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Industrial Paper

Going Green - Laser Welding and Advanced Sensor Technology for Electric Vehicles

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Abstract

It is becoming increasingly clear that there is more than just a gradual transition in the automotive industry, especially when it comes to future drive systems. Whether e-mobility or hydrogen propulsion, the laser and photonics industry is seizing the opportunity to change manufacturing processes and convince decision makers of the undisputed benefits of photonic tools in the corresponding production chains. Since most applications, e.g. in e-mobility, start from scratch, the most profitable manufacturing tools can be directly applied. There is no need to transform an already existing process from the "pre-laser age" to the modern age. This article provides an overview of some battery production applications from the perspective of a sensor and machining tool supplier, without claiming to be exhaustive. The focus is on laser welding, as process monitoring and control play an important role here; laser marking, drilling, surface machining are not part of the considerations.
This contribution to the LANE '22 conference describes the intersection between photonics and demands when it comes to efficient production tools for tomorrow's mobility. Further intersections with respect to Industry 4.0 and artificial intelligence haven't even been mentioned, but here we easily find more examples which underscore the uniqueness of the laser in the context of e-mobility.

Keywords: *Laser welding, OCT, e-mobility, hydrogen drive, battery, process control*

1. Introduction

Here The future of mobility is automated, networked, and electric. The development path towards this mobility of the future is characterized by a complex, far-reaching process of change. The transformation process towards sustainable and intelligent mobility poses a multidimensional and disruptive challenge for actors from business, politics, and society. Ambitious climate targets, new mobility concepts and social developments are changing the parameters for the automotive industry and all related economic sectors worldwide. Both the automotive product and the entire processes of development, production or sales must be consistently questioned and adapted in the face of these changes. While electrification and digitalization are accompanied by a comprehensive technological change, the structures of the automotive value-added system are also changing due to new competitors and ever shorter innovation and market cycles.

Electromobility is a megatrend which - together with the networking of vehicles, autonomous driving, and digitalized production - will significantly change the automobile, its use, and its production in the coming years. The electrification of the powertrain is changing the existing value-added and employment structures in the automotive industry, whereby classic components such as the combustion engine will ultimately lose importance, while at the same time new components of electric mobility will become more important.

There are different designs and degrees of electrification - from hybrid to pure battery vehicles - with different electrical outputs, ranges and driving shares. New components significantly change the share of value added in the vehicle. The focus of value creation is shifting further from mechanics to electrics/electronics. The battery is a core element of all electrified vehicles. It stores the energy required for propulsion in the battery cells and delivers them to the electric motor when required. The greatest technical challenge lies in the development of powerful and cost-effective battery systems to realize electrical ranges that can be can compete with today's conventionally operated

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vehicles - at similar costs. This is since, compared to petrol or diesel lower energy density of the batteries: While for 100 km Range only 6 to 7 kg conventional fuel (incl. storage system) are required in the vehicle, this value increases to over 130 kg with today's battery systems. Achieving higher energy densities is accordingly the focus of the Research and development on battery systems.

In the short to medium term, battery cells with lithium-ion technology (Li-Ion) have the greatest potential. These are already being used today in almost all relevant electrified vehicle concepts. In addition to the cells, the battery system in the vehicle also includes battery management (including monitoring), electronics and sensor technology, components for cooling, safety elements and the battery housing. The main part of the added value is with approx. 60-80 % but for the battery cells (including material) themselves. Figure 1 shows an example of the cost structure of a traction battery, subdivided according to the proportions of the materials, the battery cell, and the battery system (including assembly) in the total cost.

With all the efforts we as members of the photonics community make to leave a footprint in e-mobility, especially when talking about batteries we can work on 60%-80% of the overall costs. That is why taking care of photonics solutions in e-mobility absolutely helps increasing quality and efficiency of processes, in the end naturally decreasing final costs.

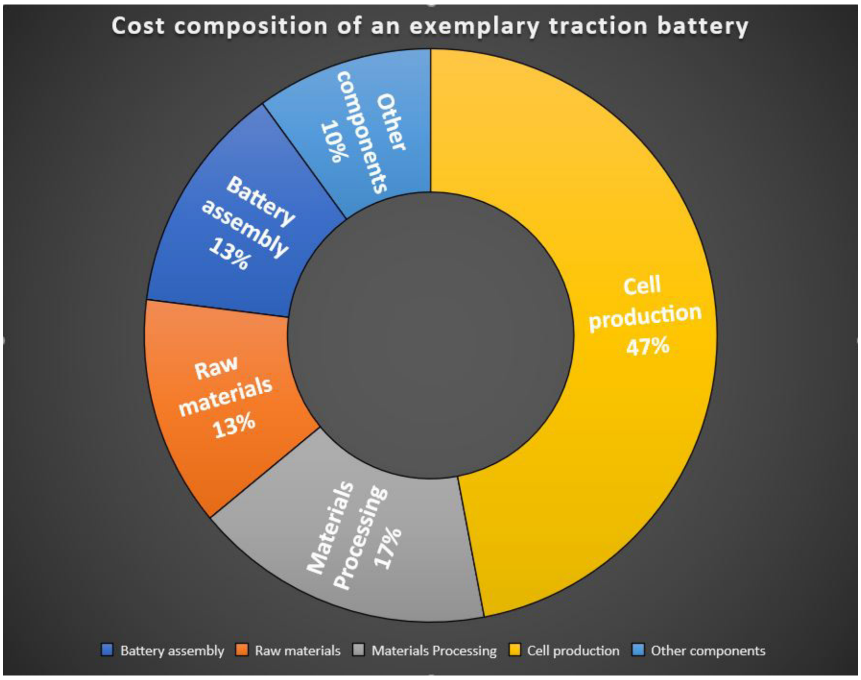

Fig. 1. Cost composition of an exemplary traction battery (1).

2. Photonics in the haze of the battery

Several key steps in the haze of battery production involve welding or bonding, which includes processing of internal components, sealing of individual cells and generating of connections between battery cells to final, customer specific individualized packs.

Welding applications emerging in this context are e.g., cylindrical, and prismatic cell seam sealing, pouch cell tab welding, battery pack connection and hairpin processing. Especially the battery systems suffer from challenges which are on the one hand the increasing number of product variants and on the other hand concepts associated with lack of standardization for process and product design. Again, the extremely high flexibility of the laser as tool comes into play as manufacturing systems are faced with the challenges of adapting to high volume production, new designs and satisfying quality targets in given production cycles. Talking about processing errors during the joining procedure especially in this application we are talking about a major disadvantage:

A damage of the battery based e.g., on uncontrolled weld penetration leading to the risk of piercing of the battery cell, with subsequent leaking of harmful gases and fire. One single defective weld can cause the whole battery pack to malfunction (i.e., voltage drop). The call for automated, reliable process sensor technology is unmistakable.

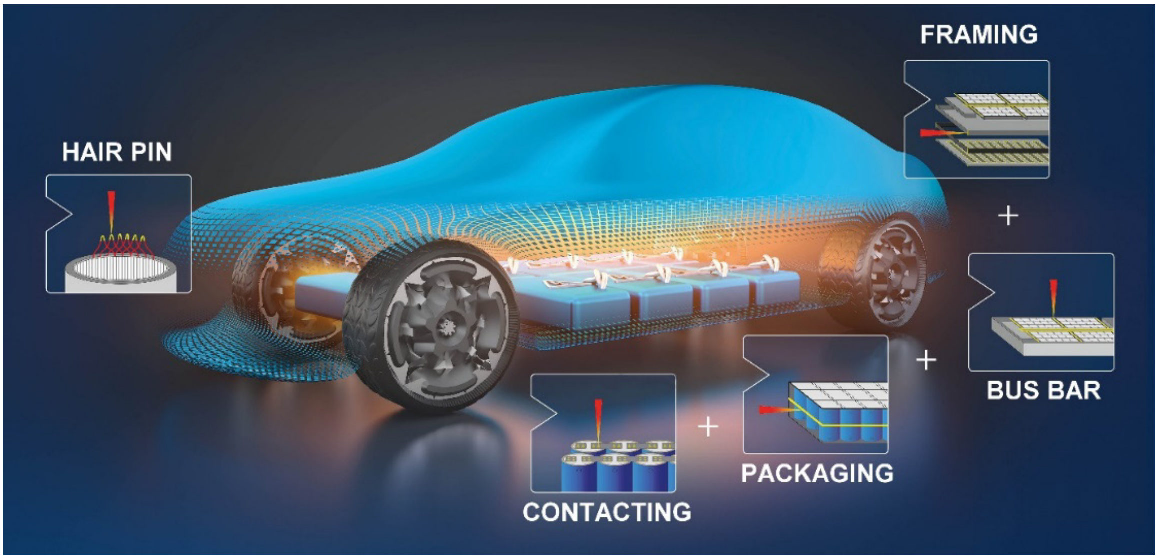

Fig. 2. Overview of typical laser welding applications in e-mobility

It is not only the high flexibility when new technological solutions are designed and tested, especially when it comes to in-process monitoring of weld quality along with corrective and/or preventive actions to achieve zero scrap the laser process plays out its advantages. Process monitoring sensors have been further developed all the years parallel to the increasing use of lasers based on the one creed: Don't stand in the way. That means, devices must be light, small, easy to integrate and must never slow down cycle times. In this context we talk about monitoring systems based on photo diode technology (2) (3), evaluating quality based on the emissions emerging from the interaction zone. We also talk about the adaptation of OCT sensor technology (4) (5) (6) (7) (8) to the processing tools being able to perform real measurements in physical units deriving a go/no go message (see Figure 3). Within laser material processing, this sensor technology came into focus about 10 years ago. The company Precitec was the pioneer and driver for the transfer of OCT from medical technology to industrial production and the success proves them right.

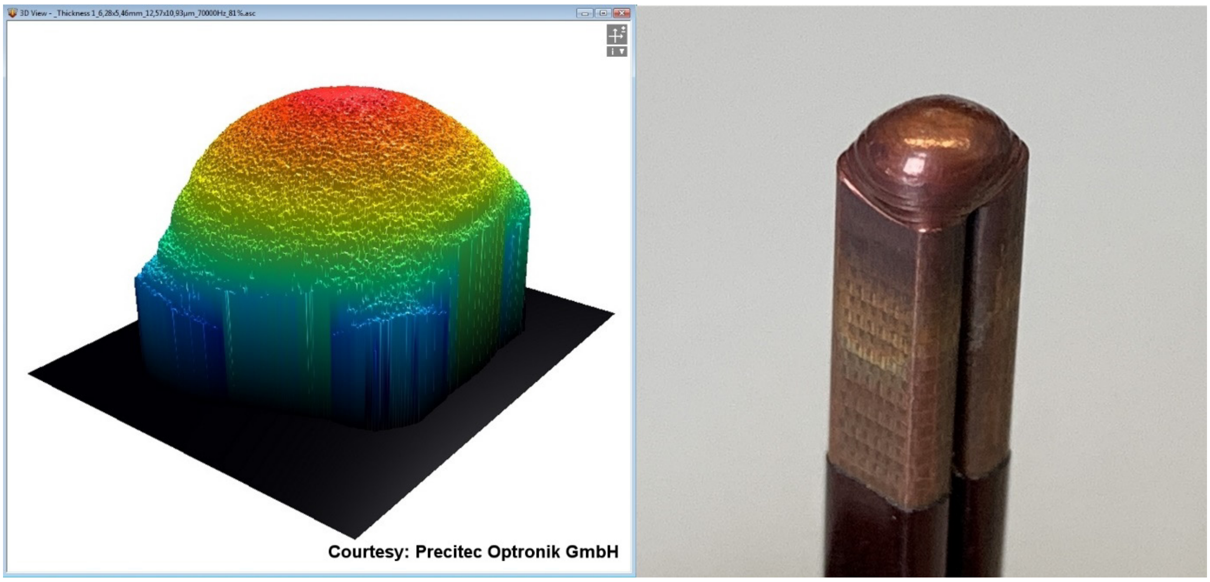

Fig. 3. OCT measured topography (left) of a laser welded hairpin (right) for quality inspection

4. Lasers applied to joining processes

A further reason why the tool laser is the preferable one is its flexibility when it comes to joining of dissimilar materials. In the mentioned applications we talk about copper to aluminum, copper to steel or aluminum to steel (9) (10). It has been shown especially with short pulsed lasers by Dr. Jack Gabzdyl (SPI Lasers UK Ltd) that there is a stable process window for a joining process which just can be driven with photons (10).

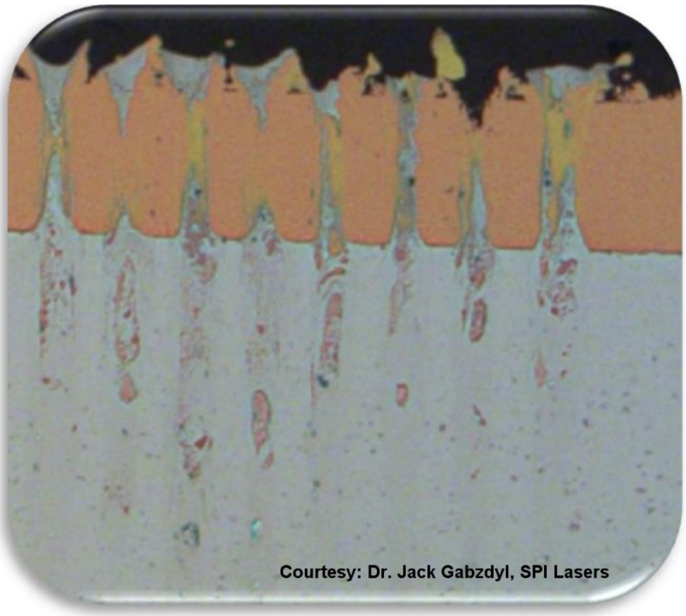

Fig. 4. Metallurgically interesting material flow after joining Copper to Aluminum with ns laser pulses

Talking about joining copper intensive activities have been deployed on investigating the use of visible laser sources with green (515nm) or blue (450nm) radiation. Looking into the physical properties, especially the absorptivity, under ambient conditions you find this value multiplied tenfold in comparison with IR lasers (12) (13) which does not mean that stable process windows also exist with the pure use of IR beam sources. At the current state, laser beam sources of 450 nm wavelength are available of output power up to 2 kW which allows the processing of laser micro welding with heat conduction welding as well as deep penetration welding (15) (16) (17). The absorptivity and therefore the energy input during the process increases from 1070/ 1030 nm to 515 nm and 450 nm wavelength. Local fluctuations during the process decrease which indicates a more stabilized energy input (Figure 5).

Fig. 5. Smooth and extremely stable weld of copper sheet prepared with three different surface conditions (etched, oxidized, polished)

In the context of energy input a new degree of freedom has opened, application specific intensity distribution. As research institutes help us more and more to understand the beam material interaction the most profitable intensity distribution can be selected for the best result. Let's name it the GPS system for photons. Basic research is the basis for this GPS system, comparable to a route planner. System developers like Precitec ensure that the photons can propagate without interference on their way to the workpiece. New devices for a flexible design of the intensity distribution have already been presented and applied to welding applications in the context of e-mobility (17)(18)(19).

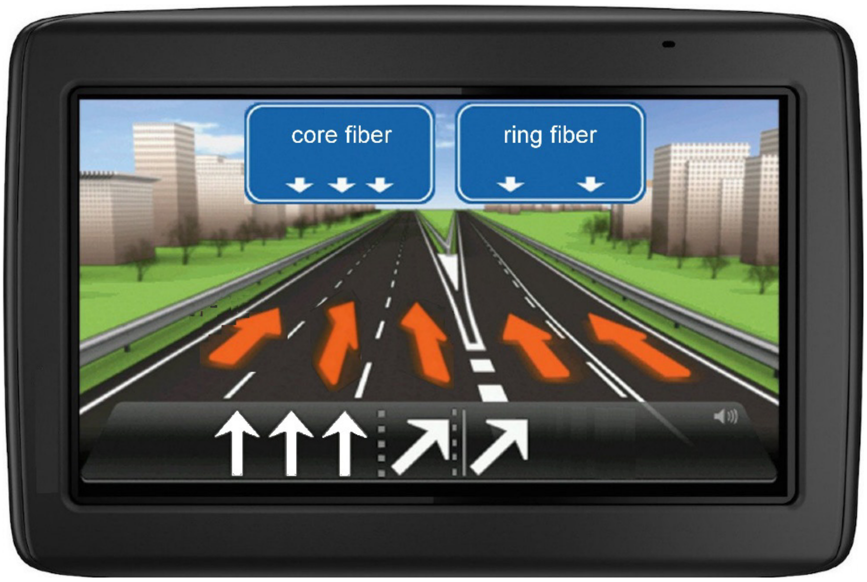

Fig. 6. The GPS system for photons – application specific intensity distribution

5. Take away messages

This article could only touch the surface of the intersection between photonics and demands when it comes to efficient production tools for tomorrow's mobility. Further intersections with respect to Industry 4.0 and artificial intelligence haven't even been mentioned, but here we easily find more examples which underscore the uniqueness of the laser in the context of e-mobility.

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