Requirements of Screen masks for Fine-line Printing on Textured Surface

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1. Objective

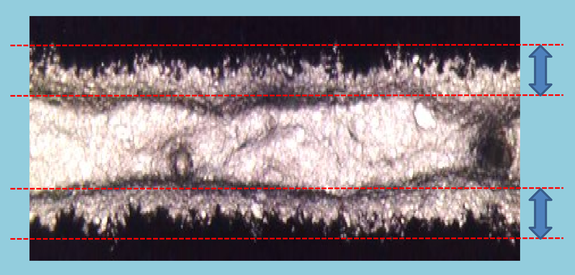
From increasing the conversion efficiency, how to reduce the line width of metallization contacts is one of the trending topics, but the thinning of the metallization line is not all favorable especially for screen printing [1]. Unfortunately, a solar cell has texture on a surface, which causes a gap between the surface of a substrate and a screen mask, which causes the paste to sneak out through this gap to make the printed line wider [2].

In addition, for printing fine lines, one more issue to be concerned about is how to resolve the fine line openings on the emulsion of screen masks. The emulsion of screen mask has to be resolved all the way of the fine lines without any bridges over the opening lines. When the printing lines become smaller, the patterned lines on the emulsion is getting hard to be resolved to remain unresolved residues due to irregularly reflecting on mesh and swelling during water-development.

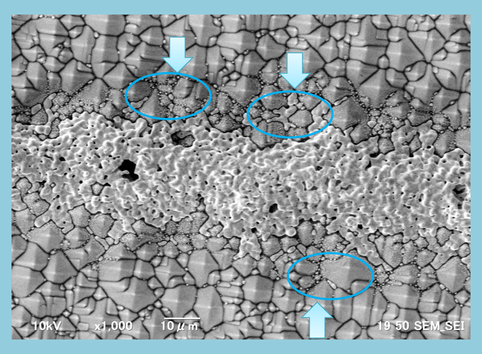
In this study, how the roughness of a screen mask and a substrate affect to the printed lines are investigated on silicon solar cells. Furthermore, how to resolve fine lines on the emulsion is also investigated.

2. Back ground

The finger lines printed on silicon solar cells are more or less jaggy at the edges of finger lines, and in some cases are bumpy and have opens at the printed lines as shown in Fig. 1 and Fig.2.

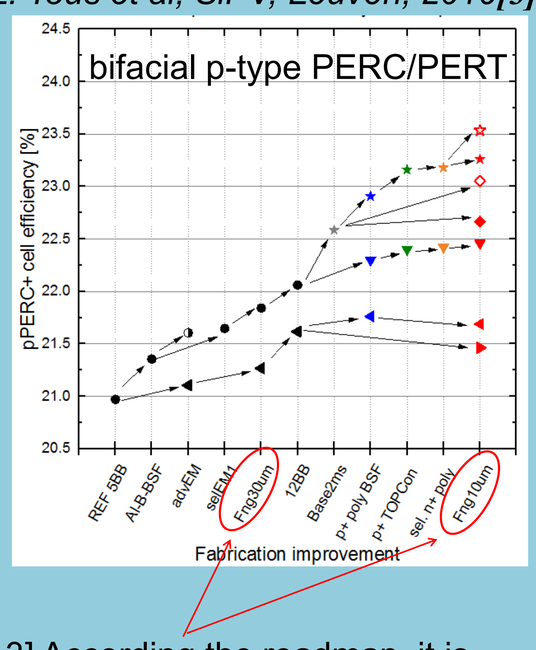


[Fig. 1] Jaggy edges of a screen printed line



[Fig. 2] SEM image of a screen printed line

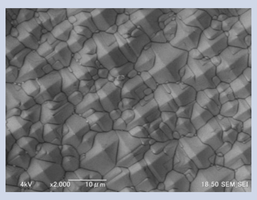
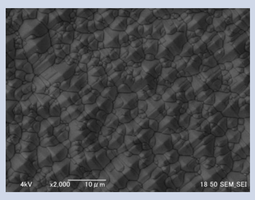
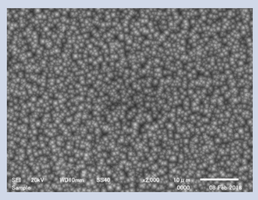
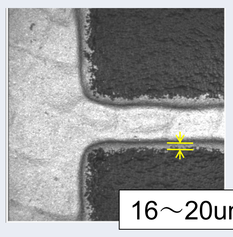
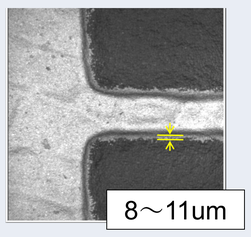
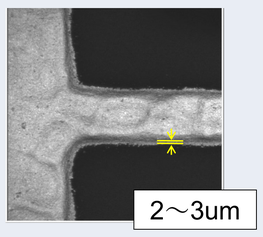
L. Tous et al, SiPV, Leuven, 2019[3]

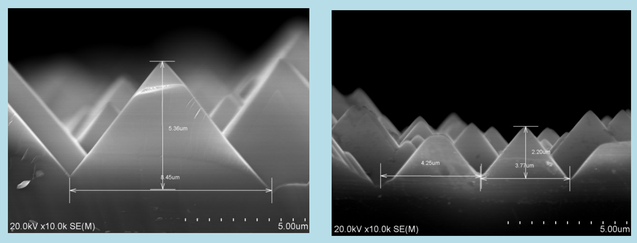


[Fig. 3] According the roadmap, it is considered that the finger lines of solar cells are getting narrower than ever to realize higher efficiency of solar cells.

3.Experiment 1. How texture size of a wafer surface affects screen printing results

Three different size of textures are prepared by controlling etching conditions. Commercially available Silver paste is printed with a nomal screen mask

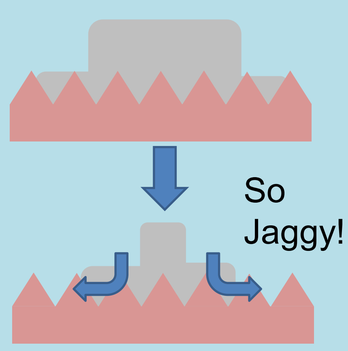
TEX. size big	TEX.size mid.	TEX. Size small
 5-8um	 2-5um	 ~1um
 16～20um	 8～11um	 2～3um



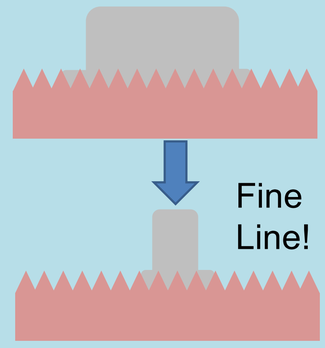
[Fig. 4] The height and width of textures are respectively, 8.5μm and 4.4μm on the left, and 3.8μm and 2.2μm on the right.

The experiment 1 shows the bleeding on the left texture becomes 2 to 3 times wider than that of the right one.

If you want to form the line which is narrower than the present



Paste bleeds out through valley extremely on a bigger texture surface.

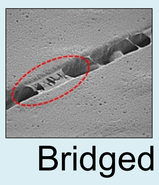


Printing lines less than 10micron requires smaller textured surface

As is concluded from the above experiments, the gasket effect can easily work well on the smaller textures to realize beautiful finger line edges.

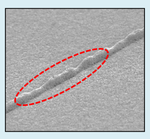
4.Experiment 2. How emulsion resolution can affect the printing results.

For the resolution test, four kinds of meshes were used to evaluate how good the emulsion on the meshes can be resolved depending on the mesh count. Designed line width 15･20･25･30･40μm



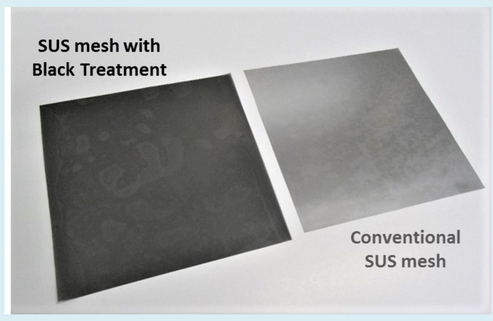
Poorly resolved emulsion due to very narrow opening

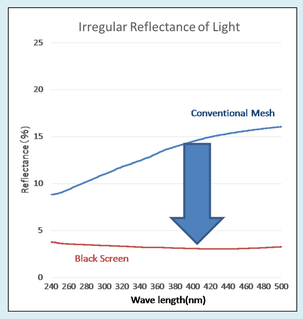
Bridged residues of emulsion

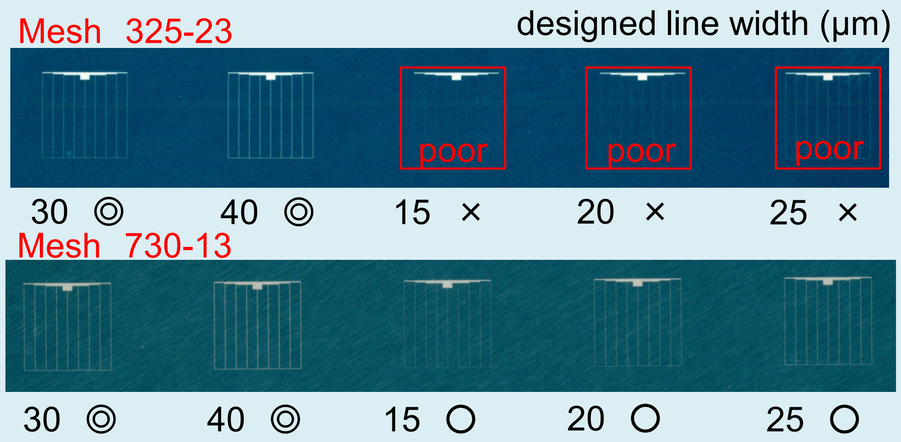


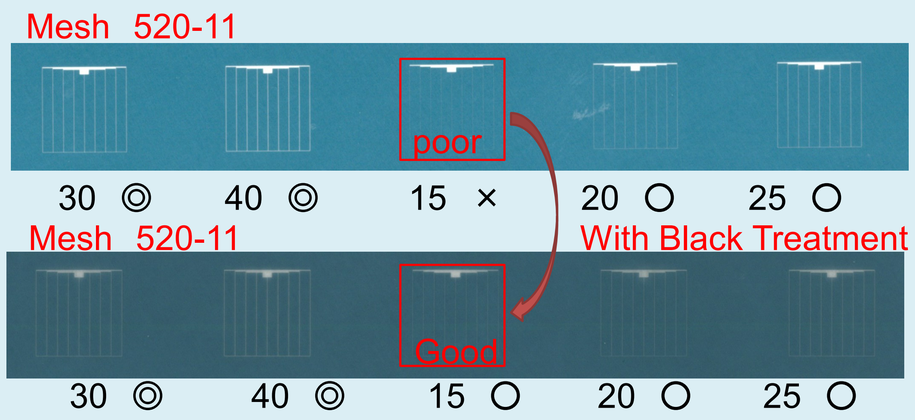
Printed results by a screen mask with such poorly resolved emulsion

mesh	Black treatment
325-23	no
520-11	no
520-11	yes
730-13	no









◎, Excellent	○, Good	×,Poor

For the case of narrow opening, emulsion on low mesh-count meshes could not be resolved uniformly, and sometimes some residues remain over the openings, which are originated by parasitic exposure due to the reflection of exposure light on the stainless steel mesh wires. Black-treated mesh is less reflective less than 4%, and can make emulsion uniformly opened at ultra-fine lines.

5. Conclusion

The experiments described above were successively proceeded.

1.Bleeding is strongly depending on the texture size.

2.How narrow the emulsion can be resolved is strongly depending on mesh count. Black treated meshes can resolved emulsion at the opening of 15μm that could not be done before.

Next Challenges

For further improvement in the near future, it is necessary to realize the texture of 300nm – 500nm in size for the ultra-fine lines of 10μm and also to make the paste rheologically thixotropic enough to reduce it viscosity during printing for passing through the channel formed by the emulsion opening and the mesh.

6.Reference

[1] H.H.C. de Moor et al. "Fine-line Screen Printing for Silicon Solar Cells" 6th Workshop Role of Impurities and Defects in Silicon Device Processing, pp.154 (1996)

[2] Mari Aoki et al. "30μm fine-line printing for solar cells" Proc. IEEE 39th Photovoltaic Spec. Conf., 2013, pp. 2162–2166

[3] L. Tous et al, "Efficiency Roadmaps for Industrial pPERC+ and nPERT+ Cells" SiPV, Leuven, 2019

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