

# MULTILAYER SLOT COATING – FIRST EXPERIENCES WITH BATTERY SLURRIES

Dipl.-Ing Harald Doell, Technical Director, [harald.doell@tse-coating.ch](mailto:harald.doell@tse-coating.ch)  
TSE Troller AG, Murgenthal, Switzerland

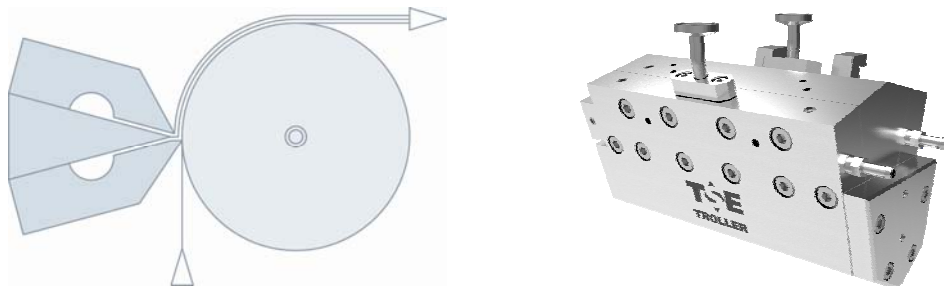
Presented at the 17<sup>th</sup> International Coating Science and Technology Symposium  
September 7-10, 2014  
San Diego, CA, USA

ISCST shall not be responsible for statements or opinions contained in papers or printed in its publications.

## **Extended Abstract (six page maximum):**

**Keywords:** slot die coating, development, multilayer, lithium-ion batteries

Premetered coating in the slot format is an attractive method to apply single or multilayer structures of functional layers to continuously running substrates or in a sheet based process. Single layer slot coating in the meantime is well known and recognized in order to apply very thin layers in the application area of organic electronic and very precise layers in the application field of batteries too.



## **Coating method**

Pre-metered coating methods are distinguished from the self-metered processes due to the lack of devices such as adjustable gaps or pressures in order to meter the excess layer down to the required target thickness.

One main characteristic of the family of pre-metered coating methods is mass conservation and the easy calculation of the average coated film thickness following the simple function

$$H = \frac{Q}{U}$$

with the film thickness **H**, the volumetric flow rate per unit width **Q** and the web speed **U**.

The main advantages of premetered coating methods are therefore:

- Coat weight or film thickness is well specified within operating range of process
- Formulation changes or changes of operating conditions do not affect average coat weight
- Reactive liquids (multi- component) systems can be coated even over longer campaigns
- Excellent uniformity of coated film in both, cross-web and the direction of the web travel
- Coating devices are closed units without any recirculation of fluids and related accumulation of air
- Multiple layers can be coated simultaneously

The possibility to apply multiple layers simultaneously was very common in the photographic industry for several decades. These structures of sometimes ten or more layers were coated in one coating pass mainly to fulfil economical requirements but also for technical reasons. More recent products such as inkjet papers combine thick ink absorbing layers with thin protection layers on top influencing the appearance of the product too. In general multilayer coating methods are attractive in different aspects:

- Functions of complex layers can be split into mono-functional structures. Thus chemistry of the single layers can be less complex and less compromises in the design have to be accepted
- Thin and ultra thin individual layers can be achieved
- Usually it is more economical to apply multiple layers simultaneously than one by one, even when the investment cost for the equipment is higher and maybe the coating speed is lower. The speed reduction might be compensated by all other relevant factors.
- The multilayer coating methods are well known and understood

Some of the new products could be improved by applying more than one layer in order to optimize both, the technical performance of the layer structure and the manufacturing process as well. One could combine for example layers with different conductivity or use one thin layer in order to improve the bonding of the layer to the base substrate to be coated. In these fields mostly slot coating is of interest.

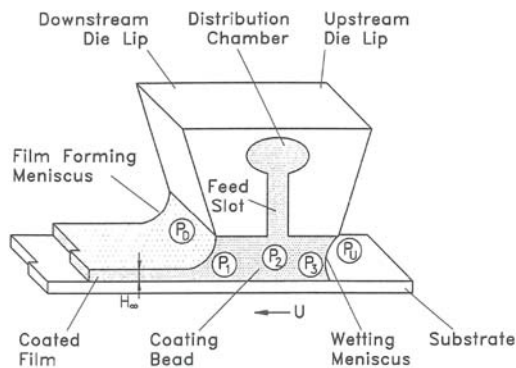


Fig. 1. Definitions Slot Coating [1]

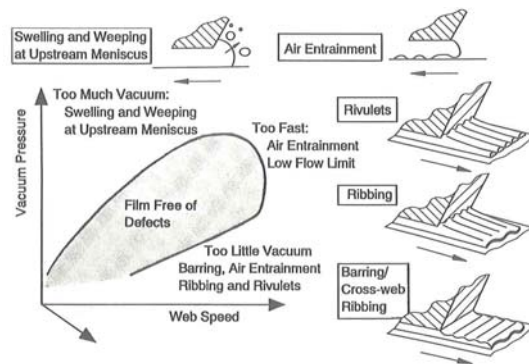


Fig. 2. Operating Window Slot Coating [1]

Premetered coating using slot dies is one of the options in this family with the above mentioned advantages. The general specification of features in the coating die and the application window for slot coating is shown in the figures shown above.

Mixing of the different layers during the coating process itself is often a concern when starting with multilayer coating methods. Here we have to distinguish between mixing due to the flow conditions and interfacial mixing on a much smaller scale. As all known coating flows either in slot dies but also in multilayer slide and curtain dies are laminar, convective mixing driven by the fluid flow is very unlikely. Due to concentration gradients between adjacent layers mixing by diffusion is possible. If this has to be avoided by all means it is generally possible to insert buffer or separation layers between functional layers - as already mentioned for the photographic products. These layers can be very thin and only have the mono-function to separate layers. Other possibilities are maintaining short diffusion times by fast drying or using phase separation [2]. Some risk for migrating of components between the layers during the drying process is given, but this of course depends on the selection of operating parameters.

Adjusting the viscosity and surface gradients in multilayer structures is also important in order to maintain a stable coating process. For example the subsequent layers must wet the underlying layer well – general guidelines are well known in order to optimize this.

## **Battery applications**

The motivations in particular to coat slurries for battery applications with a multilayer method are various. In this field it might give benefits in terms of process control but also for the function of the battery cell itself:

- By combining one thin, lower viscous, lower concentrated slurry with one thick, higher viscous and concentrated slurry the overall amount of solvent could be minimized and the requirements in the drying process can be reduced at a given speed.
- By applying one special primer layer the bonding of the active structure to the substrate can be optimized.
- The transport of energy between the active structure and the substrate to be coated can be optimized by adjusting a specific gradient of conductive material.
- By combining different active materials high charging speed can be achieved as well as high capacity of the battery.
- In case the chemical resistance of the substrate to be coated is poor versus the coating slurry a special bottom layer can inhibit the corrosion or at least slow it down.
- One obvious motivation is to develop battery cells with lower weight at comparable capacity or higher capacity at similar weight.

Nevertheless and whatever might be of interest the conductivity between the active materials and the substrate needs to be as good as possible. Layers improving adhesion or corrosion resistance should not decrease the conductivity which would sacrifice the performance of the battery of course.

## **Challenges**

In particular in the field of battery products there are challenges existing, which are not or only very seldom known from other, conventional coating applications. One requirement, which already increases the complexity of the single layer process, is the intermittent coating of battery slurries in some cases by starting and stopping the flow of coating liquid in machine direction.

Another parameter adding some complexity to the process is the need to coat both sides of the substrate economically. Both factors need to be addressed when applying multilayer processes as well as they need to be solved for single layer products.

Coating of multilayer structures of course is only one part of the process, drying is another important step. Due to the mostly existing requirement to evaporate the solvent of the bottom layer through the entire package the layer structure, the selection of solvents and the drying process itself is important to develop too. The drying process needs to be careful and not all solvents can be combined freely. Experts in drying can help with predictions for an optimized process and the demands to the drying device.

TSE Troller has a long experience in supplying multilayer coating dies. In collaboration with the Thin Film Technology group TFT from the KIT in Karlsruhe, Germany, first examinations for battery applications were performed with a dual layer pilot slot die.

The initial test results concerning mainly functional questions look quite promising and some first results shall be presented during ISCST 2014.

## **Summary**

1. Multilayer coating methods are well known and understood and combine all advantages of premetered coating methods with an optimized production setup
2. Multilayer structures help to optimize the functional performance of the product as well as the economics and the technology of the production processes
3. These methods require thorough planning and preparation for a successful implementation
4. Multilayer slot coating seems to be very feasible in the actual development of Li-Ion batteries, but needs to be optimized for these applications
5. Multilayer slot dies are available for trials on a S2S or R2R basis

## **References**

1. Kistler, S.F., and Schweizer, P.M., Liquid Film Coating (Chapman & Hall, London 1997)
2. K. Peters et al, Beschichtung von Multilagen-OLEDs, Short course coating and drying at KIT, March 2013