Issue 05 | January 2022

Hot Application
Laser Welding Aluminum Packages

THIS ISSUE
LASER WELDING ALUMINUM PACKAGES

The Challenge

- Manufacturers in the battery, aerospace, and communications industries are tasked with making reliable, hermetically sealed packages to protect the sensitive electronics contained within. Packages should be lightweight, thermally and electrically conductive, non-magnetic and with a glossy finish. To achieve this, manufacturers are turning to aluminum. But aluminum is notoriously difficult to weld, posing manufacturing challenges.

Solution:

Laser welding with a high power, single mode fiber or Nd:YAG laser are the best options due to its speed and low heat affected zone. Parts should be designed with a recessed butt joint for accessibility, repeatability and automation. Consider welding in an inert environment to keep moisture, oxygen and other contaminants outside the package.

Why Aluminum?

Aluminum – whether used for prismatic battery cans, super capacitors, or microelectronic devices including RF and microwave housings – is commonly selected due to its relatively low cost, thermal and electrical conductivity, attractive finish, light weight and limited susceptibility to corrosion. But the very qualities that make aluminum desirable, can also make it difficult to work with.

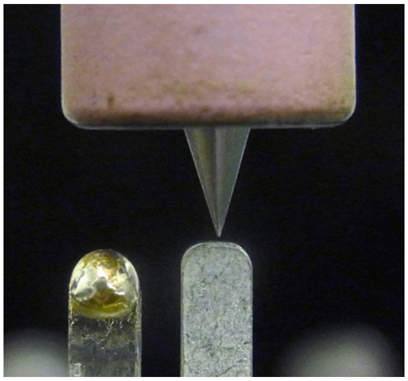
Material Challenges

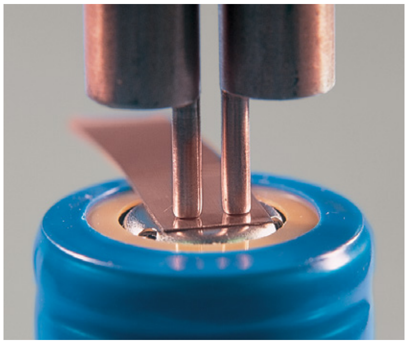
The following properties pose challenges when welding aluminum:

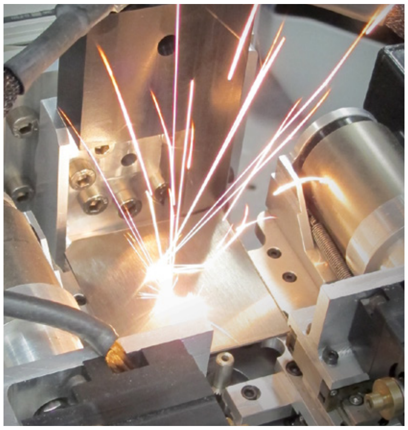
- Low melting point
- High thermal conductivity
- Susceptibility to impurities in its molten state
- Naturally occurring oxide layer

The greatest of these challenges is aluminum's low melting point (660° C / 1220° F) which results in a very small welding window and, in its molten state, susceptibility to impurities that result in weak, porous welds. Adding to the challenge, is aluminum's great affinity for oxygen, and its tough, naturally occurring oxide layer which possesses a significantly higher melting point (2072° C / 3762° F). Without additional processing, very high energy is required to burn off this layer, but that same energy in contact with the lower melting point aluminum base causes metal expulsion / spatter.

In order to overcome this challenge, the oxide layer must be cleaned from the metal before welding and processed before the oxide layer reforms. Learn more about laser cleaning here.







Welding Aluminum: Comparing Technologies

Manufacturers have a number of technology choices for welding aluminum, each with its own set of challenges. Lets look at a comparison of the three most commonly used technologies:

Technology	Challenges
Micro TIG Welding	• Aluminum oxide layer makes it difficult to control the weld process with DC controls; pulse width of AC controls is generally too wide for micro-welding applications • Creates excess heat that may damage delicate internal components • Porosity and cracking are an issue
Resistance Welding	• Aluminum's high thermal and electrical conductivity, makes it difficult to focus the energy in the desired weld area • Aluminum is soft; electrodes may stick • Porosity and cracking are an issue
Laser Welding	• Aluminum's reflective properties mean that high power, and small spot size or short pulse duration are required in order to couple the energy into the material • Burn-through can be an issue • Porosity and cracking are an issue

While all three technologies present challenges, laser welding is the best choice for welding aluminum housing packages because it generates the smallest heat affected zone, protecting the sensitive contents of the package. Although there are still some welding challenges, these have known solutions.

Tips and Tricks for Successful Laser Welding of Aluminum:

1. Because it is more prone to impurities which can lead to weak, porous welds, aluminum must be thoroughly cleaned to remove oil, grease, fingerprints and other surface contaminants.
2. Remove surface oxide using a brush, acid or laser
3. Assemble the parts quickly to avoid further contamination
4. Keep dry and at room temperature. If not welded within a few days, repeat cleaning process
5. Select aluminum alloys that are known weldable combinations

Laser Welding Aluminum Solutions

Selection of the best laser solution for your specific aluminum package welding application is dependent on many factors including part design, factory floor space, budget and more. Laser engine options include Pulsed Nd:YAG, CW fiber laser, and QCW fiber lasers. Each of these will be paired with a focus head to deliver the energy to the part.

- **Pulsed Nd:YAG** is the most traditional laser source for aluminum welding and is still preferred for several more complex geometrical welds, where stage motion limits speed in corner areas. Its larger spot sizes help accommodate for fit-up tolerances providing a fairly robust weld for production. This laser choice is most commonly configured with a fixed focus head.
- **CW fiber lasers** are becoming more popular due to low consumable nature and faster weld speeds. The limiting factor is its small beam diameter. This laser is typically mated with either a wobble head or a galvo beam delivery system that can oscillate the beam, thereby increasing the melt pool and overcoming component manufacturing tolerances (gap between parts). This laser is best for welding from the top of the package where the geometry is 1D or 2D.
- **QCW fiber lasers** provide a solution somewhere between Pulsed Nd:YAG and CW fiber lasers. In pulsed mode, these lasers behave similarly to the Pulsed Nd:YAG laser. Pulsing can be controlled to limit heat input to the part. However, these typically have small spot sizes which can make it difficult to bridge gaps between parts, thus component manufacturing tolerances need to be tighter. For pulsed mode, it is common to combine with a fixed focus head. One difference between pulsed Nd:YAG and QCW is that the QCW can pulse at much higher repetition rates when the process requires. This can reduce manufacturing time.

Package Design for Successful Laser Welding

Three basic joint types commonly used for laser welding are butt, fillet, and lap. We recommend butt welding configuration, if possible, to achieve the very best hermeticity and the greatest strength per watt of laser power as the laser penetrates directly down the interface line between the two parts. The figure below shows weld penetration for the three basic weld geometries. The strength of the weld is found along the yellow line.

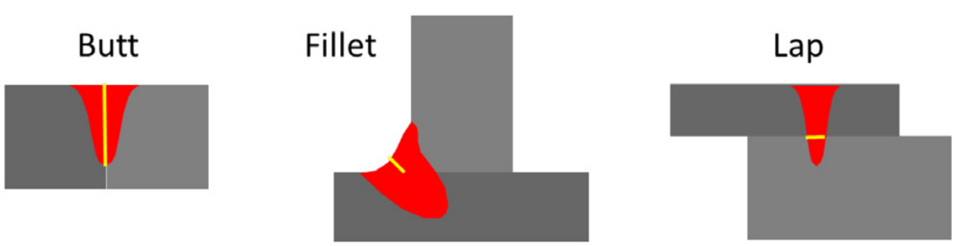


Fig.1 - Three basic joint configurations in laser welding. The red area indicates laser melt pool and the yellow bar indicates the relation of weld strength.

Package Geometry Related to Welding Parameters

The table at the right shows four common package design geometries. Of the four, the recessed butt joint weld is preferred for welding aluminum packages because of the following advantages:

- Easy, repeatable positioning of lid
- Beam access from top, limiting the number of degrees of motion
- Easier to automate, with potential for multiple up configuration

Potential risk for weld spatter onto the package and the draw process to form the packages can create tolerance issues. These can be overcome by proper laser settings in combination with a vision motion system to identify the seam and create a weld along that axis.

Recessed butt welds require complex part machining with base and lid fit tolerance of less than 0.002 in (0.051 mm). It requires 2 axes of motion and good joint line alignment.

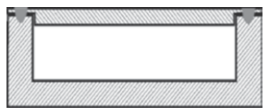
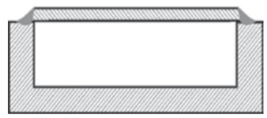
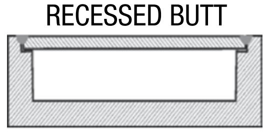
Weld geometry	Maximum lid thickness at weld interface	Laser alignment tolerance to joint line	Motion – minimum number of axes
LAP 	0.02 in (0.508 mm)	± 0.008 in (0.203 mm)	2 axes
FILLET 	0.02 in (0.508 mm)	± 0.003 in (0.076 mm)	2 axes
SIDE BUTT 	Unlimited	± 0.003 in (0.076 mm)	3 axes
RECESSED BUTT 	Unlimited	± 0.002 in (0.051 mm)	2 axes

Table 1 – Package geometry related to welding parameters

The second best choice, a side butt weld is a simple flat lid that can be used no matter the thickness of the lid. It requires at least 3-axes of motion and good joint line positioning. The weld is made using the laser beam horizontally using gravity to aid with part tooling and load/unload, however, because of package design the tool path becomes more challenging.

Laser Welding Enclosures

When hermetically sealing these aluminum packages, it is often necessary to weld in an inert environment free of oxygen and moisture. This is possible with a glovebox (left photo).

When not critical, the weld can take place in a standard CDRH Class 1 enclosure (right photo). Each type of laser can be integrated into the workcells.