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Comparison of two step printing methods for front side metallization

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ABSTRACT: In this paper two different industrial two-step printing methods are described. The first method is stencil printing of the lines combined with screen-printing of the busbars. The second method is double screen-printing where a second print is placed on top of the first print. Both methods are ready for introduction or already in use in industry. Both methods result in an increase in cell efficiency of over 0.4% absolute as compared to single step screen printing. This increase is due to lower metal coverage, but also due to an improvement of the grid resistance and therefore higher fill factor. The amount of paste does not increase due to reduction in line width and because the busbars are not printed twice .

1 Introduction.

Screen printing is presently the dominating technique in industry for the metallization of crystalline solar cells[1]. By optimizing the deposition of silver for metal contacts of the front side of the solar cell it is possible to increase the efficiency of crystalline solar cells by increasing the line height without increasing the amount of silver used

The impact of the front side metallization on the efficiency is mainly in fill factor FF (series and contact resistance) and in current density Jsc (coverage of the surface with metal). Jsc will increase when the line width becomes smaller On the other hand, with reducing line width, the line resistance will increase causing a lower fill factor. To prevent this loss in fill factor line resistance has to be decreased by printing higher lines (higher aspect ratio). To increase the efficiency, a metallization scheme is needed in which the coverage is minimized (to increase the current density) without increasing the grid resistance.

A second consideration is the amount of silver used in the manufacturing of crystalline solar cells; silver paste is one of the important cost factors in cell processing.

In this paper we compare two methods for improving the front side metallization that result in high aspect ratios. Both methods are based on the deposition of silver paste in two subsequent printing steps instead of a single step printing

2 Experiment.

In this paper two industrial two-step printing methods are compared: stencil printing of the lines [2] combined with screen printing of the busbars, and double screen-printing. Three neighboring groups of multi crystalline wafer with cell size 156 mm x 156 mm are manufactured based on the industrial ECN process using an ECN iso-texture, a uniform 65 ohm tube furnace emitter, and SiNx antireflection(figure 1).

Group 1 is the reference group: the metallization scheme consists of single screen printing front side (58 printed fingers), screen print silver backside and screen print aluminum backside. This metallization scheme is comparable to standard industrial processing.

The only difference in processing in group 2 is in front side metallization: the same number of silver fingers are printed in two consecutive screen printing steps, separated by drying of the paste. To reduce silver usage, no busbar is printed in the second print step (see figure 2).

Stencil Double print

Figure 1: Process sequence and details

The silver paste is identical to the paste used in group 1 and is commercially available.

In group 3, a metal stencil is used in the first printing step (69 printed fingers). In this step only silver fingers are deposited. The lines in the stencil are completely open, in contrast to the mesh in screen printing. This results silver fingers with a higher aspect ratio than obtained with a standard screen printing.

The busbars are printed in a second step, using the same paste as used for groups 1 and 2. The paste used for the stencil printing step is specially designed for stencil printing.

Screen print Stencil

Figure 2: Left:, Front side grid second double print step only fingers are printed; Right: stecil for printing finger, busbar in second print will connect the fingers, center remains open.

3 Results.

The three different methods of printing resulted in large differences in line height and width between the groups (measured after firing).

In group 1 a fired line width was achieved of 120 µm and a height of 17 µm, resulting in a metal coverage of 1660 mm^2 and an average Jsc of 34,41 mA/cm^2. We reached a line resistance (figure 4) of 170 mΩ/cm

Line definition after firing for double printed (group 2) were 90 µm (width) and 35 µm (height) and for stencil printed (group 3) 75 µm and 30 µm (see figure 3 and 6). The metal coverage of both groups are almost identical (1399 mm^2 group 2 and 1387 mm^2 group 3); the lower number of lines of group 2 is compensating for the difference in width. Due to this increase in open area, a theoretical increase of 1.2 % in current is calculated. The actual increases were 1.3 % for group 2 and 1.1 % for group 3. The increase in line height for group 2 and 3 results in a decrease of the total grid resistance (figure 4).

For both groups we reached a better line resistance 120 (mΩ/cm) for group 2 and 150 (

) for group 3. This lower resistance causes an increase in fill factor for both groups. As expected the Voc was not influenced by the printing method. The total efficiency improvement compared to the reference group 1 is 0,5 % for group 2 (double screen print) and 0.4 % for group 3 (stencil print).

In figure 5, the IV characteristics of the three groups of neighboring mc-Si cells comparing single print (group 1), double stencil print (group 2) and stencil print (3) are plotted. From the IV characteristics it is clear that Jsc and FF are significantly higher for both 2-step printing methods.

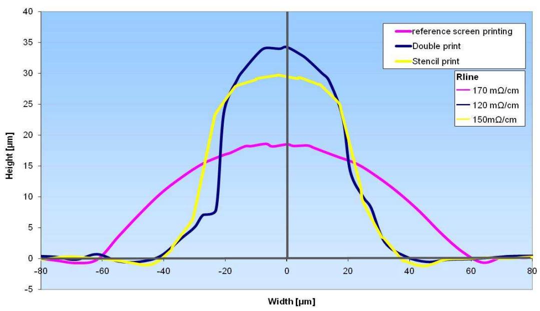


Figure 3: Cross section Lines after firing

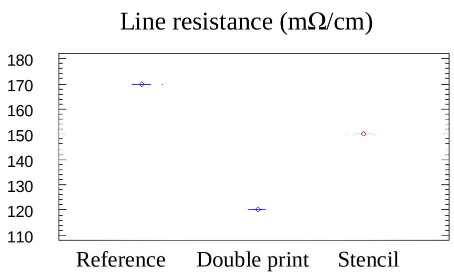


Figure 4: Line resistance of the printed lines

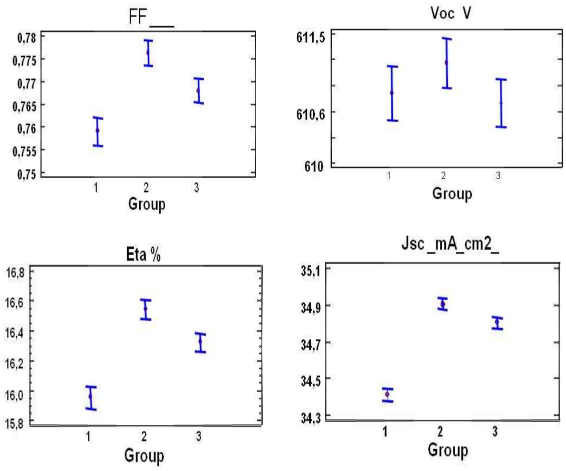
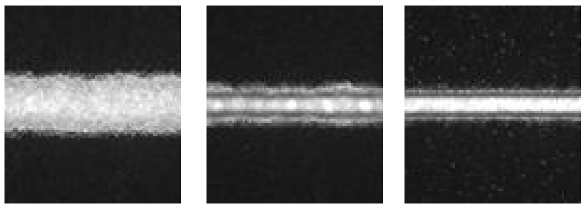


Figure 5: statistical analysis of the IV characteristics of the three different printing methods (1: single print; 2: double screen print; 3: stencil print)



Single print **Double print** **Stencil**

Figure 6: Images of 2-step and single step printing of silver fingers after firing

4. Conclusions

Two step front side metallisation results in narrower lines and higher aspect ratios. The reduction in both metal coverage and grid resistance result in an increase in efficiency of 0.4% absolute. The increase in Jsc shows a good comparison with the reduction in covered area.

The amount of silver used for the front side metallization is not increased: the increase in aspect ratio is compensated by a reduction in line width.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] Photon International issue 7 2010 page 142.
[2] Hoornstra et al., Proceedings 24st European Photovoltaic Solar Energy Conference (2009)