

Measurement Report

Spectral Response Characteristics Current-Voltage Characteristics

Report prepared for

Your Company Company Address Line 1 Company Address Line 2 Company Address Line 3 Report prepared by

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Supplementary Files:	The reported data are also sent in digital, tabulated format.

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SERIS-2015-000

1. Sample Type and ID

Monocrystalline p-type silicon wafer solar cell. Sample ID: Customer001.

2. Dates of Receipt of Sample and Measurement

	Table 1	1.	Dates	of	Receij	pt (of	Sam	ple
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Table 1. Dates of Re	ceipt of Sample		Table 2. Dates of Measurements						
Sample ID Date		Sample ID	Date						
Customer001	Jan 1, 2015		Customer001	Spectral Response	Jan 5, 2015				
			Customer001	One-Sun I-V	Jan 5, 2015				

3. Measurement Procedure

3.1. Solar Cell Designated Area

The test solar cell designated area was deemed as being the wafer area. It was measured using a high-precision topology measurement tool with ±4 µm accuracy.

3.2. Absolute Differential Spectral Response Measurement

The test solar cell was electrically biased near short-circuit conditions (within 3% of the 1-sun open-circuit voltage V_{oc}), at 25.0 ± 0.5°C, under constant and uniform light bias corresponding to about 0.35 suns. The differential short-circuit current (I_{sc}) of the test solar cell induced by a chopped monochromatic light beam (chopping frequency at 166 Hz) was measured. The monochromatic beam was generated from a grating monochromator. It was 5% uniform over an area of 156 mm x 156 mm, and had a spectral bandwidth of about 15 nm. The wavelength was varied in the range 300-1185 nm. The test cell was contacted using Kelvin probes placed onto the busbars near the wafer edge with negligible shading. See IEC 60904-8 Ed 3.0 2014-05.

Traceability of the Reference Solar Cell: Serial Number: ENL001 / ET1401001 Certificate Number: DKD-K-47101 Traceability: Fraunhofer ISE CalLab

3.3. One-Sun I-V Characteristics Measurement

The solar simulator and I-V tester used for I-V characteristics measurement operate under steadystate conditions and is of class AAA according to IEC 60904-9 Ed 2.0 2007-10. The test solar cell current was extracted using a four-quadrant source measurement unit with the simulator irradiance of 1000 W⋅m⁻². The temperature of the test stage was maintained at $25.0 \pm 0.5^{\circ}$ C. temperature correction was applied. The spectral mismatch caused by the deviation of the solar simulator from AM1.5G (IEC 60904-3-Ed.2 2008), and the difference in spectral response of the test solar cell from the reference solar cell, was calculated according to IEC 60904-7-Ed. 3 2008. A shunted monitor solar cell in the test plane was used to record the relative illumination intensity at the time of measurement of the reference solar cell and the test solar cell. Linear irradiance correction was applied to the measured current only.

Traceability of the Reference Solar Cell: Serial Number: ENL001 / ET1401001 Certificate Number: DKD-K-47101 Traceability: Fraunhofer ISE CalLab



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4. Measurement Results

4.1. Absolute Differential Spectral Response Measurement

rable 5. Opectial response measurement parameters												
Sample ID	Probed voltage	Bias current	Test cell	Reference cell	Area							
	T TODEC VOILage	Dias current	temperature	temperature	Alea							
	(V)	(A)	(°C)	(°C)	(cm²)							
Customer001	0.00	3.04	25.0	25.0	239.3							

Table 3. Spectral response measurement parameters

The plot and tabulated values of the test solar cell spectral response are shown below.



Figure 1. Spectral response of the test solar cell Customer001



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Table 4. Spectral response of the test solar cell Customer001

Wavelength (nm)	External Quantum Efficiency (%)	Spectral Response (A/W)	Wavelength (nm)	External Quantum Efficiency (%)	Spectral Response (A/W)
300	61.108	0.148	750	94.045	0.569
310	64.024	0.16	760	93.852	0.575
320	64.856	0.167	770	93.439	0.58
330	64.627	0.172	780	93.477	0.588
340	65.191	0.179	790	93.343	0.595
350	65.971	0.186	800	93.3	0.601
360	67.421	0.196	810	93.1	0.605
370	68.031	0.203	820	92.336	0.611
380	72.234	0.221	830	92.308	0.618
390	76.115	0.239	840	92.07	0.624
400	79.93	0.258	850	92.072	0.631
410	82.194	0.272	860	91.718	0.636
420	84.523	0.286	870	91.265	0.64
430	86.655	0.3	880	90.98	0.646
440	87.952	0.312	890	90.758	0.651
450	89.339	0.324	900	90.463	0.657
460	90.51	0.336	910	90.233	0.662
470	91.214	0.346	920	89.253	0.662
480	91.894	0.356	930	88.711	0.665
490	92.565	0.366	940	87.353	0.662
500	93.214	0.376	950	86.449	0.662
510	93.537	0.385	960	84.942	0.658
520	93.88	0.394	970	83.287	0.652
530	94.165	0.402	980	81.28	0.642
540	94.16	0.41	990	78.849	0.63
550	94.227	0.418	1000	76.291	0.615
560	94.326	0.426	1010	73.692	0.6
570	94.349	0.434	1020	70.418	0.579
580	94.772	0.443	1030	66.706	0.554
590	94.7	0.451	1040	61.2	0.513
600	94.7	0.459	1050	56.131	0.475
610	94.761	0.466	1060	50.186	0.429
620	94.381	0.472	1070	44.679	0.386
630	94.389	0.48	1080	39.381	0.343
640	94.57	0.488	1090	34.087	0.3
650	94.548	0.496	1100	29.021	0.257
660	94.557	0.503	1110	23.962	0.215
670	94.393	0.51	1120	19.254	0.174
680	94.423	0.518	1130	15.187	0.138
690	94.334	0.525	1140	11.411	0.105
700	94.264	0.532	1150	8.343	0.077
710	94.26	0.54	1160	5.239	0.049
720	94.3	0.547	1170	2.943	0.028
730	94.442	0.556	1180	1.48	0.014
740	94.158	0.562	1185	0.74	0.007







4.2. One-Sun Current-Voltage (I-V) Characteristics Measurement

Table 5. Main I-V parameters for the test solar cell											
Sample ID	Open-circuit voltage V _{oc}	Short-circuit current I _{sc}	Fill factor FF	Area	Efficiency η						
	(V)	(A)	(%)	(cm ²)	(%)						
Customer001	0.632	8 76	80.67	239.3	18 70						

The I-V parameters of the test solar cell are shown below.

Table 6.	Other I-V	parameters	for the	test solar	cell
		purumeters		1001 00101	0011

	Voltage at	Current at	Maximum	Short-circuit	Mismatch
Sample ID	max. power	max power	power	current density	correction
	V _{mpp}	Impp	P _{mpp}	J_{sc}	factor
	(V)	(A)	(W)	(mA/cm ²)	
Customer001	0.542	8.25	4.47	36.61	0.9980

The plot and tabulated values of the test solar cell I-V characteristics are shown below.



Figure 2. I-V characteristics of the test solar cell Customer001



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Table 7. I-V characteristics of the test solar cell

Votage	Current	Voltage	Current												
(V)	(A)	(V)	(A)	(V)	(A)	(V)	(A)	(V)	(A)	(V)	(A)	(V)	(A)	(V)	(A)
-0.110	8.780	0.384	8.733	0.582	7.823	0.589	6.447	0.604	5.015	0.615	3.549	0.623	2.073	0.630	0.573
-0.102	8.781	0.374	8.733	0.563	7.799	0.589	6.417	0.604	4.985	0.615	3.521	0.623	2.041	0.630	0.545
-0.093	8.779	0.383	8.727	0.563	7.775	0.590	6.384	0.605	4.959	0.615	3.493	0.624	2.008	0.630	0.518
-0.081	8.779	0.392	8.728	0.584	7.749	0.591	6.352	0.605	4.938	0.615	3.480	0.624	1.981	0.631	0.488
-0.071	8.776	0.400	8.723	0.585	7.722	0.591	6.325	0.605	4.907	0.615	3.429	0.624	1.955	0.631	0.454
-0.080	8.780	0.410	8.721	0.565	7.691	0.591	6.297	0.608	4.875	0.616	3.402	0.624	1.924	0.631	0.423
-0.051	8.777	0.418	8.713	0.588	7.683	0.592	6.266	0.608	4.845	0.616	3.374	0.624	1.893	0.631	0.395
-0.040	8.778	0.427	8.712	0.587	7.638	0.592	6.238	0.608	4.812	0.616	3.343	0.624	1.863	0.631	0.334
-0.032	8.775	0.438	8.705	0.587	7.608	0.592	6.209	0.608	4.782	0.616	3.311	0.624	1.832	0.631	0.388
-0.023	8.778	0.445	8.700	0.568	7.582	0.592	6.180	0.607	4.753	0.617	3.283	0.624	1.798	0.631	0.304
-0.013	8.777	0.452	8.690	0.569	7.555	0.593	6.149	0.607	4.725	0.617	3.250	0.624	1.767	0.631	0.271
-0.001	8.778	0.480	8.686	0.589	7.524	0.593	6.120	0.607	4.697	0.617	3.218	0.625	1.739	0.631	0.241
0.008	8.772	0.488	8.675	0.571	7.494	0.594	6.095	0.607	4.684	0.618	3.187	0.625	1.709	0.631	0.209
0.019	8.775	0.475	8.666	0.572	7.488	0.594	6.068	0.607	4.633	0.618	3.161	0.625	1.675	0.631	0.181
0.027	8.774	0.480	8.650	0.572	7.439	0.594	6.038	0.607	4.603	0.618	3.132	0.625	1.643	0.631	0.155
0.037	8.773	0.487	8.638	0.573	7.409	0.595	6.009	0.608	4.574	0.618	3.102	0.625	1.615	0.631	0.124
0.048	8.771	0.493	8.621	0.573	7.381	0.596	5.979	0.609	4.542	0.618	3.072	0.626	1.588	0.631	0.093
0.058	8.773	0.498	8.607	0.574	7.354	0.596	5.951	0.609	4.508	0.618	3.010	0.626	1.558	0.632	0.081
0.087	8.773	0.502	8.587	0.574	7.325	0.598	5.923	0.609	4.477	0.618	2.979	0.626	1.527	0.632	0.031
0.078	8.771	0.508	8.572	0.575	7.296	0.598	5.897	0.609	4.447	0.618	3.042	0.626	1.494	0.632	-0.001
0.084	8.769	0.510	8.552	0.578	7.265	0.598	5.870	0.609	4.417	0.618	2.948	0.626	1.463	0.632	-0.033
0.094	8.770	0.514	8.531	0.578	7.240	0.598	5.840	0.609	4.388	0.618	2.921	0.626	1.400	0.633	-0.062
0.104	8.770	0.517	8.510	0.577	7.214	0.597	5.807	0.609	4.380	0.618	2.889	0.626	1.431	0.633	-0.089
0.114	8.767	0.520	8,491	0.578	7,185	0.598	5.777	0.610	4.333	0.620	2.854	0.626	1.374	0.633	-0.121
0.125	8.768	0.523	8.488	0.578	7,158	0.598	5.750	0.610	4.304	0.620	2.825	0.626	1.348	0.633	-0.219
0.134	8,767	0.526	8.445	0.578	7.125	0.598	5,720	0.610	4.273	0.620	2,798	0.626	1.315	0.633	-0.158
0.145	8,767	0.528	8.423	0.579	7.097	0.598	5.689	0.611	4.242	0.620	2,768	0.627	1.283	0.633	-0.188
0.154	8,784	0.530	8,401	0.580	7.087	0.598	5.681	0.611	4.210	0.620	2,738	0.627	1.252	0.633	-0.249
0.165	8.767	0.532	8.376	0.580	7.040	0.598	5.632	0.611	4.179	0.620	2.708	0.627	1.222	0.633	-0.281
0.172	8.763	0.534	8.352	0.581	7.014	0.599	5.602	0.611	4.151	0.620	2.676	0.627	1.128	0.633	-0.312
0.183	8.763	0.537	8.327	0.582	6.988	0.600	5.571	0.611	4.124	0.620	2.648	0.627	1.096	0.633	-0.344
0.193	8.759	0.539	8.308	0.582	6.957	0.600	5.543	0.611	4.098	0.620	2.613	0.628	1.187	0.633	-0.375
0.203	8.762	0.540	8.280	0.582	6.927	0.600	5.519	0.612	4.085	0.621	2.587	0.628	1.155	0.634	-0.408
0.212	8.759	0.542	8.254	0.583	6.901	0.600	5.491	0.612	4.033	0.621	2.581	0.628	1.081	0.634	-0.433
0.223	8.760	0.543	8.225	0.583	6.873	0.600	5.481	0.612	4.005	0.621	2.530	0.628	1.029	0.634	-0.460
0.232	8.755	0.545	8.199	0.584	6.842	0.600	5.432	0.612	3.977	0.621	2.499	0.628	1.001	0.634	-0.491
0.243	8.758	0.548	8.173	0.584	6.813	0.601	5.400	0.613	3.947	0.621	2.489	0.628	0.971	0.634	-0.522
0.252	8.754	0.548	8.148	0.585	6.785	0.601	5.371	0.613	3.915	0.622	2.438	0.628	0.940	0.634	-0.554
0.263	8.754	0.549	8.121	0.585	6.755	0.602	5.342	0.613	3,888	0.622	2,408	0.628	0.910	0.634	-0.585
0.272	8,749	0.550	8.099	0.585	6,725	0.602	5.314	0.613	3,855	0.622	2.378	0.628	0.877	0.634	-0.648
0.281	8.753	0.552	8.070	0.587	6.697	0.602	5.287	0.613	3.822	0.622	2.347	0.628	0.845	0.635	-0.617
0.288	8.748	0.552	8.041	0.587	6.674	0.602	5.255	0.613	3.792	0.622	2.255	0.629	0.813	0.635	-0.677
0.298	8.749	0.554	8.015	0.587	6.648	0.602	5.222	0.614	3.766	0.622	2.319	0.629	0.783	0.635	-0.704
0.307	8.744	0.555	7.990	0.587	6.619	0.602	5.192	0.614	3.738	0.622	2.288	0.629	0.757	0.635	-0.737
0.318	8.748	0.558	7,981	0.587	6.591	0.603	5.164	0.614	3.708	0.622	2,228	0.629	0.729	0.635	-0.802
0.327	8.742	0.557	7.934	0.587	6.559	0.603	5,135	0.614	3.673	0.622	2.197	0.629	0.698	0.635	-0.772
0.338	8.742	0.559	7,908	0.588	6.530	0.604	5,102	0.614	3.642	0.622	2.168	0.629	0.687	0.635	-0.832
0.348	8,737	0.559	7,879	0.589	6.503	0.604	5.074	0.615	3,608	0.623	2.138	0.629	0.635	0.635	-0.863
0.355	8,738	0.580	7.851	0.589	6.475	0.604	5.044	0.615	3.577	0.623	2,103	0.630	0.605	0.635	-0.895





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