Laser Seam Sealing of Electronic and Opto-electronic Packages White Paper

A welder's tips for getting beyond 99 percent yield

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LASER SEAM SEALING OF ELECTRONIC AND OPTO-ELECTRONIC PACKAGES

Seam sealing is the process that permanently bonds the package and lid of a device, providing a barrier for the internal components for the device's operational lifetime. This is typically the last critical step in the package manufacturing process, so it is among the most important. The completed product performs a vital function and has a high dollar value, so creating a barrier to contamination ingress is essential. The stakes are high – optoelectronic packages for fiber optic cables transmitting signals sometimes in the middle of the ocean must last for a very long time since replacement is difficult and costly. Similarly, aerospace RF/microwave packages perform essential functions, making it imperative to prevent external environmental conditions from penetrating the package, even in extremely aggressive environments.

Controlling the component manufacturing process and aligning the device components to make them "laser welding friendly" will allow manufacturers to achieve process yields in excess of 99 percent. Careful attention must be paid to four key factors – proper material choice, part plating, joint geometry, and tolerances. In addition, an understanding of the role of thermal input will also be essential.

LASER SEAM SEALING BASICS – FOCUSING ON PREVENTING LEAKAGE

Seam sealing means bonding a lid to a package base to create a barrier to contamination ingress. It can be done using either laser or resistance welding. Resistance welding has been and continues to provide a solution for many seam sealing applications. Interest and usage of laser welding is increasing, as it offers some unique processing capabilities, primarily a great deal of flexibility in terms of joint geometries, package design and size, and heat input control. It also allows the welding of aluminum, which is widely used for aerospace packages and cannot be done by resistance welding. Laser equipment also facilitates equipment multi-tasking, since the laser can be used for both seam sealing and welding of internal components.

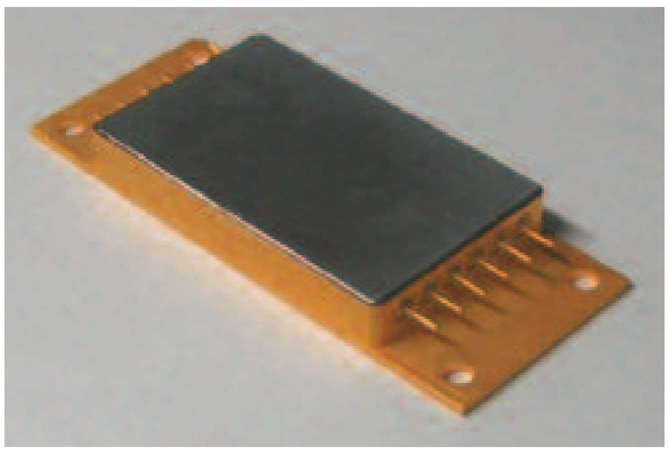


Figure 1 – Laser seam sealed electronic package

Leaks that result from poor seam sealing or micro-cracks may allow moisture and contaminants to enter the package. These may compromise the operation of the internal components either directly or by internal pressure variation caused through temperature cycling of components during operation.

In addition to laser hermetic seam sealing, RF/microwave packages also need to prevent signal spill over an adjacent part of the package. Placing a number of spot welds spaced every 1 mm (0.04 in) contains the signal within the device compartment, ensuring correct functionality of all parts of the device.

Recognizing the precept that “everything leaks”, seam sealing is done to a particular leak test MIL/IEC standard or for fitness for purpose, defined as its hermeticity, or rate of leakage. The size of a leak is measured and defined by the volume of helium in cubic centimeters (cc) that would pass through the leak each second with a pressure difference of 1 atmosphere (atm-cc/sec). A typical specification is 5 x 10-9 atm-cc/sec, which roughly equates to about 1 cc of leakage every 6.34 years.

FOUR KEY FACTORS TO CONTROL

Material choice and part preparation

Material choice is essential to getting the best possible seam seal. For optoelectronics packages, the core weldable materials are Kovar and Invar (known for their thermal expansion properties) and 304L stainless steel, a low carbon material used in heavy gauge components for improved weldability. For aerospace packages, advanced aluminum-silicon (Al-Si) alloys offer significant weight savings. When using aluminum, manufacturers must be sure to use the correct alloy for each part of the package. For example, aluminum 6061 has good formability properties, but 6061 cannot be welded to itself, so aluminum 4047 may be used for the lid. This material has more silicon, which makes the weld possible.

Once the material is selected and qualified from one vendor, manufacturers should continue to use only that particular vendor. Experience has shown that some material may nominally meet the material specification, while including filler or trace substances that can have a detrimental effect on the weld. Vendor changes can lead to weld quality deterioration; a classic problem found in aluminum and some stainless steel is a crack running down the middle of the weld after a material vendor is changed.

The key message is that it is truly “penny wise and pound foolish” to attempt to save money on a completed device worth from $5,000 to $50,000 by going with an unknown vendor whose material has not been properly qualified. If the weld is unsuccessful or does not hold, manufacturers may have to mechanically remove the lid and risk the possibility of damaging the part. Even if one is able to remove the lid and re-seal the package, this process would not be conducive to the part remaining pristine and functioning as specified.

High yield welding depends upon the absolute absence of contaminants, oil, or grease in the area of the weld. Cleanliness is essential for some of the more difficult welds to be made, so before welding, the parts should be prepared by cleaning and degreasing. For Kovar, Invar, and stainless steel, material cleaning requirements include ultrasonic cleaning, ethanol, and de-ionized water. Aluminum is extremely reactive to oxygen, so a layer of aluminum oxide will remain no matter how well the surfaces have been cleaned; this layer can have a negative effect on aluminum welding. Therefore, in addition to ultrasonic cleaning, ethanol and de-ionized water, the recommended route for successful aluminum welding also includes a wire brush cleaning immediately prior to welding.

Base and lid plating

Plating means depositing a thin surface on a base material, usually to provide corrosion protection. Many manufacturers will obtain base material from one vendor, machine it, and then send the base to a plating house, which plates it according to requirements. The package housing is then sent back to the manufacturer, who will then populate it with components. Then the lid is sealed to the top of the base.

Base and lid plating before seam sealing is usually done with nickel only or nickel/gold and must be done using electrolytic plating. This is a galvanic process that involves immersing the part into an electrolyte containing one or more dissolved metal salts as well as other ions that permit the flow of electricity. The part to be plated is the cathode of the circuit and the anode is the metal to be plated on the part.

Plating is done first with nickel, and then overlaid with gold. Thin layers are extremely important in the laser welding process; the nickel should be from 5 to 8 micrometers (200-320 micro in) and the gold plating must be controlled to < 0.75 micrometers (30 micro in) per surface. Apart from the sheer expense associated with gold plating, if the gold is too thick, there can be cracking in the weld.

Similar to the earlier discussion on material choice, it is very important to select and qualify a plating vendor source and then stay with that vendor. There is somewhat of a tendency to apply plating layers on too thickly, especially if the vendor is migrating from resistance to laser welding. Be sure plating thickness is reduced to the required level, specifically for gold.

When welding Kovar or Invar, there should ideally be no plating in the weld area, although a small amount of nickel and gold is acceptable. When welding aluminum, there must be absolutely no plating in the weld area. The plating house should mask the part so plating does not occur in the weld zone. Alternatively, they may machine the surface down to the base.

Joint geometry to achieve best lid/base weld

Three joint types are commonly used for laser welding: butt, fillet, and lap, shown on **Figure 2**.

Figure 2 – Joint types for laser welding

Three joint types are commonly used for laser welding: butt, fillet, and lap, shown on **Figure 2**. From a purely welding perspective, there are preferred geometries for package welding based upon the thickness of the lid and simplification of the laser alignment to the weld seam and part clamping. **Table 1** provides an overview of package geometry to welding parameters.

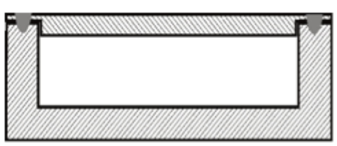
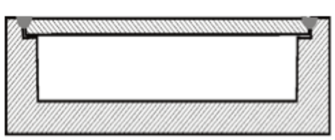
Weld geometry	Maximum lid thickness at weld interface	Laser alignment tolerance to joint line	Motion – minimum number of axes
LAP 	0.02 in	± 0.008 in	2 axes
FILLET 	0.02 in	± 0.003 in	2 axes
SIDE BUTT 	Unlimited	± 0.003 in	3 axes
RECESSED BUTT 	Unlimited	± 0.002 in	2 axes

Table 1 – Package geometry related to welding parameters

Lap weld geometry is typically used for packages with a maximum lid thickness of about 0.02-inches (0.5 mm) for ferrous materials and 0.25mm (0.01-inches) for aluminum. The lap joint provides the simplest method, requiring only a 2-axes motion and minimal joint alignment. This makes a better and cheaper weld because the weld is more stable and easier to accomplish. The slight compromise is that the laser must penetrate the thickness of the lid to make the weld. If the main part of the lid is thicker than 0.25 / 0.5 mm (0.01 / 0.02 in) it can be machined down near the area of the weld to achieve a step down to the correct thickness.

Fillet welds are used for packages with a maximum lid thickness of about 0.02 in (0.5 mm). The fillet weld is welded with a straight down weld head so only 2-axes motion is needed. However, in contrast to the lap weld the laser must closely follow the joint line otherwise incomplete weld fusion will occur.

A side butt weld is a simple flat lid that can be used no matter the thickness of the lid. It requires a 3-axes motion and good joint line following. The weld is made using the laser beam horizontally using gravity to aid with part tooling and load/unload. Note that the butt geometry is the most efficient in terms of power as the laser penetrates directly down the interface line between the lid and base.

Recessed butt welds require complex part machining with base and lid fit tolerance of less than 0.002 in. It requires a 2-axes motion and good joint line following.

Weld gap tolerance

The key tolerance for laser welding is the gap between the weld faces. Essentially for all four weld geometries, the maximum allowable gap between the weld faces is 0.002 in (50 microns). It is also worth noting that complying with these tolerances is a simple tooling proposition for all joints except the recess butt, which requires not only that the laser closely tracks the joint line but that the lid is machined to fit into the recess with less than 50 microns gap (0.002 in).

THERMAL INPUT

In addition to the key factors listed, sometimes heat input can be an issue, especially for small packages or for larger packages where there is concern about distortion. Laser welding is a low heat input process and one can precisely control the laser power input to minimize heat input. As important to the laser parameters is maintaining consistent heat input throughout the entire length of the weld that includes both straights and 90 degree corners while optimizing process speed. This is achieved with fully integrated motion and laser control software that makes the suitable adjustments based on speed and acceleration/deceleration profiles. If the package is sensitive to temperature or high power input is required for increased welding speed, conformal tooling known as chill plates can be used. These plates, made of copper (sometimes water-cooled), draw heat from the weld to maximize power and welding speed without overheating or damaging components.

Some package bases have a metal top section bonded to alumina, in which case a certain thickness of metal is needed to prevent the alumina from cracking or the alumina/metal bond from being compromised. A metal thickness of at least 0.06 in (1.5mm) is recommended to prevent overheating the alumina.

LASER WELDING SYSTEM COMPONENTS – HOW TO CONFIGURE A DEVICE FOR 99+ PERCENT YIELD

Configuring the right laser welding system is important to seam sealing success. **Figure 3** illustrates the elements of a laser welding system, which include the laser, beam delivery, the focusing head, the process, glovebox enclosure, and tooling, with a fully integrated laser, motion, and environment software package. Each part is of equal importance in successful welding.

Figure 3 – Example of a laser seam sealing system

In summary, manufacturers who want to ensure hermetic seam sealing in even the most aggressive environments should control their manufacturing processes by selecting material carefully, following plating guidelines, choosing quality vendors (and staying with them once qualified), and selecting joint geometry that works best for the particular application. **Table 2** summarizes the elements needed to achieve the highest possible yield.

Parameter	Recommendation
Materials	304L stainless steel, Kovar, Invar, aluminum (6061+4047)
Plating	Electrolytic No gold at joint No plating at all for aluminum
Material and plating vendor	Quality / consistent
Joint geometry	Lap, side butt, fillet, recessed butt
Interface gap	Gap < 0.002 in

Table 2 – Package design for 99+% yield

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