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Enduring bonds: optimising EV battery reliability

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Enduring bonds: optimising EV battery reliability

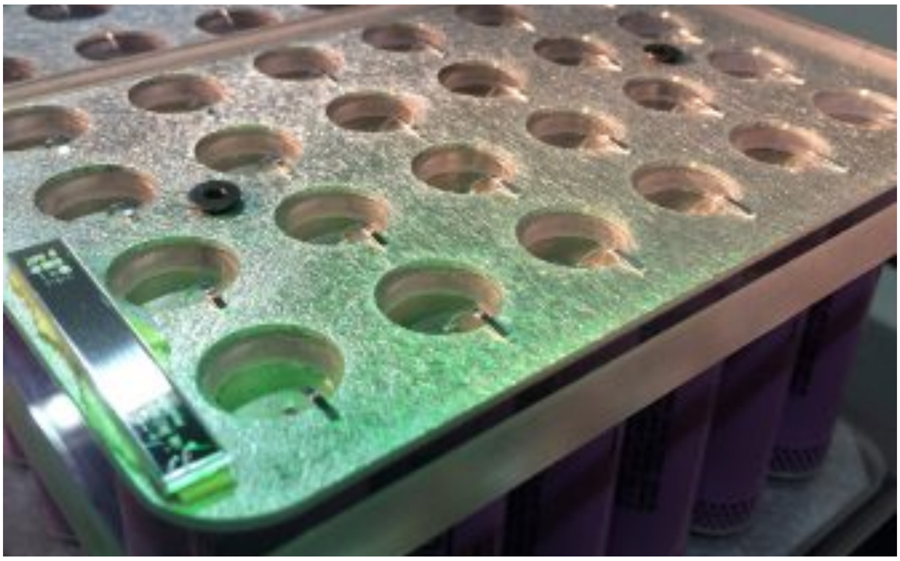
*The reliability of battery pack and power modules used in electric vehicles depends largely on the performance and integrity of hundreds of wire bonds. Here, **electronics engineer, technical writer & founder of technical communications agency, Declaration, Richard Warrilow talks to supplier to the microelectronic & advanced technology research & industrial sectors, Inseto and electronic manufacturing solutions provider, Custom Interconnect Limited (CIL)** and explores production challenges and solutions.*

The global electric vehicle (EV) battery market is predicted to see a CAGR of a little over 18% running up to 2027, by which time it will be worth more than $133billion, according to data analysis company, Verified Market Research (VMR). This market will be served by a variety of battery types, of which lead-acid and lithium-ion (Li-ion) are but two.

An EV's battery is its 'defining component'. It sets the range, which potential customers typically ask about even before price. The role played by the battery, its chemistry and size will be governed by the type of vehicle and, as readers will certainly be aware, a battery's electrical 'size' is expressed in terms of energy capacity (in kWh) and power (in kW).

For example, the role of a 12V lead-acid battery in a solely internal combustion engine (ICE)-powered vehicle is mainly for energising the starter motor. Transient currents (cranking amps) are high, warranting a power of a few kW, and battery energy is circa 1kWh. In sharp contrast, a purely electric vehicle with a lithium-ion (Li-ion) battery pack will have a power requirement of about 100kW and an energy capacity of tens of kWh. The potential difference will be much higher too, typically several hundred volts.

Between these two extremes, we have mild hybrid, full hybrid and plug-in hybrid electric vehicles (MHEV, HEV and PHEV, respectively) which mainly differ by how much mobility is provided by their electric drivetrain components.



Above, a 24 Li-ion cell battery module. The interconnects are made with ribbon using the ultrasonic wirebond (cold weld) process, which removes the risk of heat altering the cell chemistry & potentially leading to failures in the field

Battery packs

For EVs, the battery is technically a 'battery pack'. Fitting the largest pack possible for a given vehicle body is not practical because of the weight penalty. More prohibitive, though, is cost, as according to a paper written for the 53rd CIRP Conference on Manufacturing Systems in July 2020, an EV's battery pack accounts for some 30% of its cost. Of that percentage, about 40% is associated with manufacturing.

Not surprisingly, battery pack manufacturers are looking to get the most from well-established and proven manufacturing technologies to make increasingly dense and complex battery packs, while keeping costs as low possible.

A battery pack is made up of multiple battery modules, connected (using bars, bolts and heavy gauge cables) in parallel and series com-

The reliability of battery pack & power modules used in EVs depends largely on the performance & integrity of hundreds of wire bonds.

The K&S Asterion large diameter wire/ribbon wedge bonder (the white unit) is located in CIL's BEV facility and is part of a £1.6million investment to process & package WBG material die for EV power modules

binations to produce the desired energy and power characteristics. Each module contains several cells – of pouch, prismatic metal can or cylindrical type – and, in many cases, dedicated power and thermal management systems.

The two most popular methods for connecting cells are laser welding and ultrasonic wire bonding. Of these, the latter is more popular. Jim Rhodes, a Director of Inseto (a technical distributor of equipment and materials for advanced engineering sectors), comments: "Unlike the laser weld process, minimal heat is generated with ultrasonic wirebonding. Indeed, the process is dubbed 'cold weld', so there's no risk of overheating and damaging the cell, which can result in thermal runaway during manufacture."

Rhodes goes on to say that while laser welding tends to be used for higher current applications, where cell-to-cell and cell-to-busbar interconnects are concerned, multiple wires or ribbons can always be placed in parallel. "That said," Rhodes adds, "you actually want to limit the current. Matching the wire cross sectional area and length to the required current carrying capability of the cell effectively makes the bond wire into a fuse. In the event of excess current, the cell will isolate and protect the rest of the module."

As for bond integrity, it is the product of the physical force and ultrasonic energy (in other words, power over time) applied. These parameters are controlled to ensure the bond takes and can even be adjusted to account for some levels of surface contamination.

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Rhodes: "The cleanliness and plating quality of commercial cylindrical cells often used for battery packs can be problematic. If levels of contamination are high, cleaning will be required to remove hydrocarbon deposits and oxidisation from the battery surfaces. But you must remember, the battery cells are effectively live during assembly – typically 30% charged – so it's important not to have more process steps than necessary for safety and, of course, cost reasons."

Collaboration

One company that recently took delivery of a wire bonder is Custom Interconnect Limited (CIL). The company has several fine wire bonders – where 'fine' is considered to be about 25micron diameter – but its latest purchase is a Kulicke & Soffa Asterion large diameter wire/ribbon wedge bonder, capable of placing wire or ribbon of between 150 and 600microns diameter or width.

The Asterion is to play a crucial role in two major EV projects in which CIL is extensively involved. In the first, CIL is engaged with BMW on APC15@FutureBEV to maximise the potential for future battery electric vehicle (BEV) systems. In the second case, CIL is the project lead on GaNSiC – a project that stems from UK Research & Innovation's (UKRI) 'Driving the Electric Revolution' challenge, and brings together CIL and the Compound Semiconductor Applications Catapult (CSA Catapult). It is set to develop novel ways of applying silver sinter pastes to wide bandgap (WBG) semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN) devices, to optimise their thermal coupling and solve complex power module assembly challenges.

John Boston, Managing Director of CIL, comments: "Some SiC-based power module designs are aiming to switch up to 800VDC and handle up to 600A – a staggering 480kW. For that, you need heavy gauge. However, heavy gauge wire bonding of wide bandgap materials is a relatively new technology. More than ever before, there's a need for collaboration and trust within the industry."

Boston goes on to say that with keeping costs low such an imperative in the automotive sector, the use of advanced manufacturing tools likely to produce the best results is essential: "Particularly when some vehicle manufacturers are demanding zero defects and stipulating that reworks are not allowed."

Electronic solutions provider, CIL has one of the largest independent 'chip and wire' facilities in the UK, and its micro-electronics packaging facility is regarded as being at the forefront of the EV power revolution. In addition to APC15@FutureBEV and GaNSiC, CIL is a manufacturing partner on many other EV projects, and the company has many customers in the aerospace sector, active under initiatives like the More Electric Aircraft and the All-Electric Aircraft.

The K&S Asterion is located in CIL's BEV facility and joins an automatic die bonder and a high-pressure silver sinter press, both of which are for the packaging of WBG materials.

Boston: "We also have a scanning acoustic microscope. Because of the high currents involved, you need to die bond the WBG devices to very thick copper to give adequate thermal transfer. However, x-ray inspection can't see through very thick copper, and if you power a device with significant voids in the die attach, the results are likely to be catastrophic when 480kW are involved."

Summary

The EV industry is big business, and whilst Li-ion is the dominant chemistry for battery packs, nickel-metal hydride is popular too. There are also a number of promising alternatives to both, including solid state batteries, lithium-sulphur (Li-S), sodium-ion (Na-ion) and metal-air batteries. However, not all are rechargeable, so would need to be implemented as easy-to-remove battery packs.

Whether easily removable or more of a serviceable item in place for several years, the fact remains that within any given battery pack module, current needs to be conducted through dozens of reliable interconnects that may also need to act as fuses. Elsewhere in the EV architecture, power modules are needed to switch extremely high currents. This requires the use of heavy-gauge wire or ribbon to bond out from WBG die.

Common to both requirements for bonding is the commercial imperative of keeping yield high and manufacturing costs low.

Above, Custom Interconnect Limited's (CIL) new Kulicke & Soffa Asterion large diameter wire/ ribbon wedge bonder is to play a crucial role in two major EV projects

About the author:

Richard Warrilow *began his engineering career in the 1980s, before becoming a technical journalist in the mid-1990s. He established* ***Declaration Limited*** *in 2000, since when he has worked closely with organisations – including CAD/EDA vendors, industry bodies, materials suppliers, semiconductor foundries and systems developers – at the forefront of developments taking place in the aerospace, automotive, electronics, industrial and power sectors.*

Is there an after-life?

As we all know from using any product with a rechargeable battery, efficiency decreases over time. Two things determine the lifespan of a rechargeable battery cell:

- *Time spent at minimal discharge capacity.*
- *The number of times the cell is charged and discharged.*

For EVs, a battery's end-of-life (EOL) is considered to have been reached when it can no longer be charged to more than 80% of its intended capacity.

According to an IDTech report ('Li-ion Battery Recycling: 2020-2040), the rapid adoption of EVs is set to result in 7.8 million tonnes of EOL Li-ion batteries per year by 2040.

Though 'end of the road' for automotive applications, the batteries could be repurposed and used in less demanding applications, such as stationary energy storage (for a while anyway, as once that 80% marker is reached, storage capacity degrades quickly).

Recycling cells for their raw materials is not only inevitable, it will be a market worth $31billion per year by 2040, IDTech forecasts.

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