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FULBRIGHT

Investigation of Local Parameters of PERC Solar Cells Metallized with Screen Printed Cu-paste

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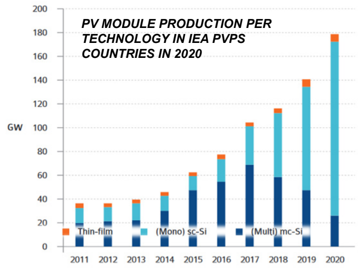
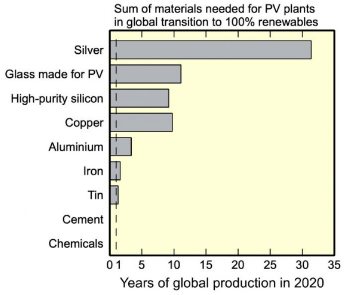
Introduction



Source: IEA PVPS, RTS Corporation



https://www.changeanyway.com/is-solar-electricity-sustainable/

For 40 TW of PV required to transition our planet to 100% renewables, the silver (Ag) should disappear from PV production.

Advantages of Copper (Cu) Over Silver (Ag)

1. Bulk Cu has a similar conductivity to Ag (1.7 μΩ-cm for Cu, 1.6 μΩ-cm for Ag
2. Cu is ~100 times cheaper than Ag, making it an excellent potential replacement

Problems Associated with Copper (Cu) Contacts

1. Easy oxidation
2. Diffusion into the Si cell and recombination activity

Fabrication of PERC solar cells

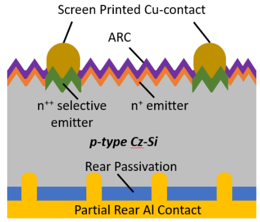


Fig. 1 Schematic diagram of selective contact PERC solar cell

Solar Cell Parameters

J_{sc}	(mA/m^2)	40.07
V_{oc}	(V)	0.657
FF	**(%)**	**66.07**
Efficiency	(%)	17.39
Rs	(Ω-cm^2)	2.93
Rsh	(kΩ-cm^2)	19.95

Champion cells~77% FF

Fill Factor Loss Analysis

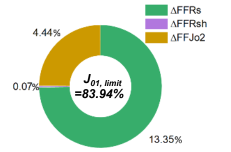


Fig. 2 Pie diagram indicating FF loss analysis [Ref: Khanna et al., IEEE J. Photovol., 3, 4 (2013).]

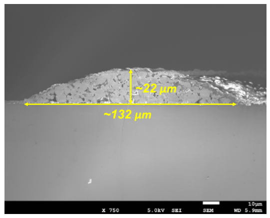


Fig. 3 SEM image of Cu finger (aspect ratio~ 0.17)

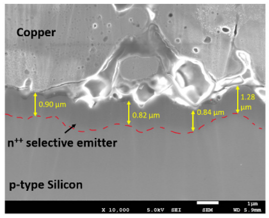


Fig. 4 Selective doping visible under the contacts in SEM

Selective emitter PERC cells

- M6 sized (166 mm × 166 mm) monocrystalline p-type wafers.
- Front grid screen-printed with Cu paste and partial Al contacts at the rear side.
- Peak firing temperature ~590°C.

Biased Photoluminescence (PL) Imaging for Series Resistance Mapping

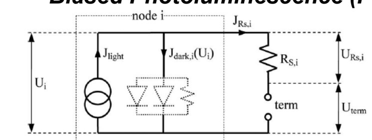


Fig.5 Equivalent circuit of one node at position i, for image pixel i

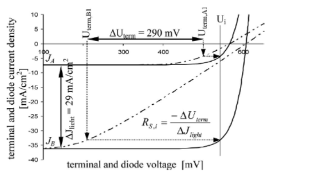


Fig. 6 I-V curves of one node i at two illumination intensities

Ref: Kampwerth et al., Appl. Phys. Lett. **93**, 202102 (2008).

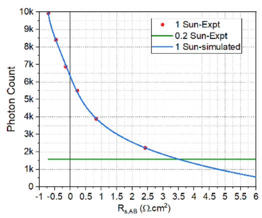


Fig. 7 Offset-corrected luminescence signal as a function of $R_{s,i}$ for the measured cell

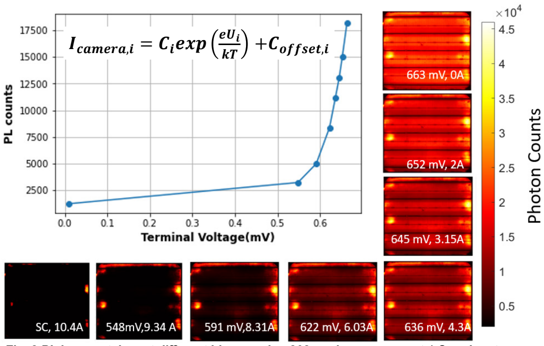


Fig. 8 PL images taken at different biases using 808 nm laser source at 1-Sun. Inset shows the variation of average photon currents at different biases.

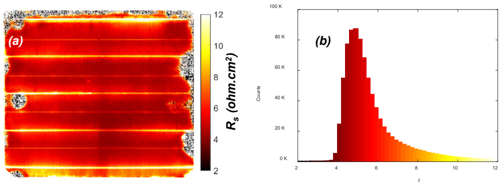


Fig. 9 (a) R_s map obtained from biased PL images at two different intensities (b) Histogram showing the distribution of R_s over the entire surface

Dark Lock-In Thermography (DLIT)

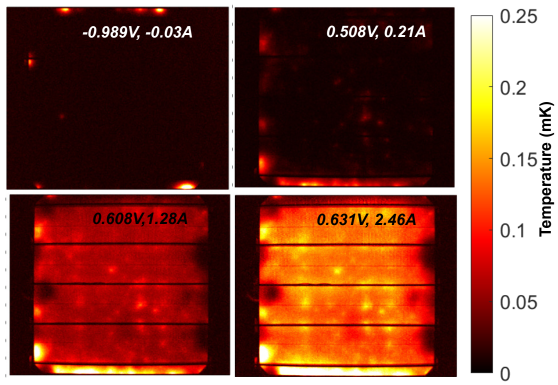


Fig. 10 DLIT images at different biases

Summary:

1. R_s map shows some regions with very high R_s, indicating no contact in those areas
2. The histogram shows the peak R_s ~5 ohm.cm^2, which explains the high FF loss due to R_s
3. DLIT indicates non-uniformity in J_{01} and J_{02}

Interface Studies by Energy Dispersive X-ray Spectroscopy (EDS)

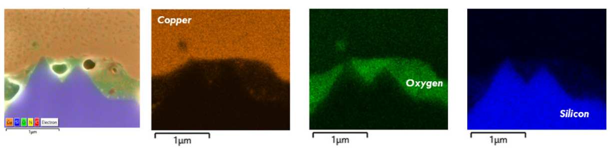


Fig. 11 EDS of the interface shows a thick oxide layer sandwiched between Cu and Si. This explains the high series resistance of the entire solar cell, leading to high FF loss.

Damp Heat testing (85°C/85% Humidity)

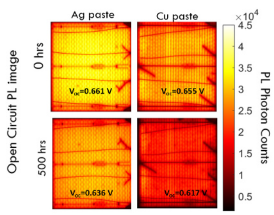


Fig. 12 PL images of mini-modules of 4cmx4cm large solar cells with Ag and Cu metallization for 0 hours and 500 hours of damp heat testing (85°C/85% humidity)

Future Work

1. Carry out SIMS, XRD and Raman spectroscopy to investigate the interface between Cu and Si.
2. Study the amount of Cu that has diffused into the Si. Does the oxide layer at the interface offer sufficient barrier to block Cu from diffusing into Si? What is the optimum thickness of the oxide layer which can prevent Cu from diffusing into Si but doesn't increase the series resistance simultaneously?
3. Use TLM method to find the contact resistance on carrier-selective contacts.
4. Improve the aspect ratio of the front Cu fingers.

Acknowledgement

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