness Institute
One International Plaza
Suite 600
Philadelphia, PA 19113
(610) 362-1200 • **FAX:** (610) 362-1290
HELPLINE: (610) 362-1320
WEBSITE: www.empf.org
www.aciusa.org

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.

EMPF Director
Michael D. Frederickson
mfrederickson@aciusa.org

In This Issue

Cold Plates for Thermal Management

As part of an Advanced Research and Development in Naval Integrated Power Systems (IPS) project, work is being done at the EMPF to determine the effectiveness of new thermal management technologies for use in high power naval applications, with the goal of validating these newer technologies using suitable demonstration vehicles. Implementation of these new thermal management methods on various power distribution systems for the DDG-1000 IPS platforms within the Integrated Fight Through Power (IFTP) systems will commence upon demonstrating the effectiveness of the newer technologies against the types currently employed. Three areas of technology are the broad focus of the overall program:

- Fiber Optic Sensors and Networks for Condition Based Maintenance (CBM)
- Wide Band Gap (WBG) High Power Semiconductor Technologies
- Advanced Heat Exchangers

The Cold Plates described here are part of the Advanced Heat Exchanger task, and deals with the new technologies of micro-channel cooling and foamed graphite.

Partnering with the Naval Surface Warfare Center Carderock Division (NSWCCD), in Philadelphia, Pennsylvania, the EMPF will ultimately demonstrate these advanced technologies at NSWCCD's Land Based Test Site (LBTS).

Advanced heat exchangers are needed to lower the operating junction temperature of the Insulated Gate Bipolar Transistors (IGBTs), as well as other thermally sensitive items used in U.S. Navy power systems. The temperature of these devices must be controlled so that their outputs, both steady state and short duration on-demand, are significantly improved over the existing design. Because of the higher power demands required by IFTP and IPS for the DDG-1000, better thermal interface materials, coolants, and high performance cold plate designs and technologies are proposed to achieve critical higher levels of heat removal.

Various kinds of Thermal Interface Materials (TIMs), Cold Plate designs (e.g. foamed graphite and micro-channel cooling), and coolants were researched and subsequently analyzed using the ALGOR® Thermal Analysis tool in order to narrow down the number of choices to the few that have the highest potential of success for this application.

Existing cold plate technologies utilize copper tubes swaged into an aluminum block.

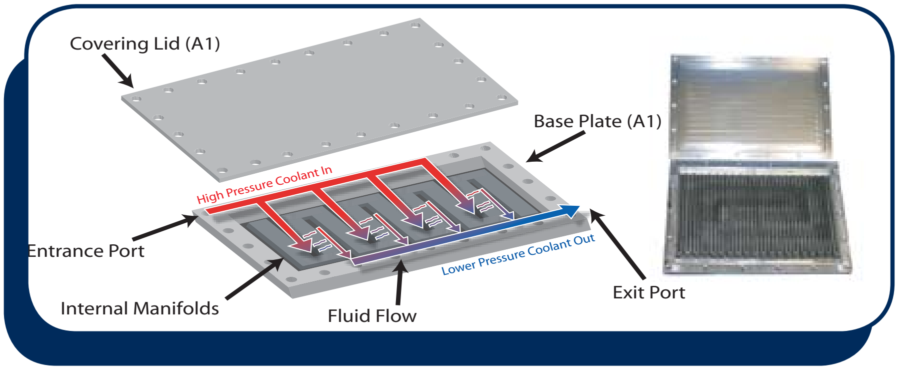

Figure 1-1-Foamed Graphic Cold Plate (Courtesy of Materials Resoures international (MRI)

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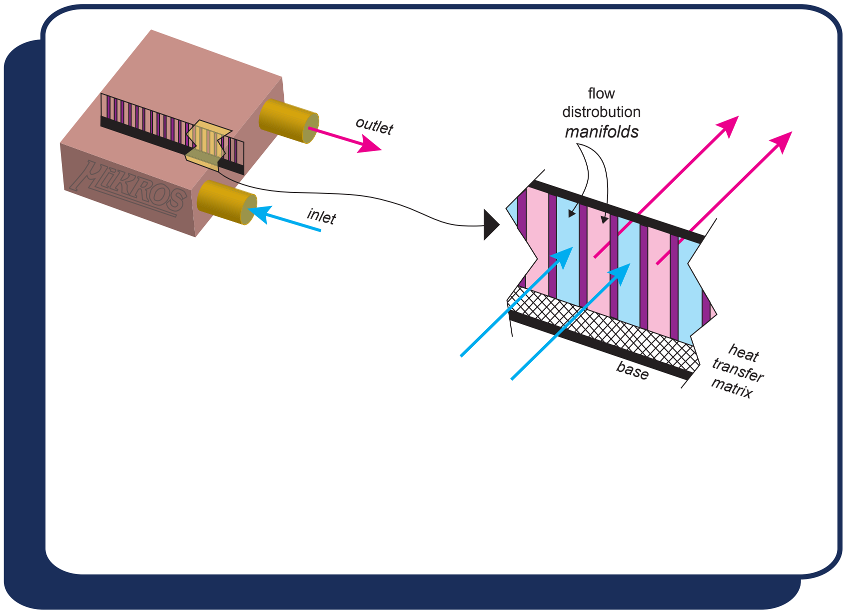
Cold Plates for Thermal Management

(Continued from page 1)

The newer cold plate designs may use one or more types of new technologies, such as foamed graphite and/or micro-channel cooling technologies. The foamed graphite cold plate is made by starting with a hollow aluminum block, brazing in a block of foamed graphite material, and then machining water channels into the foamed graphite, rather than the existing method that would have copper tubes swaged into a solid aluminum block. High pressure coolant enters the system, and filters through the foamed graphite channel walls toward the outlet fitting, where it will exit the system at a lower pressure, as depicted in *Figure 1-1*.



Because of the high thermal conductivity of the graphite and the immense surface area of the open cell structure of the foamed material, a very large volume of cooling water is exposed to the hot graphite foam. Since the foam is brazed directly to the aluminum block, and the block is in intimate contact with the hot electronics, this method of heat removal is rather effective.

The original concept for the novel Foamed Graphite Cold Plate was put forward by Material Resources International, which holds patents on the brazing of the foamed graphite to the aluminum to allow the fabrication. After successful Phase I SBIR (Small Business Innovative Research) work, MRI was invited to Phase II SBIR, and is partnering with the EMPF on the IPS application.

Another contender for high thermal management efficiency is the micro-channel cooling principle being applied by Mikros Technologies Inc. in another SBIR (Small Business Innovative Research) effort. EMPF will evaluate (side by side with the foamed graphite Cold Plate) a micro-channel cooled cold plate based on the Mikros principle. This principle employs a patented Normal Flow Cold Plate (NCP) arrangement that causes vertical (normal) flow of the coolant against the heat source. The normal flow results in a much lower pressure drop for a given flow rate and channel diameter than would occur in a standard parallel flow micro-channel cold plate system. In the standard system, the flow, parallel to the hot surface being cooled, results in long channels of small diameter having very high pressure drop. A schematic diagram of the NCP micro-channel principle appears in *Figure 1-2*. Because of the short micro-channel matrix that the coolant passes through, the pressure drop is low while the thermal resistance can be made very small.

Both of these vendors have tested their cold plate designs against conventional cold plates that are readily available in the industry. In both instances, the new technology plates have shown lower thermal resistances than the conventional ones. However, the test conditions for flow, pressure drop and thermal loading have been different in each case, making a full comparison. Carefully controlled tests reflective of the U.S. Navy's intended application for these technologies will be conducted.

The EMPF will conduct and test the new technology cold plates against the actual cold plate presently being used. Using flow rates, coolant temperatures, and pressure drops similar to those found in the actual application will be more accurate when validating cold plate performance.

Operating temperatures of IGBT's and other power electronics devices must be reduced to improve electrical performance for high power systems. Based upon technical discussions with the cold plate manufacturers, either of the Cold Plate concepts discussed in this article can potentially achieve this objective. A Design of Experiments is planned to test both prototypes using identical laboratory set-ups once prototype cold plates designed and built using these advanced concepts are obtained. The most robust, efficient, and cost effective technique will be chosen for this on-going project at the EMPF, with the goal of installation and further testing of the Cold Plate on the actual IPS equipment at the NSWC LBTS in Philadelphia, and ultimately onboard the DDG-1000.

Author of article: Fred Verdi - *Fred* is an Engineer at ACI. Comments or questions pertaining to this article can be sent to fverdi@aciusa.org

Electronics Manufacturing Boot Camp

With the rapid changes in technology, engineers and technicians face, keeping up with the latest process methods, packaging changes, business goals, time to market, scheduling, can become a daunting task. Manufacturing personnel, who have an understanding of the manufacturing process as a whole, can help to make a company more successful. This expertise is typically built over time and exposure to many different methodologies and disciplines. Very few colleges and universities provide actual "hands on" electronics manufacturing demonstrations and exercises as part of their curriculum. The inevitable learning curve for new engineers and technicians significantly lengthen the time before they can have a positive impact on the production process. The need for engineers and technicians to quickly develop a thorough understanding of the assembly process is critical to remaining competitive. Manufacturing personnel involved in the assembly process need to be able to hit the ground running, making a positive impact thus reducing the learning curve. The EMPF offers a course specifically designed for manufacturing personnel – Electronics Manufacturing Boot Camp.

Boot Camp is an intense two-week (80-hour) course held at the Electronics Manufacturing Productivity Facility (EMPF) in Philadelphia, PA. The course is structured to provide continuity between theory and application. Topics are first presented as a structured lecture in a classroom environment, followed immediately by hands-on training in the demonstration factory. Students gain knowledge and experience about electronics manufacturing through a balance of theory, lecture, and hands-on training.

The Boot Camp curriculum combines statistics, physics, metallurgy, electronics design, and materials science to provide a comprehensive understanding of the processes used to manufacture electronic devices. Participants learn how design choices may influence yields at the manufacturing level; how material and process input variables affect process outputs and interact with subsequent manufacturing processes; and how to design and monitor manufacturing processes. Not only will participants gain a thorough understanding of the science of the process involved, they will also have the opportunity to perform and "fine tune" the process, using our state-of-the-art demonstration factory. The ability to use the manufacturing equipment provides a unique opportunity to marry the theoretical with hands on application.

Participants perform each phase of electronics production under the supervision and guidance of our experienced instructors. All of our instructors encourage discussion and interaction to maximize the learning experience.

The modules included are:

1)Design for Manufacturability
2) Bare Board Fabrication
3) Component Identification
4) Design of Experiment
5) Reliability
6) Materials
7) Solder Paste Application
8) Dispensing
9) Component Insertion and Placement
10) Reflow and Thermal Profiling
11) Wave Soldering
12) Cleaning and Cleanliness Testing
13) Conformal Coating
14) Inspection
15) No Clean Processes
16) Hand Soldering and Rework
17) Statistical Process Control
18) ESD
19) Process Control Tools

Students will participate in the building of electronic assemblies. This will entail dispensing solder paste, printing, and using component placement equipment, along with thermal profiling, reflow, and wave soldering machines.

Who Should Attend?

BOOT CAMP is beneficial to many in the workforce. Design engineers, new hires, technical sales representatives, process engineers, and technicians can benefit greatly from the lessons taught. BOOT CAMP is designed to provide electronics manufacturing personnel with two weeks of intense, hands-on training in every aspect of electronics manufacturing. Upon successful completion, students are able to demonstrate a working knowledge of the electronics manufacturing process.

Author of article: Ivers Keller - *Ivers* is the Production Services Lead at ACI. Comments or questions pertaining to this article can be sent to ikeller@aciusa.org

Ask the EMPF Helpline!

A customer contacted the EMPF helpline in order to test the effect of a tin-lead (Sn-Pb) reflow profile on Pb-free BGAs

The EMPF Helpline fields a number of questions regarding the compatibility of lead-fee components with an existing tin-lead process. A customer contacted the EMPF helpline in order to test the effect of a tin-lead (Sn-Pb) reflow profile on Pb-free BGAs. The EMPF staff analyzed the BGAs and evaluated their structural integrity. The BGA solder joints were composed of tin, silver, and copper (SAC) alloys and were soldered using SN 63 solder paste.

The boards were soldered with a normal tin-lead profile where the peak reflow temperatures reached 220ºC.

Fig 1: Transmission X-ray images of SAC BGAs reflowed with Pb-free profile

Transmission X-ray analysis was conducted in order to determine the void density of the BGA solder joints. Void densities were measured against the IPC-A-610 Rev D standard that states void densities should not exceed 25% of the total solder ball area. A high density of voids was observed, as shown in the pictures below. However, none of the void densities exceeded 25%, indicating the Pb-free reflow profile did not create voids that interfere with the structural integrity of the BGAs.

The main concern when soldering with lead-free solder balls using a tin-lead profile and tin-lead solder paste is the compatibility of the two solder alloys. To investigate the solder alloys, the BGA solder joints were cross-sectioned and examined using polarized light microscopy. Of significant importance was the final microstructure of the SAC BGAs after soldering. The SAC solder has a melting temperature of 218 ºC as opposed to the tin-lead eutectic melting temperature of 181ºC.

AC solder typically does not melt when reflowed with the lower tin-lead profile. Investigation of the microstucture showed that the solder joint experienced partial reflow. The tin-lead solder paste melted and formed with the SAC solder ball. This created two very distinct regions within the solder ball. The solder balls maintained the original SAC solder microstructure near the interface of the solder ball and the component pad. However, a different microstructure was observed near the solder ball center and at the interface of the solder ball with the printed wiring board. There were clear indications of dendrites at the bottom half of the solder ball. These dendrites appear as dark regions in the optical image below. Much of the lead from the tin-lead paste is contained within the inter-dendritic regions. The non-mixing of the tin-lead paste and the SAC solder is a direct result of the low temperature reflow profile.

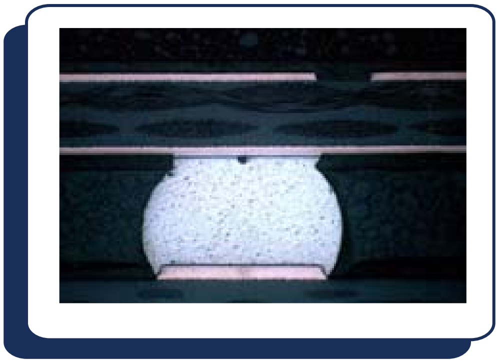
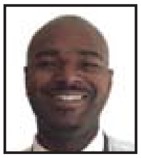


Fig 2: SAC BGA soldered with a tin-lead paste using a tin-lead profile.

Non-mixing in the solder balls degrades the structural integrity of the balls and increases the probability of cracks and failures. Thermal cycling of solder balls containing similar microstructures showed that these balls are 5 times more likely to fail than thoroughly mixed or conventional leaded solder balls.

Array components containing Pb-free solder alloy should not be reflowed using a Sn-Pb reflow profile. ACI made recommendations to the customer to utilize a reflow profile optimized for lead-free solder paste when soldering lead-free BGAs with tin-lead paste. The lead-free profile has a peak reflow temperature of 240 ºC or greater. These higher temperatures promote better mixing of the tin-lead paste and the SAC solder. A completely mixed SAC-tin-lead solder joint, like the one pictured above, is considered reliable.



Author of article: Blaine Partee - *Blaine* is an Engineer at ACI. Comments or questions pertaining to this article can be sent to bpartee@aciusa.org

Thermal Cycling Environmental Tests

One of the reliability concerns of microelectronic circuitry is the effect of temperature change on components that may occur during manufacture, storage or actual use. Since all materials expand and contract at different rates, their different Coefficients of Thermal Expansion (CTE) lead to mechanical stress on the circuit board. This can result in failures due to solder cracking or lead fracture. As seen in *Table 1*, the greatest difference in CTE of some typical circuit board materials is due to the low CTE of the silicon device.

Material	**CTE (ppm/ ºC)**
FR-4 laminate	18
Epoxy	20 - 65
Polyimide	16 - 60
Copper	18
Tin	23.5
Lead	29
63Sn37Pb solder	24.5
Silicon device	3

Table 1 CTE of Typical Circuit Board Materials

Thermal cycling is a test to determine the compatibility of electronic systems to the extremes of high and low temperatures relatively quickly. As components heat up and cool down they expand and contract causing fatigue or adhesion failure over time. Through repetitive cycling, the electronics are rapidly "aged" allowing the early discovery of material incompatibilities and/or potential failures in the field and the subsequent redesign of boards to provide high reliability.

Each temperature cycle consists of a low temperature soak, a transition to a high temperature, a high temperature soak, and then a return to the low temperature to repeat the cycle. This cycle is performed at temperatures and rates depending on the electronics under test and usually in accordance to a specified standard such as Mil-Std-883E 1010.8. EMPF has thermal chambers capable of a temperature range of -65 to 155ºC with a maximum ramp rate of approximately 10ºC/minute heating and 5ºC/minute cooling.

Thermal Shock is similar to Thermal Cycling but the transition time between temperature extremes is much shorter, as little as 5 seconds. This severe "shock" in temperature is achieved by rapidly moving the sample between two chambers filled with liquid or air held at the temperature extremes. The rapid temperature change can accelerate any inherent stress related problems on the board allowing early detection. EMPF can perform thermal shock in liquid from -75 to 160ºC per Mil-Std 883E 1011.9. Highly Accelerated Stress Testing (HAST) exposes circuitry to high temperature, high humidity, and high pressure simultaneously. This evaluates the reliability of devices by accelerating the penetration of moisture through protective materials and activating any corrosion mechanisms due to moisture. The HAST chamber at ACI has a maximum temperature of 143ºC, a relative humidity level controlled between 75% and 98%, and a pressure in the range of 0.02 to 0.2 MPa. ACI performs testing to JESD22-A110-B.

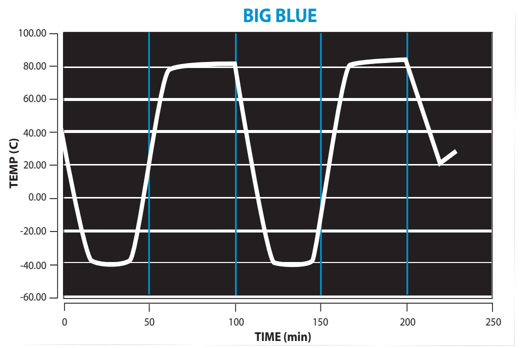


Figure 1 – Typical Thermal Cycling Profile (-40 ºC to +85 ºC)

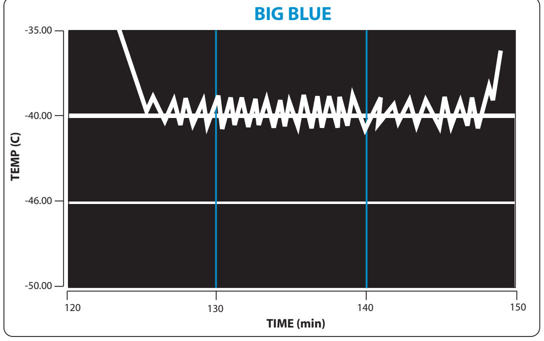


Figure 2 – Temperature control at the Low Soak Temperatures

Setup

Before testing, verification of chamber performance must be assured. Chamber size, sample size, and sample location within the chamber must all be considered during setup. Even with a circulation fan and microprocessor control, the temperature profile achieved is only highly accurate at the location of the manufacturer's thermocouples. The actual hardware under test or a sample of similar size and thermal mass should be monitored with a thermocouple. For example, the analysis of our large thermal cycling chamber using a small test circuit board showed this temperature profile of -40 ºC to +85 ºC (Figure 1).

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Thermal Analysis for High Power Naval Applications

Removing the heat quickly from the power electronics within Navy power systems, such as those planned for DDG-1000, enhances their performance. Reducing the junction temperature of semiconductor power electronic devices enables them to operate at higher electrical current flows. Lowering operating temperatures also reduces thermal stresses on the devices, which leads to improved efficiency and reduced failures. *SolidWorks Model of IGBTs, Face plate, and Current Cold Plate from which Algor FEA (Finite Element Analysis) thermal management simulations can be constructed* ALGOR based model, using dimensional information from SolidWorks *(see Figure 1-1)*, forms the basis for further advanced analysis. These analytical software tools enable high-level thermal modeling of some of the many possible thermal management solutions. The existing design uses Thermal Interface Materials (TIM) between the IGBT package and the Face plate and between the Face plate and the Cold Plate. The Face plate serves as a heat spreader, and the Cold Plate removes heat away from the entire assembly. The exploded view of the entire package appears in *Figure 1-3* . The model shows the mating of the various heat conducting elements responsible for conducting heat away from the IGBT heat source. To simplify this analysis, heat removal due to convection is neglected since it is small in comparison to heat removal due to conduction.

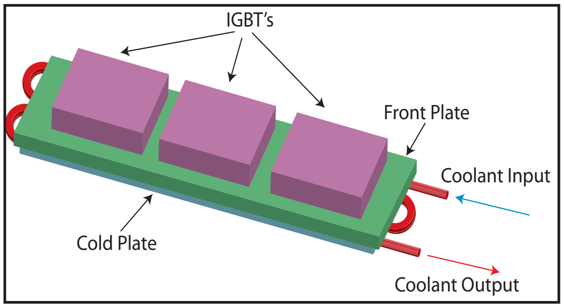

Figure 1-1. Face plate/Cold Plate Assembly

Since it is cost prohibitive and time consuming to laboratory test all possible combinations and parameters for all configurations of TIMs, coolants and cold plate designs, Algor Thermal Analysis is used as a filtering tool to reduce the number of possible solutions to a selected few by performing "what if" analyses. Once

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Thermal Cycling Environmental Tests
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The temperature in the chamber was controlled within a narrow range by cycling the heating and cooling equipment on and off. This produced the temperature oscillations at the sample thermocouple as shown in *Figure 2*. This is well within the typical 10 ºC spread allowed by the MIL-STD for thermal cycling.

Analysis

After the final cycle, the samples are typically examined under 10X to 20X magnification or higher to observe any mechanical failures. *Figure 3* shows a crack at the solder joint in a Ball Grid Array solder ball after thermal cycling. The thermal cycles caused the solder joints of the BGA to expand and contract, continually stressing the joint until failure occurs seen typically as cracks in the solder connection. Electrical testing can also be performed to determine any performance change or electrical change in resistivity across the junction.

Conclusion

Thermal testing is a critical tool to certify the reliability of electronic circuitry. By carefully selecting thermal cycle parameters according to the potential use conditions, ACI can accelerate the testing and analysis of components to ensure a reliable product.

Author of article: Paul Bratt - *Paul* is an Engineer at ACI. Comments or questions pertaining to this article can be sent to pbratt@aciusa.org

Thermal Analysis for High Power Naval Applications
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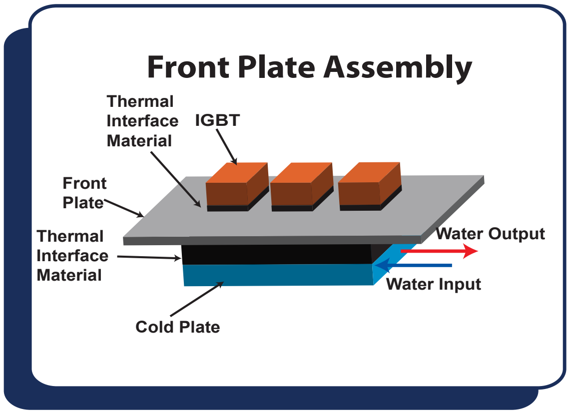

Figure 1-2 ALGOR thermal modeling results for 18 cases of current cold plate design using various soft metal and thermal grease TIMs, with various coolant media, in the current cold plate design of Figure 1-1

the screening is completed, only those solutions with high probability of success can be analyzed using a more elaborate FEA modeling. The prime thermal management candidates identified through the FEA modeling are tested and evaluated in the EMPF laboratory.

For developing any FEA model, first a 3D solid model of the existing mechanical design needs to be created using any available CAD (Computer Aided Design) software. In this case, SolidWorks 2006 software was used to create the 3D Solid Model as shown in Figure1-2. The Solid Model consists of the four main elements, namely IGBTs, TIMs between the two sets of interfaces, face plate and the cold plate. This solid model is used as an input to the first step of the FEA model in creating a nodal mesh network. Algor FEA software uses the physical dimensions from the 3D SolidWorks Model as input to generate a mesh network using a proprietary algorithm. Once the mesh network is generated, the boundary conditions are applied.

Thermal analysis needs the velocity profile of the coolant running through the cold plate copper tubes. These velocity profiles are computed using the CFD (Computational Fluid Dynamic) simulation part of the Algor software. Once the velocity profiles are generated, the data is used as an input to the thermal analysis model.

The water coolant velocity profile, along with many other properties of the IGBTs, face plate, cold plate, and TIMs, such as specific heat, mass density, thermal conductivity, and others are used by the ALGOR thermal model to calculate the 3D temperature profile. The input to the thermal analysis is simulated as a heat flux imposed on the top surface of the face plate with uniform density.

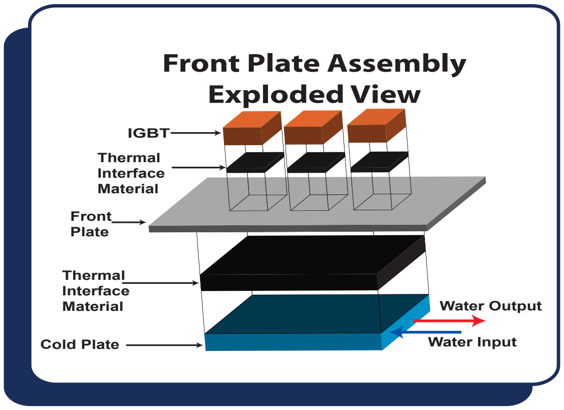

Figure 1-3 Front Plate Assembly Exploded View

Figure 4-3 shows the ALGOR output temperature profile of the face plate surface to which the IGBTs are attached. This particular Algor model shown is one of the many possible "what if" scenarios, using water as coolant and aluminum as the TIM. This temperature distribution on the Face plate is a good representation of the critical temperature distribution on the IGBT surface since the two are in intimate contact. These results allow the EMPF to construct the laboratory experiments that will validate cold plate performance.

Figure 4-3. Typical temperature map result of thermal modeling using the Algor and Solid Works software in the case of the current cold plate design using water coolant and aluminum TIM (Thermal Interface Material) to thermally manage the three-IGBT assembly shown in Figure 1-2. Examples of the maximum temperatures in the hottest spots of the plate in multiple "what if" scenarios using this design are shown in Figure 1-4.

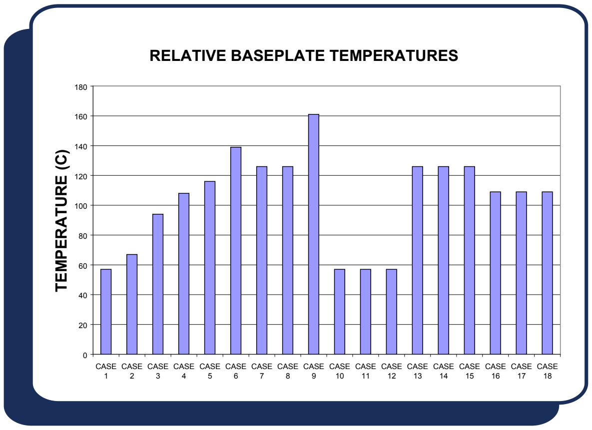

Table 4-1

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Thermal Analysis for High Power Naval Applications

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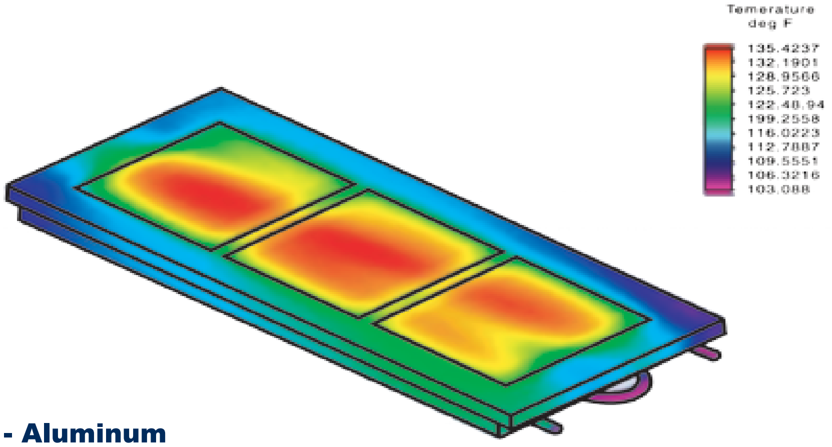


CASE 1: Water - Aluminum

Figure 4-3 Typical temperature map result of thermal modeling the ALGOR and Solid Works software in the case of the current cold plate design using water coolant and aluminum TIM (Thermal Interface Material) to thermally manage the three-IGBT assembly shown in Figure 4-3

FEA Model	Coolant	Thermal Interface Material
Case 1	Water	Aluminum
Case 2	Water	Arctic Silver
Case 3	Water	Dow Corning TP-1500
Case 4	Dynalene HC-30	Aluminum
Case 5	Dynalene HC-30	Arctic Silver
Case 6	Dynalene HC-30	Dow Corning TP- 1500
Case 7	Propylene Glycol	Aluminum
Case 8	Propylene Glycol	Arctic Silver
Case 9	Propylene Glycol	Dow Corning TP-1500
Case 10	Water	Copper
Case 11	Water	Indium
Case 12	Water	Lead
Case 13	Propylene Glycol	Copper
Case 14	Propylene Glycol	Indium
Case 15	Propylene Glycol	Lead
Case 16	Dynalene HC-30	Copper
Case 17	Dynalene HC-30	Indium
Case 18	Dynalene HC-30	Lead

From these lowest temperature arrangements (Cases 1, 10, 11, and 12), the best one can then be selected from the results of detailed laboratory DOE (Design of Experiments) testing.

These lowest maximum temperature scenarios all include water as the preferred coolant, and use various soft metal TIMs which prove superior to existing designs using thermal grease as the TIM. The new coolants, while having larger operating ranges between freezing and boiling points, do not exceed the thermal management capabilities of water for this application. The soft metal TIMs, however, exceed the capabilities of the standard thermal greases used presently.

PCMA (Phase Change Metal Alloy) and soft metal foil TIMs, in combination with cold plate designs using various new technologies such as foamed graphite and micro-channel cooling, and the new liquid coolant media, will then be modeled in the same fashion. Solutions that show a high degree of potential for improving the thermal performance of the existing design go to the EMPF laboratory for detailed testing in the subsequent part of this task.

Thermal modeling, directed by the EMPF using either Algor tools or more sophisticated programs available through the EMPF IAB (Industrial Advisory Board) partnerships, has proven to be a useful tool in power electronics thermal management design. By utilizing these tools, the EMPF will screen the new thermal management technologies for DD(X) power electronics.

Author of article: Fred Verdi - *Fred* is an Engineer at ACI. Comments or questions pertaining to this article can be sent to fverdi@aciusa.org

Tech Tips...

Thermal Interfaces and Materials

cut here and save!

Most electronic devices function more reliably at lower temperatures. However, as electronics develop smaller footprints and are packed closer together, higher heat densities will inevitably lead to elevated operating temperatures. Several issues are associated with higher operating temperatures. For example, the service life of the device or module is significantly decreased. Device interconnects and other components are more likely to experience fatigue from thermal stress. When accompanied by moisture, high temperatures can spur whisker or dendrite growth within a device. Whiskers and dendrites may form conducing lines that create shorts and eventually cause device failure. Thermal interface materials (TIMs) can help avoid failures associated with elevated device operating temperatures. Several options must be considered when choosing the best TIMs for a specific application.

Tip 1: Know the TIM properties.

When choosing a TIM for heat dissipation, one tendency is to select the material displaying the highest bulk conductivity. When considering bulk conductivities of different TIMs, note that the reported value applies only for the specific test method and test conditions employed to obtain that number. Therefore, similar test methods must be used for valid comparisons. Bulk conductivity is not the only property by which to choose a TIM. The heat removal capacity of a TIM is also determined by the TIM's ability to create an intimate contact with the relevant surface. As a result, the contact resistance is an important property to note.

Thermal resistance is another property to consider. Thermal resistance is measured by the temperature difference across the interface of a material per watt of energy moving across the said interface. Some data sheets may provide the thermal impedance, which is the thermal resistance normalized by a unit of area. Heat flows best across TIMs that have low thermal resistance.

Tip 2: Know the TIM test standards and caveats associated with these standards.

Most TIM data sheets will report the common industry or military standards to which the materials should comply, including ASTM D5470-01 and MIL-I-49456A. Unfortunately, many manufacturers are unaware of the challenges associated with building reliable test equipment. In fact, independent surveys have shown that repeatability errors within a given lab lie between 10% and 20%. As much as 40% error exists when comparing reproducibility between different labs. Because data reproducibility depends heavily on test equipment, TIM purchasers should conduct independent tests to ensure that materials comply with the given standards.

Figure 5-1 Form in place Gap Fillers

Tip 3: Know the common TIM options.

There are several different types of TIMs, each containing different advantages. Wet dispensed TIMs may be more appropriate for some applications, while pad or film TIMs may be better for others. Wet dispensed TIMs include adhesives, encapsulants, gels, and non-curing compounds. Adhesives may eliminate the need for mechanical connectors and create intimate surface contact, resulting in low contact resistance. Encapsulants can take on any thickness and offer higher mechanical strength than other wet dispensed TIMs. Gels provide stress relief and are therefore useful when protecting fragile components.

Other TIM categories include pads, gap fillers, and phase change materials. Pads are applied without dispensing or curing and therefore can be easily reworked. Gap fillers readily accommodate irregular surfaces with minimal pressure. Phase change materials have low thermal resistance, require low mounting force, and can accommodate irregular surfaces as well.

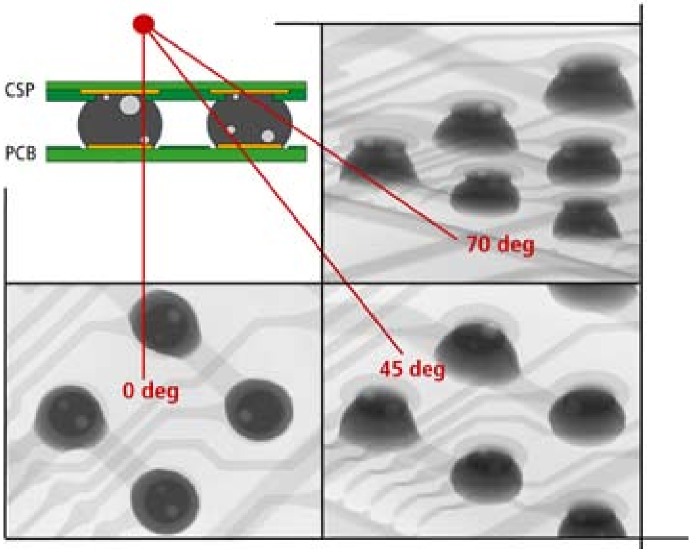
Tip 4: Know the specialty TIM options

Some applications have unique demands and hence require specialized TIMs. Some specialty options include flame resistant materials, controlled bond-line thickness materials, and controlled volatility materials. Flame resistant TIMs contain UL 94V or HB flammability classifications. Controlled bond-line thickness TIMs help avoid component misalignment in applications containing tight alignment specifications. Controlled volatility materials circumvent challenges associated with low molecular weight volatiles that may seep from TIMs and negatively affect a device in the future.

Author of article: Joyelle Harris - *Joyelle* is an Engineer at ACI. Comments or questions pertaining to this article can be sent to
jharris@aciusa.org

Manufacturer’s Corner: Phoenix 3-D X-ray Tomography System

The selection and acquisition of an X-ray inspection system requires an extensive amount of product research. Each system has ‘value’ within a defined application, ranging from a basic system requiring extensive operator intervention and interpretation of results, to a fully automated system or systems installed in a tier-one electronic manufacturing production line requiring minimal operator support. X-ray inspection confirms that the soldering process was properly executed during assembly. It is used to find solder bridges (shorts), missing or undersized solder joints (voids), misalignments, and open solder joints. To perform these diagnostic tests, the general setup of a microfocus or nanofocus® system should include a manipulation or sample table and an image collection device such as an image intensifier or digital detector. The sample table (platform)’s platform design and construction must avoid or dampen vibration to eliminate diminished image sharpness and should enable sample positioning at micrometer precision. Systems under evaluation must be configured to limit the radiation exposure and not damage sensitive ICs. Operating systems capable of providing low-dose emission options to reduce the accumulated exposure to the components are of extreme value.The most salient difference in X-ray inspection systems, however, is in the inspection methodology they employ.



Phoenix 3-D X-ray Tomography System

Customers have a choice of both 2-D imaging systems, in which the system inspects the target board from a fixed, top-down view, 2-D with Oblique View with Highest Magnification (OVHM), in which an open tube source provides a wider irradiation angle of the board, and 3-D imaging systems, in which the X-ray source and detector move and capture multiple images that are then compiled to create the 3-D image. Both types of systems use similar image and board rotation, providing oblique views of voids and other misshapen solder balls. 3-D magnification, however, is limited to 2 to 10X, whereas the top-down alignment employed by 2-D systems allows for magnification in the 200 to 400X range.

In addition to the dimensional capabilities of an X-ray inspection system’s imaging system, current technology includes digital detectors, which utilize Complementary Metal-Oxide Semiconductors to provide better, less distorted images with far superior contrast resolutions. This capability is especially valuable for imaging low contrast objects, such as those encountered in adhesives inspection. Digital detectors are especially valuable in conducting lead-free analysis, due to their ability to image contrasts between lead-free and eutectic tin-lead solders.

Because of the great differential in magnification capability, 2-D imaging systems are sufficient for most types of X-ray inspection. There are exceptions, however. For instance, the

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inspection of two-sided boards, the configuration of which demand multiple imaging rather then the fixed, top-down image capturing capability of 2-D imaging, requires 3-D imaging. Similarly, open solder joints normally require 3-D (or 2-D with OVHM) imaging to locate gaps in the solder joint and identify irregular solder mass shapes produced by insufficient wetting of the pad. Finally, to accurately inspect smaller solder joints, such as those found in Fine Ball Grid Arrays (FBGAs), µBGA$^{®a}$, CSPs, and Flip Chips, the sample table must be tilted. To avoid false positives due to the drop in magnification and long distances separating the solder joints from the X-ray source as the platform tilts, 3-D and 2-D with OVHM imaging systems should be used.

Phoenix X-Ray Systems has recently installed a 3-D X-ray Tomography System at the American Competitiveness Institute. The system provides dedicated reconstruction and imaging processing software for small samples down to approximately 100 mm in diameter. Other system features include image resolution down to 1 µm voxel, (short for Volume Pixel, the smallest distinguishable box-shaped part of a 3-dimensional image) 100-fold maximum magnification, precise dimensional measurements of samples, and 3-D visualization in sectional cuts and slices. In addition, system can be run in 2D mode without modification and provides fast and accurate data acquisition.

For additional information, or to arrange for a demonstration of the Phoenix 3-D X-ray Tomography System located at ACI, please contact Bob Berta at 610-362-1200 ext 253 or via e-mail at rberta@aciusa.org.

Author of article: Robert Berta - *Robert* is the Business Development Representative at ACI. Comments or questions pertaining to this article can be sent to rberta@aciusa.org

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WEBSITE: www.empf.org
HELPLINE: (610) 362-1320
(610) 362-1200 • **FAX:** (610) 362-1293
Philadelphia, PA 19113
Suite 600
One International Plaza
American Competitiveness Institute