Comb Nozzle©

Stand-alone drying unit based on patented Comb-Nozzle patterned array of impinging jets enabling to set defined and homogeneous drying conditions

Comb-Nozzle - Dryer

One of the most sensitive steps during the manufacturing of high technological functional films is the drying process. Performance and properties depend on drying conditions. In regular set-ups industrial drying conditions with HTC above 30 cannot be realized, particularly not at controlled conditions. Arrays of impinging jets can be used to achieve high drying rates. In terms of homogeneity, regular arrays of impinging jets highly suffer from interaction effects between adjacent jets (see Fig. 1, a).

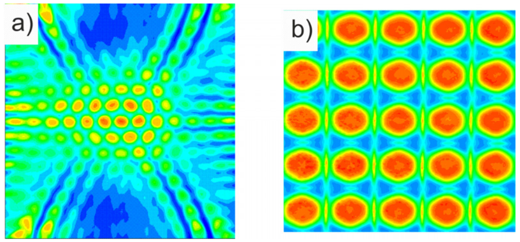

Fig. 1: Prediction of the distribution of Nusselt number by transient heat transfer experiments for a confined staggered array of impinging jets a) and for a confined inline array of impinging jets with local removal of the spent fluid b).

Hence, more sophisticated systems include an infrastructure to locally remove the spent fluid. In case of a well-designed system, phenomena like the x-flow effect can be prevented (see Fig. 1, b). This allows for the development of systems in which the drying conditions do not vary on a scale similar to the dimensions to the drying unit. Nevertheless, in case of highly sensitive materials the increase of homogeneity might not be sufficient and the inhomogeneous drying conditions possibly cause unwanted patterns throughout the film (see Fig. 2).

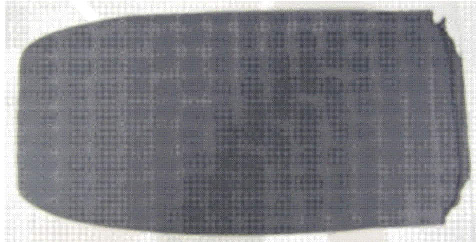

Fig. 2: Anode for Li-ion battery dried under an inline array of impinging jets. The coating shows an unwanted patterning across the film due to inhomogeneous drying conditions.

Analyzing the frequency distribution one can easily see the level of inhomogeneity that despite the local removal of the spent fluid remains (see Fig. 3).

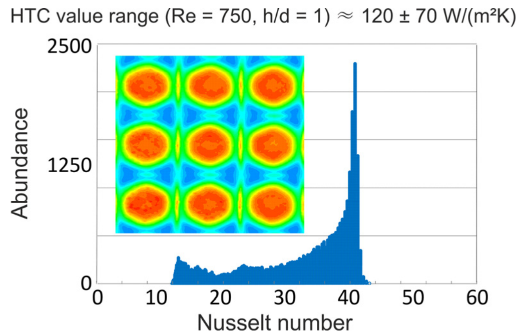

Fig. 3: Frequency distribution of the Nusselt number for an inline array of round nozzles at a separation distance h/d = 1 and a Reynolds number Re = 750.

Using CFD computations we developed a nozzle array promising a significant increase in performance. The pattern of the array is based on hexagons forming the jets surrounded by slits for the removal of the fluid (see Fig. 4).

To be able to realize the complex geometry including the infrastructure for the spent fluid removal system we use state of the art SLS processes.

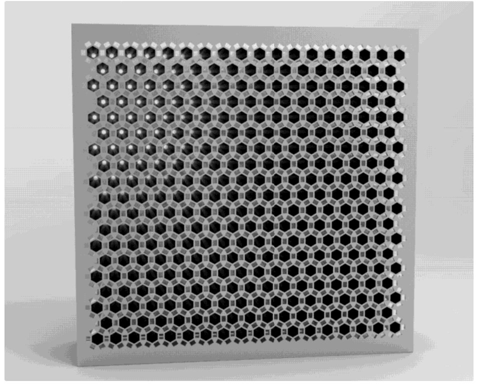

Fig. 4: Comb-Nozzle array realized in aluminum using state of the art SLS processes

The frequency distribution clearly show the superior performance of the new Comb-Nozzle system compared to a conventional system (see Fig. 5).

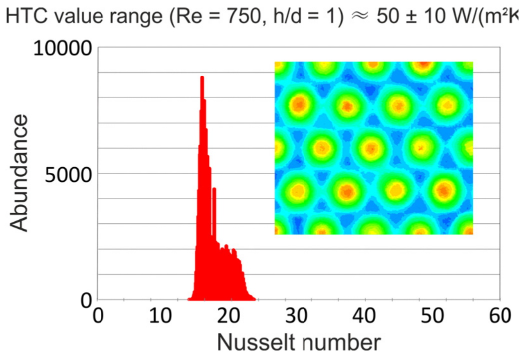

Fig. 5: Frequency distribution of the Nusselt number for the Comb-Nozzle array at a separation distance h/d = 1 and a Reynolds number Re = 750.

Varying the experimental conditions (e. g. mass flow rate and separation distance) the level of homogeneity can be adjusted. Relative deviation down to 5 % at mean HTC of $\sim 35\ W/m^2K$ possible (see Fig. 6).

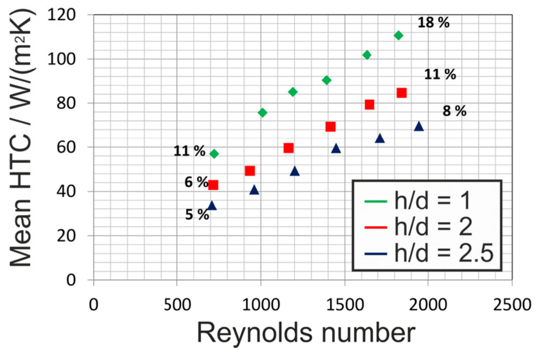

Fig. 6: Mean HTC as function of Reynolds number at several separation distances for the Comb-Nozzle-Dryer.

The system allows for easy integration and exact positioning of coating systems (see Fig. 7).

Fig. 7: Table for knife coating processes as an example for a possible coating unit integrated in the Comb-Nozzle-Dryer.

The main advantages of the Comb-Nozzle-Dryer:

1. **Homogeneous/defined drying**
2. **Easy scale up from laboratory to industrial conditions**
3. **Integrated solvent removal due to suction holes**
4. **Volatile Solvent Components (VOC) free atmosphere**
5. **Health and security aspects with coating trials using hazardous solvents**
6. **Customized solutions**

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