Karlsruhe Institute of Technology

Thin Film Technology
Alexander Hoffmann
Phone: 0721/608-45736
alexander.hoffmann@kit.edu
www.tft.kit.edu

TFT Thin Film Technology

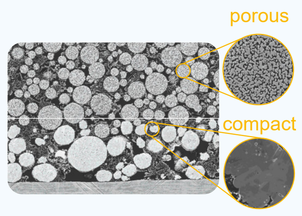
Challenges and current goals in slot-die coating of battery electrodes

Alexander Hoffmann[1,2], P. Scharfer[1,2], W. Schabel[1,2]

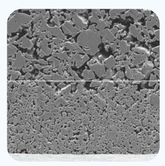
[1] Thin Film Technology (TFT),
[2] Material Research Center for Energy Systems (MZE), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Multilayer electrode applications

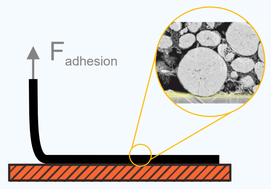
Multilayer structures enable beneficial electrode properties [1-7]



Advanced material combinations [3,4]



Particle sizes and shapes [5,6]

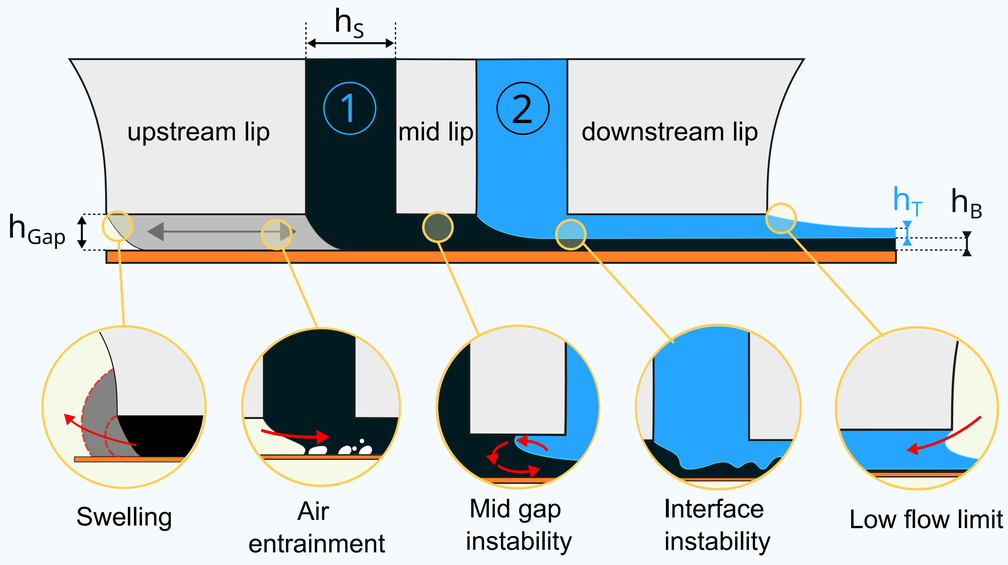


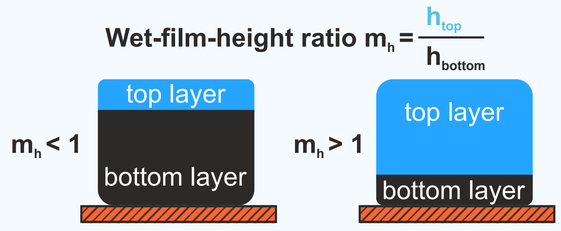
Enhanced mechanical properties by primer layers [7]

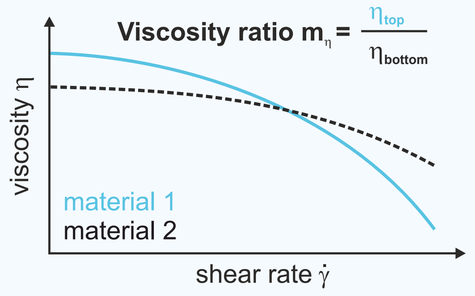
Lower production cost at higher speeds [1,2]

Simultaneous multilayer slot-die coating

Stable coating coditions require proper adjustments of process parameters and formulation properties

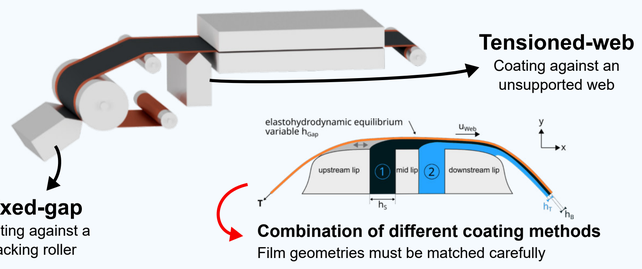


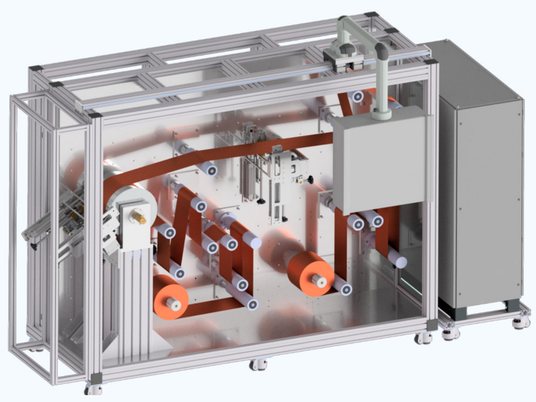




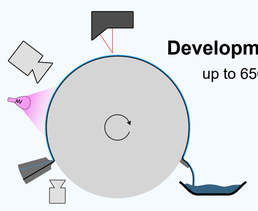
Experimental coating setup at TFT-labs

Machinery for **double-sided coatings**

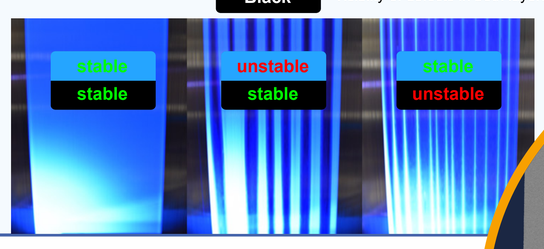


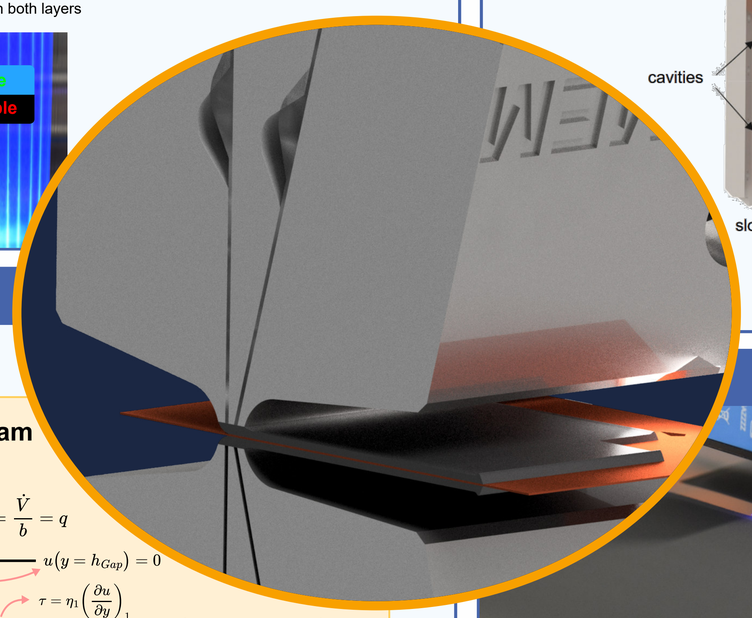


Isolated coating investigations without drying
Single- and multilayers



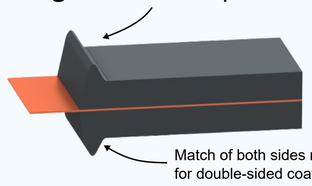
UV marker: Black
Fluid coloring
Visibilty of defects in both layers

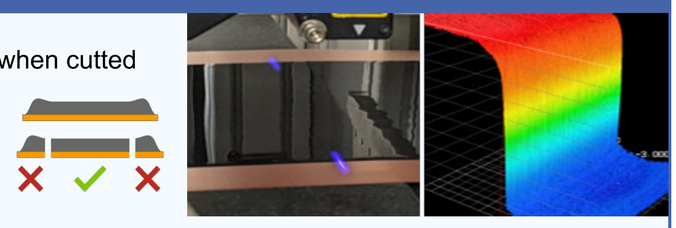




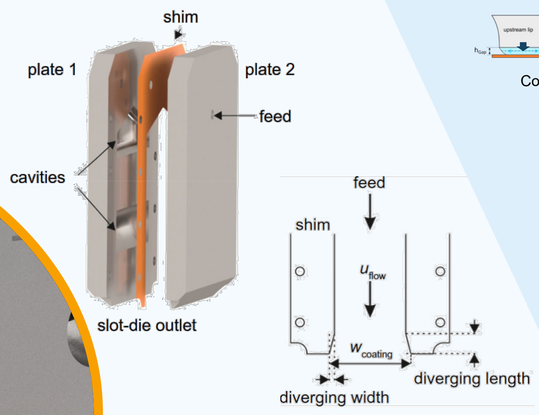
Edge formation and scrap reduction

Edge elevations produce scrap when cutted

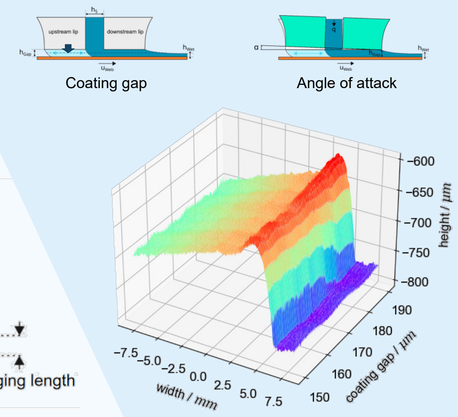




Optimized **inner die geometry** allows local influence on the flow profiles



Precise **slot-die positioning** enables a reduction of edge elevations



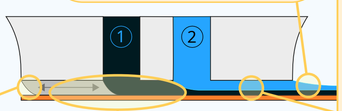
Simulations

Equation of motion $\frac{\partial p}{\partial x} = \frac{\partial}{\partial y}\left(\eta\left(\frac{\partial u}{\partial y}\right)\frac{\partial u}{\partial y}\right)$

Power Law $\eta = \kappa\left(\frac{\partial u}{\partial y}\right)^{n-1}$

Free surface

$\Delta p_{(i,j)} = f(\mathrm{Ca}), \quad \mathrm{Ca} = \frac{\eta u}{\sigma}$



Capillary pressure

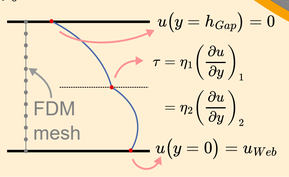
$\Delta p_{(i,j)} = \frac{\sigma}{R}(\cos\theta + \cos\phi)$

Upstream and mid gap
single layer, shear thinning

$\frac{\partial u}{\partial y} = -\left(\frac{1}{\kappa}\left(-\frac{\partial p}{\partial x}\right)(y+c)\right)^{\frac{1}{n}}$

Downstream gap

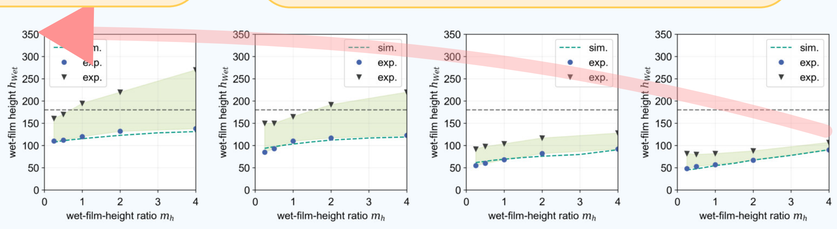
$\int_0^{h_G} \mathbf{u}(\mathbf{y})\, dy = \frac{\dot{V}}{b} = q$



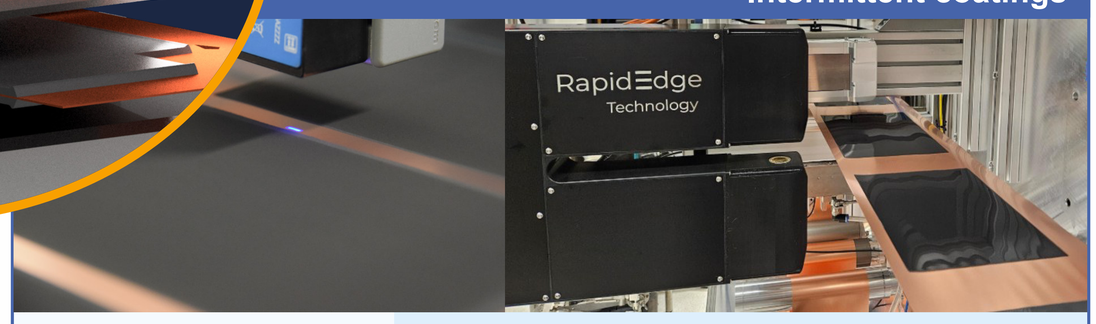
two layers, shear thinning

coupling velocity field to flow by numerical solution

Fast simplified method
to predict operability windows for stable coatings



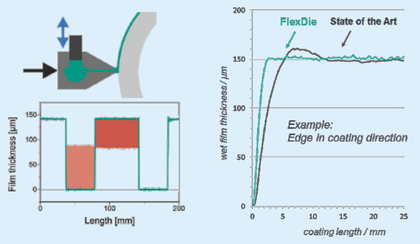
Intermittent coatings



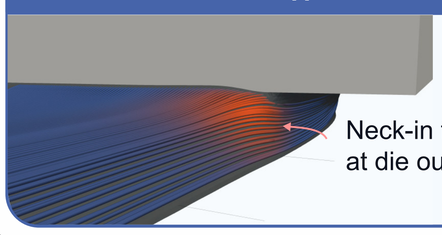
Rising and falling edges
determine pattern quality

Limited edge quality

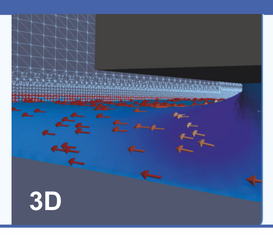
Our approach:
Local fluid storage during intermitting
Up to 150 m/min

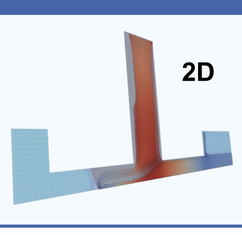


CFD simulations [8]



Neck-in flow at die outlet



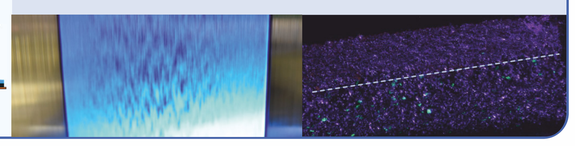


Outlook

Manipulation of flow fields and bead pressure

Angle of attack | Lip geometry | Upstream pressure

Detailed study on intermixing



References

[1] R. Diehm et al., Scharfer, Philip; Schabel, Wilhelm (2020)
[2] J. Kumberg et. al, Scharfer, Philip; Schabel, Wilhelm (2021)
[3] J. Klemens et al., P. Scharfer, W. Schabel (2023)
[4] J. Klemens et al., P. Scharfer, W. Schabel, (2022)
[5] J. Klemens et al., P. Scharfer, W. Schabel, (2023)
[6] J. Klemens et al., P. Scharfer, W. Schabel, (2023, in progress)
[7] Diehm, Ralf et al., P. Scharfer, W. Schabel (2020)
[8] Hoffmann, Alexander et. al, Scharfer, Philip; Schabel, Wilhelm (2022)