Fraunhofer FFB

tesa

Powering innovation together

Electrical insulation for battery cells: Comparing UV epoxy tape with UV coating

Introduction

By 2035, one in every two cars sold worldwide will be an electric vehicle[1]. As car makers compete for a share of the surging market, there is an increasing focus on improving EV performance.

At the heart of EV performance is the cell – the core of the battery pack. A battery pack is composed of multiple battery modules. Multiple individual battery cells are integrated in a module, which serves to provide essential physical, electrical, and thermal protection.

A trend analysis assumes that the overall demand will be in the direction of large prismatic cells. According to current announcements, more than 50 % will be prismatic cells by 2030. To make cells safe while improving efficiency, wrapping and coating especially for prismatic cells are different options to achieve this goal.

The technical results presented in this whitepaper have been prepared in cooperation with the Fraunhofer Research Institution for Battery Cell Production FFB.

[1]https://www.goldmansachs.com/insights/pages/electric-vehicles-are-forecast-to-be-half-of-global-car-sales-by-2035.html

State-of-the-art

An important step in battery pack manufacturing is the application of an insulating layer for prismatic cell formats. Application in round cells is only relevant for special applications e.g. for high-voltage applications above 800 V to avoid air and leakage current.

The current cell-to-module method of securing cells within a module relies on metal end and side plates to retain the module structure. Cell-to-module secures the structural integrity of the pack. Cell wrapping using a pressure-sensitive adhesive (PSA) provides electrical insulation keeping the batteries functioning and safe against dielectric breakdown. Cell-to-pack and cell-to-chassis battery designs (also called structural battery packs) use the cells as part of the structure, reducing the amount of metal parts. Keeping this structural integrity intact even in most demanding conditions is not possible with current PSA technology.

Current adhesives' capability

Larger cell formats as well as cell-to-pack and cell-to-chassis designs require a stronger type of adhesive solution for cell wrapping than what is currently in use. Cell wrapping tapes require higher mechanical strength to cope with the structural demands of cell-to-pack and cell-to-chassis designs. Any weakness can potentially cause a short-circuit which could lead to a fire or even an explosion. Therefore, safety must be paramount as engineers work to innovate on current capabilities.

The properties of the adhesive tapes currently used in the production of EV batteries could not cope with the demands that increased structural integrity places on them. Heat-activated film, for example, demands pressure on the substrate to attain appropriate adhesion. Along with the elevated temperature required for curing – approximately 120 °C – these processes are unsuitable for attempting to build batteries into a pack, without the fixtures that make up the module. Electrolytes inside the battery evaporate above 60 °C, which would render them useless in this process.

Not only that, but cell-to-pack means a drive to guarantee adhesion under potentially even higher forces and stresses as the performance of the electric vehicle increases. In order to meet these requirements, intensive research is being conducted into alternative insulation technologies. Two technologies in particular are in the spotlight, UV coating and UV wrapping with epoxy tape.

UV coating

UV coating of battery housings is a process for insulation battery cells. A special coating is applied to the surface of the housing and then cured using ultraviolet (UV) light. The varnish usually consists of a monomer to which photoinitiator has been added. When this comes into contact with the UV light, it reacts to form free radicals and a chain growth reaction begins, causing the monomers to crosslink.

The UV coating process has a curing time of a few seconds and no elevated temperature is required. It can also be solvent-free method, which makes this coating method environmentally friendly.

The coating creates a protective layer against corrosion, moisture and other environmental factors that could affect battery performance. However, it mainly electrically insulates the cell to prevent high voltages at the module and pack levels.

However, this process has several drawbacks, as well. Coating the edges of the cells in particular has proven difficult. Especially, a homogeneous thickness of the UV coating on the cells is challenging to achieve. The process currently involves applying up to three coats to achieve a better thickness distribution. This approach can result in uneven applications that could adversely affect the cell's performance. Furthermore, the cells are susceptible to damage caused by scratches if curing is not complete.

In summary, this technology has the following advantages:

Room-temperature curing
The applied varnish is dried at room temperature under a UV light within a few seconds.

High process flexibility
Coating by means of varnish can be done regardless of the cell dimensions.

Process robustness
The process is characterized by increased robustness due to fewer moving parts.

Product reuse
Overspray in the process can be collected and reused.

Solvent free
Can be VOC free and environmentally friendly.

UV epoxy tape

Wrapping the battery cells with UV epoxy tape is another way of insulating a battery. This film consists of a thin PET and an adhesive layer of UV-curing epoxy resin. To protect the adhesive surface, there is a siliconized liner on top, which is removed before application.

The film is activated by UV light either before or after application to the cell housing, which begins the curing process. Unlike other films, this one forms structural bonds and only requires lower temperatures around 20 °C, which is gentle on the cell.

The structural bonding and reliable electric insulation performance can be offered by the application of UV epoxy tape for cell insulation. This ensures that critical components within EV batteries can be protected against dielectric breakdowns, while coping with current trends towards increased cell size for automotive applications. Additionally, the UV wrapping is characterized by its high long-term stability and electric resistance. The production process allows for a high degree of reworkability hence leading to a decreased overall scrap rate that has a positive impact on the manufacturing process.

Not only that but the UV epoxy product has several other market-leading characteristics proven during thorough testing:

Room-temperature curing
Unlike other adhesives which requires temperatures upwards of 80 °C to apply properly, this UV epoxy can be activated at 20 °C if required.

High dynamic shear
The UV epoxy tape performs extremely well during dynamic lap-shear testing, providing high levels of cohesion and adhesion.

High elasticity
A vital factor in the protection of the battery against impact, it's also necessary when dealing with swelling and other deformation caused by temperature or other conditions.

Damp-heat-resistance
The UV epoxy tape was tested under extreme conditions – more than a thousand hours in an environment of 85 °C and 85 % relative humidity.

Flexible attachment process
UV activation of the tape can be carried out before or after it is applied, providing production lines with options of application.

Comparison

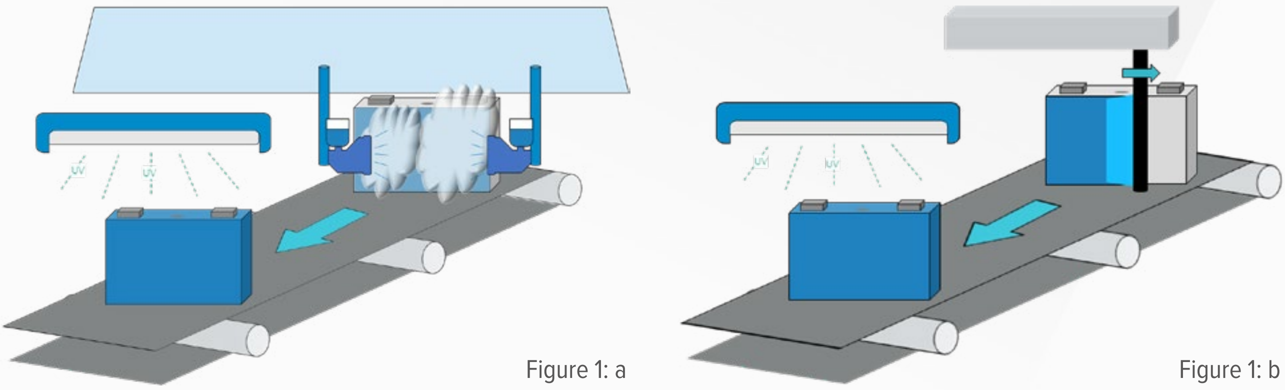

Figure 1: a

Figure 1: b

Figure 1: a) schematic process step for UV painting; b) schematic process step depiction for UV epoxy wrapping. Drawn by Fraunhofer FFB, adapted by tesa.

If the two technologies are compared, the following statements can be made:

Property	UV epoxy cell wrapping	UV coating
Investment costs	Lower - The lower investment costs result from the fact that no pre-treatment and only one drying step is necessary	High - Considering the full breadth of production: spraying equipment, coating supply & mixing, several UV activation stations, plus control technology
Material costs	Higher	Lower
Energy consumption / costs	More efficient - Only one UV station is needed, and the wrapping process requires a low amount of energy	Much higher - due to complex machine setup, many process steps and electronic procedures, plus 2-3 UV curing stations. More space is needed, and energy consumption is higher
Scaling	Very well scalable	Very well scalable - Only higher investment costs only additional pretreatment and drying steps
Process complexity	Low - From roll unwinding through UV activation and only one or two wrapping steps	High - With constant mixing of the UV coat, three coating steps, three curing steps, and a carrier cleaning step. Specialists must also be on hand in case of issues
Process flexibility	Lower - wrapping is not flexible for different cell designs	Higher - coating flexibility for different cell designs

Property	UV epoxy Cell Wrapping	UV Coating
Yield rate / reliability	High - more than 95 %.	Lower - less than 90 %, as non-coated parts subjected to dust and particles cause loss of insulation.
System solution options	System can be combined with PSA cell wrapping tapes - with crossover cost benefit. Insulation tape can be combined with tailored mounting tapes.	
Cell type	Prismatic & cylindrical	Prismatic & cylindrical
Cell pretreatment	Not necessary, as cleaning by plasma is sufficient.	Plasma cleaning and Laser structuring
Reworkability / recycling	Tape can be removed without residues by hand or machine, for short-term reworkability. It's also possible to strip by laser.	Paint stripping by laser involves removal of a few micrometres of aluminium.
Elasticity	High - 100 % elongation can be applied to convex or concave cell housing shape and have no problem with radius thickness	Limited - poorer uniform varnish application due to convex and concave cell housings and radius thickness.
Abrasion resistance (transport)	The product design (PET film + epoxy adhesive) is very robust against dents and scratches.	High risk for scratches and abrasion (potentially causing reduced or complete loss of insulation), especially during transport and assembly.
Damp-heat-resistance	High (tested at over 1000 hours in 85 °C and 85 % relative humidity)	Critical - With limited elasticity, there's a high risk of cracking.
Chemical resistance	High	High

The UV epoxy application process provides a more efficient and more effective solution than UV coating:

- With one wrapping layer vs three UV coatings, you can save time and resources.
- Tape can be colour-coded as it's folded around the cell, to ensure the correct application.
- Tape can be removed by hand or machine, without residues, while removing UV coating requires the use of a laser, which will also cost a few micrometres of aluminium underneath.
- UV epoxy-wrapped cells can be handled straight after application, aiding production efficiency. UV coating can be scratched before curing is completed, which slows down the process.

Changes needed on the production line would be minimal and would even drive further efficiencies.

- The space required is no more than a standard wrapping line.
- There are no solvents or fumes to deal with, so no additional spend required on HVAC/protection.
- Only one UV station is needed, and when in the off position it can even stay part of the standard wrapping line.
- Stations can be 100 % adapted to project needs.
- The process is clean and simple, with minimal maintenance required.

Process overview

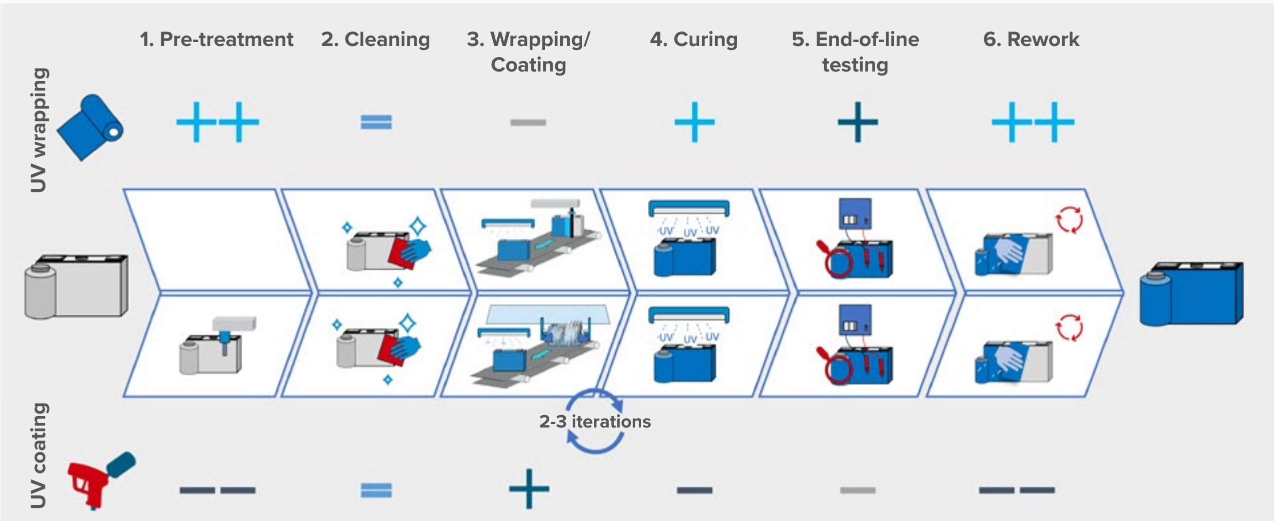

Figure 2: Process overview including pairwise comparison of the individual process steps

Conclusion

A combination of complex product requirements and industrial limitations calls for an equally innovative solution. Performance and efficiency are key driving forces in the future of EV battery design. With UV epoxy we can help to deliver both.

We can assess customers' application processes and work together to find the right tape and automation solution.

Furthermore, our product can highlight the importance of collaboration with our partners to develop cutting-edge products.

EV battery designers need the freedom to create products that can help lighten the load whilst maintaining performance levels. With UV epoxy they can do just that.

Talk to an expert about the tesa product line today and see what it can do for your projects.

Future trends

EV battery designers are seeking a solution which can facilitate removal of the supporting metal structure, reducing weight and therefore potentially increasing performance. Cell-to-chassis is emerging as a viable candidate, but the more immediate potential solution is cell-to-pack.

Using cell-to-pack to design EV batteries means you can cut back on using supporting components such as side plates. The volume saved within the pack design gives manufacturers the choice between increasing the amount of cells, potentially increasing range (provided other accommodations have been made in the vehicle design), or reducing the overall weight of the pack. The utilization of cell-to-pack technology can enhance the efficiency of battery packs, potentially resulting in improved performance of electric vehicles.

To make cell-to-pack a viable option, there must be a strong type of structural bonding.

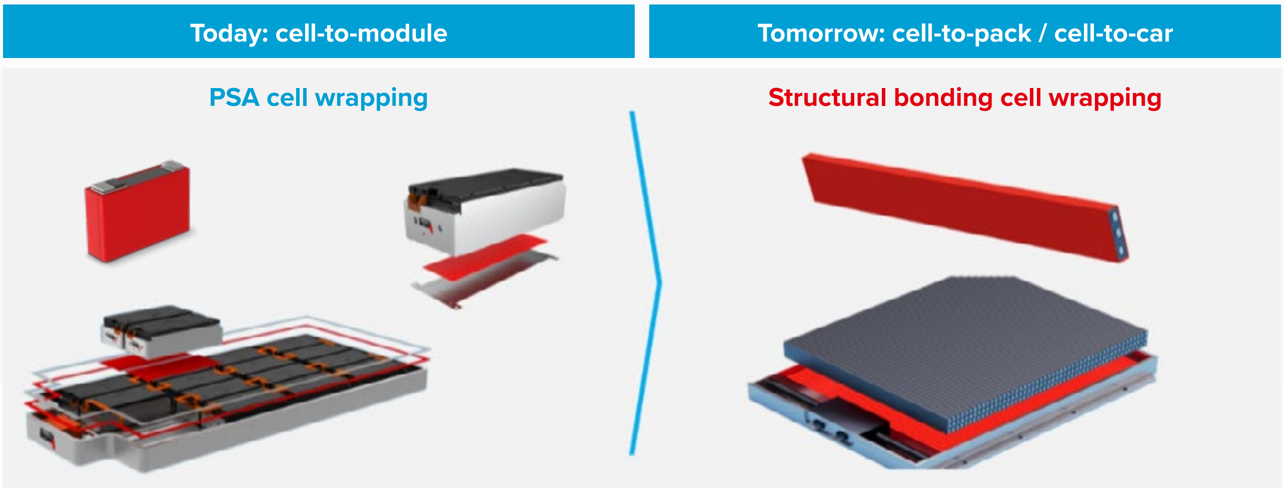

Figure 3: Comparison between cell-to-module and cell-to-pack technology

Jan-Darius Plöpst | Miha Podbreznik | Marcel Diehl | Marius Böhmer

Fraunhofer Research Institution for Battery Cell Production FFB
Bergiusstraße 8
48165 Münster, Germany
www.ffb.fraunhofer.de

tesa SE
Hugo-Kirchberg-Str. 1
22848 Norderstedt, Germany
www.tesa.com