The ever-increasing demand for portable electronic devices, cordless power tools, energy storage and hybrid and EV cars has become an integral part of everyday life, driving the need to produce batteries and battery packs to meet these needs. That, in turn, drives the call to manufacture batteries that meet or exceed the quality and production requirements of the same.

In battery manufacturing, there are a number of materials joining requirements. Depending on the specific type, size and capacity of the battery these may include internal terminal connections, can and fill plug sealing, tab to terminal connections and external electrical connections. There are a number of joining options that can be considered for each of the requirements including resistance, ultrasonic and laser welding. Ultrasonic welding is commonly used for the joining of the internal electrode battery materials that 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 both resistance and laser welding; the decision to use one or the other is generally dictated by the specific type of weld required and production requirements. For can and plug applications (seam sealing) laser welding is the joining technology of choice.

**Lead Acid Batteries**

The manufacture of reliable, high-performance lead-acid batteries for use in demanding automotive, marine and storage applications poses significant challenges. The welding application requires that a series of lead castings (tombstones), which constitute the cores of the individual battery cells, be joined. These lead tombstones must be linked together using consistent and precisely controlled weld nuggets in order to assure the proper operation and long-life of the final battery assembly.

The welding challenge arises due to the high level of resistance variability that occurs based on the age of the lead, and these variations happen over a period of less than 72 hours. Controling batch parts according to age, therefore, is not viable in production. The resistance variation makes it very difficult to achieve consistent results with traditional AC resistance welding, which is susceptible to current spikes and inherent variability in the welding process. Even the use of advanced AC weld controls, which have a more consistent secondary current output, is not sufficient; operators must continually adjust weld parameters to maintain acceptable welds.

The most effective approach to the unique challenges of lead-acid battery welding is to use advanced inverter (DC) solutions that combine precision controlled secondary power (V x I) with comprehensive monitoring and real time feedback mechanisms.
By sensing and adapting for differences in resistance in the lead castings, as well as other variations in the weld process (e.g. electrode wear, cabling, etc.), these systems can automatically maintain constant power and consistent heating profiles at the weld nugget. As a result, inverter controls using constant power feedback are able to deliver dramatically increased yields while simultaneously eliminating the inefficiencies and inconsistencies of operator-dependent process tweaking. Among the most significant benefits is the expansion of the effective process window from only 15 minutes between schedule updates for AC controls, to as long as 72 hours without any necessary operator adjustments for the inverter.

**High Speed Seam and Plug Sealing of Battery Cans**
Laser welding is an excellent method for seam sealing, resulting in a high speed, high quality hermetic 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.

**Welding Tabs to Terminals**
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 based or bi-metal tab material above and beyond 0.04 inch thickness.

**Resistance Welding**
Resistance welding is 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 0.007 inch the tab can be welded without modification. Beyond this thickness, and to prevent electrical shorting 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.

**Laser Welding**
Although able to weld both thin and thick tab materials, laser welding is particularly well suited to addressing the needs of high power battery welding. The tab material used in the development of high power cells must be able to accommodate the associated higher capacities and power levels. In order to provide efficient energy transfer, a tab thickness of 0.015 inch or greater is required, as is the use of more conductive materials. For high power lithium ion cells, the terminal material for certain battery manufacturers is different. Therefore the need for bi-metal and smart terminal design solutions is required. Defining the optimal tab material may require some development work both on the welding and material costing. In these cases, the laser is an invaluable tool that offers outstanding welding performance and flexibility.
Laser Welding - High Speed Solutions

As the process is non contact and the beam is steered by motion, the welding speed is determined by the tab materials and thickness and the terminal material along with the selection of laser power. As an example shown in Figure 5 a 0.012 inch thick nickel plated copper tab is welded to an aluminum terminal at 4”/s.

Pack Manufacturing Solutions

When planning an automated or semi automated solution, the primary factors to consider are loading/unloading, motion and tooling that fit the planned production flow and production rate. Loading and unloading can range from manual to conveyor or pick-and-place, motion options center around whether the resistance/laser head or the part will be moved, with options including XYZ tables and gantry’s or robotic manipulators. For tooling, resistance welding occurs by the actuation of an electrode onto the tab, and is therefore self tooling. The laser is non contact, so tooling of the parts can be achieved either by using a fixture that the batteries and tabs are loaded into, or using actuated tooling that is deployed prior to the welding process.

The most suitable technology and process for battery pack manufacture relates to a number of factors including the pack size, thickness and material of the tab itself, and the necessary production rate. Both laser and resistance welding processes enable high quality volume production, and, as there is welding overlap of the two joining technologies, the selection is usually made based on the specific requirements in each situation.