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Fabrication and Comparison of Bifacial to mono-facial Si Solar Cells

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Bifacial silicon solar cells are among the fastest growing cell technologies, due to its inherent design ability to gather light from both front and rear surfaces. Numerous studies have demonstrated real-world advantages of 10-30% power gain under various installation configurations. Assuming a 20% rear albedo, a moderate efficiency bifacial cell such as a 23% bifacial with 90% bifacial-factor can generate in excess of 27mWcm^{-2}, exceeding the power generation of even the most technologically advanced single junction mono-facial Si solar cell. Further development of bifacial cells are therefore of great interest, and comparison to mono-facial cells provides further insight into the pros and cons of the technology.

In this work, we present the design, and fabrication of laboratory scale n-type and p-type bifacial and mono-facial PERL cells, demonstrating high efficiency bifacial cell designs, and providing a direct comparison between the technologies. Notably, the fabrication of all cell designs were implemented using identical surface passivation and furnace processing conditions, therefore providing a well-controlled comparison study between the two cell designs.

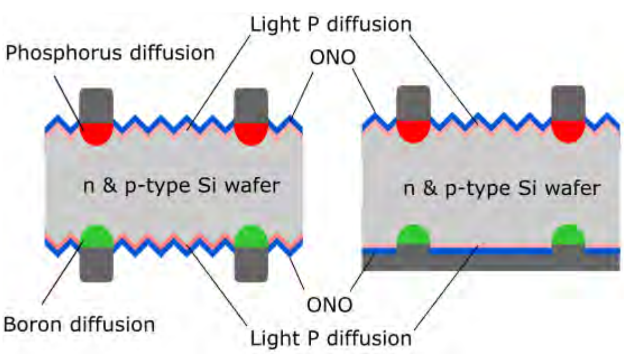

Figure 1: Cross-sectional view of bifacial and mono-facial cell design in this work

The basic cell structure is as presented in Figure 1, illustrating the cross-sectional layout of the device. The key differences lie in the design and texturing of the rear surface. The rear surface of the bifacial solar cells are textured, with local finger diffusions, and silver-plated metal fingers, in a structure which is nearly identical to the front. On the other hand, the mono-facial cells has local diffusions in circular patterns, and contacted via evaporated Aluminum, through small circular openings through the ONO passivation.

The optimum geometry is deduced from 3D device simulations based on empirically determined input parameters. Results of a simulation assuming 1sun single side illumination is presented in Figure 2. The evolution of the optimum geometry under bifacial illumination will be presented in further details in the presentation.

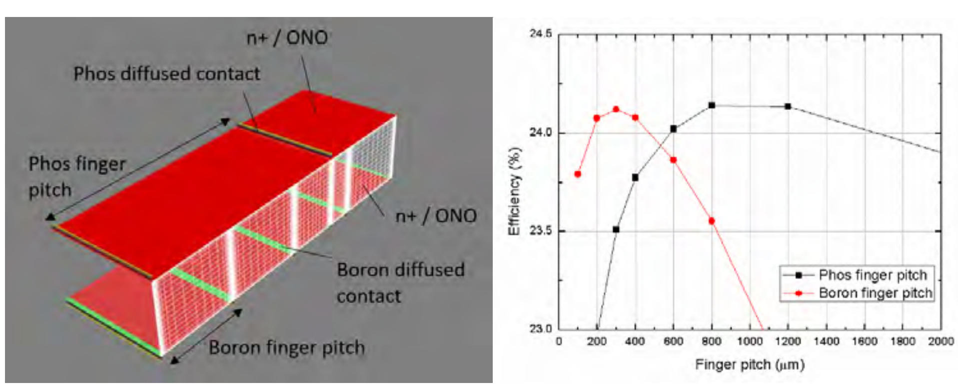

Figure 2: (Left) 3D mesh of bifacial unit-cell simulation, and (Right) the 3D simulation results to deduce optimum n-finger and p-finger pitch.

An example of a bifacial cell fabricated in this work is presented in Figure , illustrating the finger structures and the rear surface in the reflection. The results of the cell measurements are presented in Table 1, demonstrating high efficiencies of 23.1% on n-type bifacial, and 23.2% on p-type bifacial cell, with very high bifacial factors of 97.4% and 94.5% respectively. The fabricated monofacial cell measured the highest single side efficiency, at 24.3%, and has significantly higher V_{OC}, FF and Jsc, thus indicating that advantages were beyond purely optical gains.

Table 1: Champion cell efficiency and I-V parameters

	Side	Efficiency (%)	V_{OC} (mV)	J_{SC} (mA cm^{-2})	FF	R_s (Ω cm^2)	Bifacial Factor
n-type	Front	23.1	692	40.4	82.8	0.15	
bifacial	Rear	22.5	690	39.4	82.9	0.16	97.4%
p-type	Front	23.2	689	41.9	80.3	0.42	
bifacial	Rear	21.9	688	39.4	80.7	0.37	94.5%
p-type monofacial	Front	24.3	713	42	81	0.35	-

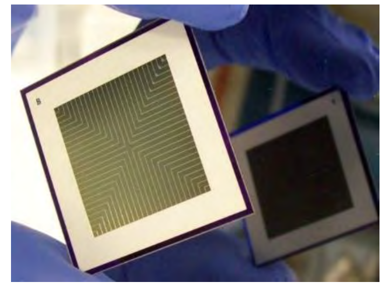

Figure 3: Completed bifacial solar cell fabricated for this work.

Finally, an in-depth optical and electrical loss analysis based on ray-tracing and free-energy-loss-analysis (FELA) via 3D device simulation is presented in Figure 4. The key differences are the derived maximum efficiency based on the FELA methodology, the significantly reduced bulk resistance and changes to the ratio of surface recombination loss due to the reverted position of the p-n junction. Further in-depth comparison to mono-facial cell shall also be included in the full presentation and manuscript.

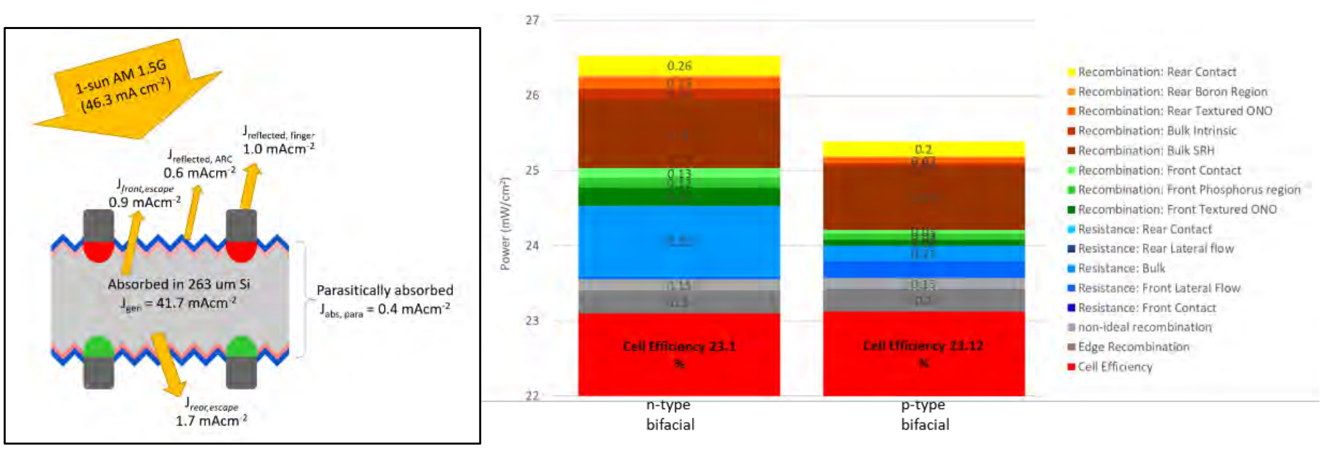

Figure 4: (Left) Optical loss breakdown, (Right) Free-Energy-Loss-Analysis comparison between n-type and p-type bifacial solar cells.