Numerical and experimental investigation of the heat transfer coefficient distribution under arrays of impinging jets with local removal of the spent fluid

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In academic and industrial research, high effort is spent to develop methods for coating functional films for application in the field of organic electronics from solution. To preserve the parameters set, e .g. component distribution and surface topology, during coating procedure until the final product, a homogeneous and well-defined drying process is necessary. In many industrial applications arrays of impinging jets are used for the drying process. As a result of interaction effects between neighboring jets the distribution of the heat and mass transfer coefficients of impinging jet arrays is highly inhomogeneous (Fig. 1, a)).

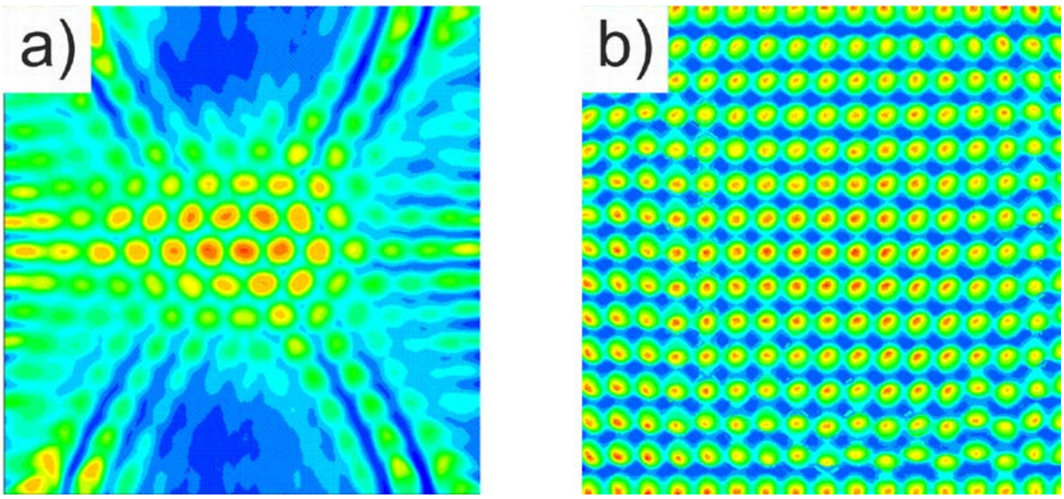

Fig. 1: Qualitative prediction of the distribution of the heat transfer coefficient by transient heat transfer experiments for a confined staggered array of impinging jets (a), qualitative prediction of the distribution of the heat transfer coefficient by transient heat transfer experiments for a confined inline array of impinging jets with local removal of the spent fluid (b).

To minimize the effects caused by interaction (see Figure 2, a) and b)) of neighboring jets that appear by densely grouping jets to arrays, the spent air has to be extracted pre-interaction. Since the target plate can't be used to route the spent fluid out of the domain, the extraction has to be realized using holes in the orifice plate (see Figure 2, c)).

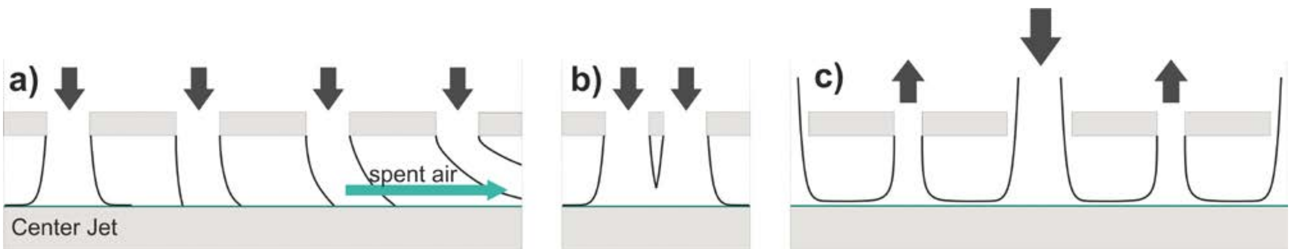

Fig. 2: Interaction effects appearing in arrays of impinging jets. Cross-flow effect a), merging of jets pre impingement b), spent fluid removal pre-interaction over the orifice plate c).

Removing the spent fluid through the orifice plate, the x-flow effect can be reduced and unit cells can be created (see Fig. 1, b)). Since solely removing the spent fluid is not guaranteeing an optimal result in the final product (Fig. 3) we did further investigation optimizing the nozzle structure.

Fig. 3: Anode for Li-ion Battery dried under an inline array of impinging jets. The coating shows an unwanted patterning throughout the film due to the inhomogeneous drying conditions.

In this work, we present the investigation of arrays of impinging jets with local removal of the spent fluid regarding homogeneity of the distribution of the heat transfer coefficient. Based on numerical calculations using the commercial solver ANSYS FLUENT we perform transient heat transfer experiments for the most promising configurations. Case studies including a variation in nozzle design, array structure, mass flow rate and separation distance have been performed. Finally a configuration has been developed minimizing the percentage standard deviation relative to the mean value of the heat transfer coefficient down to five percent at an average HTC of around 40 $W/(m^2 \cdot K)$.