Fraunhofer ISE
TestLab PV Modules

Final Report – FUE 11016 – BYD Company, Ltd.

Enhanced Thermal Cycling, Damp-Heat and UV-Test

for:
BYD Company, Ltd.
No. 1, Baoping Road, Longgang
518116 Shenzhen
China

Endorsed by:
Daniel Philipp

April 2012

Address:
Fraunhofer-Institute
for Solar Energy Systems (ISE)
Division of Photovoltaic Modules, Systems and Reliability
Heidenhofstraße 2

79110 Freiburg (Germany)

Index

This report contains 14 pages. It shall not be published in an incomplete or distorting context. The disclosure to a third part needs the approval of Fraunhofer ISE. Confidentiality is regulated in the existing Non-Disclosure Agreement (NDA) between BYD and Fraunhofer.

Fraunhofer-Institute for Solar Energy Systems ISE,
Division of Photovoltaic Modules, Systems and Reliability

Freiburg, 27. April 2012

Dipl.Ing (FH) Georg Mülhöfer
Test Engineer

Dipl.Ing (FH) Daniel Philipp
Project Leader

1 Preliminary remarks

In order to conduct different climatic stress tests three PV-modules were sent by BYD Company, Ltd. to the Fraunhofer Institute for Solar Energy Systems ISE.

The climatic test conditions followed the requirements of the type approval standard for crystalline silicon PV modules (IEC 61215). However, the total test duration was increased significantly compared to the standard. Following test sequences were conducted:

Sequence 1: Enhanced thermal UV-Test (one module):

UV test including initial and final characterisation, total UV-dose: 180 kWh/m² (standard requirement 15 kWh/m²).

Sequence 2: Enhanced thermal cycling test (TC) (one module):

Thermal cycling test, 800 cycles 85 °C / -40 °C, including initial and final characterisation as well as interim characterisation after 200, 400 and 600 cycles, (standard requirement 200 cycles).

Sequence 3: Enhanced damp heat test (DH) (one module):

Damp heat test, 4000 hours, 85 °C / 85% RH, including initial and final characterisation as well as interim characterisation after 1000, 2000 and 3000 hours (standard requirement 1000 hours).

This document contains the results of the initial characterisation, UV test as well as characterisation measurements after 4000 hours damp heat and 800 thermal cycles.

2 Summary and result overview

2.1 Summary

The initial inspection was performed on all modules. The enhanced UV-Test of sequence 1, the 800 thermal cycles of sequence 2 (four times standard requirement) and the 4000 hours damp heat test of sequence 3 (four times standard requirement) were conducted successfully. The test sample of sequence 3 shows power degradation and damage to the backsheet after 4000 hours of damp heat. The other two samples fulfil the standard requirements with respect to their performance and electrical insulation resistance after the conducted stress tests.

The test results provided in this report allude to a good quality of the tested modules, used components and manufacturing process.

After 3000 hours damp heat the performance loss was still insignificant (-1 %). The performance loss of -11.7 % after 4000 hours damp heat is significant but still a good value due to the test duration.

Concerning the manufacturing process and constructional details of the test specimen no closer description is available. Therefore, it cannot be said in which way the test result is representative for other samples of the same module type.

2.2 Result overview

No.	Test	Result	Evaluation		Date
Module 1:# PV-Module [SN SH101231BYDP630S10]					
1	10.1 Visual Inspection			pass	13.05.2011
2	10.2a Performance at STC (inbound)	229,43	W		14.04.2011
3	10.3a Insulation Test	>500	MOhm	pass	13.05.2011
4	10.10 UV Test	90000	Wh/m²		11.08.2011
5	10.1 Visual Inspection			pass	12.08.2011
6	10.2c Performance at STC	228,27	W	pass	11.08.2011
7	10.3a Insulation Test	>500	MOhm	pass	12.08.2011
8	10.10 UV Test	90000	Wh/m²		29.02.2012
9	10.1 Visual Inspection			pass	07.03.2012
10	10.2c Performance at STC (outbound)	224,74	W	pass	07.03.2012
11	10.3a Insulation Test	>500	MOhm	pass	07.03.2012

Module 2:# PV-Module [SN SH101231BYDP630S06]					
1	10.1 Visual Inspection			pass	13.05.2011
2	10.2a Performance at STC (inbound)	229,23	W		14.04.2011
3	10.3a Insulation Test	>500	MOhm	pass	13.05.2011
4	10.11b Thermal Cycling (200 cycles)				31.08.2011
5	10.1 Visual Inspection			pass	02.09.2011
6	10.2b Performance at STC	224,88	W	pass	01.09.2011
7	10.3a Insulation Test	>500	MOhm	pass	02.09.2011
7	10.11b Thermal Cycling (200 cycles)				07.10.2011
9	10.1 Visual Inspection			pass	11.10.2011
10	10.2b Performance at STC	224,5	W	pass	14.10.2011
11	10.3a Insulation Test	>500	MOhm	pass	11.10.2011
12	10.11b Thermal Cycling (200 cycles)				23.11.2011
13	10.1 Visual Inspection			pass	24.11.2011
14	10.2c Performance at STC (outbound)	226,5	W	Pass	29.11.2011
15	10.3a Insulation Test	>500	MOhm	pass	24.11.2011
16	10.11b Thermal Cycling (200 cycles)				23.01.2012
17	10.1 Visual Inspection			pass	14.02.2012
18	10.2c Performance at STC (outbound)	223,5	W	Pass	10.02.2012
19	10.3a Insulation Test	>500	MOhm	pass	14.02.2012

Module 3:# PV-Module [SN SH101231BYDP630S02]					
1	10.1 Visual Inspection			pass	14.04.2011
2	10.2a Performance at STC (inbound)	228,92	W		14.04.2011
3	10.3a Insulation Test	>500	MOhm	pass	14.04.2011
4	10.13 Damp Heat Test				26.05.2011
5	10.1 Visual Inspection			pass	27.05.2011
6	10.2b Performance at STC	229,29	W	pass	07.06.2011
7	10.3a Insulation Test	>500	MOhm	pass	08.06.2011
8	10.13 Damp Heat Test				20.07.2011
9	10.1 Visual Inspection			pass	21.07.2011
10	10.2b Performance at STC	228,24	W	pass	21.07.2011
11	10.3a Insulation Test	>500	MOhm	pass	20.07.2011
12	10.13 Damp Heat Test				23.09.2011
13	10.1 Visual Inspection			pass	26.09.2011
14	10.2c Performance at STC (outbound)	226,54	W	pass	27.09.2011
15	10.3a Insulation Test	>500	MOhm	pass	26.09.2011
16	10.13 Damp Heat Test				02.02.2012
17	10.1 Visual Inspection			fail	03.02.2012
18	10.2c Performance at STC (outbound)	202,25	W	fail	02.02.2012
19	10.3a Insulation Test	>500	MOhm	pass	10.02.2012

3 Definitions

3.1 Sample description

An overview of the investigated modules and their internal ID is given in the following table:

Serial number	Internal ID	Type number
SH101231BYDP630S10	FUE11016 M01	BYD230 P-30
SH101231BYDP630S06	FUE11016 M02	BYD230 P-30
SH101231BYDP630S02	FUE11016 M03	BYD230 P-30

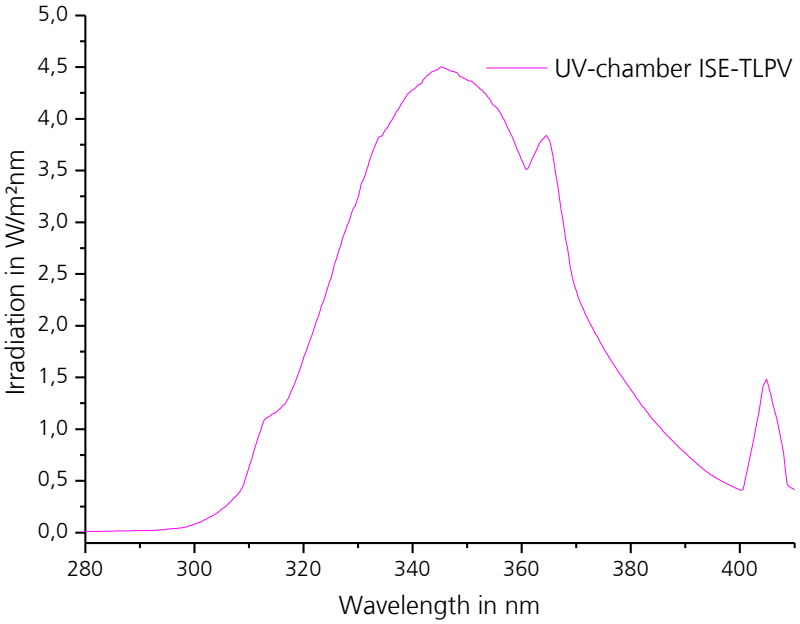
A closer description of the samples with respect to used component materials cannot be given.

3.2 Climatic stress tests

Exposure to enhanced UV light (UV90)

The sensitivity of the samples with respect to UV light shall be examined. In the IEC 61215 the UV test is to be understood as preconditioning for following climatic stress tests.

The test is conducted in accordance to IEC 61215, 10.10 but with an increased total UV dose of at least 90 kWh/m² instead of 15 kWh/m². The sample temperature is kept at 60 °C ± 5 °C. The total UV dose refers to wavelengths between 280 nm and 400 nm. About 6 % of the irradiance refers to wavelengths between 280 nm and 320 nm. The following graphic shows the spectra of the used UV sources. The UVA/UVB ratio of the UV spectrum is close to common natural conditions.



Graphic 1: Spectrum UV test

Thermal-Cycling 200 (TC200)

The test procedure focuses on the ability of the samples to withstand thermal and mechanical stress due to fast thermal cycling.

The test is conducted according to IEC 61215, 10.11b. The samples are exposed to changing ambient temperature. The lower temperature is -40 °C the upper temperature is 85 °C. When the module temperature is above 25 °C the samples are operating at their individual nominal operating current @ STC (Impp) by means of reverse biased electric supplies. The temperature ramp rate for cooling and heating is less than 100 K/h.

Damp-Heat Test

The ability of the samples to withstand high temperatures and very high humidity for a long period of time is examined.

The test is conducted according to IEC 61215, 10.13. The modules are exposed to 85 °C and 85 % relative humidity for a period of 1000 hours.

4 Results

4.1 Performance at STC

The following tables show the performance of the modules before and after the stress tests. Furthermore the relative deviation from the nominal values (initial measurement) as well as the relative change due to the stress tests can be seen.

Module M1	Uoc / V	Isc / A	Umpp / V	Impp / A	Pmax / W	eff. / %	FF / %
Label	**36**	**8,59**	**30**	**7,67**	**230**	**14**	**74**
Inital	36,9	8,51	29,1	7,89	229,4	14,1	73
Dev. Label / %	2,5	-0,93	-3	2,87	-0,25	0,71	-1,35
after 90 kWh	36,81	8,48	29	7,87	228,27	14,06	73,16
change in %	-0,24	-0,35	-0,34	-0,25	-0,51	-0,28	0,22
after 180 kWh	36,64	8,43	28,93	7,77	224,74	13,84	72,79
change in %	-0,70	-1,86	-0,58	-1,52	-2,03	-1,84	-0,29

Module M2	Uoc / V	Isc / A	Umpp / V	Impp / A	Pmax / W	eff. / %	FF / %
Label	**36**	**8,59**	**30**	**7,67**	**230**	**14,2**	**74,4**
Inital	36,9	8,49	29,1	7,86	229,2	14,1	73,2
Dev. Label / %	2,5	-1,16	-3	2,48	-0,33	-0,7	-1,61
after TC200	36,63	8,39	28,92	7,78	224,88	13,85	73,21
change / %	-0,73	-1,18	-0,62	-1,02	-1,9	-1,77	0,01
after TC400	36,73	8,36	28,89	7,77	224,5	13,82	73,07
change / %	-0,46	-1,53	-0,72	-1,15	-2,06	-1,99	-0,18
after TC 600	36,86	8,41	28,99	7,81	226,5	13,95	73,06
change / %	-0,11	-0,95	-0,38	-0,64	-1,21	-1,08	-0,19
after TC 800	36,61	8,41	28,69	7,79	223,52	13,76	72,59
change / %	-0,79	-0,94	-1,41	-0,89	-2,48	-2,41	-0,83

Module M3	Uoc / V	Isc / A	Umpp / V	Impp / A	Pmax / W	eff. / %	FF / %
Label	**36**	**8,59**	**30**	**7,67**	**230**	**14,2**	**74,4**
Inital	36,9	8,45	29,1	7,86	228,9	14,1	73,3
Dev. Label / %	2,5	-1,63	-3	2,48	-0,47	-0,7	-1,48
after 1000 h	36,9	8,49	29,03	7,9	229,29	14,12	73,19
change in %	0	0,47	-0,24	0,51	0,16	0,14	-0,15
after 2000 h	36,97	8,46	29,01	7,87	228,24	14,05	72,94
change in %	0,19	0,12	-0,31	0,13	-0,3	-0,35	-0,49
after 3000 h	36,81	8,53	28,65	7,91	226,5	13,95	72,12
change in %	-0,24	0,95	-1,55	0,64	-1,04	-1,06	-1,61
after 4000 h	36,83	8,35	28,65	7,06	202,25	12,45	65,77
change in %	-0,19	-1,18	-1,55	-10,18	-11,64	-11,7	-10,27

4.2 Electrical safety

Following table shows the measured insulation resistance at dry conditions at the beginning and after the conducted stress tests. The measurements have been performed according to IEC 61215, 10.3 (dry insulation).

	Dry insulation resistance in Ohm	**Required minimum insulation resistance in Ohm**	**Pass/Fail IEC requirements**
M1 initial	>500	27	Pass
M1 after UV 90	>500	27	Pass
M2 after UV 180	>500	27	Pass
M2 initial	>500	27	Pass
M2 TC200	>500	27	Pass
M2 TC 400	>500	27	Pass
M2 TC 600	>500	27	Pass
M2 TC 800	>500	27	Pass
M3 initial	>500	27	Pass
M3 DH 1000 h	>500	27	Pass
M3 DH 2000 h	>500	27	Pass
M3 DH 3000 h	>500	27	Pass
M3 DH 4000 h	>500	27	Pass

4.3 Visual Inspection

At the beginning and after each stress test a visual inspection was performed. Each inspection is documented with a picture of the front and the rear side of the sample. In the following the results of the inspections are given.

Module M1 – UV90	
initial	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
Final	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.

Module M2 – Thermal cycling	
initial	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
200 cycles	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
400 cycles	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
600 cycles	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
800 cycles	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.

Module M3 – Damp-Heat	
initial	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
1000 hours	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
2000 hours	No major visible defects acc. IEC 61215, 10.01 Nothing remarkable.
3000 hours	No major visible defects acc. IEC 61215, 10.01 Little yellowing (Fig. 1)
4000 hours	FAIL: Major visible defects acc. IEC 61215, 10.01 Yellowing, strong backsheet delamination (Fig. 2)

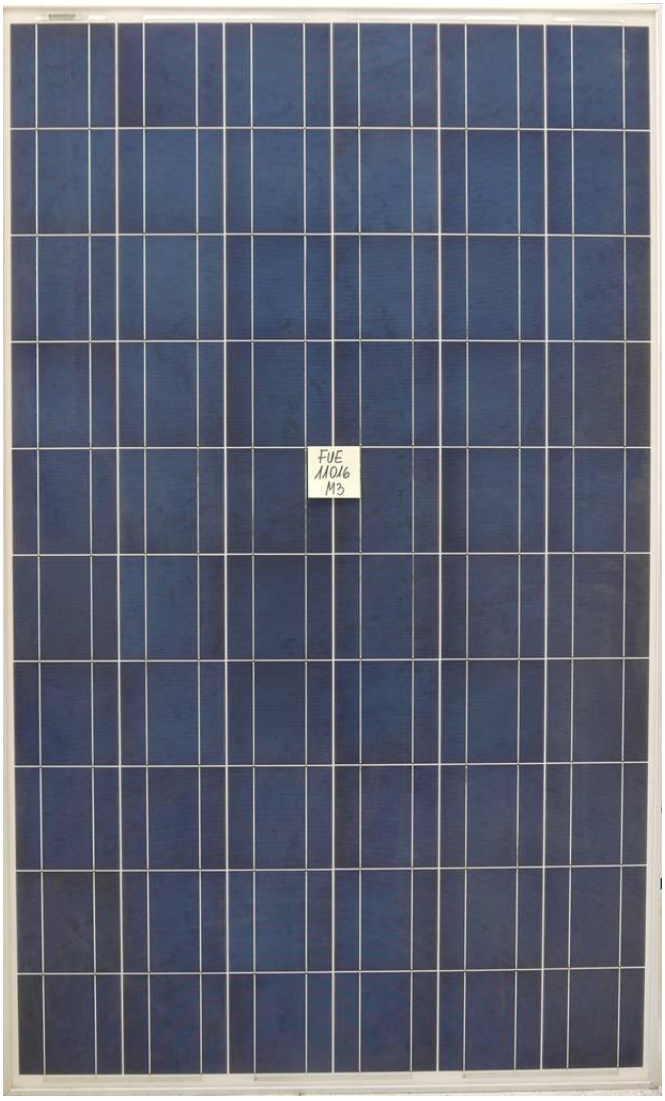


Fig. 1 M3, yellowing

Fig. 2 M3 strong backsheet delamination