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ENVIRONMENT MANAGEMENT SYSTEM IN SOLAR MANUFACTURING INDUSTRY- A STUDY ON CTM LOSSES

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Abstract: In today's world of energy crisis the use of conventional source of energy is not a solution also they are non-renewable sources and the use of them leads to pollution of natural attributes and leads to global warming. Hence, there is a need for alternative energy sources which are green, renewable and available in abundance. One such source of energy is solar energy the solar energy practice is a sustainable practice, recharged by nature at a much faster pace than it can be consumed than the non-renewable source. Harnessing the Solar energy makes energy consumption more efficient and ultimately results in reduction of pollution conventional sources of energy are not a solution but there are challenges of depending completely on them since it is constantly fluctuating. The present study deals with the harnessing of Solar Energy and the problem faced by the solar industry during the CTM process. The reduction in cost of electricity is important when it comes to solar PV to compete against the other different sources of energy. That's why there is need to not just focus onto improving the efficiency of solar cells but to reduce the losses during the CTM Process.
Key words:Solar Energy, Photo Voltaic cell, CTM loss

1. INTRODUCTION

Crystalline silicon technology has been dominant in the Photovoltaics (PV) industry for the last decades because of its efficiency which are quite higher when compared to other technologies. The Production has exploded in the last few years and Si-wafer based PV technology accounted for about 92% of the total production in 2014. The share of multi-crystalline technology is now about 56% of total production. There are industries which continuously work on the methods to improve the performance of solar cells by using new technologies such as back contact solar cells, etc. and they are trying to get the maximum power output from the module.

One of the major challenges in converting the solar cell to module is to get the maximum power output from the given design. Although there has been a steady increase in the cell efficiency, the industries face the problem known as Cell to Module (CTM) losses. In order to provide mechanical protection, electrical isolation, and chemical protection, the crystalline silicon solar cells are generally encapsulated in a sandwich like structure. Hence leading to lesser output power from the crystalline silicon solar module when compared to the sum of the maximum output power of the constituents because of optical and electrical power loss. Many processes are involved in the conversion of solar cells to a module, hence CTM losses are introduced.

Cell electrical parameters, module process parameters and quality of the module materials are also the parameters that contribute to module efficiency that is the module power. The conversion power losses are due to parameters like shadow, properties of the solar cells, materialsused for fabricating the module, contact design and metallization also play the major role in conversion losses.

Reducing the CTM losses would increase the performance of solar Cells. Determining the CTM losses of Solar cells Manufacturing Industry as well as other manufacturers and also determining the factors that contribute to them and finding ways to reduce CTM losses is the goal of our project.

2. REVIEW OF LITERATURE

The review presents various facts that supports sustainable development and focuses on switching to solar energy. Every solar PV manufacturing industry faces the problem of CTM losses. From a solar cell to a solar module, about 3- 10% ofCTM losses can occur. This high amount of loss results from a combination of various loss and gain mechanisms. During module manufacturing, processes like EVA encapsulation leads to gain and there are processes that lead to losses. The factors contributing to CTM were determined and they are shown below.

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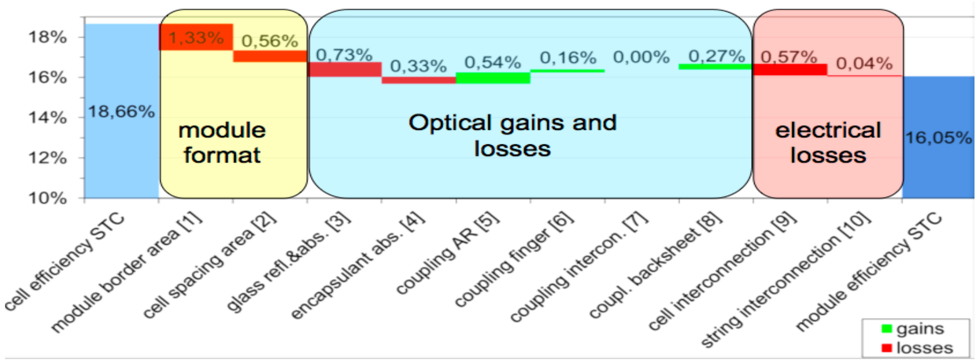

Figure 1: Gains and Losses during CTM process

From the above figure,there are several gains and losses associated with manufacturing process of the cell to module conversion process, but finally losses are higher and hence the final module efficiency reduces. One such experiment was conducted at Fraunhofer ISE, it was seen that the efficiency decreased from 18.66% at cell level to 16.05% at module level. During Solar Photovoltaic module manufacturing, in terms of wattage losses, at critical process steps such as Tabbing and Stringing (T&S) and Lamination have been analyzed and a comprehensive electrical and optical model was presented [(Roy 2016)]. The literature and research studies provide information regarding mathematical approach that is focused on losses during CTM process.

3. METHODOLOGY

3.1 Analysis of the parameters causing CTM losses

To determine the Cell to Module power conversion loss factors in the cells of Solar Manufacturing Industry, the electrical parameters of cells and modules produced at the plant were compared with other suppliers. Cells of similar efficiency were taken from four different suppliers and 25 units of 250W modules, containing 60 cells each, were manufacture for cells from each of the suppliers. The CTM loss was determined in accordance to the system in the plant measuring efficiency in order to maintain uniformity in the scale.

3.2 Wet Edge Optimization Trial

Objective: Wet Edge Optimization for Increasing Rshunt to 200 Ohms

Approach: Increasing etch rate through higher circulation frequency of chemical at the etch bath. (1000 cells at each group)Therefore, we tried to determine whether the etch rate would affect the cell shunt in any way and hence, the cells were made in three batches and three different pump speeds.

Base: Pump speed 72% ,Batch 1: 75% - P75 , Batch 2: 78% - P78 , Batch 3: 80% - P80

3.3 Manufacture of modules with cells of varying refractive indices

Cells with the base refractive index of 2.10 are produced at the Solar industry. The RI of the cells was varied to see which RI would have the least amount of CTM losses. This experiment was to obtain optical matching of the ARC layer with the glass and EVA.

3.4 Pull Test

Determine the minimum temperature required for soldering

Use a range of temperature from 300°C to 470°C for soldering the TCI on the solar cells

Making modules with a reduced temperature

4. EXPERIMENTS CONDUCTED

4.1 Analysis of the parameters causing CTM losses

Table 1: Analysis of the parameters causing CTM losses

Comment		Pmax	FF	Voc	Isc	Vpm	Ipm	Rs	Rsh
Solar Cells of manufacturing Industry	Module	249.70	0.757	37.558	8.7744	30.571	8.1680	0.4725	71.9492
	Cell		0.793	0.6301	8.646	0.5342	8.0895	0.0044	102.26
	Delta		4.5%	0.67%	1.50%	4.60%	0.97%		
Supplier A	Module	253.29	0.766	37.506	8.8148	30.435	8.3224	0.4737	108.285
	Cell		0.796	0.6289	8.7183	0.5324	8.2001	0.0046	289.8
	Delta		3.8%	0.60%	1.10%	4.70%	1.49%		
Supplier B	Module	256.86	0.773	37.683	8.8102	30.887	8.3159	0.4715	105.948
	Cell		0.802	0.6307	8.6351	0.5380	8.1235	0.0041	747.4

	Delta		3.6%	0.43%	2.00%	4.30%	2.37%		
Supplier C	Module	253.54	0.761	37.841	8.8019	30.557	8.2971	0.4901	96.2476
	Cell		0.789	0.6346	8.7182	0.5371	8.1344	0.0045	488.4
	Delta		3.6%	0.62%	1%	5.20%	2%		
Supplier D	Module	254.97	0.761	37.840	8.8519	30.708	8.3030	0.4765	76.4876
	Cell		0.795	0.634	8.7433	0.5374	8.2069	0.0044	189.4
	Delta		4.3%	0.53%	1.20%	4.80%	1.17%		

4.2 Wet Edge Optimization Trial

Observed increase in etch rate with respect to increase in pump frequency up to 78%. At 80% pump speed etch rate is not increase as expected

No significant increase in shunt at any of the pump frequency compared to base(72%)

Efficiency of P75 is little higher side compared to base

Repeating P75 at larger run to further fine tune the etching by adjusting KOH conductivity.

4.3 Manufacture of modules with cells of varying refractive indices

Table 2 - process parameters for cells with RI 2.02

RI:2.02

Sl. No	Parameter	Layer-1	Layer-2
1	SiH_4 (sccm)	782	450
2	NH_3 (slm)	3.1	8.525
3	Power (w)	6000	6000
4	Ton	5	5
5	Toff	40	40
6	Pressure(mtorr)	1500	1500
7	Time	80	565

Table3- process parameters for cells with RI 2.18

RI:2.18

Sl. No	Parameter	Layer-1	Layer
1	SiH_4 (sccm)	782	810
2	NH_3 (slm)	3.1	3.9
3	Power (w)	6000	6000
4	Ton	5	5
5	Toff	40	40
6	Pressure(mtorr)	1500	1500
7	Time	80	410

4.4 Pull Test

Table 2: Pull Test

Temperature	Tab 1	Tab 2	Tab 3	Tab 4	Tab 5	Tab 6	Tab1	Tab 2	Tab 3
300	316	404	398	456	500	660	251	428	541
310	425	323	251	251	370	517	292	275	163
320	183	F	F	F	F	422	316	214	115
330	626	449	122	166	442	520	224	231	432
340	479	503	646	496	687	360	289	306	598
350	292	326	724	507	561	479	248	816	323
360	173	377	F	156	358	432	398	394	425
370	333	381	432	517	629	445	231	360	302
380	231	268	510	473	561	544	173	370	592
390	146	207	282	347	221	527	408	650	432
400	343	370	364	282	214	650	510	490	302
405	279	313	289	176	221	330	289	258	493
408	211	245	241	204	262	408	330	588	564
410	238	299	493	415	367	398	166	456	575
412	323	425	279	377	360	347	394	394	415
415	360	456	527	381	142	398	466	411	313
418	200	479	285	211	425	483	496	306	452
420	115	200	241	224	193	418	439	350	466
425	296	333	343	343	282	115	609	520	238
430	520	520	411	353	316	279	183	483	445
440	190	404	486	350	404	353	524	684	690
450	476	476	599	282	F	370	415	333	214
460	156	262	442	377	507	200	622	292	316
470	272	323	364	418	578	588	547	272	445

5. RESULTS AND DISCUSSIONS

The experiments were conducted for the purpose of analysis by Analysis of the parameters causing CTM losses,Wet Edge Optimization Trial,Manufacture of modules with cells of varying refractive indices and Pull Test. For all the test box plots have been plotted.

5.1 Analysis of the parameters causing CTM losses

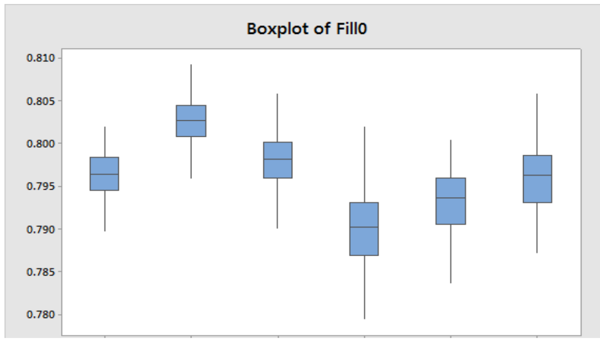

Fig. 2 - Boxplot of Fill Factor

On comparing the Fill Factor (FF) values of all the modules, the ones manufactured in the industry have the least value of FF. From this we infer that modules made from the cells of all the suppliers have a better ratio of Imp and Isc; and a better ratio of Vmp and Vsc.

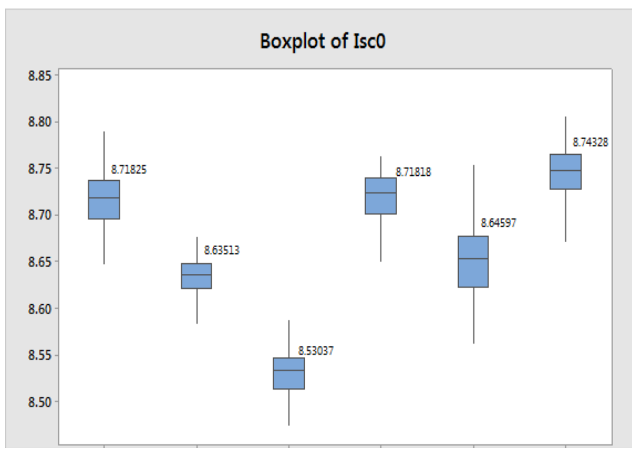

Fig. 3 - Boxplot of short-circuit current

5.2 Wet Edge Optimization Trial

Efficiency of P75 is little higher side compared to base

Repeating P75 at larger run to further fine tune the etching by adjusting KOH conductivity

NO INCREASE IN CELL SHUNT RESISTANCE.

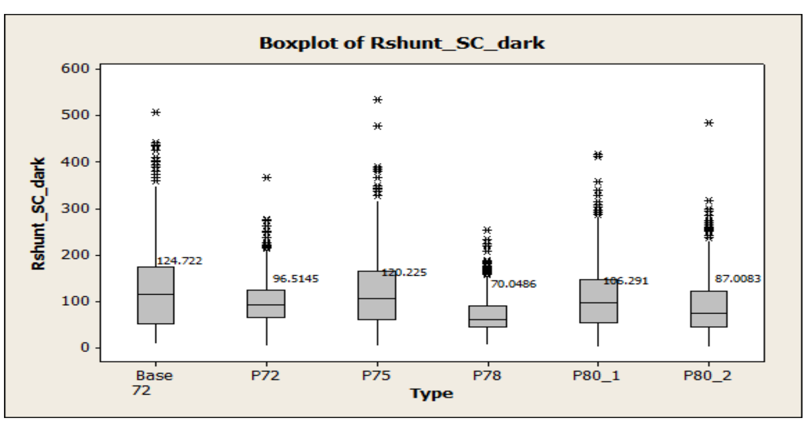

Fig. 4 - Boxplot of Wet-edge optimization test results

5.3 Manufacture of modules with cells of varying refractive indices

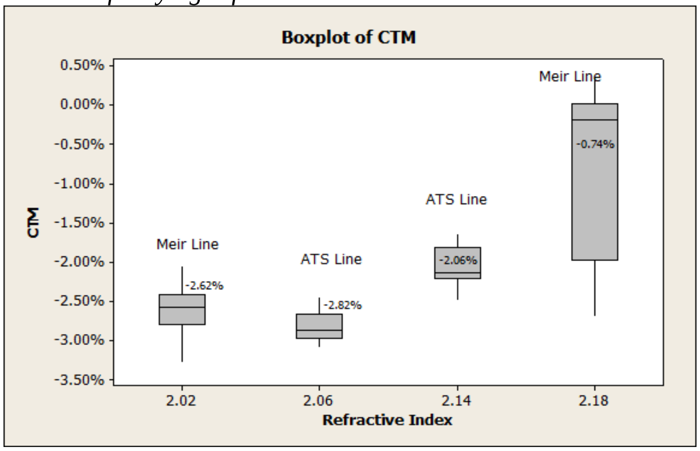

Fig. 5 - CTM losses for the modules manufactured with cells of different RI

5.4 Pull Test

For temperatures below 360 degrees Celsius, there was no cohesion between interconnect and the silicon cell's tab.
There was breakage when pull test was performed for temperatures above 380 degrees Celsius.
Hence, the optimum temperature for soldering was found to be 380 degrees Celsius.

6. CONCLUSIONS

The experiments that were conducted gave an idea about which parameters directly affect the CTM losses, which are as follows:

The first experiment to determine the CTM loss of Solar Manufacturing Industry cells with respect to other cell suppliers showed that the cells have the highest CTM loss compared to other manufacturers.

The second experiment to change the cell shunt resistance was not successful whereas, the third experiment where the refractive index was varied to see the effect on CTM gave good results. There was a reduction in CTM losses from approximately 3.66% to 0.74% when the optimized Refractive Index of 2.18 was used during the PECVD process. This was a significant decrease in CTM losses and there need to be more trials done to see the best possible parameters for cells to be manufactured at this value of refractive index.

The third experiment, pull test gave the optimum soldering temperature to be 380 degrees Celsius. Further experimentation needs to be done to see the effect it has on the CTM losses.

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