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Study of the Twelve Busbar Technology and the Stress-Induced Degradation within the Solar Modules

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Abstract. To achieve cost reduction and efficiency increase of module products, the multi-busbar technology has recently been applied in photovoltaic crystalline silicon modules. Compared with the current five busbar modules, the multi-busbar modules use round ribbons to reduce the resistance loss and increase the secondary utilization of the light on the surface of the ribbon, thereby increasing the power output of modules. However, the use of multi-busbar technology requires redesign of the cell pattern, and thicker solder ribbons may probably lead to more degradation due to inner stress. This stress-induced degradation of the twelve busbar modules was investigated by thermal cycling test and electroluminescence test. The test results demonstrate that by increasing the thickness of EVA, the cracking of the cells caused by the stress during the thermal cycle can be effectively reduced. Our twelve busbar modules exhibited good reliability in the damp heat and UV sequence tests.

Introduction

Multi-busbar technology is an effective means to increase the output power of the module due to the reduction of the silver paste consumption during cell fabrication[1], decrease of the current loss [2-3] as well as increase of the secondary utilization of light. In recent years, it has received widespread attention in the PV industry [4-6]. Unlike conventional flat ribbons, the MBB technology typically uses round ribbons that are typically thicker than conventional flat ones, which requires adjustment and optimization of the corresponding material and process.

To ensure the amount of power generated by the module throughout its lifetime, special attention needs to be paid to the power degradation and reliability of the module during outdoor applications. The modules are affected by the complex environment during outdoor use, and the degradation inducements are also diverse [7-11]. At present, most of the large domestic power stations are distributed in the northwestern region, with large temperature difference between day and night and strong ultraviolet radiations. Therefore, modules should also be designed and verified for this environment.

In this paper, to improve the output power of our products, we studied the power gain of the twelve busbar (12BB) technology compared with the conventional five busbar one. We also evaluated the reliability of the welding between the interconnecting ribbon and the cell. The thermal cycle and electroluminescence (EL) tests were used to study the stress-induced degradation of the 12BB module. The effect of thicker EVA encapsulant film on reducing the stress-induced degradation was investigated. The EL results are consistent with the output power degradation of the module. The damp heat and ultraviolet sequence tests demonstrate that the 12BB modules possess good weathering resistance.

Experimental Section

The 12BB and 5BB cells were fabricated using silicon wafers of the same quality. The silicon wafers were all made of the same processing materials and parameters for texturing, diffusion, etching and

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PECVD. Only different screens for the 12BB and 5BB cells were respectively used for electrode printing. A total number of 940 12BB cells were fabricated, and the 5BB cells produced via the same process were selected for encapsulation and module power comparison. All modules were encapsulated through the module encapsulation process of CECEP Solar Energy Technology (Zhenjiang) Co., Ltd. The structure of the module after encapsulation is glass/EVA/cell/EVA/backsheet. Thermal cycling, damp heat, and UV sequence tests were performed in accordance with the procedures specified in IEC61215. Power and EL tests were performed on the modules after environmental tests. The maximum power of the modules is performed under STC (25ºC, 1000 W/m^2, AM 1.5) condition.

Results and Discussion

The fabricated 12BB cell has 20 silver pads for soldering on each front busbar and eight segmented electrodes for each back busbar. The appearance of one 12BB cell after printing is shown as Figure 1.

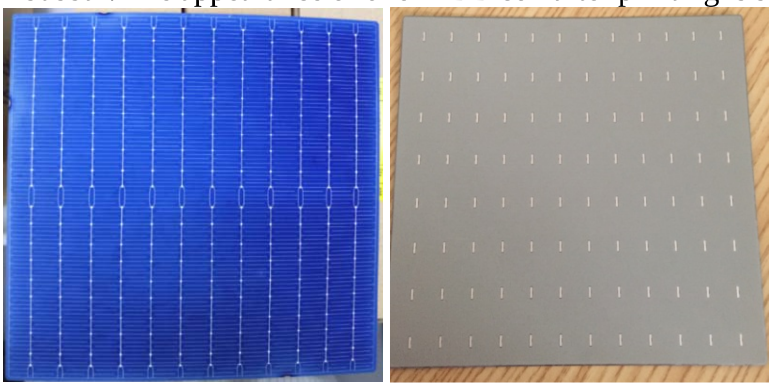

Figure 1. Front and back side pictures of the 12BB cells

200 pieces of 12BB cells were selected for electrical performance test to evaluate the cell efficiency distribution, as shown in Figure 2. The mainstream efficiency of the 12BB cells was tested to be in the range of 19.1-19.3%, which is significantly higher than the mainstream efficiency 18.6-18.7% of the 5BB cells produced by silicon wafers of the same quality tested in our company. After module encapsulation, the actual improvement in the efficiency of the cell can be derived through reverse reasoning calculation.

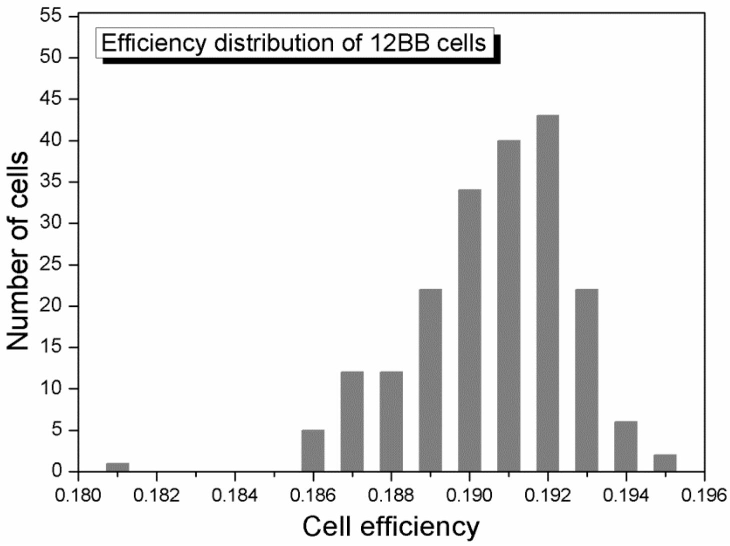

Figure 2. Efficiency distributions of the 12BB cells

To evaluate the welding quality between the 12BB cell and the round interconnecting ribbon, we conducted the 90° and 180° peel test on the soldered 12BB cells. The results are shown in Table 1. The 90° peel force was tested to be higher than the 180° peel force.

Table 1. Peel test of 12BB cells after soldering

Method	Front side peel force（N）	Back side peel force（N）
90°	3.5	4.2
180°	2.5	2.7

Meanwhile, 12BB cells of the mainstream efficiency (19.1-19.3%) and 5BB cells of the mainstream efficiency (18.6-18.7%) produced by silicon wafers of the same level were encapsulated through the same process for comparison. Then the output power of the modules was tested to obtain the power gain of the 12BB technology. The data is shown in Table 2.

Table 2. Power contrast of 12BB and 5BB technology

Cell	Efficiency	Module Power（W）	Average Power（W）
12BB	19.1%-19.3%	278.07	278.07
5BB	18.6-18.7%	273.71	273.98
	18.6-18.7%	274.24	

After the silicone gel was cured, the power test of the modules was performed. The average power of the 12BB module was 278.07W, and the average power of the 5BB module was 273.98W. Our results suggest that the 12BB technology can increase the output power of the module by about 4.1W. According to the power gain of the module, the cell efficiency gain of the 12BB technology relative to 5BB can be derived to be around 0.3%. It can be noted that there are some differences between the derived cell efficiency gain and the tested cell efficiency from another company. The causes may be: 1) the difference between the reference cells; 2) the difference between the test instruments. Then the reference cell and instrument parameters were revised and optimized according to the derived results from module power gain.

To study the weathering resistance performance of the modules, the modules were first encapsulated using a conventional 0.5mm thick EVA. It was found that some cells in the modules were cracked during the lamination process. The EL-tested modules were subjected to the thermal cycle test to verify the stress-induced degradation inside the module during the thermal cycle process. Before and after TC200 test, the electrical and insulation performance were measured. The data obtained are shown in Table 3.

Table 3. Electrical performance of the 12BB module with 0.5mm EVA after TC200 test

Module	Thickness（mm）	Test Item		I-V Test						Wet Leakage Test	Power Degradation
				Voc [V]	Vmp [V]	Isc [A]	Imp [A]	FF	Pmp [W]		
A1	0.5	TC200	before	38.27	31.49	9.37	8.89	78.09%	280.06	Pass	7.06%
			after	37.79	30.60	9.25	8.50	74.45%	260.30		

As can be seen from the above table, the initial power of the 12BB module was 280.06W, and the power of the module after the TC200 test was 260.3W. The power degradation is 7.06%, which exceeds the 5% range allowed by the IEC61215 standard, and cannot meet the requirements of outdoor applications. To analyze the reason for the large degradation, the module after the TC200 test was subjected to the EL test, and the EL pictures are shown as Figure 3. It can be seen that different degrees of cracking occurred in most of the cells of the module after TC200, mainly at the edge. This can be attributed to the thermal stress generated during the thermal cycle, which was not effectively buffered within the module.

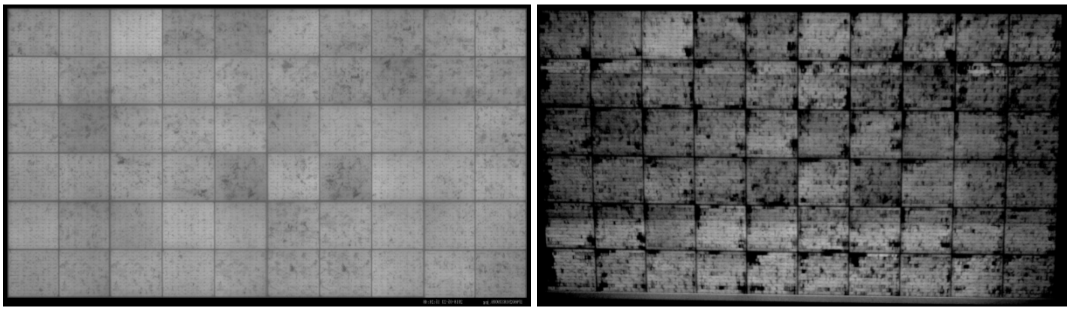

Figure 3. EL pictures before and after TC200 test (EVA thickness 0.5mm)

Considering that the 12BB round interconnecting ribbon is significantly thicker than the conventional 5BB flat ribbon, the film thickness between the ribbon and the glass is reduced after lamination, which is the main reason why the module cannot effectively release the stress during the thermal cycle process. Therefore, we increased the thickness of EVA and performed the thermal cycle test again. Then the 0.6mm and 0.7mm thick EVA were adopted in the 12BB module for module encapsulation, and the encapsulated modules were tested for TC200. Voc, Isc, FF and Pmp data before and after the test are listed in Table 4. The power degradation after TC200 for modules with 0.6mm and 0.7mm thick EVA is 1.26% and 1.48%, respectively. It can be noted that the degradation after TC200 with the thicker EVA module is significantly lower, which indicates that increasing the thickness of the EVA can effectively reduce the stress damage of the module during the thermal cycle. The 0.6mm thick EVA is enough for good stress release.

Table 4. Electrical performance of the 12BB modules with EVA of different thickness after TC200 test

Module	**Thickness**	**Test Item**		**I-V Test**						**Wet Leakage Test**	**Power Degradation**
				Voc [V]	**Vmp [V]**	**Isc [A]**	**Imp [A]**	**FF**	**Pmp [W]**		
A2	0.6mm	TC200	before	38.31	31.51	9.33	8.87	78.25%	279.84	Pass	1.26%
			after	38.17	31.33	9.27	8.81	78.04%	276.32		
A3	0.7mm	TC200	before	38.33	31.55	9.36	8.87	78.01%	279.92	Pass	1.48%
			after	38.2	31.27	9.31	8.82	77.48%	275.77		

The EL of the modules before and after the TC test is shown as Figure 4. The stress-induced crackings are significantly reduced, and the degradation of the electrical properties of the modules is consistent with the EL test results.

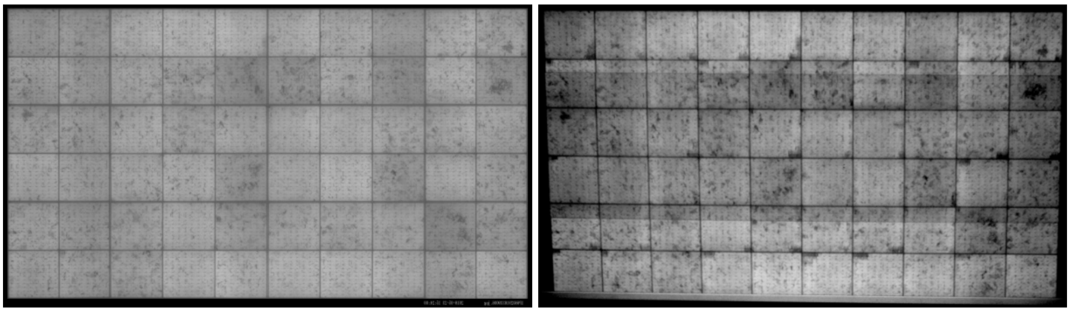

Figure 4. EL pictures before and after TC200 test (EVA thickness 0.6mm)

To verify the weathering resistance performance of the 12BB module in hot and humid environment and ultraviolet region, modules encapsulated with two thicker EVA with better TC performance were subjected to the DH1000 and UV15-TC50-HF10 sequence test, respectively. The test results are shown in Table 5. The degradation of the modules before and after the test meets the IEC 5% standard. All modules were tested for insulation after environmental tests, which all showed good insulation performance. Based on the above test results, the 12BB modules encapsulated with optimized matching materials can have good weathering resistance.

Table 5. Electrical performance of the 12BB modules with EVA of different thickness after DH and UV-TC-HF sequence test

Module	Thickness	Test Item		I-V Test						Wet Leakage Test	Power Degradation
				Voc [V]	Vmp [V]	Isc [A]	Imp [A]	FF	Pmp [W]		
B2	0.6mm	DH1000	before	38.36	31.58	9.38	8.91	78.22%	281.46	Pass	3.32%
			after	38.29	32.03	9.17	8.5	77.48%	272.11		
B3	0.7mm	DH1000	before	38.31	31.51	9.38	8.88	77.93%	279.91	Pass	1.63%
			after	38.23	31.17	9.24	8.79	77.65%	275.34		
C2	0.6mm	UV15-TC50-HF10	before	38.32	31.49	9.37	8.89	77.95%	279.86	Pass	1.77%
			after	38.2	31.28	9.28	8.79	77.57%	274.91		
C3	0.7mm	UV15-TC50-HF10	before	38.33	31.56	9.36	8.89	78.15%	280.34	Pass	1.78%
			after	38.21	31.36	9.26	8.78	77.82%	275.36		

Conclusion

The 12BB technology can effectively increase the module power by about 4.1W. The peel force test indicated good welding between the round ribbon and cell silver pad. When the 12BB module was encapsulated with a conventional 0.5mm thick EVA, the power degradation was 7.06% after the TC200 test, which exceeds the 5% range allowed by the IEC61215 standard. To reduce the stress risk of thicker solder ribbons, we studied the stress-induced degradation of the 12BB module through thermal cycling and EL tests. The test results show that by increasing the thickness of EVA, the power degradation caused by stress during thermal cycling can be effectively reduced. The 12BB modules perform well in wet heat and UV environments.

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