

# The many roads to LFP-Recycling: A Toolbox for Cathode Delamination

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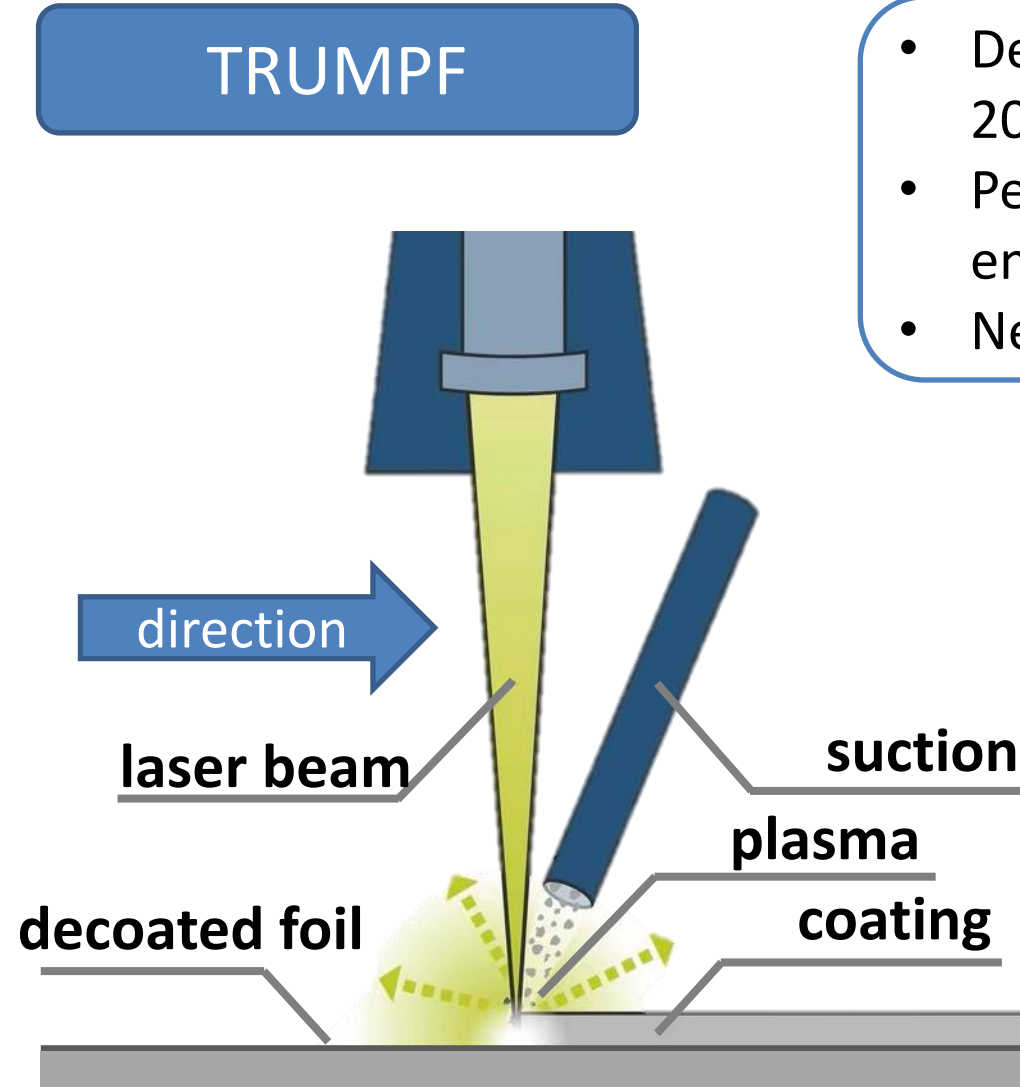
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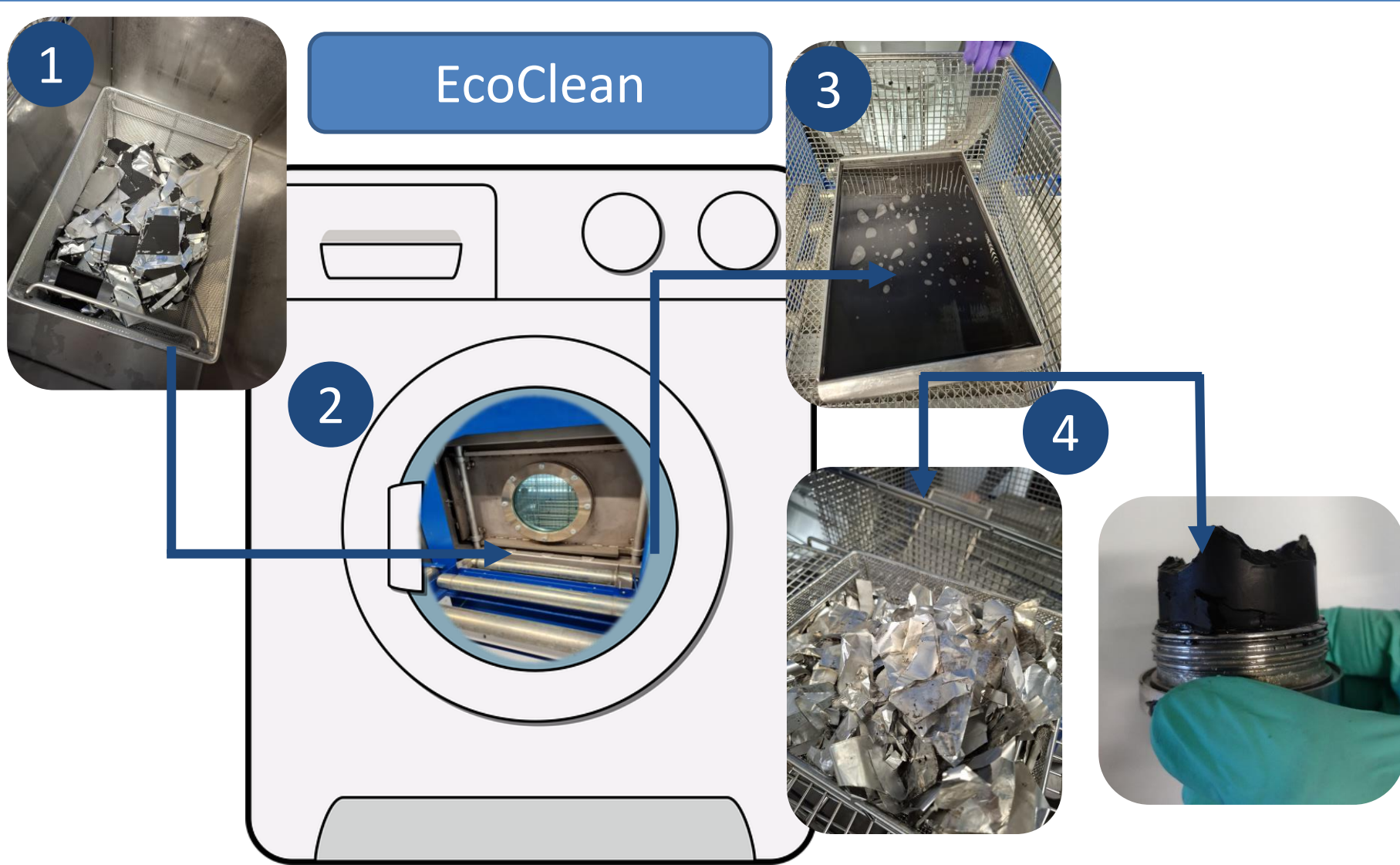
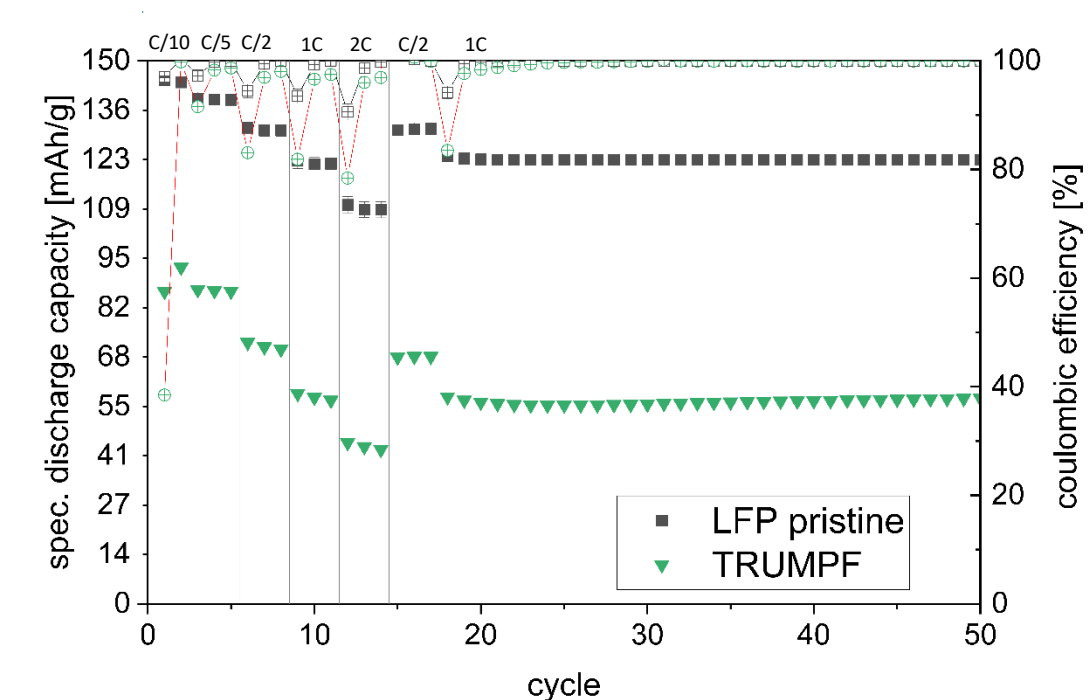
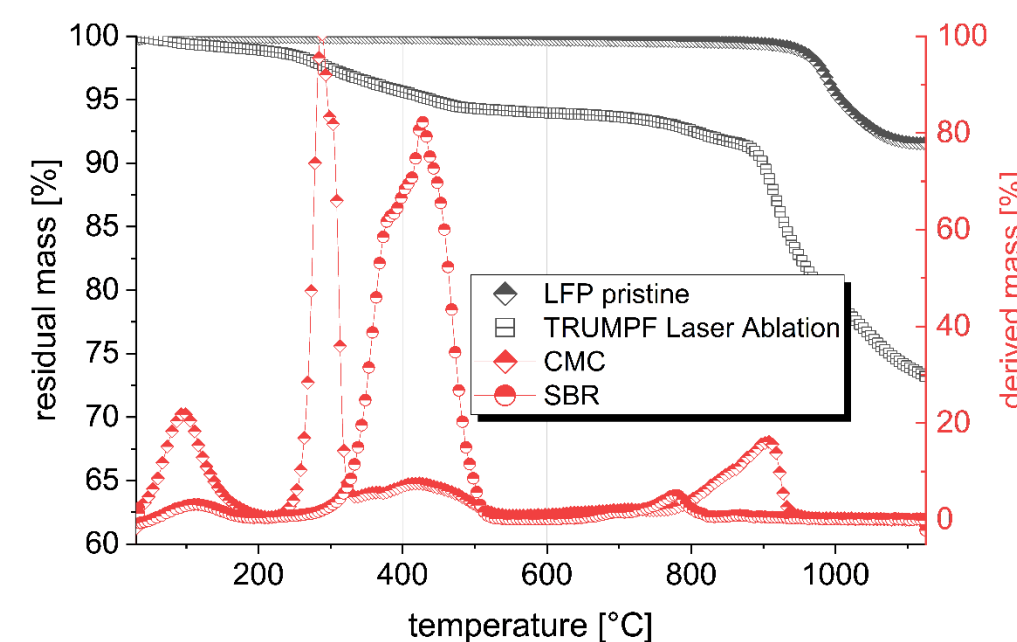
## Introduction

The delamination of battery electrodes is a critical step in direct recycling strategies for lithium-ion batteries, enabling the physical separation of active materials from current collectors while preserving their chemical integrity. This work presents three approaches for precise electrode delamination for both shredded and wound feedstocks. Each method presents distinct advantages and downsides.



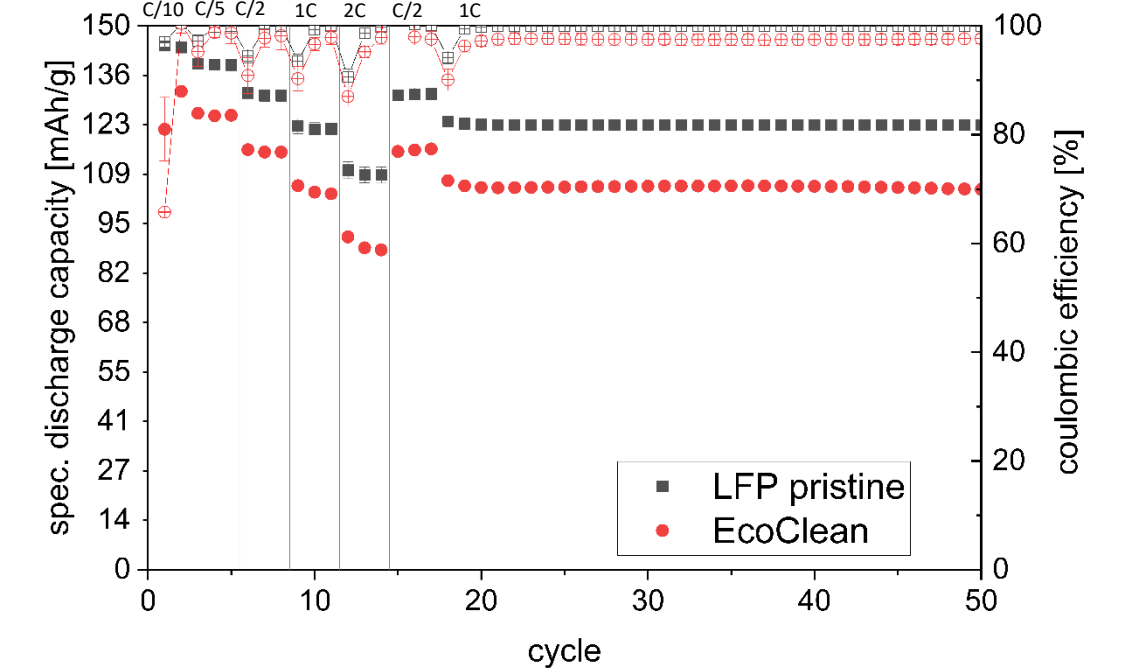
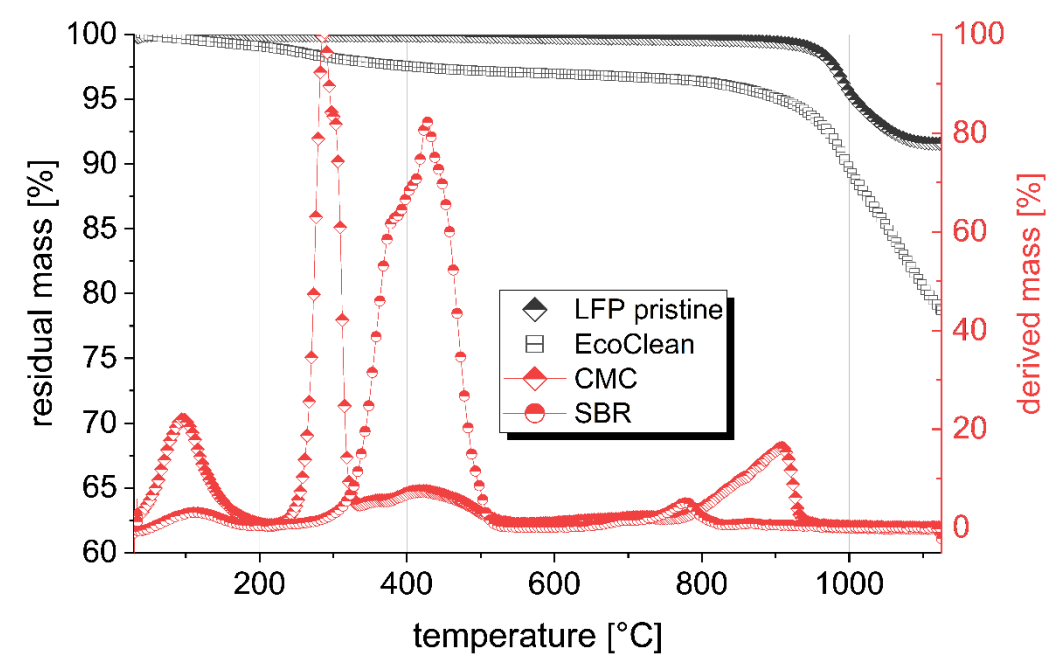
- Decoating of current collectors utilizing a 200 W fiber laser ( $\lambda=1062$  nm)
- Penetration depth, decoating speed and energy input freely adjustable
- Nearly complete binder removal observable

- Electrochemical testing is misleading due to a polluted suction unit
- Rate stability at least suggests functioning active material

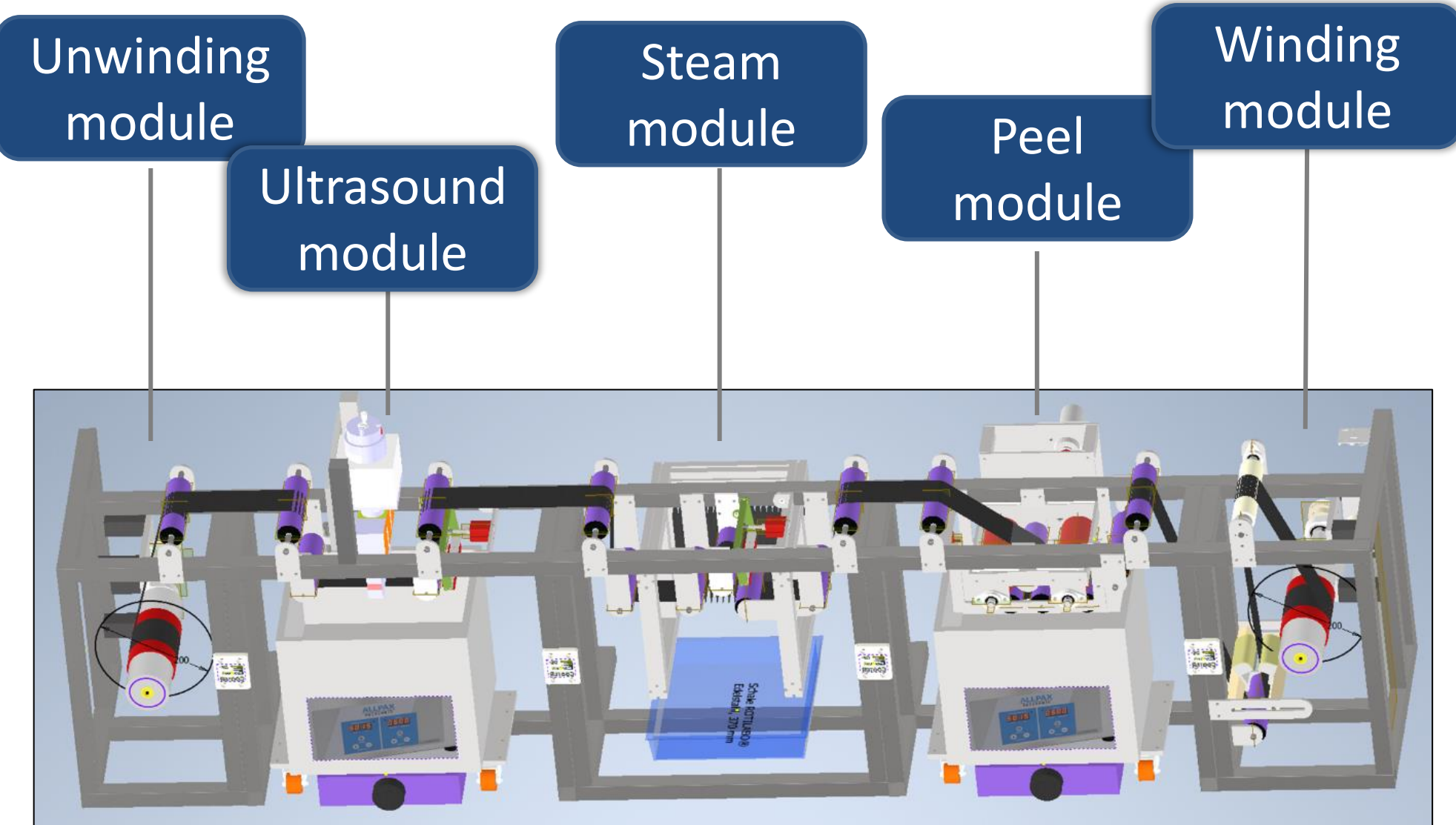


- EcoClean offers cleaning solutions for various industrial applications
- Aqueous delamination of shredded electrodes with ease

- Solid materials yielded after centrifugation
- TGA suggests CMC dissolution during process
- Promising first results seen in testing

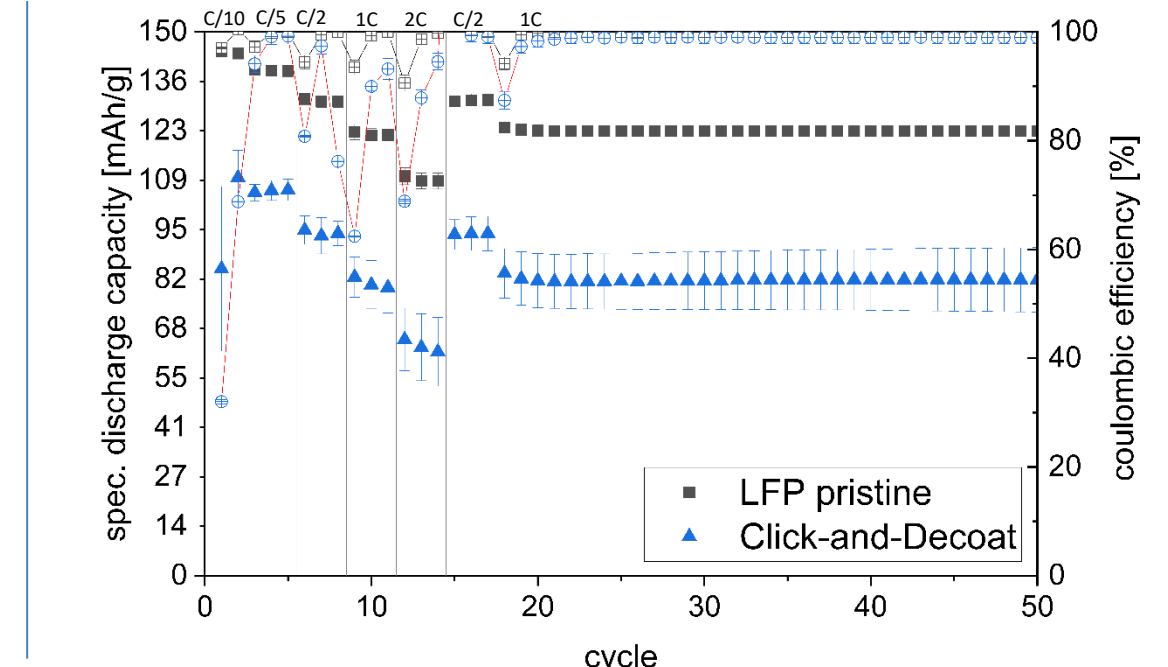
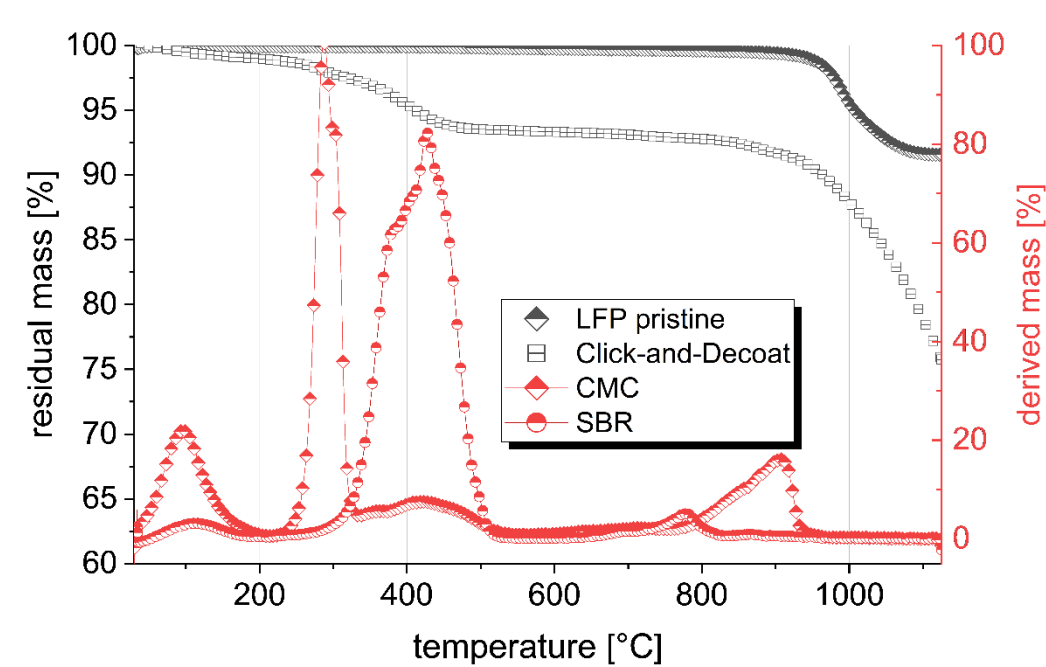


## Click-and-Decoat



- In-house solution for continuous roll-to-roll delamination of production scraps
- Fully modular and customizable to meet requirements depending on material input (more modules addable)

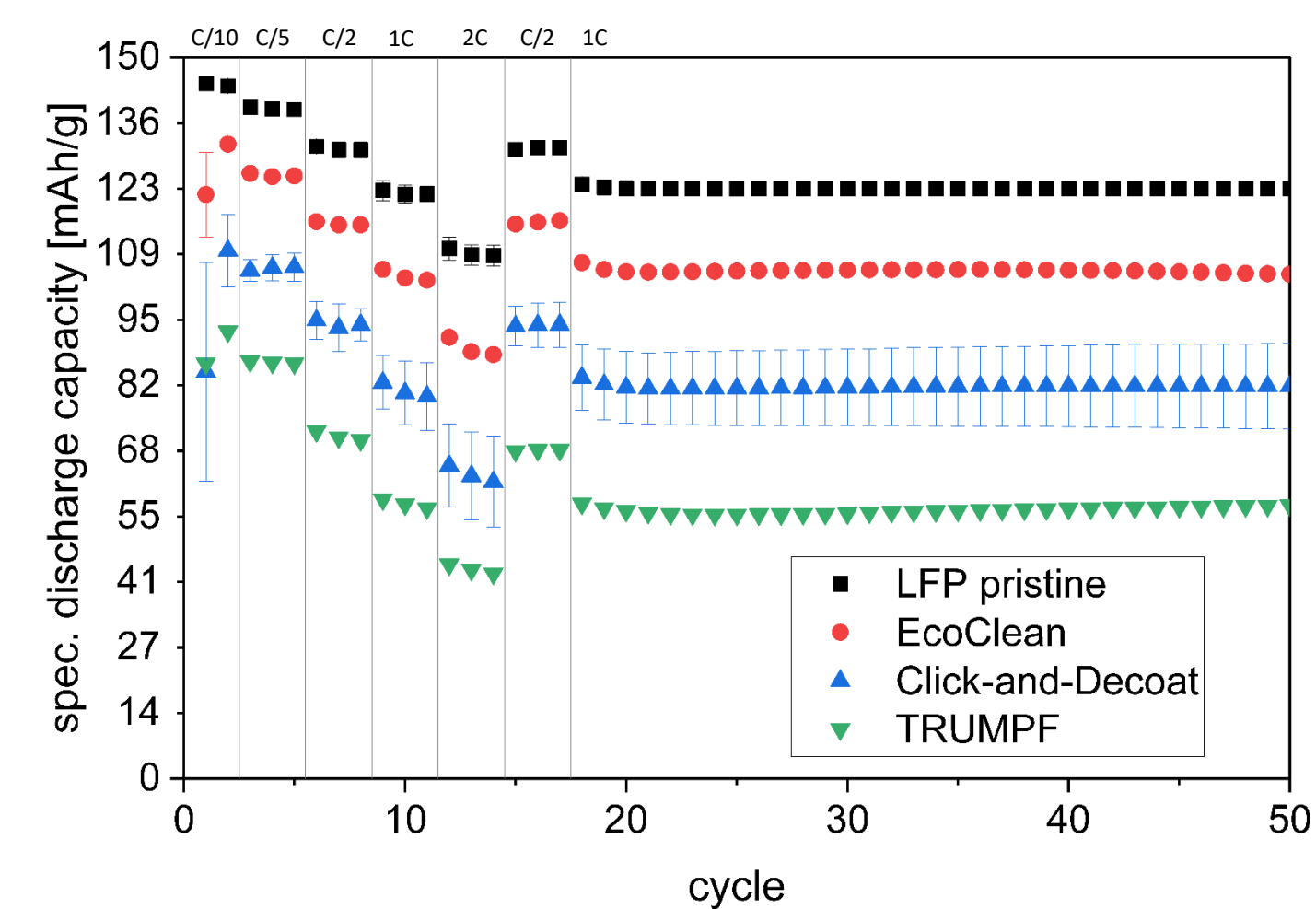
- Exploiting approach of aqueous delamination combined with mechanical peeling
- Implementation of ultrasound remains challenging  $\rightarrow$  diminished electrochemical performance



## Summary

Laser ablation enables fast, highly precise delamination with a wide range of adjustable parameters; however, electrochemical performance is currently hindered by contamination from the suction unit. Delamination using an industrial cleaning solution from EcoClean is a fast and effective method for shredded materials, though it is limited by batchwise feeding. The electrochemical results are promising. The in-house Click-and-Decoating system is fully modular and allows precise adaptation to material requirements, but it remains to be evaluated which modules are sensible and meet the defined criteria.

	TRUMPF Laser Ablation	EcoClean Industrial cleaning	ISC Click-and-Decoat
feedstock	winded electrodes	shredded	winded electrodes
method	thermal	aqueous	mechanical/aqueous
throughput	continuous	batch	continuous
accessibility	+	+++	++
complexity	+++	+	+
adjustability	+++	+	+++



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[1] Rettenmeier et al. (2023) – Battery recycling – Exploitation of laser technologies for dismantling and recycling processes, in Lasers in Manufacturing Conference 2023.  
[2] trumpf.com/de\_INT/loesungen/anwendungen/oberflaechenbearbeitung-mit-dem-laser/laserentlackung/