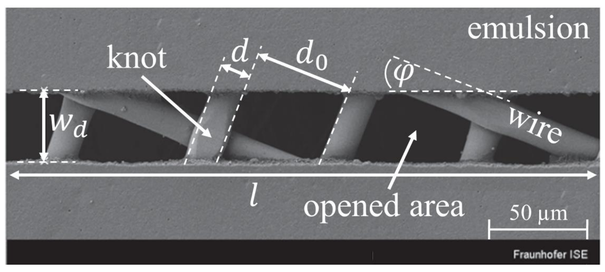
FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE

Optimization of Fine Line Screen Printing Using In-Depth Screen Mesh Analysis

L. Ney[1], S. Tepner[1], N. Wengenmeyr[1], M. Linse[1], A. Lorenz[1], S. Bechmann[2], R. Weber[2], M. Pospischil[1] and F. Clement[1]
[1] Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany, Phone +49 761/4588-5484, linda.ney@ise.fraunhofer.de
[2] KOENEN GmbH, Otto-Hahn-Str. 24, 85521 Ottobrunn-Riemerling, Germany

INTRODUCTION TO SCREEN PARAMETERS

- Reducing finger width further creates new challenges in optimization of screen design parameters
- Detailed knowledge of all existing opened areas and locations of knots inside the channel is necessary to improve paste-transfer



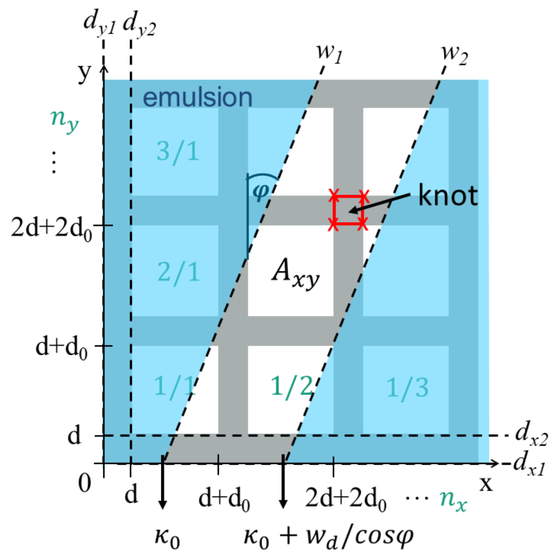
Screen parameters (SEM image adapted from A. Lorenz, Dissertation Thesis, 2017)

MODEL DESCRIPTION

Two-dimensional MATLAB-Model with

- Previously adjustable parameters: MC, d, w_d, φ, l, κ_0
- Mesh definition: d_{x1}, d_{x2}, d_{y1}, d_{y2}
- Emulsion (channel edges): w_1, w_2
- Calculation of all intersections in each iteration step n_y
- Sorting intersections with Boolean program structure to calculate all opened areas A_{xy}

→ **Simulation output: shape, area and exact location of every opened area as well as number and location of knots inside the channel**

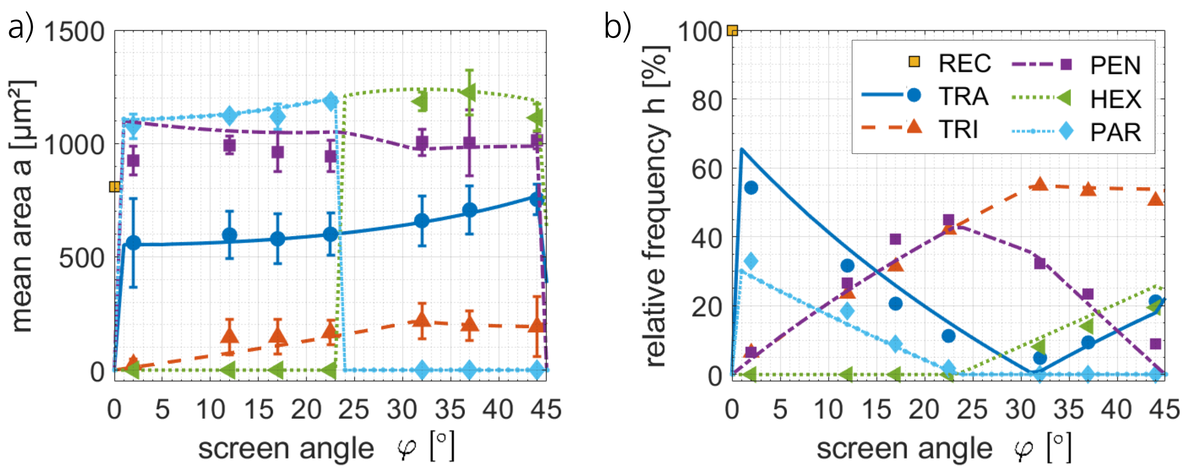


Analytical model for screen construction

MODEL VERIFICATION

Verification with microscopic images of 430/13 mesh, four different channel widths from $w_d = 15\ \mu m - 24\ \mu m$ and six different screen angles between $0° < \varphi < 45°$

- Shape differentiation between rectangles (REC, only at $\varphi = 0°$), trapezoids (TRA), triangles (TRI), pentagons (PEN), hexagons (HEX) and parallelograms (PAR)
- Triangles have smallest area and occur most frequently of all shapes for $\varphi > 23.38°$
- Smaller screen angles ($\varphi < 23.38°$) are beneficial in terms of lower number of clogged areas due to particle size in the paste



Verification approach: simulation results (lines) and measured data (symbols) for different geometrical shapes in dependence on the screen angle

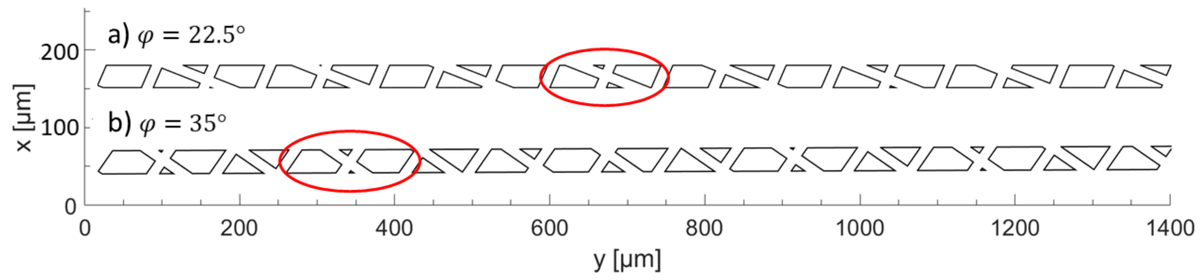
CONCLUSION

- New evaluation parameters (standard deviation and periodic length of the local open area) have been introduced
- Reducing channel width requires higher screen angles (e.g. 35°), finding a new optimum of a small periodic length and low standard deviation

IMPROVED SCREEN ANGLE

Advantages of $\varphi = 35°$

- Reduced standard deviation, periodic length and number of knots
- Larger opened area around the knots



Comparison of screen angle $\varphi = 35°$ with standard $\varphi = 22.5°$ (380/14 mesh, $w_d = 30\ \mu m$)

THE LOCAL OPEN AREA

Standard deviation σ_{OA}[%]

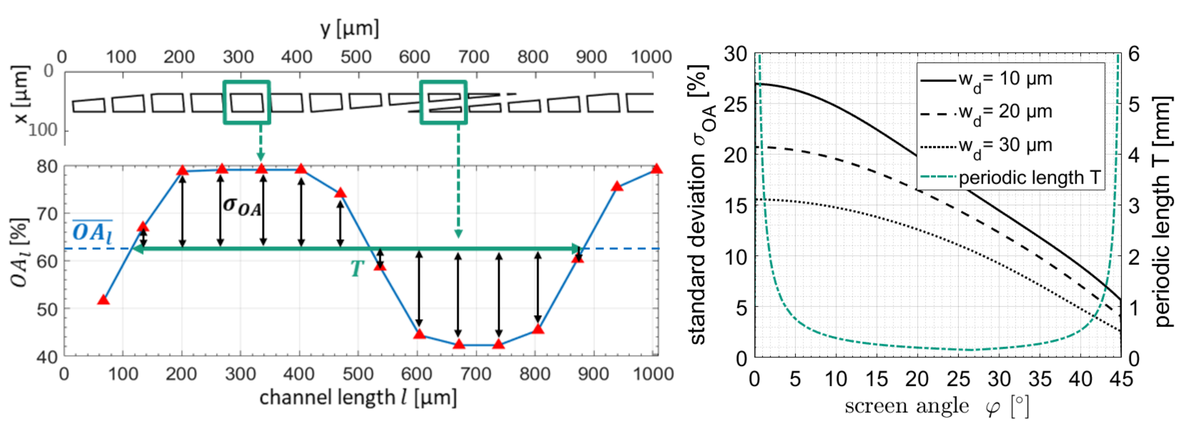
… should be decreased with e.g.

- Increasing the screen angle or channel width or
- Decreasing the wire diameter

Periodic length T [mm]

… should be decreased with

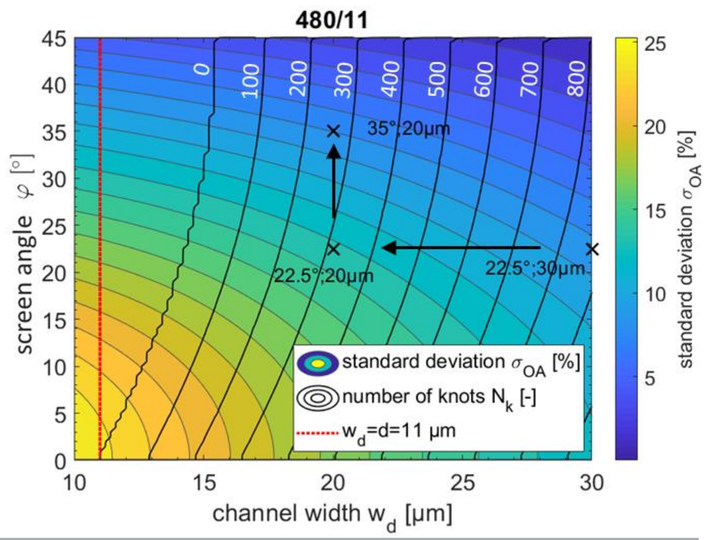
- Increasing the mesh count or
- Minimum between screen angles 20° - 30°



Oscillating behavior of the local open area OA_l and derived evaluation parameters: standard deviation and periodic length with a 380/14 mesh and $w_d = 30\ \mu m$ (left: $\varphi = 5°$)

CUMULATED RESULTS

- Standard deviation is maximal at narrow channel widths and small screen angles
- Reducing the channel width
  - … requires higher screen angles to maintain (or reduce) the standard deviation
  - … decreases the number of knots, however resulting in unfavorable ratios of d/w_d



This work was partly funded by the federal ministry of economic affairs (contact number 0324098B) and supported by KOENEN GmbH, KISSEL + WOLF GmbH and Wickon Hightech.