CURRENT STATUS OF HIGH-EFFICIENCY Q.ANTUM TECHNOLOGY AT HANWHA Q CELLS

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ABSTRACT: In this paper we present the latest results of the high-efficiency Q.ANTUM technology during pilot production at Hanwha Q CELLS. With this dielectric passivated rear cell concept we reach average efficiencies above 18.2% on multicrystalline silicon on continuous running production. The high efficiency cells are converted in an industrial module production with power classes reaching up to 270 Wp. We furthermore present field data which show the superior yield performance of modules based on the Q.ANTUM technology during the whole year.
Keywords: Solar Cell Efficiencies, Multicrystalline Silicon, Passivation, PV Module, Energy Yield

1 INTRODUCTION

In order to further increase the cell efficiency in photovoltaic high volume production, a change over from the standard Al-BSF concept to cells with a dielectric passivated rear and local contacts is inevitable. This cell design is most suitable on low ohmic material to enhance the lateral conductivity and reduce recombinative losses with a minimized metallization area. To furthermore lessen light induced degradation due to the oxygen contamination of the highly doped silicon material, multicrystalline wafers are the best choice for the dielectric rear cell concept.

In recent years Q CELLS reported on several record cells and modules [1-3] utilizing the Q.ANTUM technology on mc-Si material which were fabricated in the Rainer-Lemoine research center with batch sizes of some hundred wafers. Since the beginning of 2012 this technology is ramped into a full shift pilot production in an industrial environment. The Q.ANTUM cell concept is applied to the rear side of p-type mc-Si cells while maintaining the front side of the standard Al-BSF cell. It is therefore possible to reuse already optimized productive equipment and processes of the standard cell production and to focus solely on enhancing processes of the new technology.

As the Q.ANTUM cells are still double-side contacted it is furthermore possible to convert the cells into high power modules with minimal adaption of an industrial module production line. The modules passed the Hanwha Q CELLS high quality standards of VDE Q.tested and assure the Hanwha Q CELLS yield security.

In this paper we show the latest results of the cell and module pilot production and outdoor energy yield performance data of several month including different seasons.

2 CELL

The design of the Q.ANTUM cell is sketched in Fig. 1. The front side of the 180 µm to 200 µm thick 156 mm p-type multicrystalline wafers is textured with an isotropic inline texturing process. After forming the emitter via a $POCl_3$ tube diffusion, a wet chemical etch isolation is applied and the dielectric passivation is deposited on both sides. The front side metallization consists of a standard mc-cell Ag-front-grid whereas the rear side is contacted with laser fired point contacts (LFC).

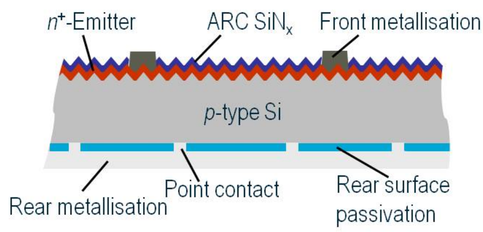

Figure 1: Schematic cross section of the Q.ANTUM solar cell design.

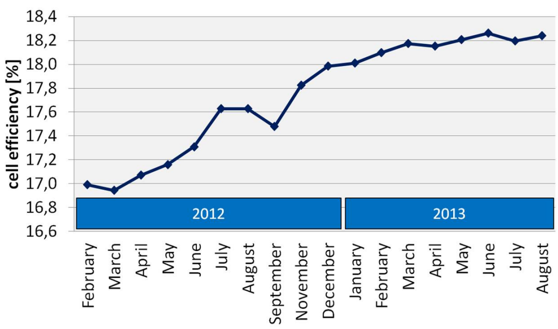

Figure 2: Average efficiency per month of the Q.ANTUM pilot line production in 2012/2013.

The wafer material is not presorted and equals the typical mix of the standard Al-BSF cell production at Hanwha Q CELLS. Fig. 2 shows the average monthly production efficiency. It was possible to raise the efficiency starting from 17% in January 2012 by more than 1.2% to values exceeding 18.2% since May 2013. Best individual runs of over 18.4% efficiency are reached. The slightly deviating September 2012 value is due to a different material mix.

Fig. 3 shows a typical efficiency distribution of one of the May 2013 runs consisting of several thousand wafers. The main classes are 17.8% to 18.6% and contain over 92% of all cells. Efficiencies up to 19% are reached by single best cells.

As one additional performance parameter besides the total cell efficiency, the gain relative to Al-BSF cells with neighboring sorted material and equal front side parameters is monitored. Due to the changing base conductivity a rising gain towards low resistivities is expected which is furthermore influenced by wafer material and LFC contact quality. This method allows separating effects which are due to material or front side

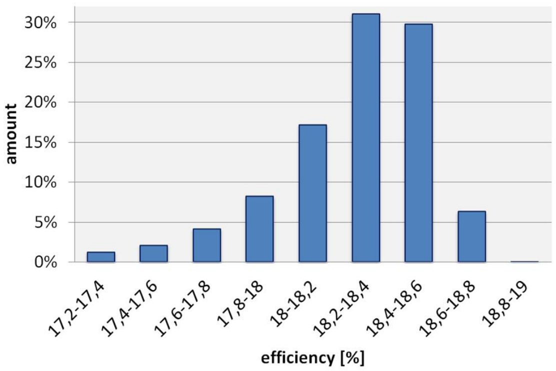

Figure 3: Distribution of cell efficiencies of a typical Q.ANTUM cell production run.

related enhancements from effects which are based on the Q.ANTUM technology only. Fig. 4 shows the gain of 0.5% up to 0.8% within a resisitivity range of 1.1 Ohm cm to 2.6 Ohm cm. The efficiency gain scales as expected and remains positive over the full resistivity range of standard multicrystalline wafer material thus showing the high performance adder due to the Q.ANTUM technology. For further analysis, a PC1D simulation assuming constant life time is carried out which is in good agreement with the measured values. The trade off at high resistivities can be explained with the varying bulk life time of the production wafers.

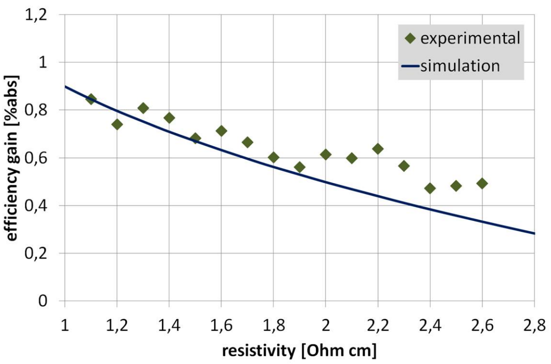

Figure 4: Experimental and simulated efficiency gain of Q.antum relative to Al-BSF cells on sorted material.

3 MODULE

The Q.ANTUM cells are converted at Hanwha Q CELLS into high power 60-cells modules with a bill of materials similar to modules consisting of Al-BSF cells. However, the new rear side technology calls for additional process analysis to fully transfer the efficiency gain of the dielectric rear into the modules. If the module built parameters and the cell rear side characteristics are poorly matched a loss in rear side passivation can arise. This loss emerges as a drop in internal quantum efficiency (IQE) at long wavelengths. Fig. 5 presents internal quantum efficiency (IQE) curves of Q.ANTUM cells before and after encapsulation. In Fig. 5 a) the IQE curve of the Q.ANTUM cells after encapsulation clearly drops at large wavelengths leading to an additional encapsulation loss of about 1%. Hanwha Q CELLS was capable to understand and eliminate this effect and build modules which preserve the full efficiency gain of the Q.ANTUM technology. Fig. 5 b) shows the IQE curves

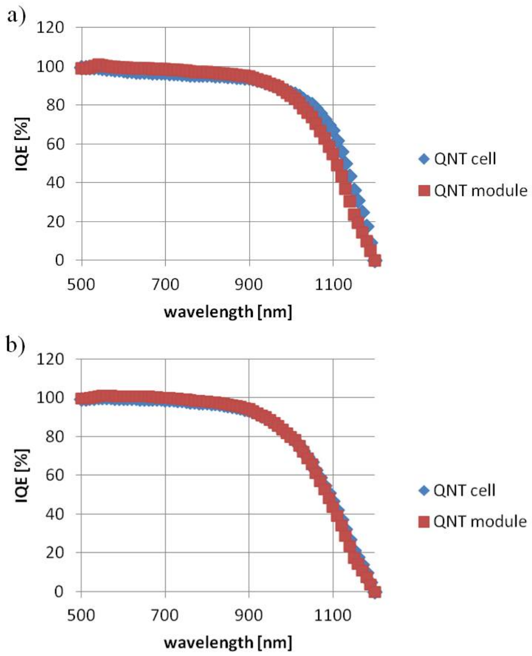

Figure 5: Quantum efficiency curves of Q.ANTUM cells before and after encapsulation with a) wrong and b) optimized module built parameters.

before and after encapsulation for the adapted process. There is no drop at longer wavelengths anymore. The module production is set up for a short feedback loop to the cell production. It is therefore possible to control on a module level the process enhancements of the cell line and to populate module power classes above 270 W.

At Hanwha Q CELLS, all products need to pass the tightened quality criteria of VDE Q.tested according to VDE-QTPV001:2012/01. These tests comprise 400 cycles temperature cycle test, 1500h damp heat test and 30 cycles of humidity freeze test, which is much longer than standard IEC 61730-1 (ed. 2), IEC 61730-2 and IEC 61215 test conditions. The modules build with the Q.ANTUM technology passed all tests with a degradation of below 5% as is required by the test. Additionally the modules ensure the high standards of the Q CELLS yield security which prevents potential induced degradation, gives increased security and performance safety regarding hot-spots and lets all cells be 100 % traceable with the help of Tra.Q laser marking.

The Q.ANTUM technology makes use of rear local point contacts to both minimize passivation damage and optimize contact resistance. However, due to the lower contact area compared to an Al-BSF cell, the higher series resistance should lead to better low light behavior. To prove this, two comparable systems with Al-BSF and Q.ANTUM cell based modules were installed on the Hanwha Q CELLS outdoor test field in Thalheim, Germany. The field data such as temperature, irradiance, and module output power is logged for further analysis. Fig. 6 shows the monthly average of daily specific energy yield and the gain of the Q.ANTUM based modules in comparison to the Al-BSF based modules. Days with low irradiance of less than 1 kWh/m^2, periods with shading due to snow and periods with known measurement problems were filtered out. Based on indoor measurements of the low-light behavior and the temperature coefficient at P_{mpp} and I_{sc} the theoretical gain prediction for this location is plotted additionally.

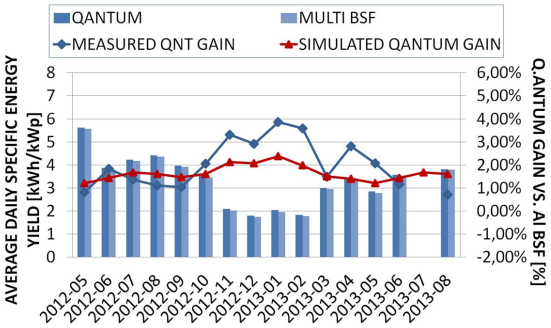

Figure 6: Monthly average of daily specific energy yield of Q.ANTUM modules relative to Al-BSF modules.

The graph shows that the Q. ANTUM based modules generate due to their superior low light performance a gain in specific energy yield throughout the whole year. The one-year Q.antum gain measured from June 2012 until May 2013 amounts to 1.7% and thus exceeds the simulated gain, which is calculated to 1.58% for this location.

4 CONCLUSION

This paper showed the current status of the dielectric passivated multicrystalline Q.ANTUM cell technology at Hanwha Q CELLS. The cells are produced in a full volume industrial production environment with average cell efficiencies above 18.2% and best cell efficiencies up to 19%. The cells are built into modules with power classes reaching above 270 Wp. These modules fulfill the high reliability standards of VDE Q.tested and show an additional energy yield gain in free field operation.

ACKNOWLEDGEMENTS

This work was partly supported within the Spitzencluster Solarvalley project *xμ-Clip* (FKZ 03SF0452) by the German Federal Ministry of Research and Technology.

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