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Thin Film Technology
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Stability of multilayer electrode coatings with different properties of the layers

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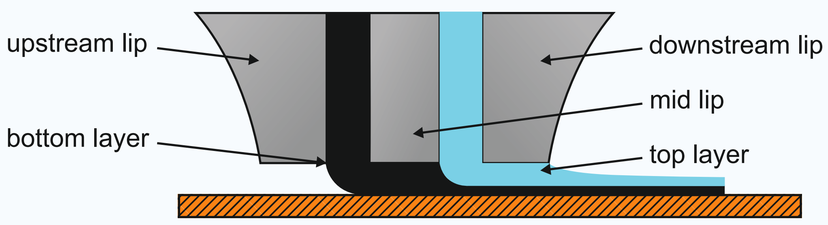
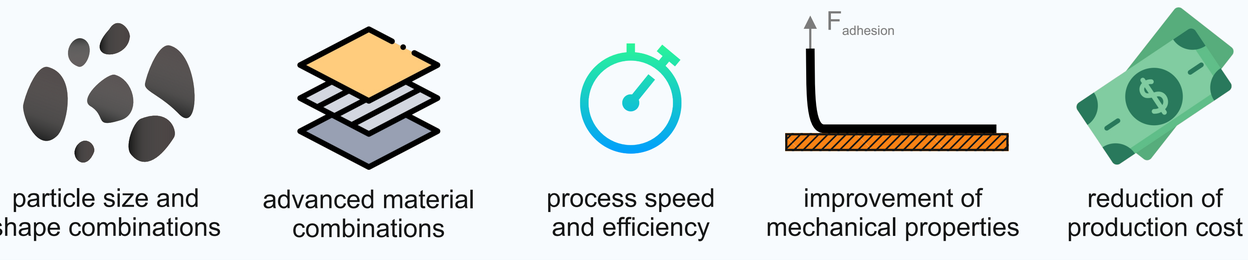
Optimization by multilayer approach

multilayer configurations enable a wide range of optimizations in battery production [1,2,3]

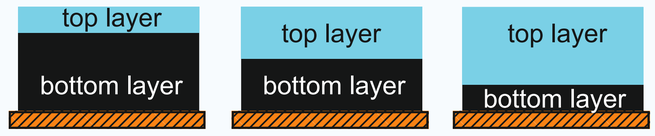




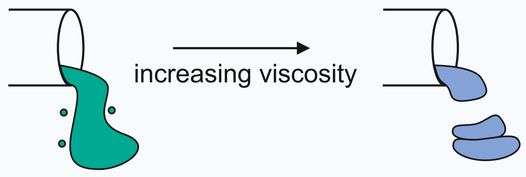
particle size and shape combinations | advanced material combinations | process speed and efficiency | improvement of mechanical properties | reduction of production cost

Process abstraction

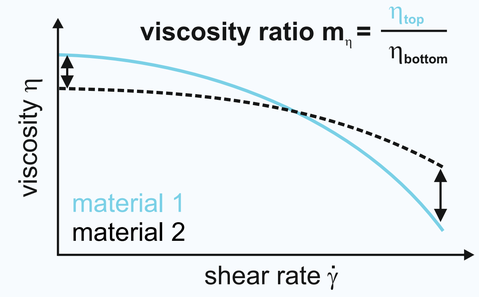
applications may require unequal layer heights [1]: **wet-film-height ratio** $m_h = \frac{h_{top}}{h_{bottom}}$



combinations of materials result in different rheological properties (shear-thinning behavior)

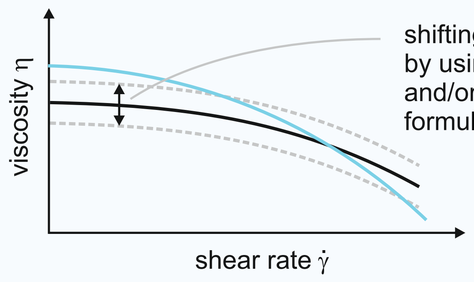


viscosity ratio $m_\eta = \frac{\eta_{top}}{\eta_{bottom}}$



Scientific issue

1. **To what extent is the adjustment of rheological properties necessary to establish stable coatings?**



shifting viscosity curves by using thickening additives and/or changing the battery slurry formulations

2. **How is the coating stability influenced by**
   - wet-film-height ratios and
   - viscosity ratios?
3. **Where is the maximum or minimum value for the wet-film-height and viscosity ratio?**
4. **How can these limits be predicted in simulations?**

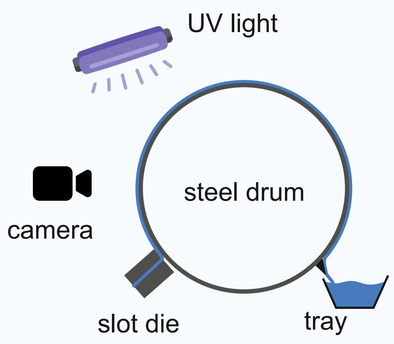
experimental approach

- systematic investigation of operating limits
- use model systems for defined material properties
- use of experimental data for the development of calculation models

Experimental procedure

coating setup

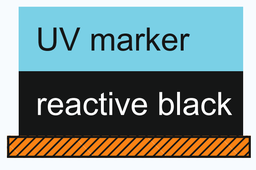
- development coater (TSE)
- coating speeds from 0.1 to 650 m min^{-1}
- coating on a steel drum, isolated investigations of the coating process
- no substrate required



fluid coloring

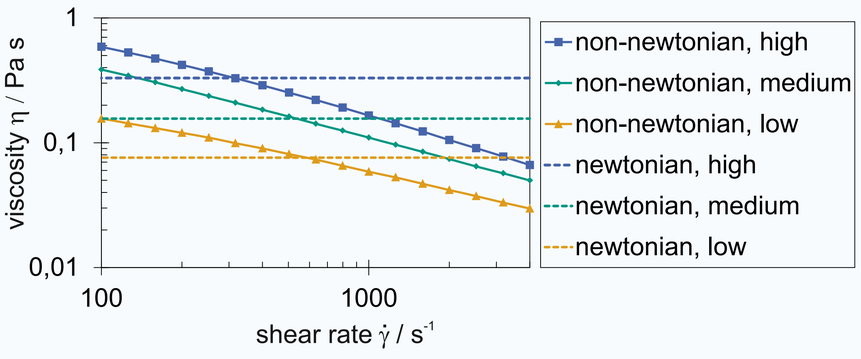
- top layer: UV marker DSBB (TCI)
- bottom layer: Reactive Black 5 (Merck)

→ defects in both layers are visible



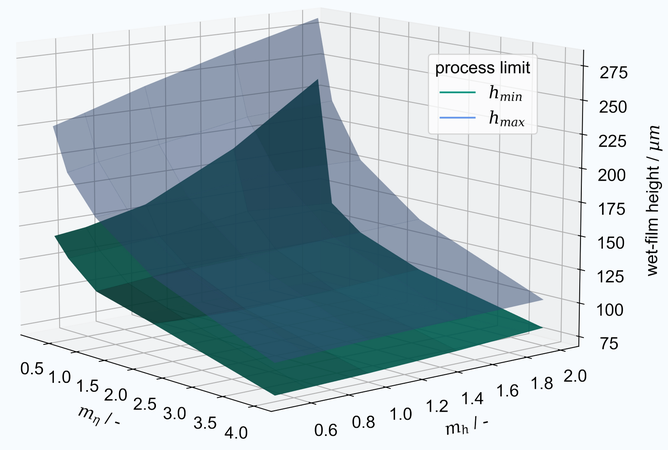
model system fluids

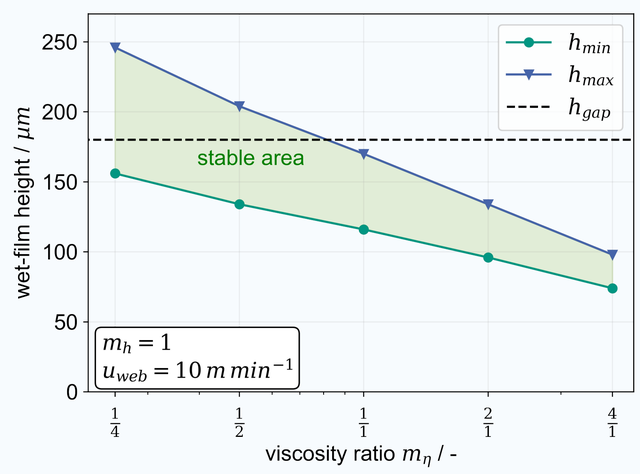
- glycerin-water mixtures (newtonian) with 95, 90 and 85 wt.-% glycerin
- CMC-water solutions (non-newtonian) with 1.5, 1.2 and 0.8 wt.-% CMC



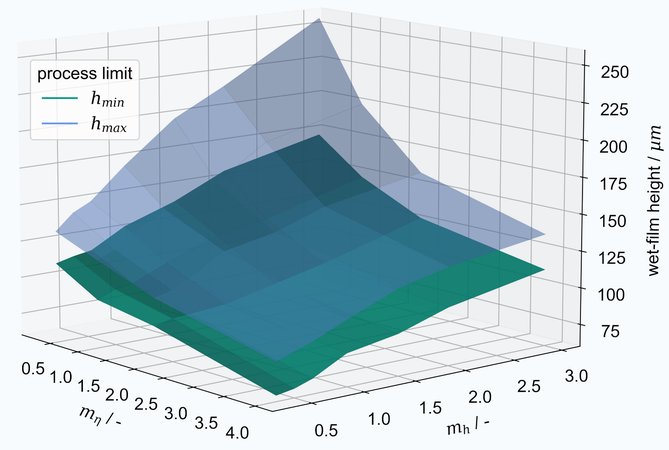
Results

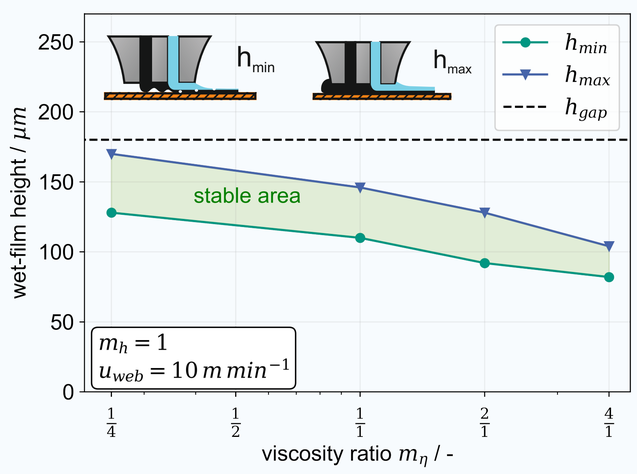
newtonian glycerin-water mixtures





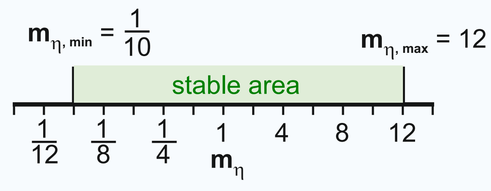
non-newtonian CMC-water solutions





- experimental data shows decent operability windows in the investigated range of viscosity ratios
- the influence of the viscosity ratio is comparable between the newtonian and non-newtonain systems
- the influence of the wet-film-height ratio is higher for newtonian systems

experimentally determined minimal and maximal values for m_η (m_h=1)



[1] Diehm, Ralf; Kumberg, Jana; Dörrer, Christopher; Müller, Marcus; Bauer, Werner; Scharfer, Philip; Schabel, Wilhelm (2020): In Situ Investigations of Simultaneous Two-ayer Slot Die Coating of Component-raded Anodes for Improved High-nergy Li-on Batteries. In: Energy Technol. 8 (5), S. 1901251. DOI: 10.1002/ente.201901251.
[2] Kumberg, Jana; Bauer, Werner; Schmatz, Joyce; Diehm, Ralf; Tönsmann, Max; Müller, Marcus et al. (2021): Reduced Drying Time of Anodes for Lithium-Ion Batteries through Simultaneous Multilayer Coating. In: Energy Technol. 9 (10), S. 2100367. DOI: 10.1002/ente.202100367.
[3] Klemens, Julian; Schneider, Luca; Herbst, Eike Christian; Bohn, Nicole; Müller, Marcus; Bauer, Werner et al. (2022): Drying of NCM Cathode Electrodes with Porous, Nanostructured Particles Versus Compact Solid Particles: Comparative Study of Binder Migration as a Function of Drying Conditions. In: Energy Tech 10 (4), S. 2100985. DOI: 10.1002/ente.202100985.