

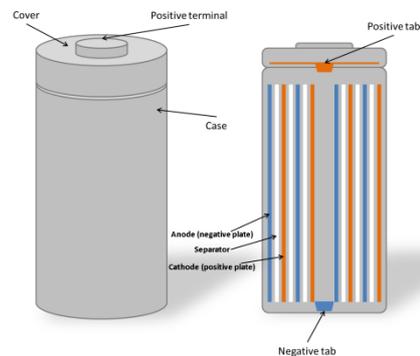
- An overview of aluminium wirebonding of Lithium-Ion Battery Packs versus Laser Welded Connections (IKB-083)

With the electrification of the automotive power train, battery manufacturers are looking to get the most from well-established and proven manufacturing technologies to make increasingly dense and complex battery packs.

Within the packs, modules are electrically connected in parallel and series combinations to produce the overall power characteristics for the intended application. And within the modules, cells (typically 12 or 24) are electrically connected in parallel, certainly for EV applications.

Interconnects - which are cell-to-cell, cell-to-busbar and within the battery management system (BMS) electronics – are typically made in one of two ways: laser weld or ultrasonic wire bond.

Before comparing those techniques, let's remind ourselves of the cell's structure. A typical lithium-ion cell comprises four key elements: an anode, a cathode, an electrolyte and a separator. In a cylindrical cell, the anode and cathode are foils that are rolled-up together with a dielectric separator material (to prevent short circuit) in-between. This "Swiss-roll" is then placed into a suitable housing (or 'can') for electrolyte fill and sealing.



### **The Interconnects**

For laser welding, these typically use 99.99% copper busbars or "tabs" (sometimes nickel plated), ranging in size from 5 to 10mm wide and up to 0.5mm thick. Other widths and thicknesses are easily accommodated in laser welding, but these must be prefabricated (for the application) prior to welding. Laser welding of aluminium is also emerging as a potential alternative to copper laser welds.

For wire bonding, these typically use 99.99% aluminium wires or ribbons, in diameters ranging from 200 to 500µm (ribbons up to 2000 x 400µm).

### **Laser weld**

Laser welding is a typical weld process where two compatible materials are heated and diffuse into each other; the laser providing sufficient energy to melt the busbar to the battery terminal. For this process to be successful, the busbar and battery terminal must remain in close contact throughout, which does pose challenges to manufacturing setup and fixture design tolerances.

Also, beware thermal issues. Localised heat from the welding process penetrating the negative terminal can alter the cell chemistry and lead to catastrophic thermal runaway. The 'floating' positive terminal is less vulnerable because of the air gap.

### **Ultrasonic wirebonding**

Ultrasonic 'wirebonding' is well established (60+ years), dominating power electronics manufacture as a flexible and robust method of making electrical interconnects in hybrids, switches and regulators.

Ultrasonic bonding is effectively a 'friction welding' process, however, the majority of the energy transfer occurs within the bonding materials; with minimal localised heating to the wire or battery surface.

Therefore, aluminium wirebonding is known as an ambient temperature process, so there's no risk of altering the cell chemistry and having thermal runaway issues during manufacture.

In ultrasonic wirebonding the controlling variables that determine the process are:

- ultrasonic energy;
- bonding force; and
- (bond) cycle time.



Some wirebonding systems now offer 'response-based' programming where the process engineer inputs process requirements (bond width, strength) and variables (wire diameter, ribbon cross section) and the machine offers parameter suggestions based on these criteria.

### **Considerations**

There are advantages and limitations to both manufacturing technologies and processes. It all comes down to what you are trying to achieve and how you go about it.

#### **#1 - Fusing**

Do you want the interconnection to act as a fuse, and isolate any given cell in the event of excess current and thus protect the rest of the pack? If so, this will take you down the wirebonding route. Matching the wire cross sectional area and wire length to the required current carrying capability of the cell effectively makes the bond wire a fuse.

#### **#2 - Clamping**

Due to the application of ultrasonic energy in the wirebonding process, all components (e.g. cells, busbar etc.) must be clamped sufficiently to ensure no harmonic resonance can occur to compromise bond integrity. This is a particular challenge in *cylindrical cells* where the positive terminal is unsupported, floating in the centre of the top of the cell.



With laser welding, both busbar and battery terminal must be held securely in direct contact throughout the welding cycle, demanding bespoke tooling and setup for each design variant.

Wirebonding equipment manufacturers intend to overcome these issues by offering ultrasonic modelling of customers' battery packs to identify the exact bonding responses expected from the unsupported end cap, eliminating the need to invest in complex tooling and fixtures.



#### **#3 - Contamination**

Surface contamination (organic materials, metal oxides, etc.) can affect the interconnection quality, irrespective of how it is made (laser weld or wirebond). The cleanliness and plating quality of commercial *cylindrical cells* often used for battery packs can be problematic, especially for prototyping etc.

If levels of contamination are high, cleaning will be required to remove hydrocarbon deposits and oxidation from the cell surfaces. As the battery cells are effectively live during assembly (typically 30% charged) the cleaning process must not electrically short the cells or impact the internal battery chemistry.

For lower levels of contamination, the process parameters can generally be adjusted. For example, with wirebonding, ultrasonic energy and bonding force can be easily modified to overcome this problem.

#### **#4 - Harsh Environment**

Battery packs may be subjected to significant vibration and mechanical shock depending on application. Any interconnect technology must withstand the external forces expected, to ensure a good operational lifetime. If the intended application is in a harsh environment, this might take you down the wirebonding route. It allows for the use of multiple wire diameters and ribbon sizes without the need to change expensive components or fixtures; only simple consumables on the bonder itself (bondtool, cutter blade, for example). The aluminium wire can be specified to adapt the material properties to fine-tune corrosion resistance and wire softness (annealing).

#### **#5 - Rework**

For any high value manufacturing process, the ability to rework process steps to improve assembly yield is key, especially in the initial prototyping and pilot production stages. Failing or weak bonds can be reworked at wire level in ultrasonic bonding and most manufacturers offer real time data-logging of process parameters to identify and alert operators of failures and offer the chance to rework.

Reworking a failed or imperfect laser weld joint is more problematic as the battery is exposed to another temperature process and the busbar design can prevent individual rework of joints.

#### **#6 – Cost of Ownership**

Ultrasonic bonding is a mature interconnection technology with a large scale, stable, global supply chain for equipment and materials to support battery pack manufacturing. Laser welding is also an established technology in use within the microelectronics sector, but poses a considerably higher cost of ownership (than wirebonding); with the need to design and tool busbars, and tightly control the process to ensure no thermal stresses are placed on the cells during manufacture of the battery packs.

To serve any growing market with products, and to keep manufacturing costs low, it is essential to use proven processes. Both laser welding and wirebonding are well established.

Of these, wirebonding currently more widely used being a room temperature process, while the interconnection (if wire is used rather than ribbon) can accommodate some movement in high vibration applications and act as a fuse to protect the pack if a cell suffers thermal runaway. However, care needs to be taken when clamping the battery packs to prevent harmonics undermining the weld quality.

As for laser welding? As equipment manufacturers provide more novel solutions to overcome the thermal implications and busbar design considerations required to make it an affordable and robust manufacturing process it may become a more attractive alternative to wirebonding. But until then manufacturers will rely on the processes and technologies most likely to meet their current and near-term goals.