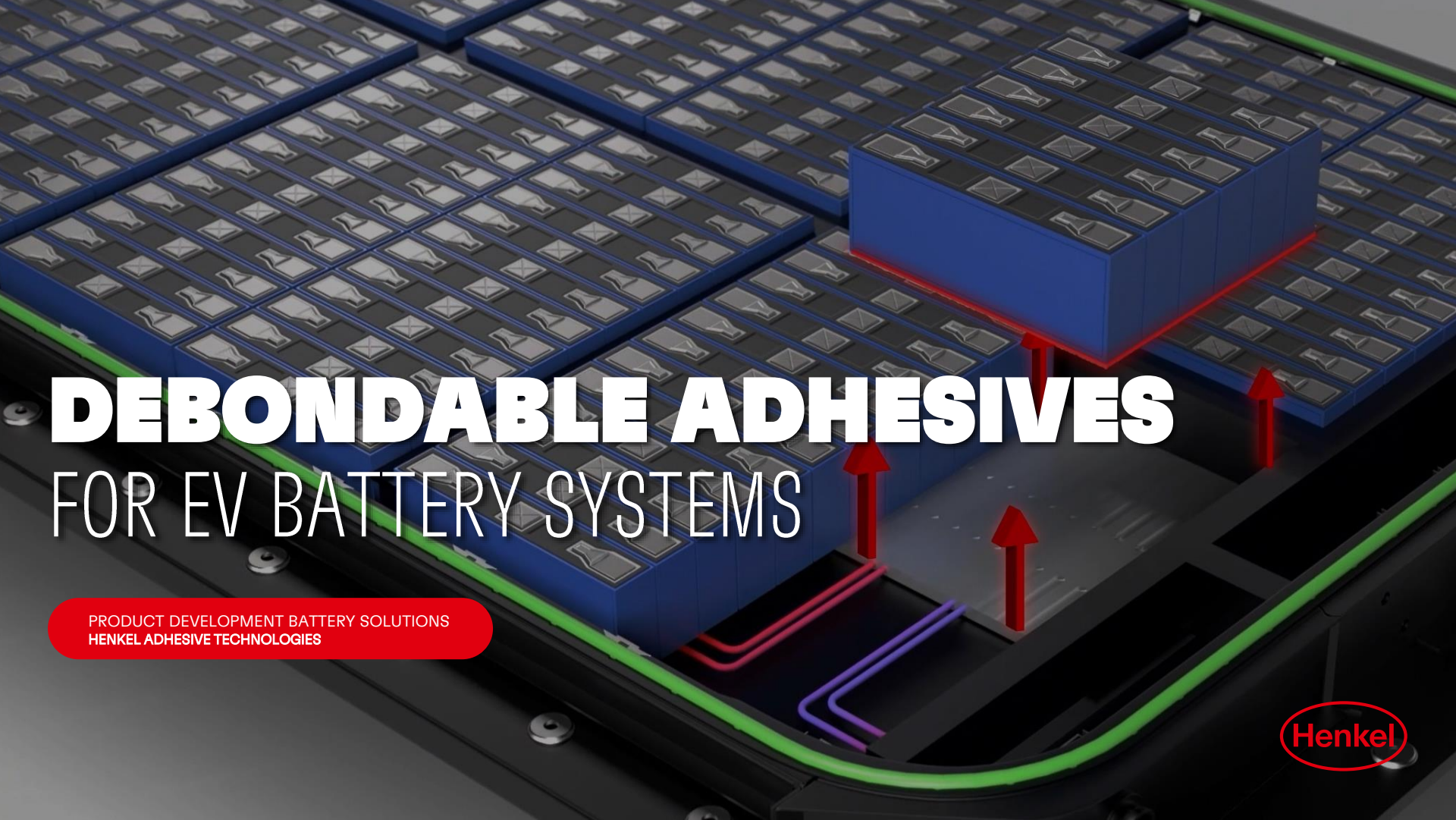


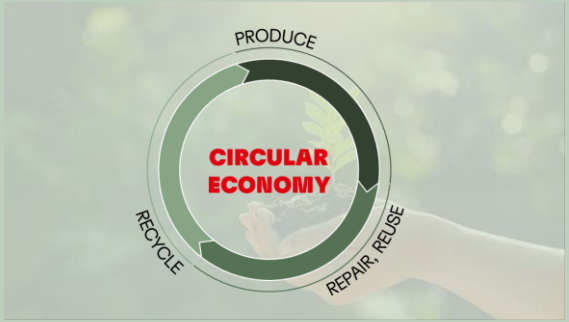
DEBONDABLE ADHESIVES
FOR EV BATTERY SYSTEMS

PRODUCT DEVELOPMENT BATTERY SOLUTIONS
HENKEL ADHESIVE TECHNOLOGIES

Henkel

INCREASING RELEVANCE
OF CIRCULARITY IN EV BATTERIES

REGULATORY REQUIREMENTS



Circular Economy Action Plan (EU)

- Active promotion of transition to a circular economy, including measures to reduce waste and promote recycling
- Not specific to automotive electronics but can impact recycling and sustainability efforts in the automotive sector

End-of-Life Vehicles (ELV) Directive (2000/53/EC)

- Reduction of environmental impact of ELVs, by promoting recycling and proper disposal
- Requires member states to establish systems for proper treatment, recycling, and recovery of ELVs
- Producers are also encouraged to design vehicles with recycling in mind

Eco-Design Directive (EU)

- Eco-design requirements for various product categories, including energy-related products
- May impact design of automotive electronics to make them more energy-efficient and recyclable

Henkel

INCREASING RELEVANCE
OF CIRCULARITY IN EV BATTERIES

END-CUSTOMER DEMANDS

4R

Repairability, Reusability, Repurposing and Recyclability
to extend component lifetime & close material loop for resilient value chains

Right-to-repair
Initiative originating in electronics to allow **easy dismantling**, might spill over to automotive

Capturing the value
of end-of-life materials; maintaining access to scarce raw materials & preserve depletable resources

Henkel

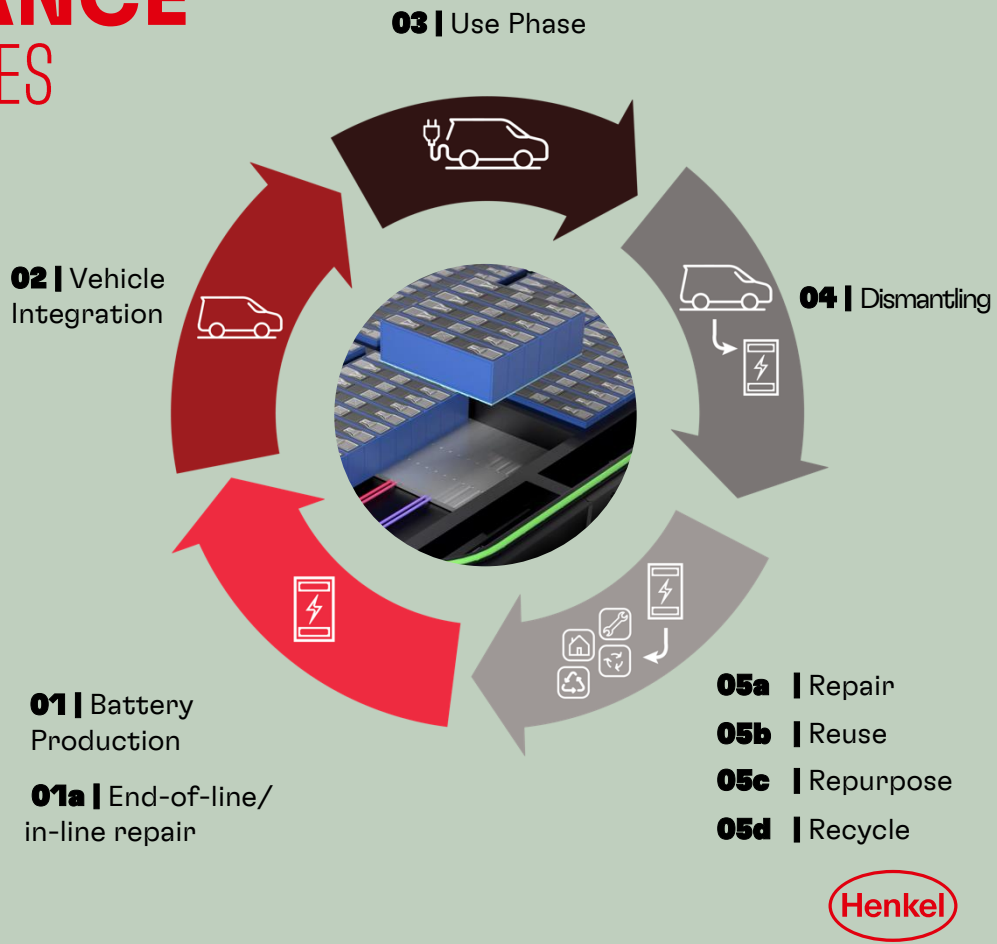
INCREASING RELEVANCE
OF CIRCULARITY IN EV BATTERIES

Battery debonding technology will enable end-of-line repair and disassembly of batteries in the field

Non-destructive dismantling is a key feature of sustainable EV batteries.

Advantages for OEMs and battery makers:

- Repair in production: Possibility to rework structural batteries where defects are detected in end-of-line test
- Repair in market: Possibility of exchanging defect modules/ stacks/ cells while the battery is already in the market
- Recycling: Ease of dismantling of the battery pack to allow for separation of cells from the frame which allows for high recovery rates for the recycling process



TRIGGERS FOR DEBONDING

TRIGGER IN SCOPE OF HENKEL AUTOMOTIVE

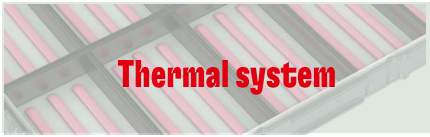
THERMAL
Softening, decomposition or expansion of the adhesives' polymers, triggered by heat

ELECTRICAL DELAMINATION (EDL)
Obtaining a weak boundary layer that leads to accumulation of the adhesives at interfaces, triggered by electrical current

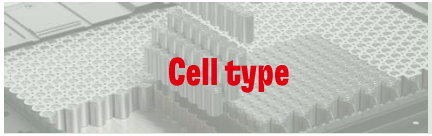
IMPORTANCE OF WORKING ON DIFFERENT TRIGGERS

Depending on the design, debonding solution needs to be adapted based on customer requirements:

- Module to pack
- Cell to pack
- Cell to chassis



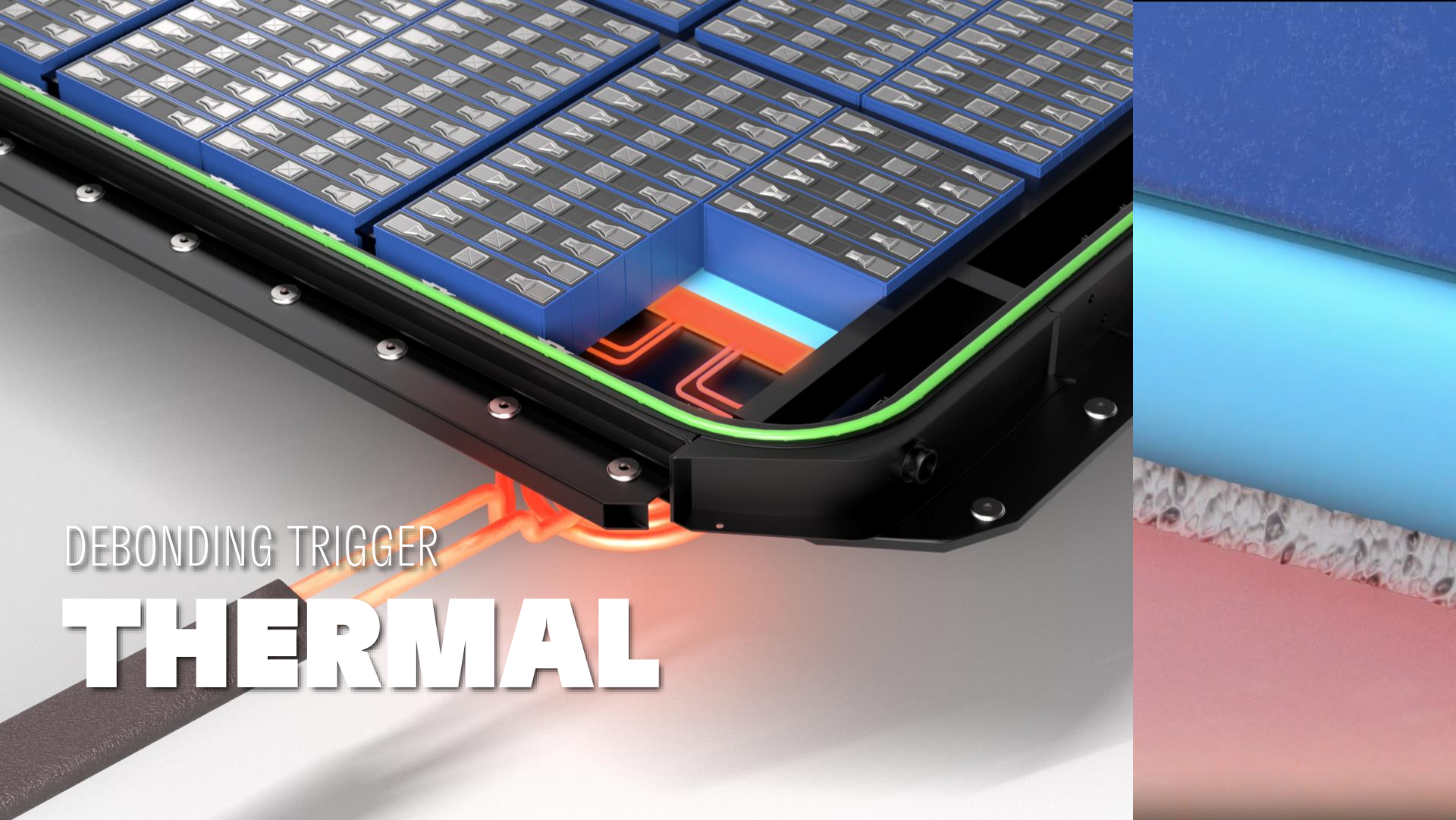
- Central cooling plate
- Modular cooling plates
- Cooling ribbons



- Cylindrical
- Prismatic
- Pouch

- Repair
- Repurpose (e.g., 2nd life)
- Recycling

Henkel


DEBONDING TRIGGER
THERMAL

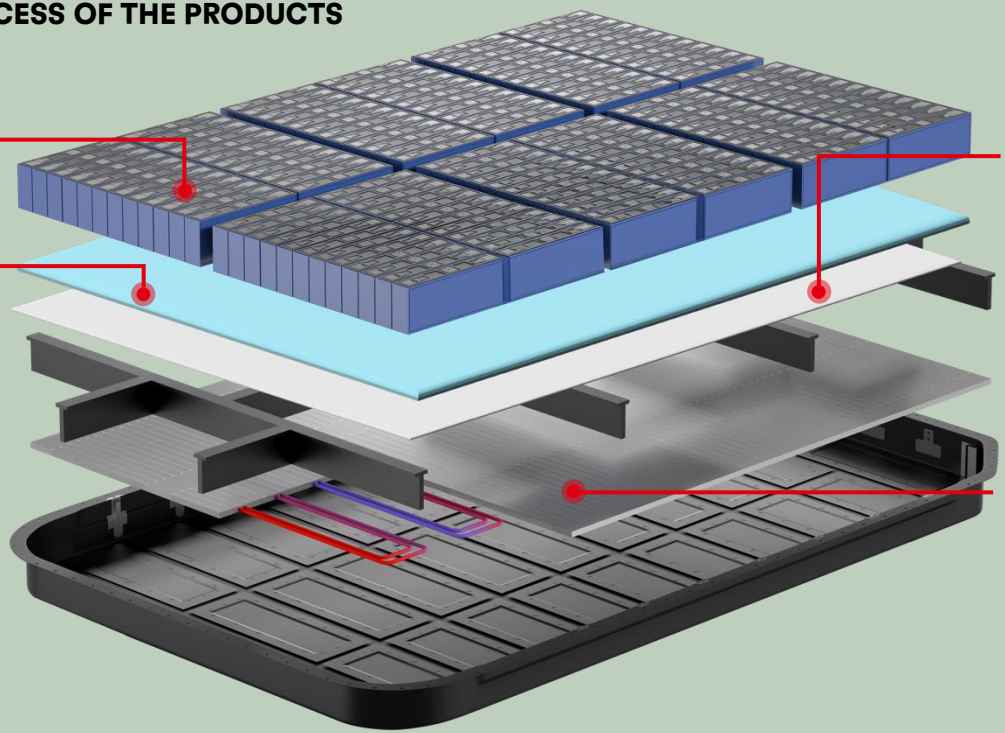
DEBONDING THERMAL TRIGGER
SYSTEM LAYOUT

SIMPLE APPLICATION PROCESS OF THE PRODUCTS

Substrate 1
(e.g., battery cell)

Henkel Adhesive

- Application of the adhesive with standard equipment
- No process change in the production line necessary



Henkel Debonding Layer

- Automated spray application of the debonding dispersion
- Application and drying of the Henkel debonding layer before the assembly process

Substrate 2
(e.g., cooling plate)

Cross section Debonding-System

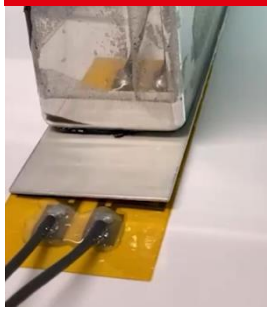
DEBONDING THERMAL TRIGGER FUNCTIONALITY

PRINCIPLE: HENKEL DEBONDING LAYER FOAMS WHEN EXPOSED TO TEMPERATURE AND IS THUS STRUCTURALLY WEAKENED

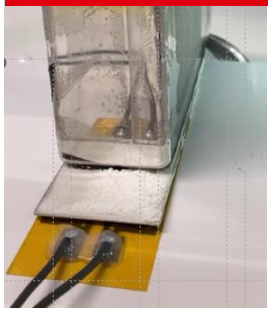
The temperature of the battery cell remains below 60°C during debonding

- Henkel debonding layer also acts as thermal insulation for the battery cell during expansion
- Irreversible mechanism: cell stack can be removed either directly after heat input or after the substrates cooled down

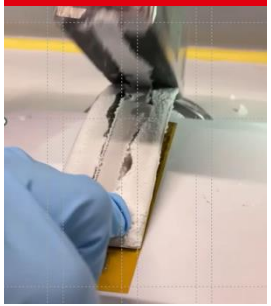
Before heat trigger



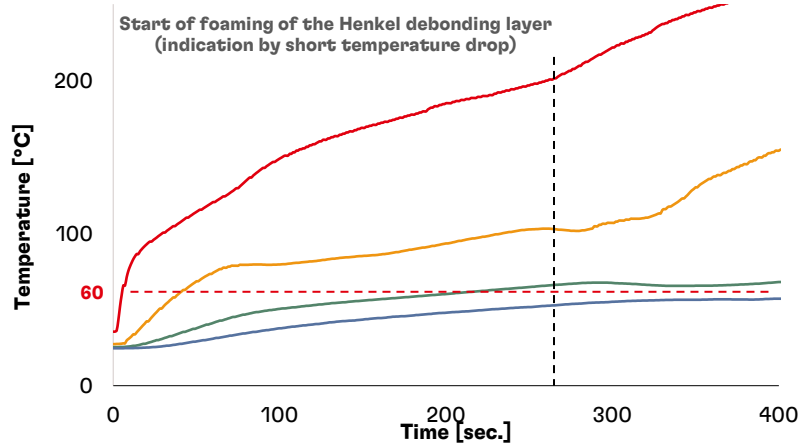
Debonding layer foams



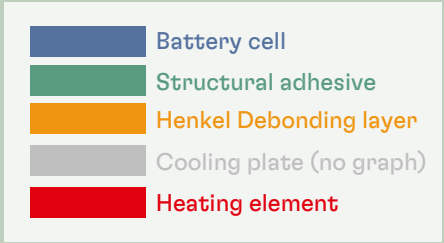
Manual disassembly

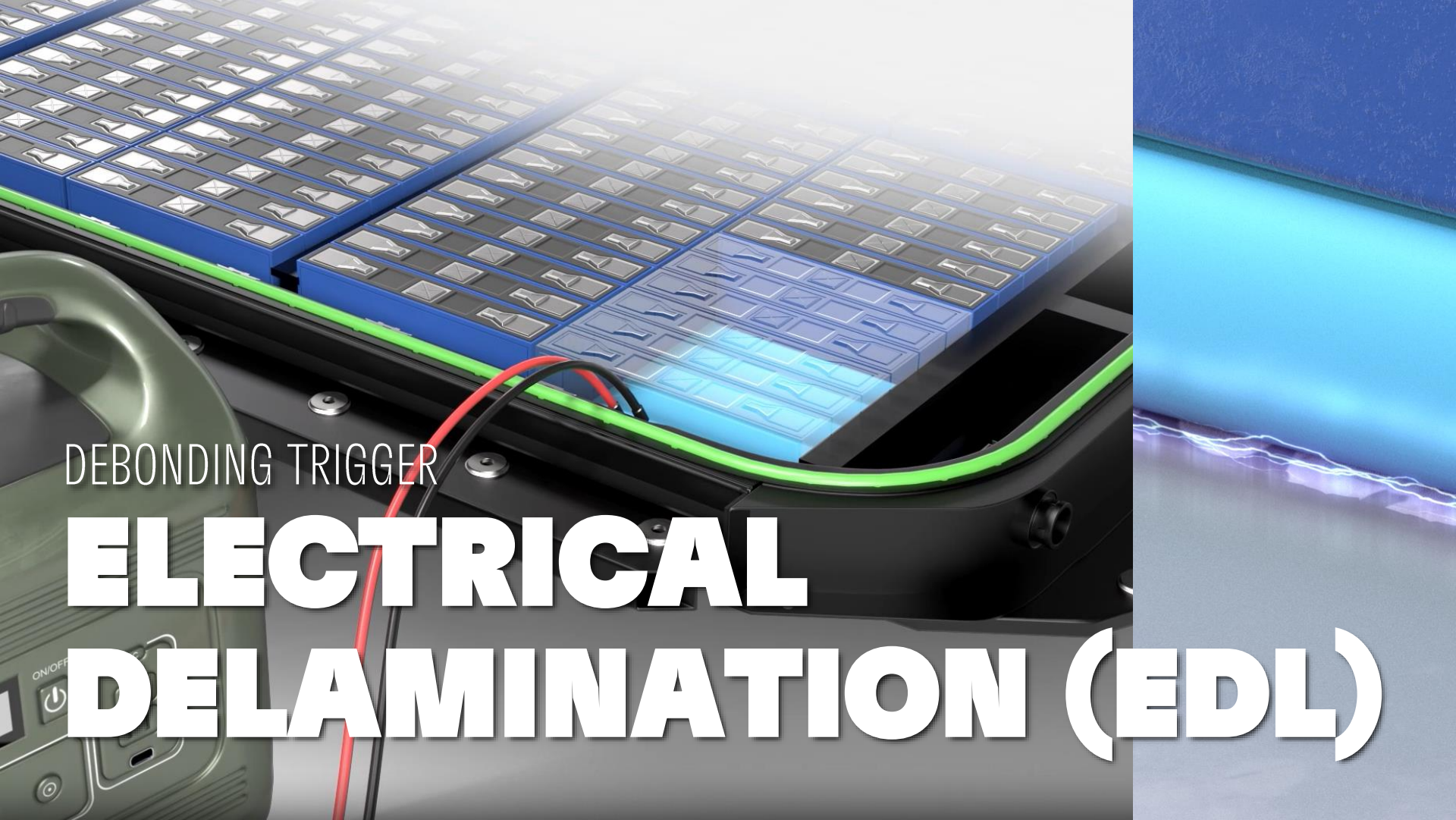


Temperature curve Debonding



Cross section thermal debonding system




DEBONDING TRIGGER
ELECTRICAL
DELAMINATION (EDL)

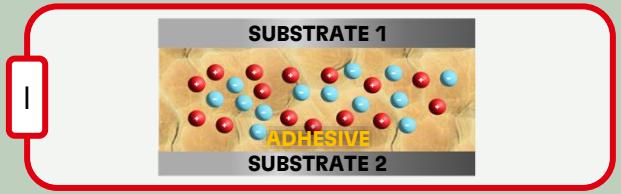
ELECTRICAL DELAMINATION
FUNCTIONALITY

PRINCIPLE: FORMATION OF A WEAK BOUNDARY LAYER WITHIN THE HENKEL DEBONDING LAYER BY ION DIFFUSION TO ELECTRODES WHEN VOLTAGE IS APPLIED

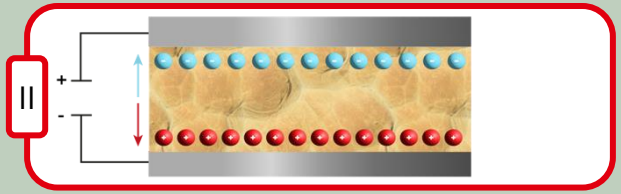
- High automation capability and process reliability by applying an electrical voltage to designated points on the battery pack (electrically conductive substrates)
- Debonding is carried out at room temperature
- Debonding progress easily readable by current intensity (amperage converges towards 0 A)

  → Creation of clean surfaces for rebonding

Dispensing of **electrically debondable adhesive**



Diffusion of **ions** in **electrical** field



Adhesive failure by creation of weak boundary layer

EVALUATION OF DEBONDING CONCEPT
HIGHLIGHTS

Thermal Trigger

- Expansion of the debonding system is irreversible, allowing disassembly at room temperature
- Application process of the debonding system can be automated using spray technology
  → Process is scalable
- Surface can be cleaned and thus allows possibility for rebonding

Electrical Delamination (EDL)

- High process and application safety as the temperature in the system remains at room temperature during debonding
- Suitable for variable geometries and designs
- Cleaning of surfaces very well possible due to adhesive fracture pattern on any side which allows rebonding

THANK YOU.