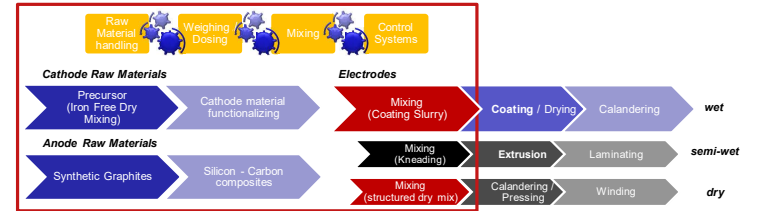




Trocken ist das neue Nass:
 Von innovativer Mischtechnik bis hin zu skalierbaren Anlagen-Konzepten für die lösungsmittelfreie Elektrodenfertigung

Dr.-Ing Stefan Gerl
 Project Director LIB & Head of Process Technology

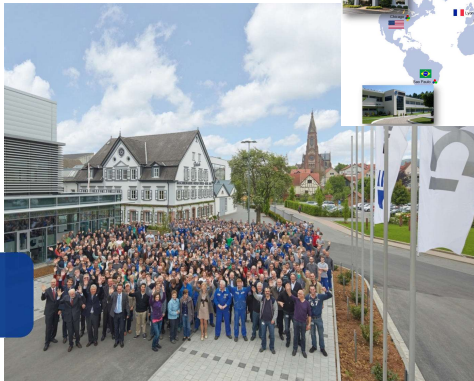
Eirich Core Competences (not only) in LIB manufacturing



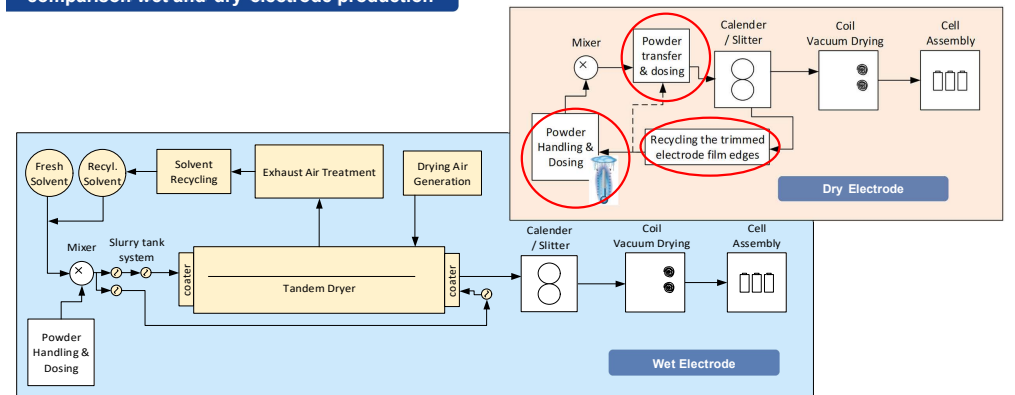
family owned Eirich Group - more than 160 years of experience



Germany: 550 employees
 Worldwide: 1100 employees
 Turnover : ~ 150 - 200 Mio €



comparison wet and dry electrode production

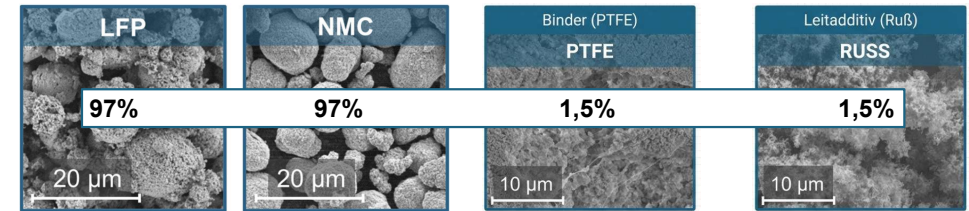


Comparison of different process routes

Electrode Production Route	TRL Level	Company / R&D Institution	Raw Materials	Final product
Powder Application (e.g. brush, spray), 3D Printing, Hot Rolling	4-5	AM Batteries, Sakuu, FHG ISIT,	Active, Conductive, PVDF	Homogeneous Powder mix with tendency of coarse grained binder demixing
Dry Powder Melt Calendaring	7	TropMelt - FHG ISIT / UniverCell	Active, Conductive, meltable Polymer / Electrolyte	Direct extruded film / melt granulated mix
Direct Calendaring from fibrillated mix	5	DryTrec - FHG IWS, PowerCo?*	Active, Conductive, PTFE	Structured mix forming granules with very wide size distribution
Free Standing Film from fibrillated mix				
- Dry Electrode	9 (Anode), 7 (Cathode)**	Tesla/Maxwell	Active, (Conductive), PTFE, UHMW, PVDF	Structured mix with narrow size distribution
- Activated Dry Electrode (ADE)	7 - 8	Licap / Dürr	Active, Conductive, PTFE, Solvent for Activation***	Structured mix with narrow size distribution

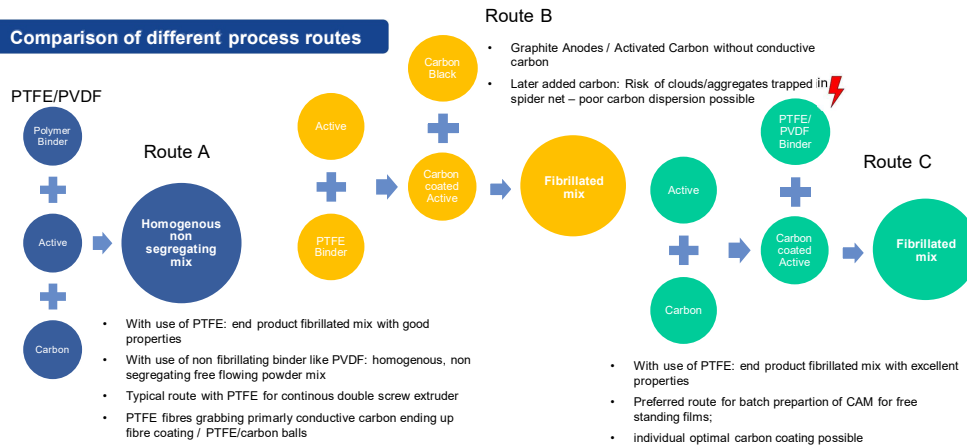
* „Dry Coating process of PowerCo, the powdered base ingredients are rolled directly onto the film, similar to a printing process.“, Press release Volkswagen Group
 ** „The dry electrode problem ... is really quite a hard problem“; we acquired Maxwell really just for the dry electrode ... technology, but ... just illustrates what a **gigantic gap there is between something working at small scale and at large scale.**“ Elon Musk, Investors Day March 2023
 *** fibre activation improves thin film formation

Raw materials: Challenges for material handling



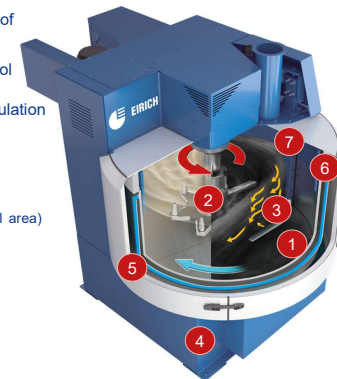
- Sensitive to humidity & carcinogenic (NMC)
- NCM high bulk density ~ 1700 – 2200 g/l
- needs containment (OEB3/4) and Micro-Environments
- critical: temperature must stay < 20 °C – chilled dumping and dosing units
- Risk of early fibrillation in dosing
- Need of cooling chain
- high specific surface
- Low bulk density ~ 60 g/l
- Tendency to absorb humidity

Comparison of different process routes



Eirich Mixer Battery Design used for DBE

- 1 Rotating mixing chamber for transport of material
- 2 variable, slow to fast running mixing tool - 1 – 45 m/s tip speed - for mixing, coating, kneading, fibrillation and granulation
- 3 Static, scraping wall scraper
- 4 Installation on 0° angle
- 5 Double-jacket cooling (100% bottom, 100% product contacting wall area)
- 6 OEB3 sealing system
- 7 Specially designed discharge system



Dry Battery Electrode (DBE)

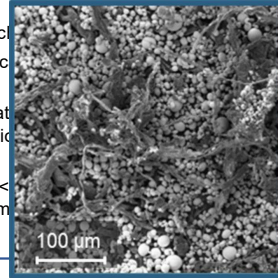


Mixing & Fibrillation: PTFE Network formation by high shear mixing in an Eirich mixer



3-STEP EIRICH Batch-Process (ProLiT Approach)

- 1. CB Dispersion:** Active material + conductive carbon heating up to >70 °C possible/favorable
- 2. Fibrillation:** Addition of PTFE at high temperature homogenization – followed by high shear fibrillation 70-90°C
- 3. Cooling / Chopping:** Mix temperature below < 70°C optimization of bulk properties / particle size for manufacturing dosing.



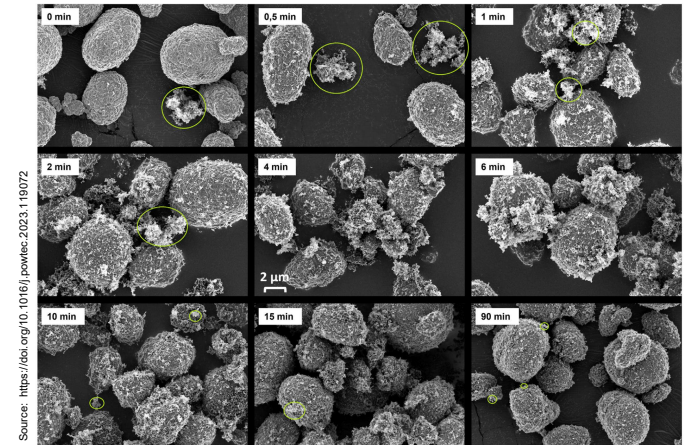
Insight

Mechanics: Van-der-Waals-Forces adhere particles by shear to the formed PTFE Fibrill (Spider Net) Network.

Dry Battery Electrode (DBE)



CB Coating of NCM

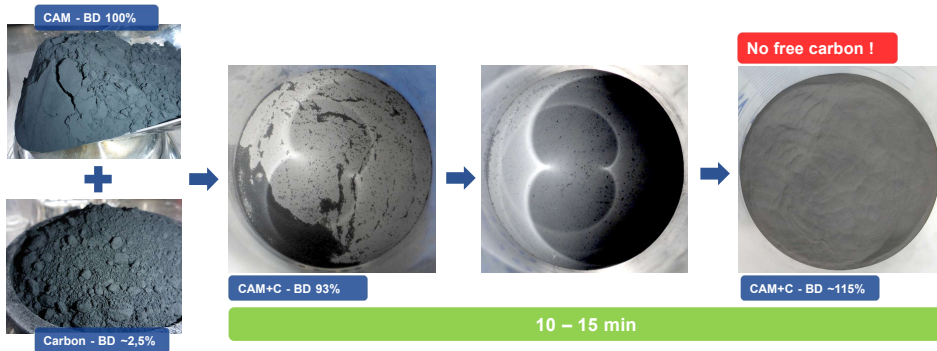


Source: <https://doi.org/10.1016/j.powtec.2023.119072>

Dry Battery Electrode (DBE)



Dry mixing – Coating of Active Material with Carbon



Dry Battery Electrode (DBE)

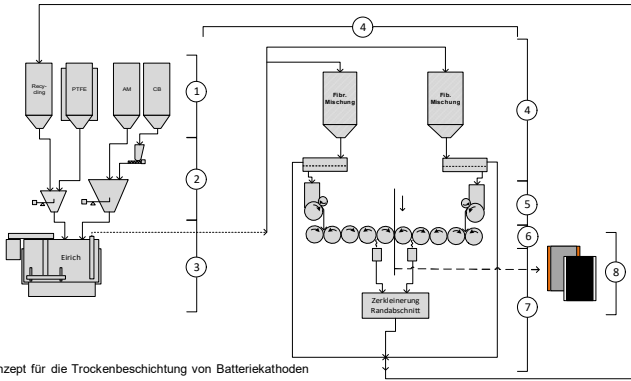


Fibrillating / Structuring coated Active Material with Polymer Binder



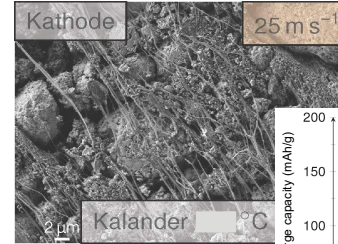
Material transfer and Calandring of a freestanding film – scalable 1 GWh concept

1. Rohstoffhandlung: Rohstoffaufgabe für Einsatzstoffe und Recyclingmaterial mit Zwischensilos.
2. Feststoffdosierung in ein Mischsystem.
3. Mischsystem (Extruder oder Batch-Mischer (hier: Eirich-Mischer)) und die dort stattfindende Funktionalisierung des Pulvergemisches.
4. Materialüberführung in Zwischensilos mit Schutzklebung im Austrag auf Materialaufgabebesen/Pulverdosierung.
5. Pulverdosierung in den Kalenderspalt über die geforderte Walzenspaltbreite.
6. Schichtbildung im Mehrwalzenkalander.
7. Rückführung/ Recycling von Randschnitt am Kalander sowie Grobputz aus der Schutzklebung in den Mischprozess.
8. Fertige beidseitig beschichtete Elektrode

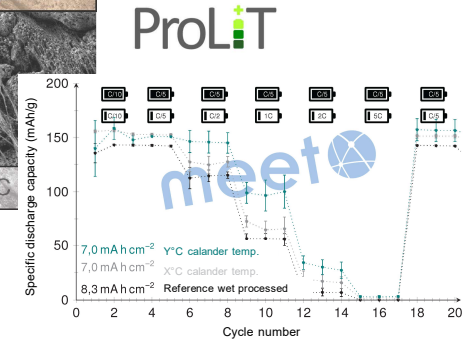


Source: ProLit – Whitepaper Industrialisierungskonzept für die Trockenbeschichtung von Batteriekathoden

NCM Free Standing Film made with Eirich Mixer



Source: MEET battery research center



Source: MEET battery research center



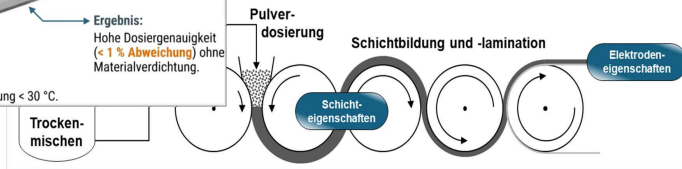
Material transfer and Calandring of a freestanding film

Der Rollendosierer: Präzision an der Schnittstelle

Problem: Fibrillierte Mischung ist kohäsiv (klebrig) und brückt in Standard-Vibrationsrinnen.
Lösung: Zwei synchron laufende Rollen.

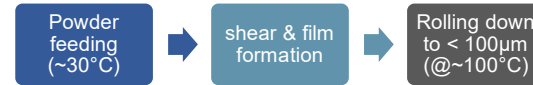
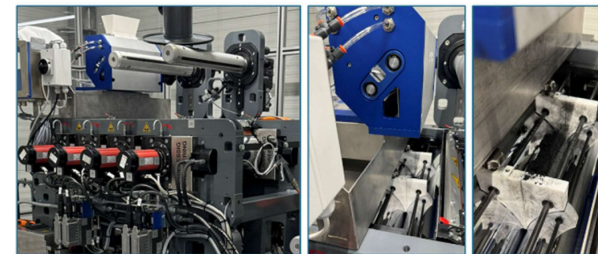
Detail: Dosierrolle mit Kavitäten trägt Material aus; zweite Rolle streift ab.
Ergebnis: Hohe Dosiergenauigkeit (< 1 % Abweichung) ohne Materialverdichtung.

Prozess-Parameter: Materialtemperatur vor Dosierung < 30 °C.



Source: ProLit – Whitepaper Industrialisierungskonzept für die Trockenbeschichtung von Batteriekathoden

Saueressig Multi-Roll Calander with Coperion K-Tron DBE Dosing unit



Source: ProLit – Whitepaper Industrialisierungskonzept für die Trockenbeschichtung von Batteriekathoden

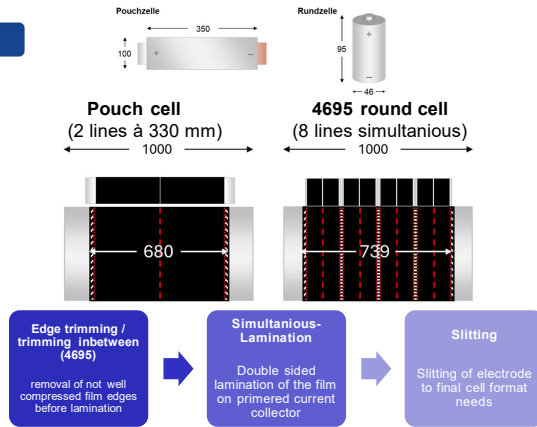
technical need:
target: film thickness < 100 μm
solution: multi-roll calander (> 8 roller) e.g. from Saueressig

Insight
 A single „Powder to Film“ step is not recommended for Gigafactory quality and speed

Lamination & Forming/Slitting: from film to cell

Tabelle 3: Materialverbrauch und Durchsatz für 1GWh/a Produktion von NMC- und LFP-Kathoden

Parameter	Einheit	Aktivmaterial	Ruß	Binder (PTFE)
NMC-Kathode				
Materialverbrauch	t/a	~1300	~20	~20
Durchsatz	kg/h	~160	~2,5	~2,5
LFP-Kathode				
Materialverbrauch	t/a	~1800	~30	~30
Durchsatz	kg/h	~220	~3,5	~3,5



Source: ProLit – Whitepaper Industrialisierungskonzept für die Trockenbeschichtung von Batteriekathoden

Fazit & Perspektive

1 Machbarkeit validiert

- 1+ GWh-Linie ist mit skalierter deutscher Maschinenteknik realisierbar

2 Technische Hürden gelöst

- strukturierte Mischungen (LFP, NMC) mit guten Verarbeitungseigenschaften
- Dosiersysteme für Aufgabe in Kalenderspalt
- Labor Qualitätskontrollmethoden entwickelt

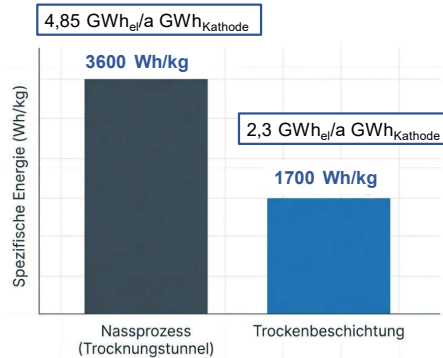
3 Nächster Schritt

- Pilotlinien inkl. Materialtransport
- Inline Qualitätskontrolle
- Recycling-Methoden für Randbeschnitt, An-/Abfahrmaterial sowie Elektroden

Die Trockenbeschichtung ist der Schlüssel zur nachhaltigen und kompakten Gigafactory der Zukunft in Europa

EIRICH ist ein wichtiger Teil davon

Energy consumption



Material efficiency:

- Close to **100%** material efficiency by direct recycling possible.
- Approx. **15% Recycling** material estimated – direct recycling to mixing process
- Higher energy density of electrodes possible due to binder reduction (PTFE < 2 %).

Source: ProLit – Whitepaper Industrialisierungskonzept für die Trockenbeschichtung von Batteriekathoden

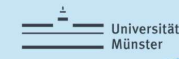
Das ProLIT – Whitepaper Konsortium



CustomCells



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