Battery Welding –
A Guide to Selecting and Using Laser, Micro-TIG and Resistance Technologies

Batteries and battery packs have become an integral part of everyday life, in response to the ever-increasing demand for portable electronic devices, cordless power tools, energy storage, and hybrid and EV cars. This in turn, drives the need to manufacture batteries and battery packs that meet the quality and production requirements for these products.

There are a number of materials joining requirements for battery manufacturing, depending on the specific type, size and capacity of the battery. Internal terminal connections, battery can and fill plug sealing, tab to terminal connections, and external electrical connections are a few key examples.

Several joining options can be considered for each of these requirements, including resistance, ultrasonic, micro-TIG and laser welding, including the newest fiber laser options. The decision to use one or the other is generally dictated by the specific type of weld required and production requirements.

Ultrasonic welding is commonly used for the joining of the internal electrode battery materials, which are usually constructed of thin foils of aluminum and copper. The remaining joining requirements – including the connections inside the can, and external terminal tab connections – are well suited to resistance, microTIG, and laser welding. For can and plug applications (seam sealing), laser welding is the joining technology of choice.

The following is an overview of resistance, microTIG and laser welding technologies, along with examples of battery joining applications, detailing when and where to use each technology.

RESISTANCE, MICROTIG, AND LASER WELDING FOR BATTERY MANUFACTURING

Resistance welding has been an established joining technology for more than 40 years and has been used in the battery industry for almost as long. Since then, a steady stream of advances in resistance welding systems has given users significantly improved capabilities to control various aspects of the process. For example, the introduction of DC inverter power supplies with basic closed-loop electrical modes provides the ability to accommodate changes in the secondary circuit (the electrical loop from cable connection on the negative side of the power supply or transformer, through the weld head and the parts returning to the positive side) to specifically address part resistance. Also, polarity switching for capacitance discharge supplies to enable balancing of the weld nuggets, and more recently, the addition of displacement and electrode force measurement, provide manufacturers with more tools to ensure weld quality.

Similar to resistance welding, tungsten inert gas welding (TIG), also known as gas tungsten arc welding, has been used in manufacturing for many decades and has traditionally been used for the more challenging welding applications for nonferrous materials. Advances in high frequency power supplies increased low current control and arc stability, enabling much finer welding. This process became known as micro-TIG, a generally non-contact process that offers excellent copper joining while offering a fairly relaxed process window with respect to part fit-up and positioning tolerances of the electrode to the parts.

Laser welding is a newer technology, introduced in the manufacturing marketplace in the mid-1980s. As laser technology has matured, and the awareness of its benefits spread, it has become an established process. Today it is simply another tool in the manufacturing engineer's toolbox to be used and implemented as needed.

The laser provides a high intensity light source that can be focused down to very small diameters (0.01-inch). The concentration of light energy is sufficient to melt metals rapidly, forming an instantaneous weld nugget. The process is non-contact, has no consumables, offers instantaneous welding once positioned at the weld point location, provides sufficient control over the process to size the weld nugget according to requirements, and provides a number of implementation methods that can be geared toward individual manufacturing requirements. Laser welding enables joining of many materials and material combinations, can weld thick parts, and has no limitation on proximity of weld spots.

There are two types of laser that provide solutions for battery applications: pulsed Nd:YAG and fiber. Both of these lasers offer different joining characteristics that can be selected as appropriate.

HIGH SPEED SEAM AND PLUG SEALING OF BATTERY CANS

Laser welding is an excellent method for seam sealing, resulting in high speed, high quality seams in both steel and aluminum. Laser welding offers significant advantages over mechanical clinching and adhesive methods based on joint reliability, joining speed, and ease of manufacturing. As laser welding is an extremely efficient joining process, the heat input into the battery is minimized. **Figure 1** shows a few examples of seam welding of aluminum cans, including a weld cross section, and ball and plug sealing application examples.

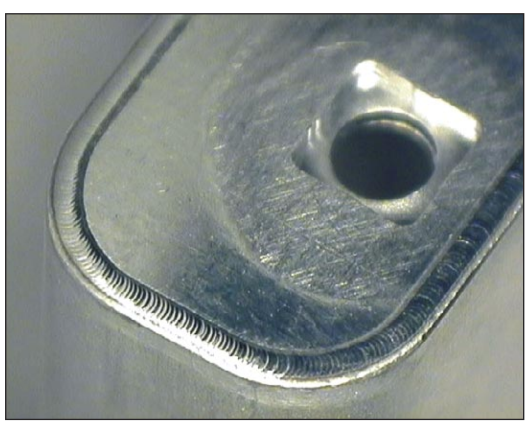


Figure 1 – Seam welding of aluminum cans

WELDING TABS TO TERMINALS, AND BUSS BARS

From a welding perspective, the important aspects of tab welding are the thickness and material of both the tab and the terminal. Resistance welding is extremely well suited to welding nickel tab material up to 0.015-inch thickness, and nickel or steel clad copper tab material to around 0.012-inch thickness to a wide variety of terminal materials. Due to a different welding mechanism, laser welding is able to weld both thin and thick tab materials, with a capability of welding copper or aluminum tab material above and beyond 0.04-inch thickness. Avoiding penetration of the can and overheating the battery are important aspects of tab to terminal welding.

Welding tabs or terminal connections to buss bars generally does not require as much penetration of heat input control as the tab to terminal welds. The materials, material thickness and combination of materials determine the best welding technique.

Resistance welding

Resistance welding has been, and continues to be, the most cost-effective method for joining tabs on a wide range of battery types and sizes, using both DC inverter closed loop and capacitor discharge power supplies. With fast rise times, closed loop feedback control, polarity switching, and options for displacement and force sensing, the process can be finely tuned and monitored to ensure both high quality and yield.

For nickel tab thicknesses up to 0.0070-inch, the tab can be welded without modification. Beyond this thickness, and to prevent electrical shunting and excessive electrode wear, a slot and projections are placed in the tab as part of the stamping process. The projections act not only as energy concentrators for the weld, but also greatly increase electrode lifetimes. **Figure 2** shows several examples of the wide range of resistance tab welding applications.

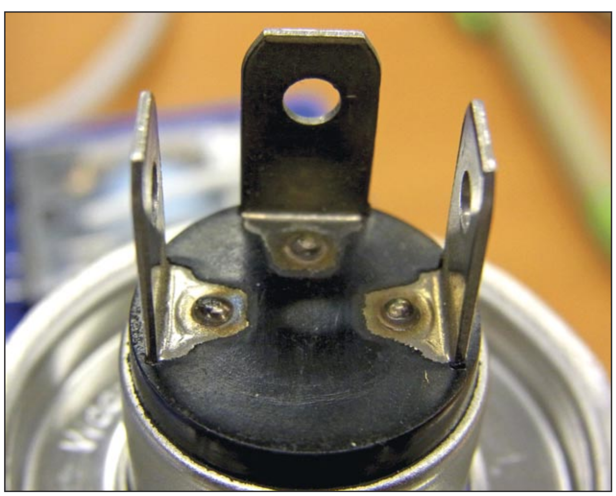


Figure 2 – Resistance tab welding applications

Micro-TIG

Micro-TIG offers excellent welding of copper, and so presents a good solution for buss bar welding that would require a brazing material for resistance welding or a large power laser welder. Both butt, fillet and lap welds are possible up to and beyond thickness of 0.02 in thick copper are routinely welded. When welding copper using micro-TIG it is extremely important to use a pulsation function that creates the weld without porosity, as show in **Figure 3**.

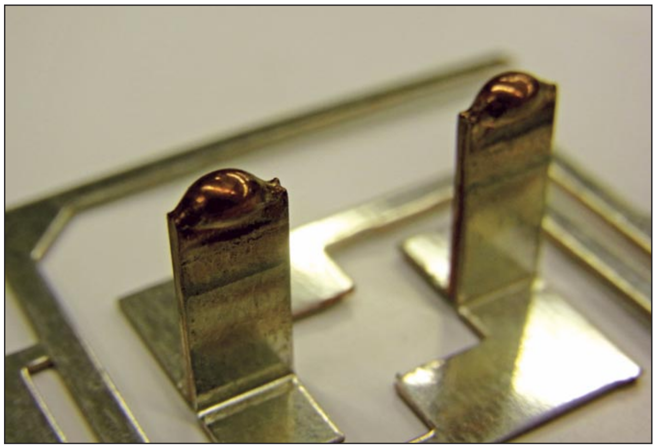


Figure 3 – Buss bar welds in 0.04 in copper and the effect of pulsation on weld porosity.

Laser welding

For tab and buss bar joining, laser welding offers a high degree of flexibility, welding both thin and thick tab materials, and materials such as copper, aluminum, steel and nickel as well as dissimilar material combinations. Two example welds are shown in **Figure 4**.

Figure 4 – Examples of laser welding conductive tabs

When welding a tab to a terminal, the general rule of thumb is that the tab should be thinner than the can terminal thickness. As the can thickness decreases the tab usually must be 50 percent of the can thickness for a safe processing window that provides the weld strength and conductivity whilst not penetrating the can.

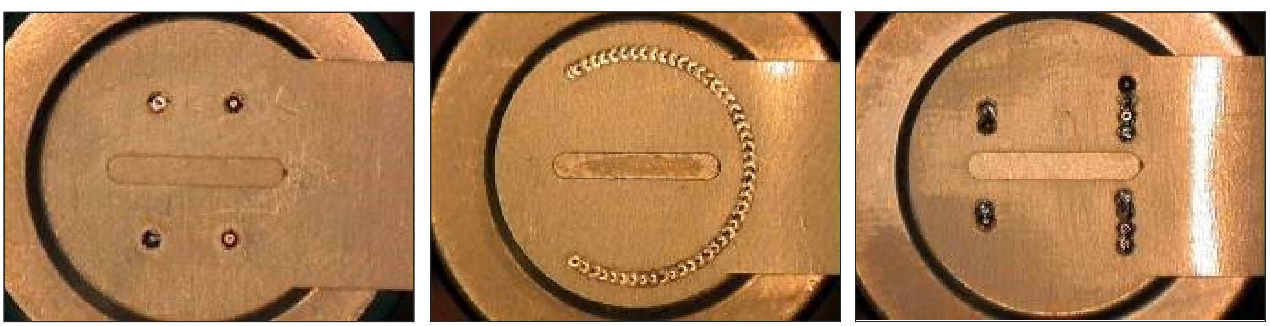
As laser welding has no limitation on the proximity of the welds, the laser can place any pattern of weld spots on the tab according to strength requirements. It is worth noting that, in nearly all cases, if the joint's weld strength is achieved, conductivity follows. For more conductive materials, the weld area required for strength can be as much as 10 times that required for conduction.

As shown in **Figure 5**, the placement of the weld spots on the tab is completely flexible, and can be tuned to the strength requirements of the pack or tab. For example, peel strength is often used as a metric for weld quality. Therefore the welds can be positioned accordingly. The peel strength of (a) is 15 lbs. and (b) is 60 lbs.

The time needed to add additional weld spots is very short; sufficient tab strength can be achieved with very little impact on cycle time.

Although peel strength remains an important weld test, vibration is also important. As vibration strength places an emphasis on having good weld strength in any direction, the circle of weld spots shown in (c) provides the solution.

Figure 5 – Examples of flexible weld placement for tailoring weld strength and weld



15 lb peel strength ***40 lb peel strength*** ***60 lb peel strength***

BATTERY PACK MANUFACTURING SYSTEMS

The two main production options available are continuous flow in-line or offline systems. It should be noted that the manufacturing flow can have an impact on the welding technology selected and this should be factored in at the technology selection stage. A consideration of materials, joint geometry, weld access, cycle time and budget will normally point in the direction of the required joining technology.

PRODUCTION VOLUME DRIVEN BY CONSUMER DEMAND

The production volume of batteries continues to be driven by the demands of consumer electronics and electric vehicles. Likewise, the manufacturing and joining needs of these batteries are also pushed by capacity, size, materials and usage. Resistance, microTIG and laser technologies each have specific features that align well to these joining needs. A clear understanding of the technologies and application is needed to implement an efficient and reliable production welding system. The tables below offer some guidelines on the available methods and a few parameters including suitability for a variety of applications.

Technology	Key Benefits
Resistance welding	Closed loop feedback welding, cost effective, self-tooling
MicroTIG	Large process window, cost effective for copper welding
Laser	Non-contact, high speed welding, tailored weld patterns, weld any joint geometry

Joining Application	Technology	Details
Can and plug sealing	Laser	Barrier sealing of aluminum, nickel and cold rolled steel with minimal heat input
Tab to electrode/case	Resistance	< 0.015 in thick nickel/steel straps < 0.007 in thick copper straps
	Laser	Up to 0.04 in+ thick tab material Electrode/case thickness > 1.5x tab thickness
Tab to busbar	Laser	Multiple materials and layers can be welded Up to 0.04 in+ weld penetration in any material
	Micro-TIG	Thick copper welding, single spot nugget dimensions up to 0.15 in x 0.15 in Seam welding capability
	Resistance	Material thickness range as for tab welding. Thicker materials can be brazed.