0.35% Absolute Efficiency Gain of Bifacial N-type Si Solar cells by Industrial Metal Wrap Through Technology

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***Abstract* — N-type Metal Wrap Through (n-MWT) is presented as an industrially promising back-contact technology to reach high performance of silicon solar cells and modules. It can combine benefits from both n-type base and MWT metallization. In this paper, the integration of the MWT technique with a commercial industrial bifacial n-type Si Solar cell (239 cm^2) process is described. After the integration, 0.35% absolute efficiency gain was achieved, and Voc gain and Isc gain up to 0.42% and 2.45%, respectively, were obtained, mainly attributed to reduced shadow loss and surface recombination. Based on calculations, the anticipation of further improvements for n-MWT solar cells, by taking better advantage of this integration, is also presented.**

***Index Terms* — bifacial, metal wrap through, n-type, silicon, solar cells.**

I. Introduction

At present, fabrication of solar cells with higher efficiency and lower cost (lower cost/watt) is still one of the key issues [1] in the Si-based photovoltaic industry. The p-type silicon solar cell is still the mainstream in the commercial market, but compared with p-type, solar cells from n-type Si wafers have potentially higher efficiency thanks to advantages of n-type materials, such as higher minority carrier recombination lifetime[2,3], higher tolerance to impurities in silicon feedstock[4,5], low light-induced degradation of performance[6,7].

Up to now, there have been only 3 companies which realized the mass production of n-type Si solar cells with high efficiency: Sanyo, Sunpower and Yingli Solar. Sanyo is producing so-called HIT (Heterojunction with Intrinsic Thin-layer) cells. SunPower is manufacturing fully back-contacted (Interdigitated Back-Contacted, IBC) cells. In 2010, commercial n-type solar cell named PANDA cells were introduced by Yingli Solar. PANDA cells are bifacial N-type Si solar cells (239 cm^2), which use conventional non back-contacted H-Pattern metal contact grids. So far, the best cell efficiency of 19.89% in production has been reported [8].

Metal wrap through (MWT) technology has been regarded as industrially promising because of its high cost-effectiveness for increasing cell and module efficiency [9]. In MWT cells, the front metal grids will be wrapped through the via-holes to the rear side of the wafer inducing reduced shading losses, and reduced surface recombination, and as a result the cell efficiency will be improved [10]. On MWT module part, the strategy of full back interconnection of the cells results in lower cell-to-module loss thanks to avoiding much of the resistive loss existing in the normal double-side interconnection of H-pattern solar cells with tabs [11,12]. Recent reports on combination of MWT techniques with commercial solar cells mainly focus on the p-type solar cells [13, 14]. The utilization of MWT on n-type materials is also very promising and allows to target even higher cell and module efficiencies. In this paper we investigate the integration of MWT technology with our commercial production process for bifacial n-type solar cells (PANDA cells).

II. EXPERIMENTAL METHODS

At present, in Yingli Solar, small pilot operation of n-MWT cells is running, and several process flows which have industrial perspectives have been tested or are being tested, and in pilot tests, to analyze and optimize the MWT processes, Panda and MWT cells are often processed in parallel. The results in this section and next section are from a recent test with one promising process flow.

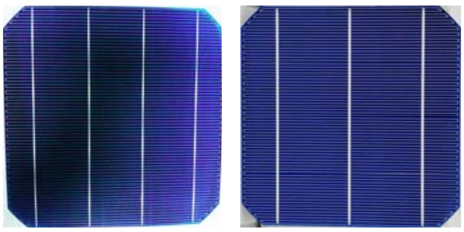

Fig. 1. Front images of n-MWT cell (left) with normal PANDA cell (right).

For the fabrication of these cells (239 cm^2), to guarantee the good comparison, all the cells were processed in parallel. Based on the normal PANDA cell process, steps such as texturization, BSF and emitter formation, and passivation, would be the same. Fig. 1 shows the front design of n-MWT cells compared to normal PANDA cells. After the metallization of both sides by screen printing, the cells were fired in one single step in an IR heated belt furnace. The IV characteristics of n-MWT cells and PANDA cells were measured by using a corresponding chuck, under the same illumination condition in the same tester.

III. RESULTS AND DISCUSSIONS

In Table 1, the mean values of the main electrical parameters of the solar cells are given. The experimental results show that compared to PANDA cells with 3 busbars, the n-MWT cells with 4 busbars have higher Isc and Voc. The absolute efficiency gain is 0.35%, and Voc gain and Isc gain are 2.7mV (0.4%) and 0.22A (2.5%) respectively.

TABLE 1
COMPARISON OF ELECTRICAL PARAMETERS OF N-MWT CELLS AND PANDA CELLS (MEAN VALUES OF 25P CELLS)

	Uoc(mV)	Isc(A)	FF(%)	Eta(%)
PANDA	639.8	8.97	77.1	18.54
n-MWT	642.5	9.19	76.25	18.89
Delta	2.7	0.22	-0.85	0.35

In solar cell devices, the Isc is dependent on the generation and collection of carriers from harvested light, and Voc is dependent on the saturation current and Isc. In our devices, the shadow difference will be one important factor: less shadow area will increase the light absorption and reduce surface recombination which will result in the current gain directly, and reduced surface recombination will also reduce saturation current, especially related to emitter metal contact[15,16]. These two factors (Isc and saturation current) together will lead to the Voc gain.

In this experiment, the number and width of fingers for all the cells are the same, the difference from the shadow area will be mainly from the narrower width of busbar in the front side for n-MWT cells. In this case, the shadow area reduction is about 1.7%. If this reduction of shadow loss can induce Voc gain of 0.4%, then the current gain from reduction of recombination will be 0.25% (according to PC1D model), if put together, there will be overall 2.0% Isc gain from shadow loss reduction. In our result, there is still 0.5% Isc gain from other parts, the reason for which is still under investigation. It should be noted that there are uncertainties in the measurements, which may be different for the MWT and Pasha chuck in our tester. The bifacial character of cells further complicates measurements (need to define reflectance underneath the cell). The cells have not been independently certified. We plan to implement use of hybrid PANDA-MWT cells to increase accuracy of comparisons like in this experiment [17].

Considering the front pattern design, for the n-MWT cells with one more busbar than PANDA, the front fingers can be even thinner, and the number of fingers can also be different. In this regard, we investigated by calculation the influence of width (Fig. 2) and number (Fig. 3) of fingers in the front grid on the performance. The performance is represented by overall-loss, i.e. the power-loss including the FF-loss and shadow-loss. (In Fig. 2 and Fig. 3, the contact design of n-MWT is 4X4, and the PANDA cell is contacted by 8 probes per busbar.)

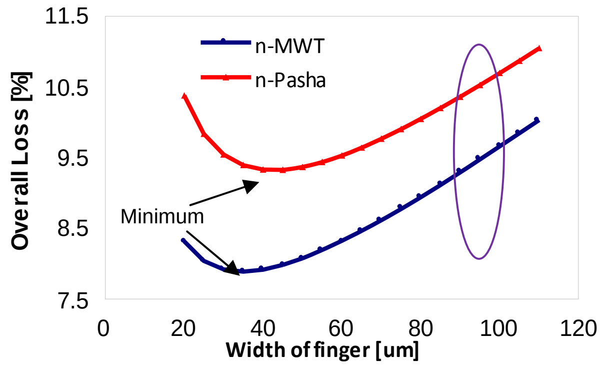

Fig. 2. Calculated relationship between width of front-side fingers and the overall-loss, for both n-MWT and PANDA.

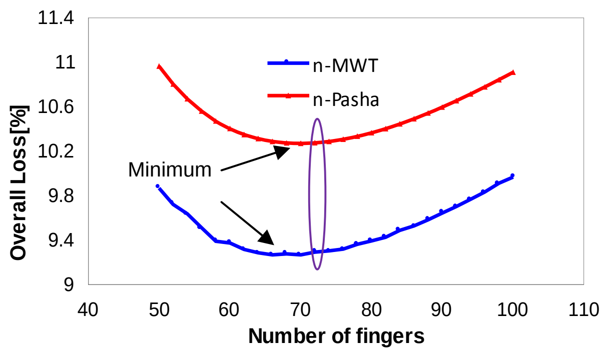

Fig.3. Calculated relationship between number of front-side fingers and the overall-loss, for both n-MWT and PANDA.

The parameters of the front pattern in this experiment are located within the purple rings. It can be noticed that there is still space to improve the performance of n-MWT solar cells by reducing the number and width of fingers on the front side. As indicated in these figures, the best finger parameters for n-MWT and PANDA will be a little different (which will probably allow a larger efficiency gain of n-MWT over

PANDA), such difference will mainly originate from the different busbar design.

Based on the optimization of the finger pattern on the front side, the number of via-holes, and correspondingly, busbar pattern, can also be further optimized.

Fig. 4 shows by calculation the efficiency potential of optimization of number of via-holes. In this calculation, the busbar pattern is maintained to be the same for simplicity.

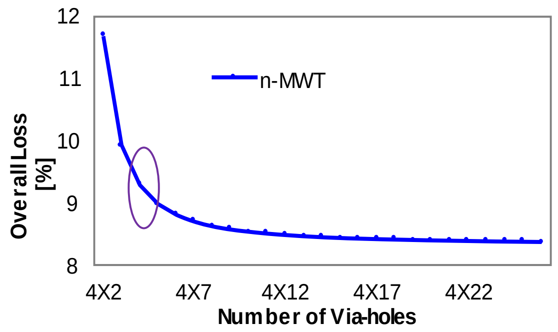

Fig. 4. Influence of n-MWT via-hole number on the overall loss.

Apart from all the above optimizations related to the pattern for metallization, there is another specific factor that cannot be neglected for the n-MWT cells. That is the plug paste. We have also made several comparisons of different plug pastes (data is not shown here). Undoubtedly, the properties of plug paste (such as conductivity and printability) will also influence the performance of the n-MWT solar cells.

IV.CONCLUSIONS

By integration of MWT architecture into our bifacial n-type solar cells by industrial processes, 0.35% absolute efficiency gain has been achieved, and Voc gain and Isc gain can be up to 2.7mV (0.4%) and 0.22A (2.5%), respectively. Calculations on the optimization of the screen pattern, especially on the front side, such as number and width of fingers, number of via-holes, and busbar pattern, show that these n-MWT cells have potential of further efficiency gain over PANDA cells.

Simultaneously, the plug paste will also play an important role for the performance of MWT cells, by influencing the FF directly.

ACKNOWLEDGEMENTS

We thank Ard Vlooswijk and Peter Venema from Amtech Tempress for their technical supports.

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