Enabling Advanced Data Analytics through Markerless Sheet-Level Traceability in Battery Production

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Challenges

- Missing **sheet-level traceability** prevents full exploitation of **data-driven optimization methods**
- Difficulty establishing reliable, markerless identification in continuous **roll-to-roll processes**
- High **variability in material** appearance complicates consistent, software-based tracking
- Integrating traceability seamlessly into **existing production and IT infrastructures**
- **Scaling** the solution across **different production environments** without loss of accuracy or reliability

Goals

- **TRAICELL research project:** Develop a **fully automated, non-invasive, software-based** traceability system enabling reliable identification of each **electrode sheet in roll-to-roll manufacturing**
- Facilitate detailed correlation analyses between **manufacturing parameters** and **resulting cell properties**
- Gradually **scale and validate** the traceability approach across the production environments of the **TRAICELL project** partners **PEM, FFB, and UniverCell**
- **Reducing energy/material waste** and increase efficiency to **strengthen German/European battery industry competitiveness**

Approach for “Markerless Traceability” concept

1. High-resolution camera systems **capture surface images of electrodes or foils** during production
2. Computer vision algorithms **identify unique surface patterns** that act as inherent identifiers
3. Extracted features are converted into **compact, reproducible fingerprint IDs** representing each sheet’s texture
4. Fingerprint IDs are **stored in a traceability database and linked to process and production metadata**
5. Subsequent image captures enable **re-identification and localization of sheet sections** within the production process

Targeted concept at PEM within TRAICELL project

TRL 7

Scale up

TRL 4

Series-near prototype by

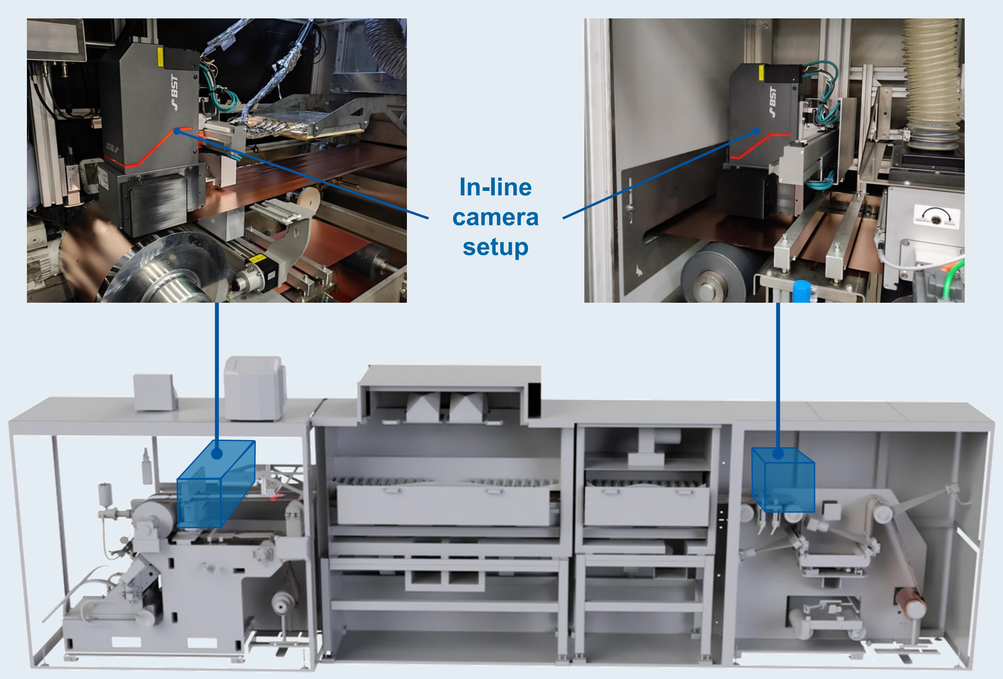
UniverCell

Research prototype by

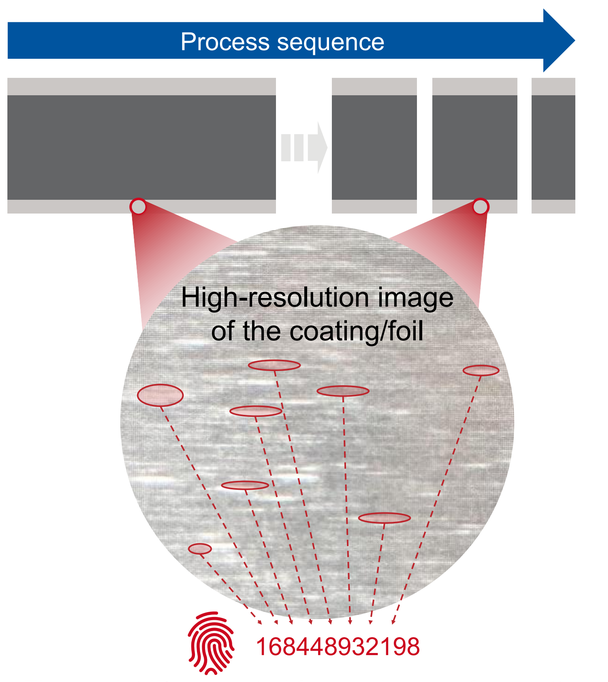
Fraunhofer FFB

Pilot prototype by

PEM | RWTH AACHEN UNIVERSITY



“Markerless Traceability” concept



Challenges of traceability on electrode sheet level

- Comprehensive sheet-level traceability **enables detailed correlation analyses between manufacturing parameters and resulting cell properties**, enhancing understanding of cause-and-effect relationships across the battery value chain.
- **Product-process relations** form the **basis for adaptive, data-driven process control**, allowing dynamic parameter adjustment during production to improve flexibility, shorten ramp-up phases, and support robust process optimization.
- Conventional approaches using physical markers **can impair component quality and long-term cell performance**:
  - **Ink-based printing** may dissolve in the electrolyte during assembly, causing contamination and reduced lifetime.
  - **Laser marking** can introduce local thermal damage and surface modifications that degrade electrode quality and weld seam integrity.
- **High integration costs** arise from the need for specialized printing and scanning equipment.
- **Loss of markings** during downstream processing, such as slitting, results in **information loss and reduced traceability**.

Results and Discussion

- **Distinct surface features (“identifiers”)** on the electrode foil, **enable precise product identification** across multiple process stages
- **Surface features** allowed **precise correlation of product characteristics with process parameters**, forming the basis for marker-free traceability
- The markerless identification capability provides a **foundation for adaptive, data-driven process control**, illustrating the potential impact of precise traceability on process parameter adjustments and production performance

Outlook

- **Setup and validation of the traceability system** to identify surface ID patterns under various process modifications, particularly after calendering
- **Systematic scaling of the concept** in collaboration with the research partners of TRAICELL at Fraunhofer FFB and UniverCell, advancing the technology readiness up to TRL 7

Consortium:

MERANTIX MOMENTUM · PEM | RWTH AACHEN UNIVERSITY · Fraunhofer FFB · BST an ELEXIS company · UniverCell

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