CHAPTER IV

RESULT AND DISCUSSION

Production Cost calculation [16]

Production cost for In-house TCO glass was calculated based on the assumptions and criterion as below.

1. Related assumptions:

1.1 Cost of In-house TCO glass coating line	THB 87,500,000
1.2 Calculated depreciation	5 years
1.3 Total TCO glass production capacity	150,000 pieces per year
1.4 Number of working days	313 days per year
1.5 Number of working hours	24 hours per day
1.6 Number of direct labour	3 persons
1.7 Cost of direct labour inc. over-time	THB 15,000/month
1.8 Electric power requirement	200 kW
1.9 Electricity cost	THB 3.50 per kWh

2. Estimated production cost

2.1 Depreciation cost of the equipment	THB 116.67 per piece
2.2 Cost of soda-lime glass	THB 100.00 per piece
2.3 Cost of labour, maintenance etc.	THB 14.80 per piece
2.4 Cost of electricity	THB 35.08 per piece
2.5 cost of consumable materials	THB 61.33 per piece
2.6 Production overhead	THB 32.80 per piece
Total production cost	**THB 360.68 per piece**

Note: The investment cost of glass preparation equipment is not included in the production cost estimation as it is already available as part of the normal production process. For detailed cost estimation, please refer to Appendix 1.

Form the above production cost estimation, the cost of In-house TCO glass can be as low as THB 360 per piece which is only 60% of the price of commercial in-line TCO glass (THB 600 per piece). In case In-house TCO glass coating line can

deliver the required quantity and specification, such investment is therefore quite feasible and can render approx 40% reduction on the cost of TCO glass for a-Si thin-film silicon PV modules manufacturing.

Tests Run and Measuring Results

1. Commissioning Test

The objective of commissioning test was to test-run, adjust and calibrate the In-house TCO glass coating machine after it has been re-assembled in the factory. The commissioning engineers from the equipment manufacturer to check, clean, set and calibrate vacuum of the chambers, power to all metallic target, and gas flows. During commissioning test, only sheet resistance and ITO layer of the successful runs to be measured.

At the time the TCO glass coating line was installed and commissioned, the new factory building was not yet completed i.e. without walls and air-conditioned system. For effective operations of the equipment, enclosed room is normally required to control the surrounding temperature, dust and humidity.

The TCO glass coating line was mechanically and electrically commissioned by the engineers from the equipment supplier on 2nd, 3rd, 10th and 13th June 2009. For the normal process and for each test run, to produce vacuum level of chambers and warming-up of the carriers takes approx. 4 hours and another 1 hour for warming-up of metal targets and the chambers to required temperatures. After each successful test run, measuring of the sheet resistance was made on sampled In-house TCO glass plates. The sheet resistance data is used for generation of thickness uniformity graphic report for each tested plate.

Due to only 6-7 hours were available for the engineers to run the TCO glass coating line, there was very short time left to produce the samples for measuring during the day.

Five plates were sampled and tested on June 2, 2009,

Four plates were sampled and tested on June 3, 2009,

Five plates were sampled and tested on June 10, 2009 and

Twelve plates were sampled and tested on June 13, 2009 with different production parameters.

Measuring Result

Below are measuring result reports of both sheet resistance and uniformity of sampled plates produced during the commissioning test of the In-house TCO glass coating line.

1.1 Test-run result from June 2, 2009

Test-run condition for Run no. 1:

Warm-up carrier: 4 hours

Warm-up target: 10 minutes

ITO targets power: 3.7 kW

SiO_2 target power: 5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Table 1 Sheet resistance and Uniformity of plate no.1 of run no.1

	Plate no. 1 of run no. 1				
Position	**A**	**B**	**C**	**D**	**E**
1	16.41	16.85	16.62	16.93	16.59
2	16.44	16.03	15.70	16.44	16.10
3	16.41	16.84	18.80	17.06	16.96
	Max.	**18.8**		**Min.**	**15.7**
	Avg.	**16.68**		**%Uniformity**	**8.99**

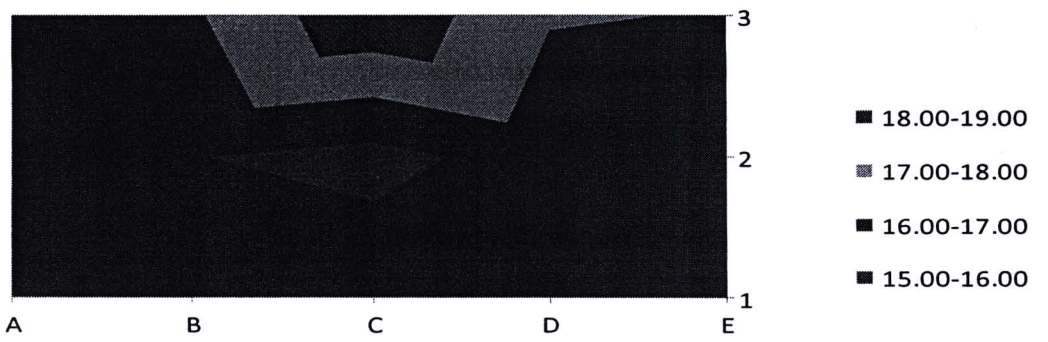

Figure 48 Sheet resistance and Uniformity of plate no.1 of run no.1

Table 2 Sheet resistance and Uniformity of plate no.2 of run no.1

	Plate no. 2 of run no. 1				
Position	**A**	**B**	**C**	**D**	**E**
1	20.96	20.58	18.05	18.94	16.6
2	20.13	21.44	18.12	18.5	16.11
3	20.13	22.29	18.86	18.96	16.93
	Max.	**22.29**		**Min.**	**16.11**
	Avg.	**19.11**		**%Uniformity**	**16.09**

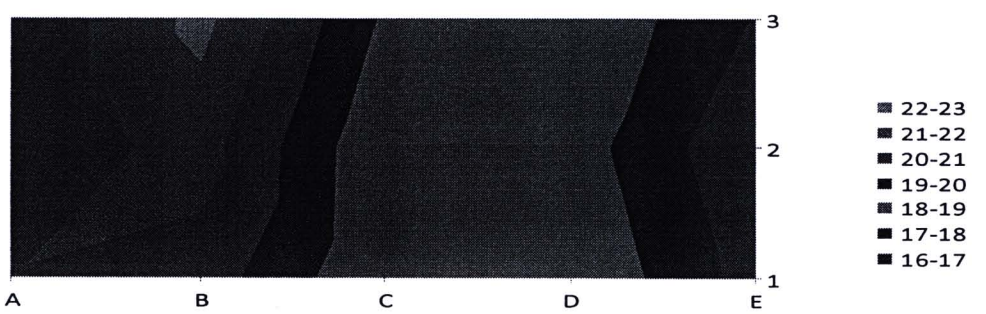

Figure 49 Sheet resistance and Uniformity of plate no.2 of run no.1

Table 3 Sheet resistance and Uniformity of plate no.3 of run no.1

	Plate no. 3 of run no. 1				
Position	**A**	**B**	**C**	**D**	**E**
1	17.82	17.14	17.15	17.42	16.98
2	17.17	17.39	17.44	17.41	16.81
3	17.6	18.15	17.71	18.18	17.22
	Max.	**18.18**		**Min.**	**16.81**
	Avg.	**17.44**		**%Uniformity**	**3.92**

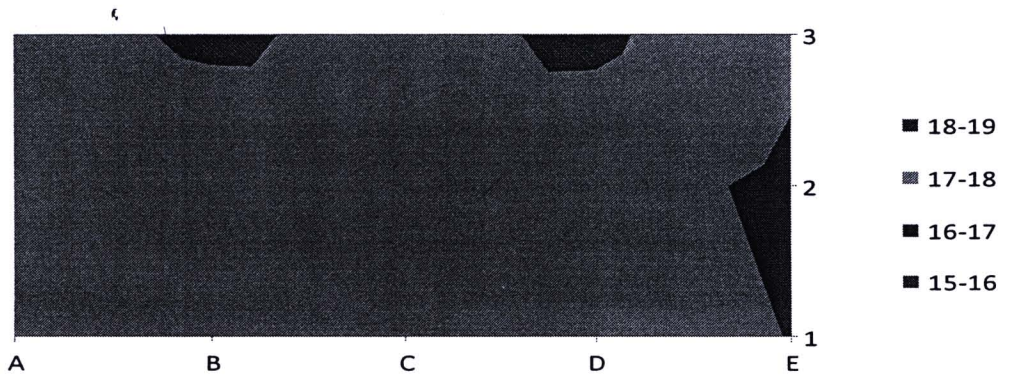

Figure 50 Sheet resistance and Uniformity of plate no.3 of run no.1

Table 4 Sheet resistance and Uniformity of plate no.4 of run no.1

	Plate no. 4 of run no. 1				
Position	**A**	**B**	**C**	**D**	**E**
1	17.8	17.41	16.84	16.77	16.65
2	19.92	17.39	16.93	16.9	16.03
3	17.72	17.88	17.34	17.15	16.77
	Max.	**19.92**		**Min.**	**16.03**
	Avg.	**17.30**		**%Uniformity**	**10.82**

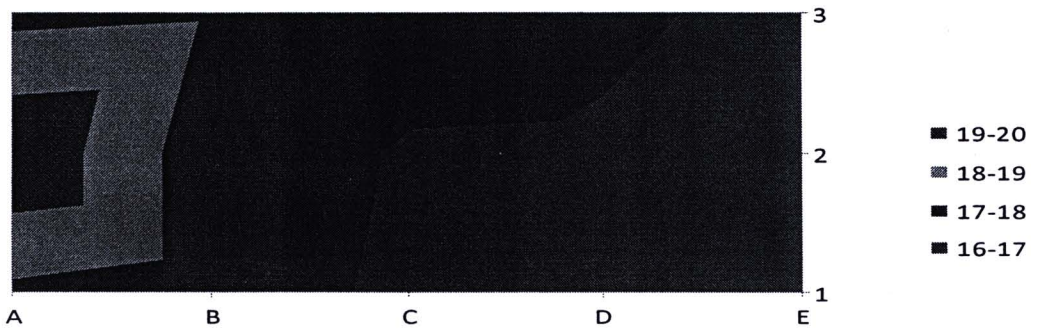

Figure 51 Sheet resistance and Uniformity of plate no.4 of run no.1

Table 5 Sheet resistance and Uniformity of plate no.5 of run no.1

	Plate no. 5 of run no. 1				
Position	**A**	**B**	**C**	**D**	**E**
1	17.01	17.88	17.02	16.52	15.32
2	16.77	17.74	17.6	17.15	15.7
3	17.34	18.86	18.23	17.9	17.02
	Max.	**18.86**		**Min.**	**15.32**
	Avg.	**17.20**		**Uniformity**	**10.36**

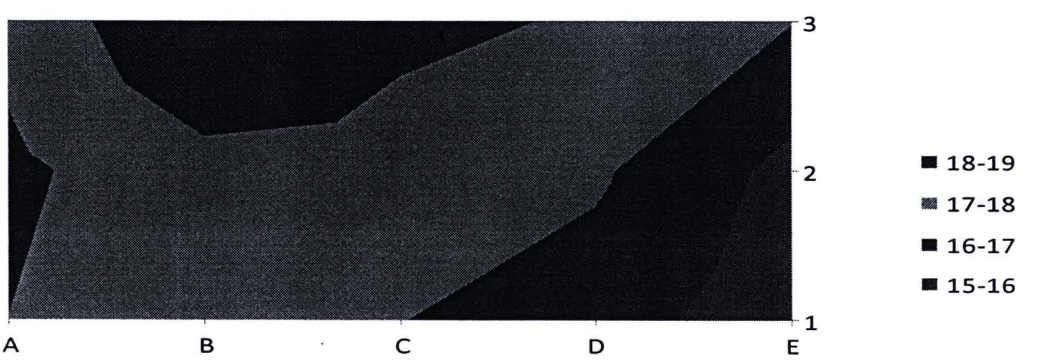

Figure 52 Sheet resistance and Uniformity of plate no.5 of run no.1

1.2 Test-run result from June 3, 2009

Test-run condition for run no. 2:

Warm-up carrier: 4 hours

Warm-up target: 1 hour

ITO targets power: 3.7 kW

SiO_2 target power: 5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Table 6 Sheet resistance and Uniformity of plate no.1 of run no.2

	Plate no. 1 of run no. 2				
+Position	**A**	**B**	**C**	**D**	**E**
1	14.47	15.08	15.07	15.18	14.66
2	14.07	14.91	14.89	15.13	14.86
3	14.63	15.07	14.89	15.27	15.12
	Max.	**15.27**		**Min.**	**14.07**
	Avg.	**14.89**		**%Uniformity**	**4.09**

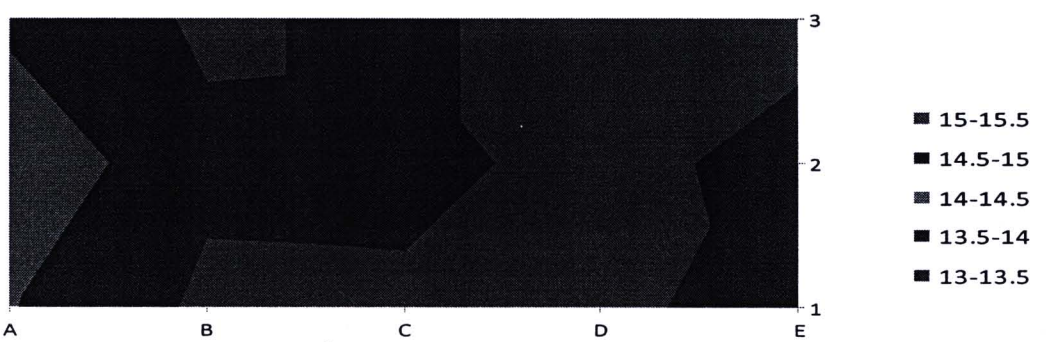

Figure 53 Sheet resistance and Uniformity of plate no.1 of run no.2

Table 7 Sheet resistance and Uniformity of plate no.2 of run no.2

	Plate no. 2 of run no. 2				
Position	**A**	**B**	**C**	**D**	**E**
1	14.91	15.62	15.31	15.4	15.42
2	14.61	15.65	15.37	15.59	15.08
3	14.97	16.03	15.29	15.7	15.97
	Max.	**16.03**		**Min.**	**14.61**
	Avg.	**15.39**		**%Uniformity**	**4.63**

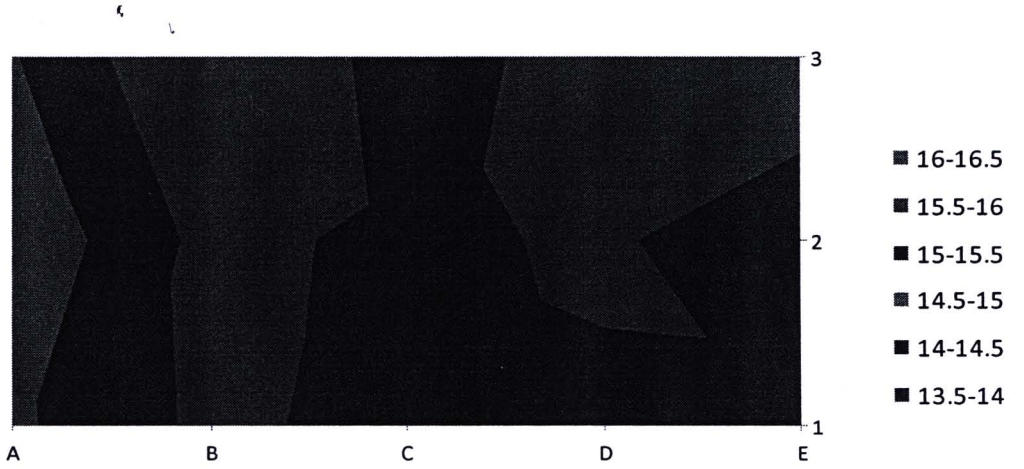

Figure 54 Sheet resistance and Uniformity of plate no.2 of run no.2

Table 8 Sheet resistance and Uniformity of plate no.3 of run no.2

	Plate no. 3 of run no. 2				
Position	**A**	**B**	**C**	**D**	**E**
1	15.12	15.59	15.89	15.78	15.89
2	15.24	15.59	16	15.75	15.97
3	15.05	16.21	16.14	16.22	15.89
	Max.	**16.22**		**Min.**	**15.05**
	Avg.	**15.76**		**%Uniformity**	**3.74**

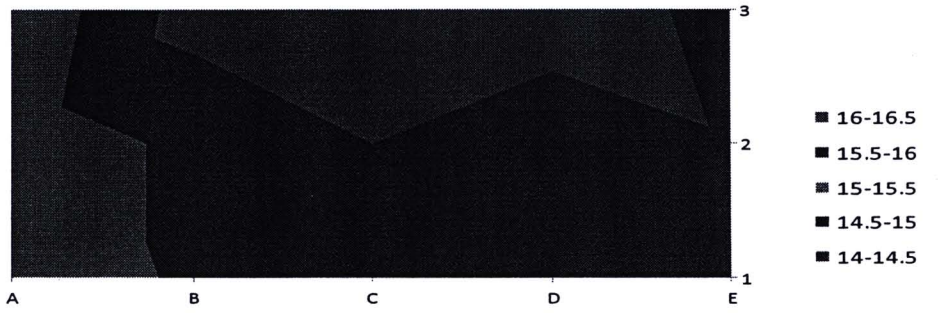

Figure 55 Sheet resistance and Uniformity of plate no.3 of run no.2

Table 9 Sheet resistance and Uniformity of plate no.4 of run no.2

	Plate no. 4 of run no. 2				
Position	**A**	**B**	**C**	**D**	**E**
1	15.61	15.92	15.78	15.27	15.64
2	15.34	15.27	15.71	15.54	15.91
3	15.12	15.56	15.81	15.84	15.68
	Max.	**15.92**		**Min.**	**15.12**
	Avg.	**15.60**		**%Uniformity**	**2.58**

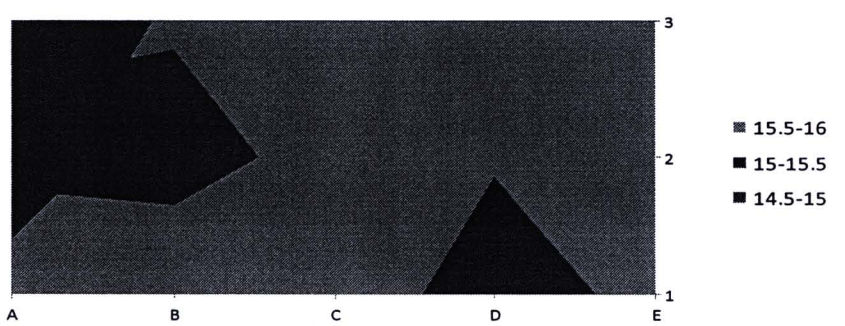

Figure 56 Sheet resistance and Uniformity of plate no.4 of run no.2

1.3 Test-run result from June 10, 2009

Test-run condition of run no. 3:

Warm-up carrier: 4 hours

Warm-up target: 1 hour

ITO targets power: 3.9 kW

SiO_2 target power: 5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Table 10 Sheet resistance and Uniformity of plate no.1 of run no.3

	Plate no. 1 of run no. 3				
Position	A	B	C	D	E
1	16.22	17.91	16.74	16.65	17.23
2	15.15	15.57	15.15	15.24	15.05
3	17.49	17.06	17.17	16.44	17.02
	Max	**17.91**		**Min**	**15.05**
	Avg.	**16.41**		**% Uniformity**	**8.68**

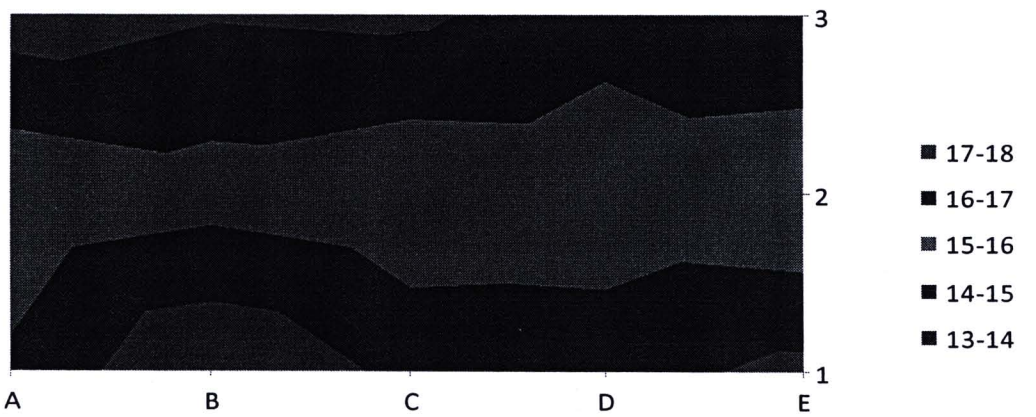

Figure 57 Sheet resistance and Uniformity of plate no.1 of run no.3

Table 11 Sheet resistance and Uniformity of plate no.2 of run no.3

	Plate no. 2 of run no. 3				
Position	**A**	**B**	**C**	**D**	**E**
1	17.09	17.82	17.52	17.3	17.3
2	15.32	15.7	15.27	15.92	15.27
3	16.84	16.82	16.32	17.04	17.12
	Max.	**18.62**		**Min.**	**15.27**
	Avg.	**16.58**		**% uniformity**	**9.88**

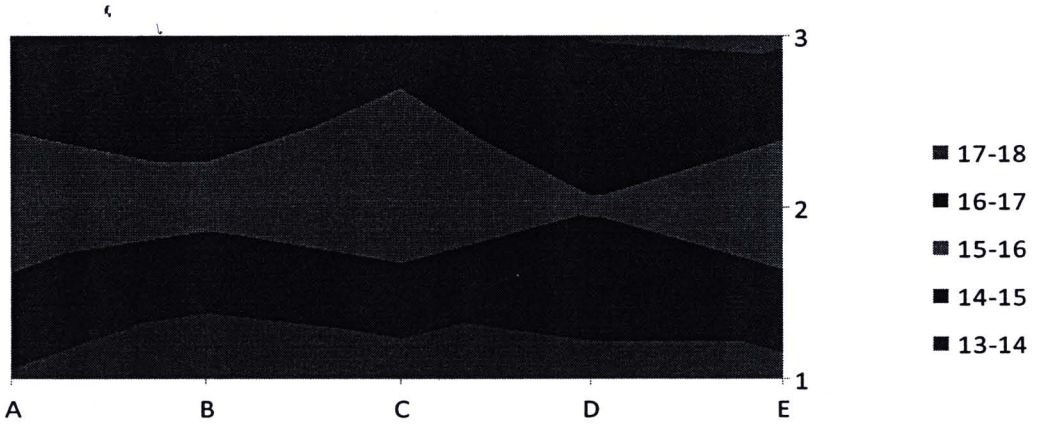

Figure 58 Sheet resistance and Uniformity of plate no.2 of run no.3

Table 12 Sheet resistance and Uniformity of plate no.3 of run no.3

	Plate no. 3 of run no. 3				
Position	**A**	**B**	**C**	**D**	**E**
1	17.11	17.77	17	17.71	17.18
2	15.23	15.8	15.15	15.67	15.61
3	16.93	16.81	17.06	17.5	17.17
	Max.	**17.77**		**Min.**	**15.15**
	Avg.	**16.65**		**% Uniformity**	**7.96**

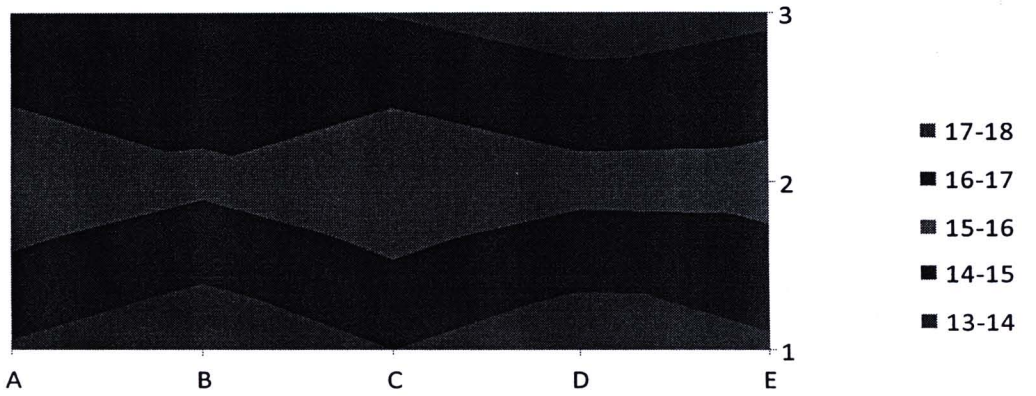

Figure 59 Sheet resistance and Uniformity of plate no.3 of run no.3

Table 13 Sheet resistance and Uniformity of plate no.4 of run no.3

	Plate no. 4 of run no. 3				
Position	**A**	**B**	**C**	**D**	**E**
1	16.56	17.42	17.88	17.61	17.31
2	15.81	15.92	16.13	16.11	15.41
3	17.34	17.04	17.39	17.15	16.89
	Max.	**17.88**		**Min.**	**15.41**
	Avg.	**16.80**		**% Uniformity**	**7.42**

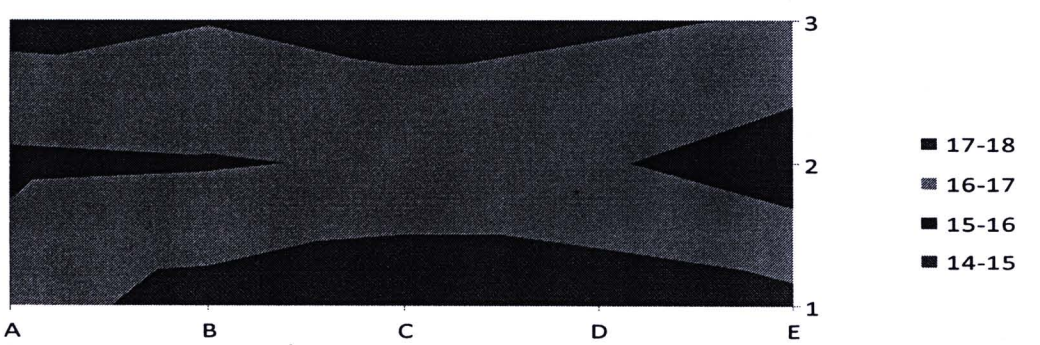

Figure 60 Sheet resistance and Uniformity of plate no.4 of run no.3

Table 14 Sheet resistance and Uniformity of plate no.5 of run no.3

	Plate no. 5 run no. 3				
Position	**A**	**B**	**C**	**D**	**E**
1	16.84	17.34	17.31	18.01	17.86
2	16	15.7	15.8	15.8	15.67
3	18.72	17.07	17.07	17.17	16.87
	Max.	**17.77**		**Min.**	**15.15**
	Avg.	**16.88**		**% Uniformity**	**7.96**

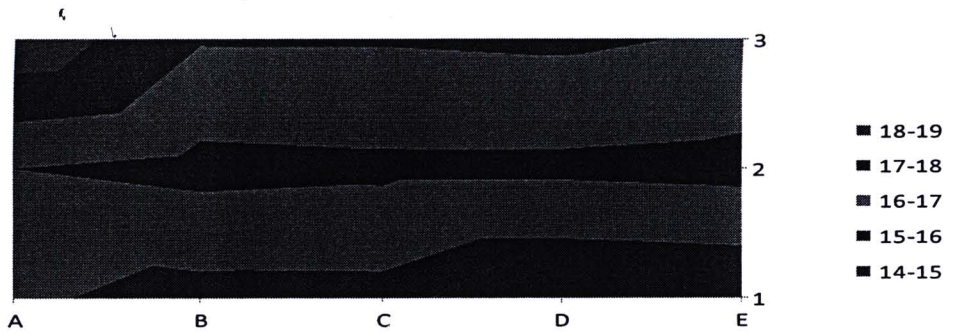

Figure 61 Sheet resistance and Uniformity of plate no.5 of run no.3

1.4 Test-run result from June 13, 2009

Test-run no. 4, condition 1:

Warm-up carrier: 4 hours

Warm-up target: 1 hour

ITO targets power: 3.5 kW

SiO_2 target power: 5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Table 15 Sheet resistance and Uniformity of plate no.1 of run no.4

	Plate no. 1 of run no. 4 (condition 1)				
Position	**A**	**B**	**C**	**D**	**E**
1	18.54	19.45	18.07	19.13	19.22
2	18.34	18.91	17.49	18.59	18.1
3	19.24	19.25	18.94	19.57	18.47
	Max.	**19.45**		**Min.**	**17.49**
	Avg.	**18.75**		**% Uniformity**	**5.31**

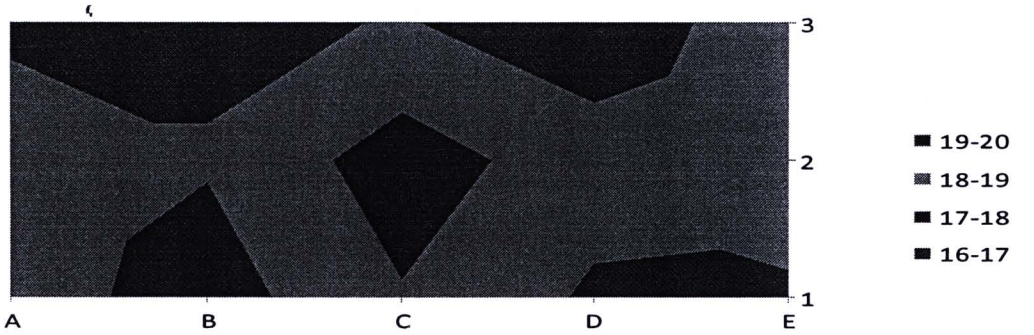

Figure 62 Sheet resistance and Uniformity of plate no.1 of run no.4

Table 16 Sheet resistance and Uniformity of plate no.2 of run no.4

	Plate no. 2 of run no. 4 (condition 1)				
Position	**A**	**B**	**C**	**D**	**E**
1	18.15	19.89	18.15	19.29	19.1
2	18.12	18.58	18.12	18.4	18.88
3	19.9	20.06	20.14	19.35	20.8
	Max.	**20.8**		**Min.**	**18.12**
	Avg.	**19.13**		**% Uniformity**	**6.89**

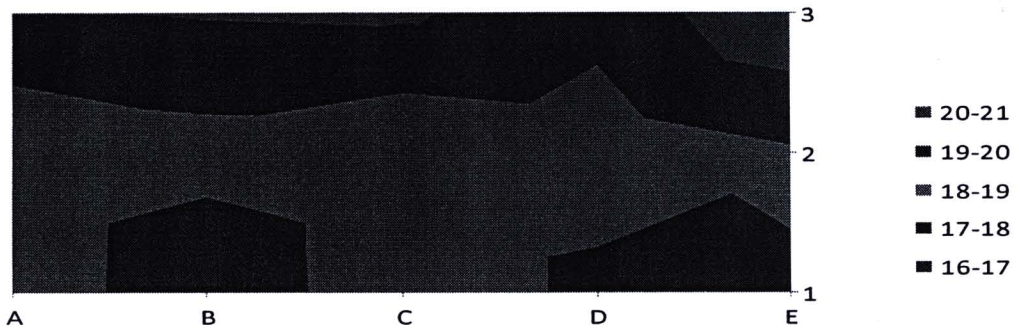

Figure 63 Sheet resistance and Uniformity of plate no.2 of run no.4

Table 17 Sheet resistance and Uniformity of plate no.3 of run no.4

	Plate no. 3 of run no. 4 condition 1				
Position	**A**	**B**	**C**	**D**	**E**
1	19.43	20.99	20.68	20.54	21.44
2	18.65	19.35	18.75	19.27	19.11
3	19.52	19.76	19.65	19.95	20.66
	Max.	**21.44**		**Min.**	**18.65**
	Avg.	**19.85**		**% Uniformity**	**6.96**

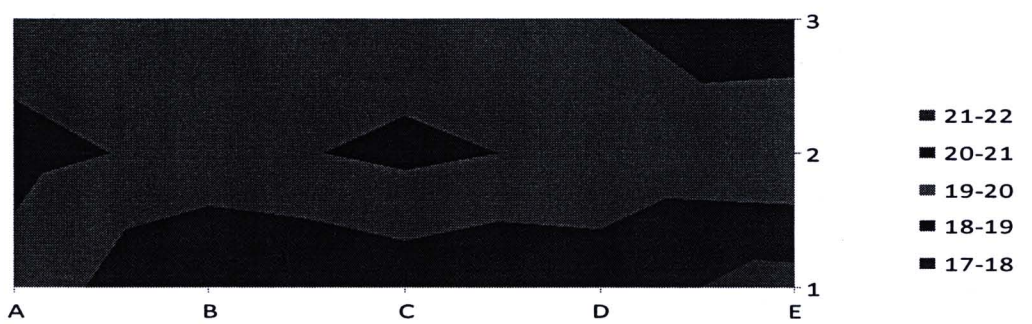

Figure 64 Sheet resistance and Uniformity of plate no.3 of run no.4

1.5 Test-run no. 4 condition 2:

Warm-up carrier: 4 hours

Warm-up target: 1 hour

ITO targets power: 3.7 kW

SiO_2 target power: 5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Table 18 Sheet resistance and Uniformity of plate no.5 of run no.4

	Plate no. 5 of run no. 4 (condition 2)				
Position	**A**	**B**	**C**	**D**	**E**
1	18.15	18.86	18.01	18.88	18.95
2	17.99	17.5	17.3	18.13	17.2
3	18.45	18.77	18.29	18.59	18.17
	Max.	**18.95**		**Min.**	**17.2**
	Avg.	**18.22**		**% Uniformity**	**4.84**

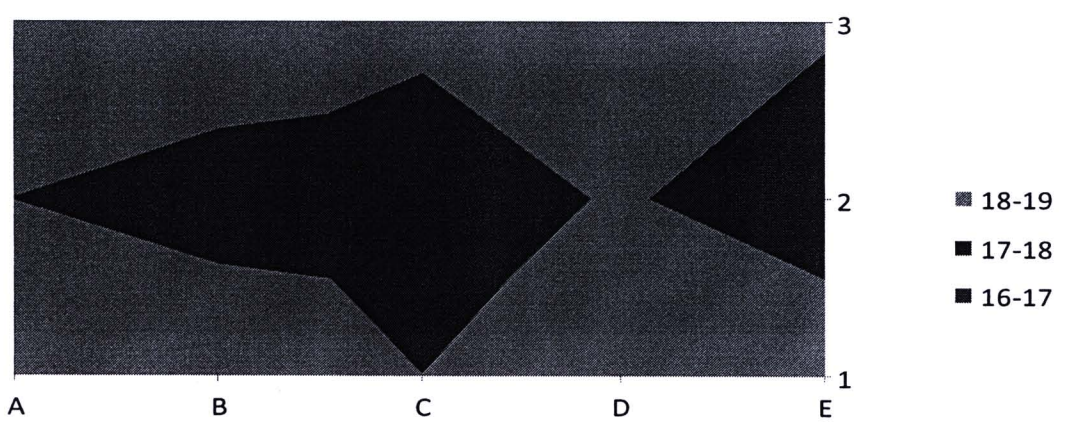

Figure 65 Sheet resistance and Uniformity of plate no.5 of run no.4

Table 19 Sheet resistance and Uniformity of plate no.6 of run no.4

	Plate no. 6 of run no. 4 (condition 2)				
Position	**A**	**B**	**C**	**D**	**E**
1	18.18	19.13	19.6	19.21	18.12
2	18.29	18.29	18.29	18.51	17.71
3	18.55	19.24	19.24	19	18.99
	Max.	**19.24**		**Min.**	**17.71**
	Avg.	**18.69**		**% Uniformity**	**4.14**

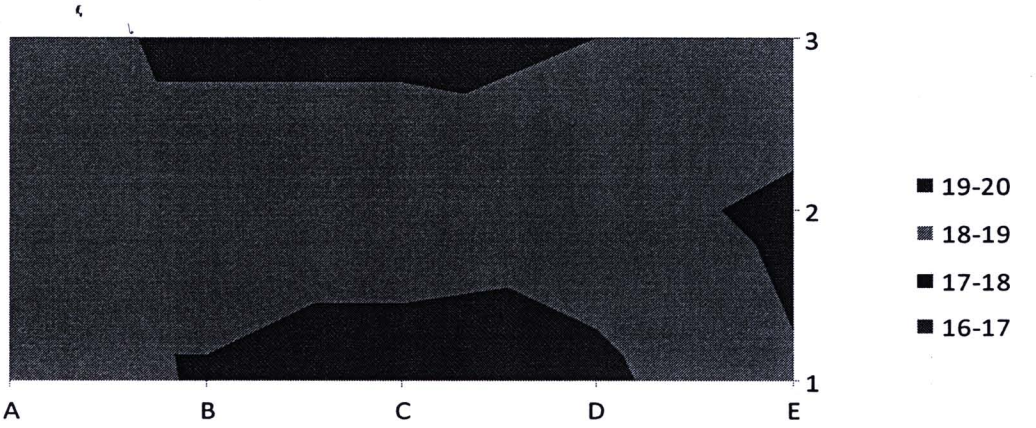

Figure 66 Sheet resistance and Uniformity of plate no.6 of run no.4

1.6 Test-run no. 4 condition 3:

Warm-up carrier: 4 hours

Warm-up target: 1 hour

ITO targets power: 3.7 kW

SiO_2 target power: 5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Table 20 Sheet resistance and uniformity of plate no.7 of run no.4

	Plate no. 7 of run no. 4 (condition 3)				
Position	**A**	**B**	**C**	**D**	**E**
1	16.66	17.44	17.3	18.07	18.7
2	16.44	17.01	16.4	16.6	15.94
3	17.3	17.04	17.14	17.44	17.72
	Max.	**18.70**		**Min.**	**15.94**
	Avg.	**17.15**		**% Uniformity**	**7.97**

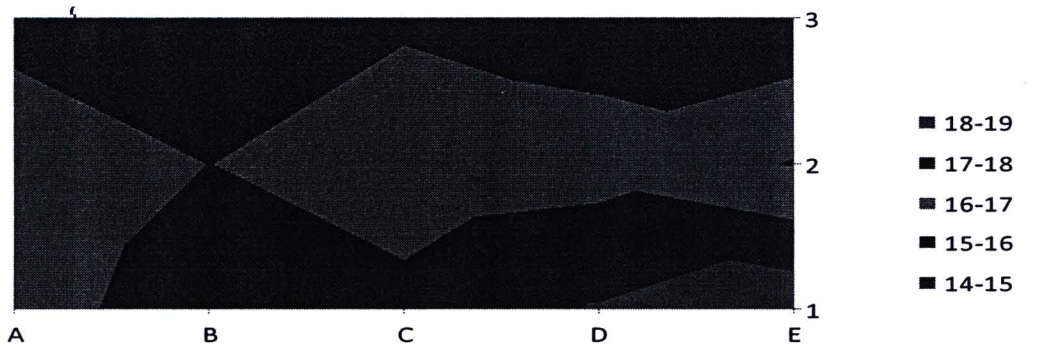

Figure 67 Sheet resistance and uniformity of plate no.7 of run no.4

Table 21 Sheet resistance and Uniformity of plate no.8 of run no.4

	Plate no. 8 of run no. 4 (condition 3)				
Position	**A**	**B**	**C**	**D**	**E**
1	17.06	17.69	17.41	18.1	17.64
2	16.89	16.73	16.6	19.9	16.89
3	17.44	17.47	17.91	17.88	17.8
	Max.	**19.99**		**Min.**	16.6
	Avg.	**17.56**		**% Uniformity**	9.26

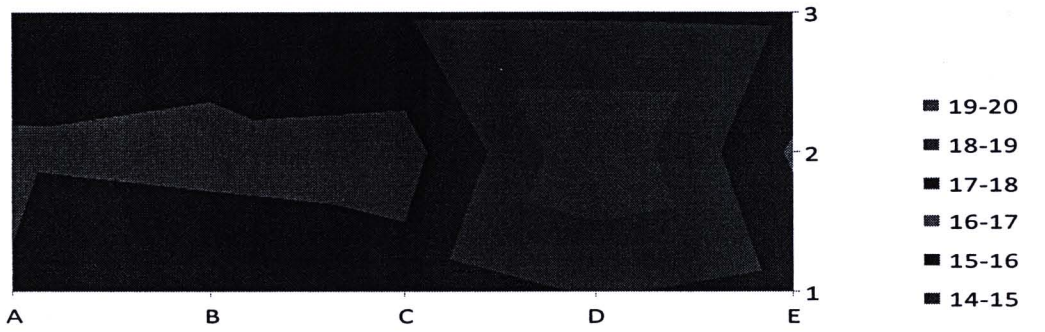

Figure 68 Sheet resistance and Uniformity of plate no.8 of run no.4

Table 22 Sheet resistance and Uniformity of plate no.9 of run no.4

	Plate no. 9 of run no. 4 (condition 3)				
Position	**A**	**B**	**C**	**D**	**E**
1	17.3	18.67	18.26	17.74	18.64
2	16.7	16.79	16.99	16.89	17.5
3	17.74	18.23	18.1	18.07	18.4
	Max.	**18.79**		**Min.**	16.7
	Avg.	**17.73**		**% Uniformity**	5.89

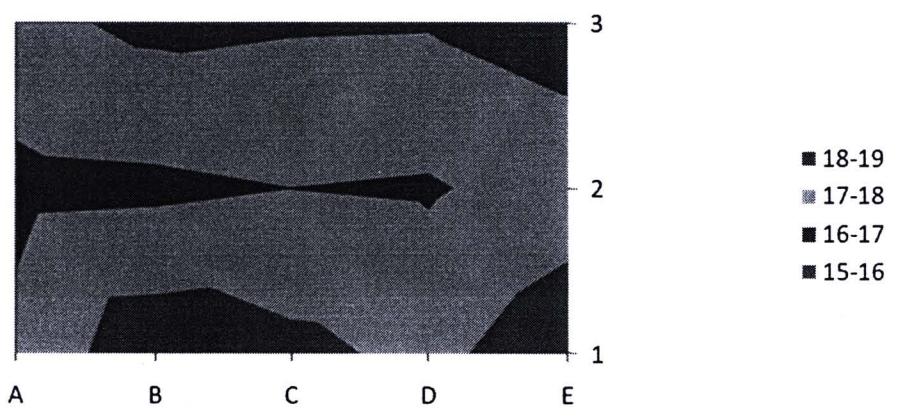

Figure 69 Sheet resistance and Uniformity of plate no.9 of run no.4

1.7 Test-run no. 4 condition 4:

Warm-up carrier: 4 hours

Warm-up target: 1 hour

ITO targets power:3.7 kW

SiO_2 target power:5.0 kW

Pressure: 5 mTorr

Recipe: Normal

Note: Ar+O2 gas = 6sccm

Table 23 Sheet resistance and Uniformity of plate no.10 of run no.4

	Plate no. 10 of run no. 4 (condition 4)				
Position	**A**	**B**	**C**	**D**	**E**
1	16.82	17.91	18.4	17.52	17.98
2	16.25	15.73	16.16	15.56	15.72
3	17.8	17.8	18.51	17.55	17.9
	Max.	**18.51**		**Min.**	15.56
	Avg.	**17.17**		**% Uniformity**	8.66

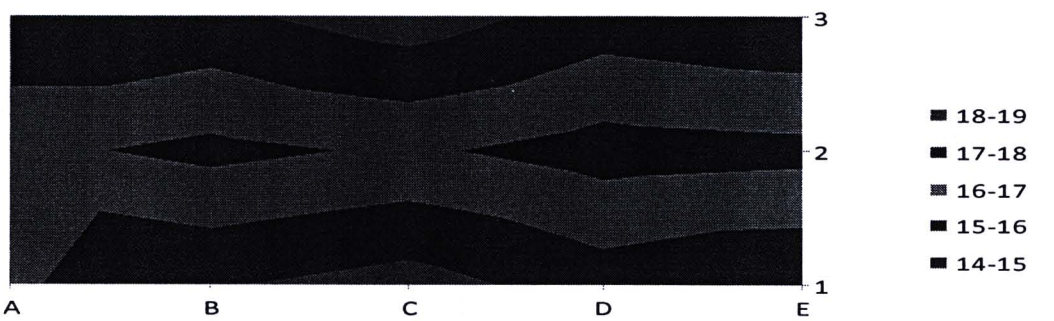

Figure 70 Sheet resistance and Uniformity of plate no.10 of run no.4

Table 24 Sheet resistance and Uniformity of plate no.11 of run no.4

	Plate no. 11 of run no. 4 (condition 4)				
Position	**A**	**B**	**C**	**D**	**E**
1	18.58	19.17	17.85	17.8	18.72
2	17.06	16.22	16.11	16.63	16.65
3	19.1	19.05	18.1	17.85	18.47
	Max.	**19.10**		**Min.**	**16.11**
	Avg.	**17.82**		**% Uniformity**	**8.49**

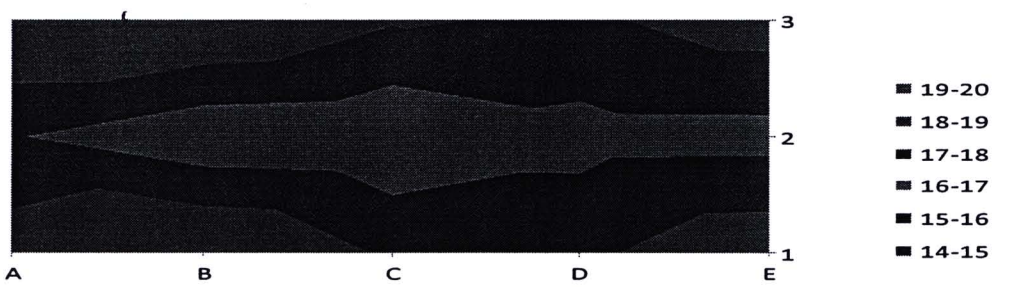

Figure 71 Sheet resistance and Uniformity of plate no.11 of run no.4

Table 25 Sheet resistance and Uniformity of plate no.12 of run no.4

	Plate no. 12 of run no. 4 (condition 4)				
Position	**A**	**B**	**C**	**D**	**E**
1	16.93	18.72	17.82	18.72	18.81
2	15.70	16.17	16.4	16.49	16.6
3	17.65	18.4	17.86	18.07	18.37
	Max.	**18.81**		**Min.**	**15.57**
	Avg.	**17.51**		**% Uniformity**	**9.42**

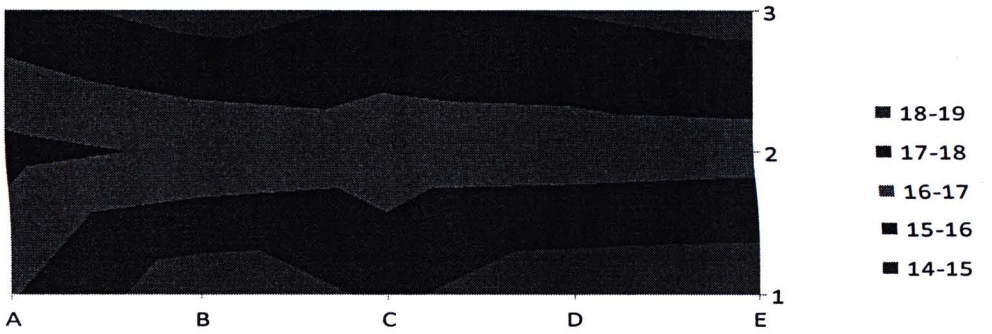

Figure 72 Sheet resistance and Uniformity of plate no.12 of run no.4

2. Production Test-run

In the middle of July, 2009, after commissioning engineers left the factory, the TCO glass coating line taken over by the factory, production team run the TCO glass coating line themselves. Following tests and measurements were made on 9 tested plates on July 17, 2009.

2.1 Light Transmission Curve

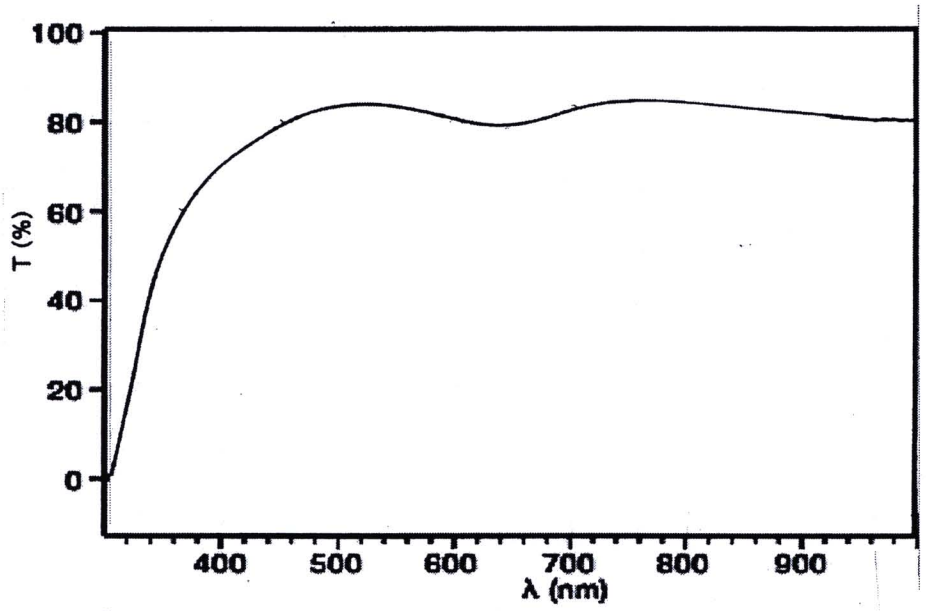

Figure 73 Light Transmittance of In-house TCO Glass

2.2 Sheet Resistance and Uniformity

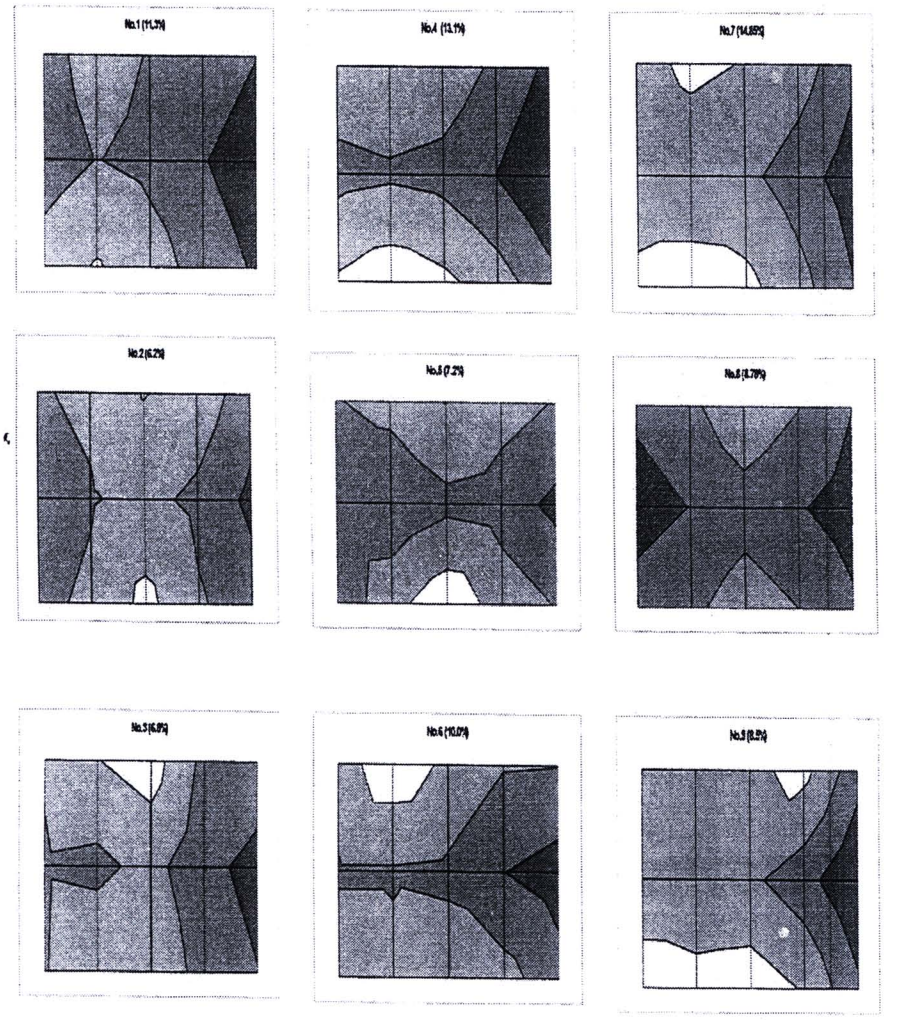

Figure 74 Sheet Resistance Distribution of Tested Plates

2. Tests Summary

Shown in the tables under Figure 60 and 61 are test summaries made on all sampled in-house TCO glass during the commissioning test in June 2009 and production test in following month, July.

Test and measurement on the sheet resistance and uniformity of the tested plates were made by commissioning engineers during the commissioning test under various RF power conditions fed to metallic targets.

Test and measurements on sheet resistance, uniformity and optical transmission were made by production team during production test run of the TCO glass coating line. The production test was intended to verify if the equipment passed all set production criterion.

3.1 Commissioning Test Summary

Table 26 Commissioning Test and Measurement Summary

DD/MM/YY	Run No.	Plate No.	Conditions					Measured Result			% Uniformity
			RF Power to Target (kW)					R sheet (Ohm/square)			
			SiO2	ITO 1	ITO 2	ITO 3	Pr(mtorr)	Max	Min	AVG	
2/6/2009	1	1	5.00	3.70	3.70	3.70	5.00	18.80	15.70	16.68	8.99
		2	5.00	3.70	3.70	3.70	5.00	22.29	16.11	19.11	16.09
		3	5.00	3.70	3.70	3.70	5.00	18.18	16.81	17.44	3.92
		4	5.00	3.70	3.70	3.70	5.00	19.92	16.03	17.30	10.82
		5	5.00	3.70	3.70	3.70	5.00	18.86	15.32	17.20	10.36
3/6/2009	2	1	5.00	3.70	3.70	3.70	5.00	15.27	14.07	14.89	4.09
		2	5.00	3.70	3.70	3.70	5.00	16.03	14.61	15.39	4.63
		3	5.00	3.70	3.70	3.70	5.00	16.22	15.05	15.76	3.74
		4	5.00	3.70	3.70	3.70	5.00	15.92	15.12	15.06	2.58
10/6/2009	3	1	5.00	3.90	3.90	3.90	5.00	17.91	15.05	16.41	8.68
		2	5.00	3.90	3.90	3.90	5.00	18.62	15.27	16.59	9.88
		3	5.00	3.90	3.90	3.90	5.00	17.77	15.15	15.92	7.96
		4	5.00	3.90	3.90	3.90	5.00	17.88	15.41	16.80	7.42
		5	5.00	3.90	3.90	3.90	5.00	17.77	15.15	16.88	7.96
13/6/2009	4	1	5.00	3.50	3.50	3.50	5.00	19.45	17.49	18.75	5.31
		2	5.00	3.50	3.50	3.50	5.00	20.80	18.20	19.13	6.67
		3	5.00	3.50	3.50	3.50	5.00	21.44	18.65	19.85	6.96
		4	5.00	3.70	3.70	3.70	5.00	Glass broken			

Table 26 (Cont.)

DD/MM/YY	Run No.	Plate No.	Conditions					Measured Result			% Uniformity
			RF Power to Target (kW)					R sheet (Ohm/square)			
			SiO2	ITO 1	ITO 2	ITO 3	Pr(mtorr)	Max	Min	AVG	
13/6/2009	4	5	5.00	3.70	3.70	3.70	5.00	18.95	17.20	18.22	4.84
		6	5.00	3.70	3.70	3.70	5.00	19.24	17.71	18.69	4.14
		7	5.00	3.90	3.90	3.90	5.00	18.70	15.94	17.15	7.97
		8	5.00	3.90	3.90	3.90	5.00	19.88	16.60	17.56	8.99
		9	5.00	3.90	3.90	3.90	5.00	18.79	16.70	17.73	5.89
		10	5.00	3.70	3.70	3.70	5.00	18.51	15.56	17.71	8.66
		11	5.00	3.70	3.70	3.70	5.00	19.10	16.11	17.82	8.49
		12	5.00	3.70	3.70	3.70	5.00	18.81	15.57	17.51	9.42

3.2 Production Test Summary

Table 27 Production Test and Measurement Summary

Test Items	Required Criterion	Measured Values	Conclusion
1. Sheet resistance	< 15 Ohm/square	14.07 Ohm/square	Passed
2. Uniformity	Less than 10%	6.26%	Passed
3. Transmission	> 80% (550nm)	83%	Passed
4. Haze	10-20%	15.60%	Passed
5. Yield	90%	> 90%	Passed
6. Cycle time	3 minutes	3 minutes	Passed
7. Capacity	> 5 MW per year	5.04 MW per year	Passed

Discussion

1. Production Cost of In-house TCO glass

From cost calculation, In-house TCO glass will cost approx. THB 360 per pce against the commercial TCO glass which costs approx. THB 600 per pce. For each a-Si PV module produced, In-house TCO glass can render THB 240 saving (equivalent 40 percent of TCO glass cost) which contributes to 20% cost reduction of each a-Si PV module.

2. Result from Commissioning and Production Tests

Sheet resistant is effected by the thickness of layer deposited on the surface of glass plate. Lower sheet resistance means thicker layer which reduce optical transmission. The designed deposition rate of the metallic layers with this PVD method is 5 Angstrom per second. The annual output of the TCO glass coating line is approx. 150,000 plates year or one plate every three minutes.

Travelling speed of glass sheet i.e. lower speed means thicker metallic layer which contributed to lower sheet resistance or higher speed means thinner metallic layer which contributed to higher sheet resistance at the same deposition rate. In practice we normally keep the speed constant to maintain throughput of the equipment.

RF power fed to target i.e. higher power means more metallic molecules of will be deposited on the plate.

Sputtering pressure in the chambers i.e the higher the vacuum, the greater chance for more metallic molecules to be released from the targets. In our process, the pressure of the sputtering chambers is control by the flow of the sputtering gas (Argon gas, in our case) at the vacuum level around 5 mTorr. Proper flow of Argon into the chambers is very important as too little Argon will not have sufficient Argon molecules to generate the ionization and ignite the plasma between the gap and too much Argon will in contrary retard the required ionization.

Sheet resistance of the in-house TCO glass from commissioning test no. 2 was 15.275 Ohm/square which is quite close to required specification. For a-Si PV module production, the factory accept sheet resistance value 14-16 Ohm/square depending on its recipe. Sheet resistance of 14.07 Ohm/square was obtained during the

production test and passed the set criterion of both general specification of 15 Ohm/square and factory criterion of 16 Ohm/square.

Uniformity is normally affected by target design and magnet shape, installed location and distance between target and the plate. The design of this in-house TCO glass coating line, the gap between the fixed sintered metallic targets and the moving plates is kept fixed is approx. 10 centimeters. Then main parameters to be varied are power fed to the metallic targets and sputtering pressure.

Required and acceptable layer thickness uniformity is normally within +/- 10%. This uniformity is calculated from 9-15 values of sheet resistance measured at various defined locations on the In-house TCO glass by four-point probe.

During the commissioning test, very good uniformity of 5% was obtained from test no. 2 while 10% uniformity was achieved under all tests. Production team reported the sheet uniformity of 6.26% average from production test in July 2009. This figure confirms that In-house TCO glass produced with PVD method is uniformed and passed the required criterion.

Light Transmission TCO glass used as front substrate, which is the optical window of a-Si PV module, shall have light transmittance better than 80% over 400-700 nm wavelengths. From Figure 62 shows that In-house TCO glass with In_2O_3:Sn (ITO glass) and TCO glass with SnO_2:F (FTO glass) can render similar optical transmission (both transparency and spectrum) and can be used as the optical window for solar cell. Light transmission curve of the In-house TCO glass as per Figure 58 measured by production team shows the transmittance of visible light of 83% over 400-700 nm wave-length which passes the required criterion.

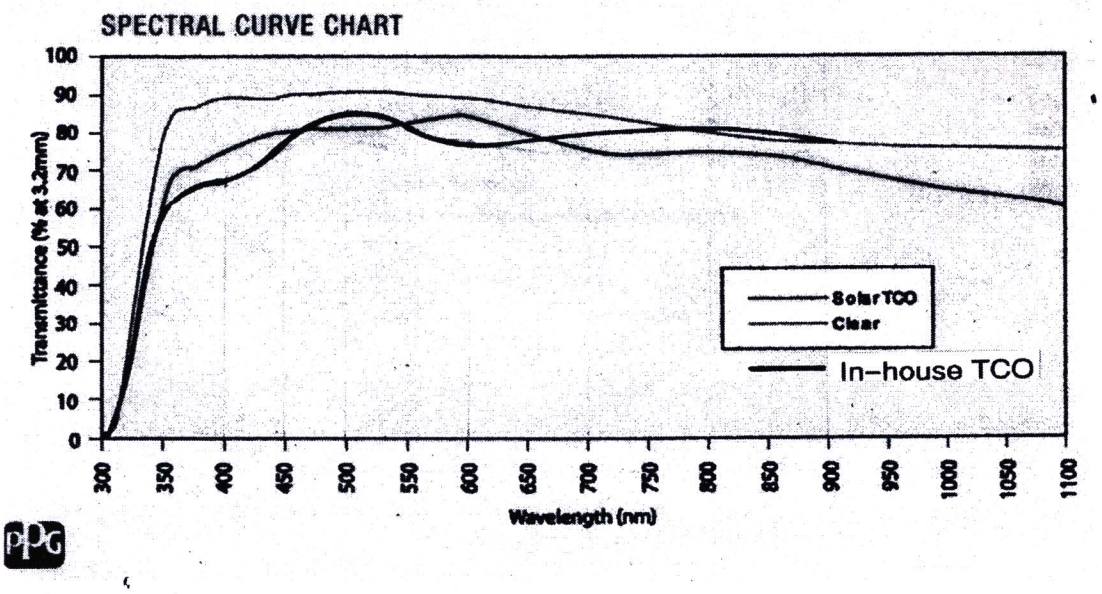

Figure 75 Optical Transmission and Spectrum of In-house TCO Glass compared to In-line Commercial TCO Glass