High Speed Intermittent Slot Die Coating for Lithium-Ion-Battery-Applications

Ralf Diehm, Manuel Schuster, Marcel Schmitt, Philip Scharfer, Wilhelm Schabel

Institute of Thermal Process Engineering, Thin Film Technology (TFT),
Karlsruhe Institute of Technology (KIT),
Kaiserstraße 12, D-76131 Karlsruhe, Germany

Corresponding author: ralf.diehm@kit.edu

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Introduction

Lithium-ion-batteries are one of the most important technologies for energy storage in electric mobility. Limiting factors are the high costs of the energy storage systems, especially the costs of the battery cells. Coating of anode and cathode materials on current collector foils is one step in a long process chain. To gain advantages in cell stacking, intermittent coating of the electrodes is often used in industry. One way of reducing the costs of lithium-ion-battery-cells is to increase the manufacturing process throughput.

In this work, we investigate the mechanisms of intermittent slot die coating of non-Newtonian battery slurries. To enable high speed intermittent coatings, a novel technology is developed which allows for starting and stopping the slurry flow within milliseconds. Therefore, fluid pressure profiles are measured inside the slot die to receive information about the slurry flow. In addition, profiles of the wet film are measured for evaluation of the coating quality. Based on this information, the start-up and break-up mechanisms are discussed as well as the influence of coating speed on the quality of the start-up and break-up edges.

Experimental

Materials

The anode slurries are produced with a waterborne latex dispersion and carboxymethyl cellulose (CMC) binder-system and dispersed graphite particles as active material. Carbon black was used as conductive agent and water as solvent. The shear thinning behavior of the slurries is shown in *figure 1*.

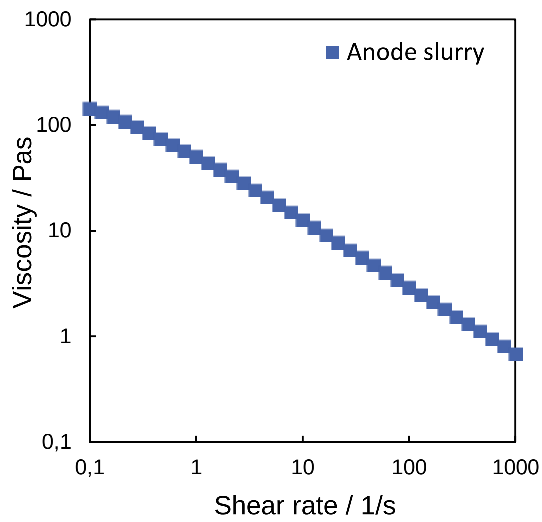

Figure 1: Shear-thinning behavior of the anode slurries. The slurry has a high viscosity of 143 Pas at a low shear rate of 0.1 1/s. With higher shear rate of 1000 1/s the viscosity degreases to 0.68 Pas.

Methods

The experimental set-up (see figure 2) was build-up with a custom developed intermittent slot die technology to stop the coating flow during the interruption of the coating. The fluid was stored inside the slot die during the uncoated areas which gives advantages regarding the switching time. A syringe pump was used to provide a constant, pressure independent volume flow. For analyzing the fluid pressure, a pressure transductor was integrated in the slot die. The coating was applied directly on a chromed roller without the use of substrate. The 3D-film profile was in-situ measured by a triangulation line-laser.

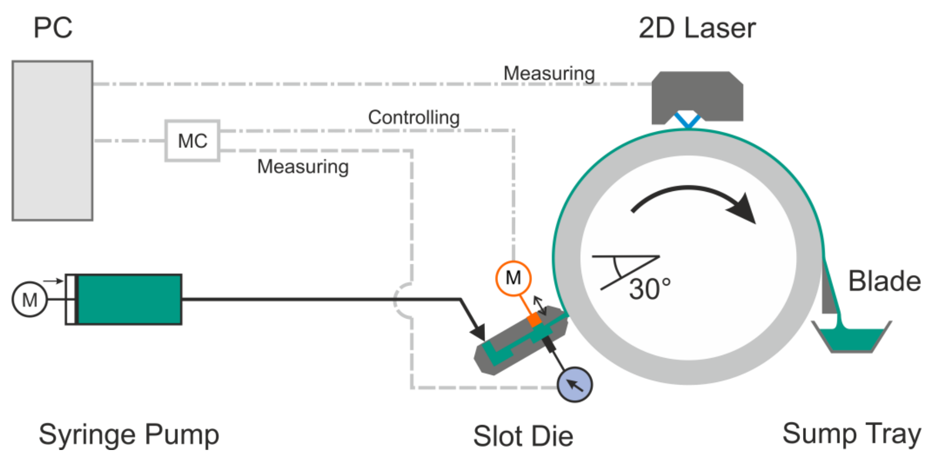

Figure 2: Schematic drawing of experimental set-up. The coating was applied directly on a chromed roller and in-situ analyzed with a laser triangulation system. A syringe pump is used for constant fluid supply. The fluid was stored inside the slot die for intermittent coating. A microcontroller was used to analyze the pressure profiles in the slot die and to control the coat-

ing.

Results and discussion

In the initial step characteristic dimensions are supposed to be defined in order to investigate the impact of coating speed on starting and stopping edges. Figure 3 shows the typical profile of the starting and the stopping edge of an intermittent coated anode layer in coating direction. The starting edge's length is defined as the length between the first rise of at least 5% of the targeted wet film thickness (X_{Start}) until the point where the distance between the film thickness and the targeted thickness is less than 5% ($X_{PlateauStart}$). Through this film build-up length, the film building time can be determined by means of the coating velocity.
The film's stopping length is determined as the length between the points where the film thickness is lower as 95% of the targeted wet film thickness and where the film height is only 5% of the targeted wet film thickness.

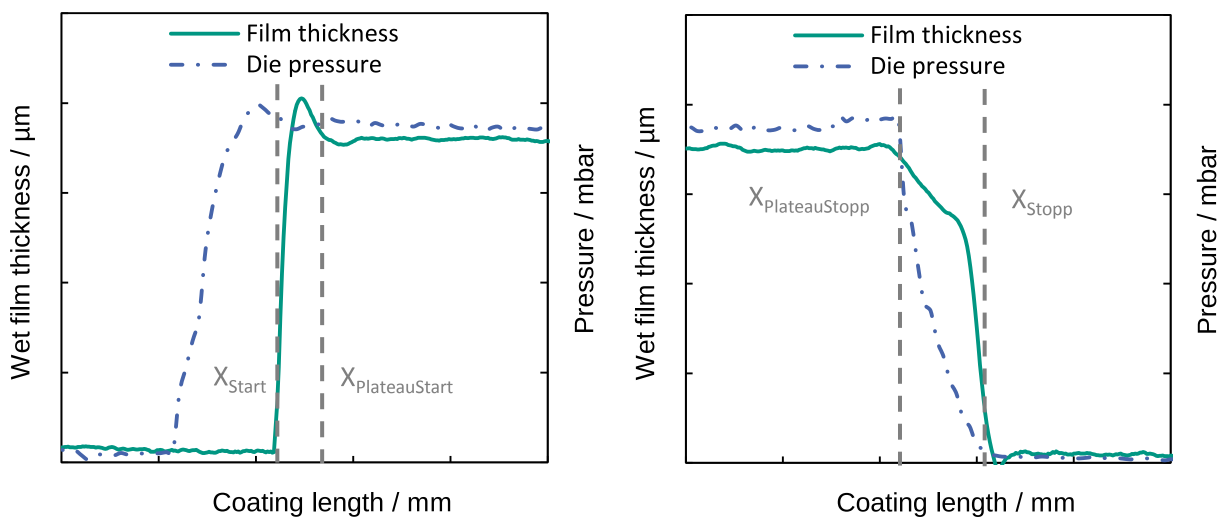

Figure 3: Schematic of the starting edges (left) and stopping edges (right). The position of the relevant points X_{Start} and $X_{PlateauStart}$ for the starting edge and $X_{PlateauStopp}$ and X_{Stopp} for the stopping edge are illustrated with dashed lines.

The focus is on the film starting time until a stable fluid flow is formed, depending on the coating velocity, as well as the comparison of the produced starting edge's film build-up length. As shown in figure 4 left side, the starting time of a stable fluid flows increases slightly at higher coating velocity from 5.2 ms at 16 m/min up to 9.6 ms at 50m/min. Whereas the starting edge's length increases from 1.3 mm at 8 m/min up to 8.0 mm at 50 m/min. The rise of the film build-up time is due to the higher fluid flow at higher coating velocity which has to be formed. Whilst the film build-up time the substrate moves forward at constant speed underneath the nozzle. Thus, the length of the starting edge rises with increasing coating velocity.
In terms of the stopping edge, the film break-up time is investigated regarding the coating velocity and the comparison of the stopping edge length respectively. As shown in figure 4 right side, the film stopping time decreases from 15.8 ms at 8 m/min up to 5.2 ms at 50 m/min. On the contrary the film stopping length increases from 2.1 mm up to 4,3 mm.

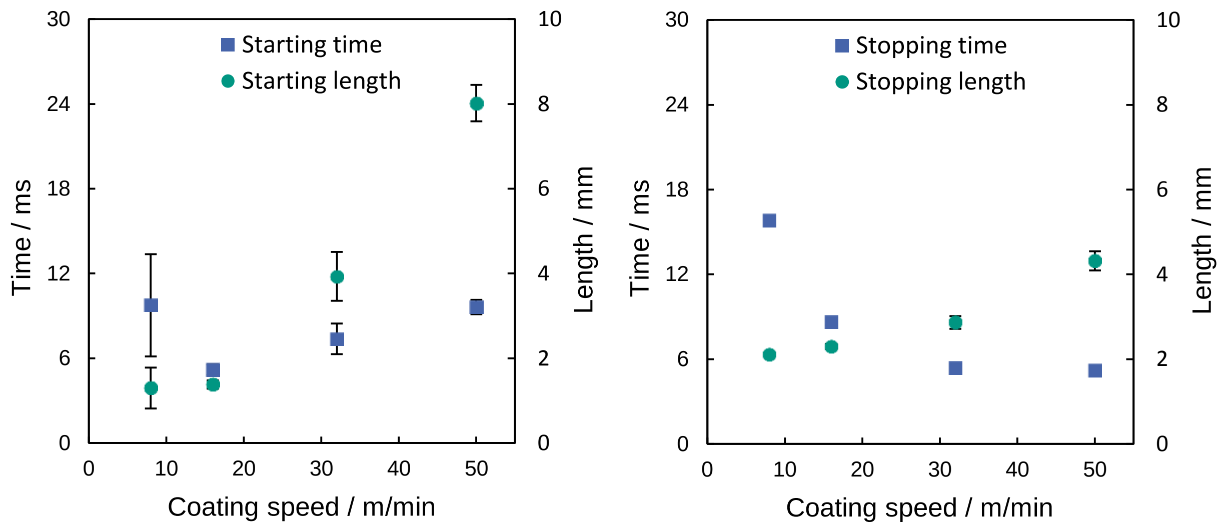

Figure 4: The diagrams shows the influence of the coating speed on the length of the starting edge (left) and the stopping edge (right). The starting time and stopping time are calculated from the respective length and coating speed.

The aim of this work is to investigate the mechanism and the limitations of intermittent coating at high web speeds. To enable high speed intermittent coatings, a novel technology is developed which allows for starting and stopping the slurry flow within milliseconds with controlled flow profiles. The results showed the relation between coating speed and length of the starting and stopping edges. The ramping time is identified as one of the most critical parameters for the quality of the starting and stopping edges at higher web speeds.

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