



测试报告

Test Report

报告编号 GXgf2025-00297
Report No.

客户名称
Client

昆山协鑫光电材料有限公司

Kunshan GCL Optoelectronic Material Co.,Ltd.

样品名称
Sample

钙钛矿晶硅叠层光伏组件

Perovskite-Silicon tandem PV module

型号/规格
Type/Model

钙钛矿晶硅叠层

Perovskite-Silicon tandem

出厂编号
Serial No.

Q40#

生产厂商
Manufacturer

昆山协鑫光电材料有限公司

Kunshan GCL Optoelectronic Material Co.,Ltd.

客户地址
Client Address

江苏省昆山市玉山镇玉杨路 366 号 6 号房

Block 6.No.366 Yuyang Road, Yushan, Kunshan, Jiangsu, China

测试日期
Date of Test

2025-01-21

批准人:

Approved by



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中国计量科学研究院



报告编号 GXgf2025-00297

Report No.

中国计量科学研究院（NIM）是国家最高的计量科学研究中心和国家级法定计量技术机构。1999 年授权签署了国际计量委员会（CIPM）《国家计量基(标)准和国家计量院签发的校准与测量证书互认协议》（CIPM MRA）。The National Institute of Metrology (NIM) is China's national metrology institute (NMI) and a state-level legal metrology institute. NIM is China's signatory to the Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates Issued by National Metrology Institutes (CIPM MRA) which is arranged by the International Committee of Weights and Measures (CIPM).

质量管理体系符合 ISO/IEC17025 标准，通过中国合格评定国家认可委员会（CNAS）和亚太计量规划组织（APMP）联合评审的校准和测量能力（CMCs）在国际计量局（BIPM）关键比对数据库中公布。NIM's quality management system meets requirements of the ISO/IEC 17025. Its Calibration and Measurement Capabilities (CMCs) that are peer reviewed both by China National Accreditation Service for Conformity Assessment (CNAS) and the Asia Pacific Metrology Programme (APMP) are published in the International Bureau of Weights and Measures (BIPM) Key Comparison Database (KCDB).

2020 年，NIM 和 CNAS 就认可领域的技术评价活动签署了谅解备忘录，承认 NIM 的计量支撑作用和出具的校准/检测结果的溯源效力。NIM and CNAS signed a Memorandum of Understanding (MOU) for Recognition of Technical Assessment in Laboratory Accreditation Field in 2020, in which CNAS recognizing the technical supporting role of NIM in laboratory accreditation and the traceability of NIM's calibration / test results.

测试所依据/参考的技术文件（代号、名称）Reference documents (Code,Name)

参照 JJF 1622-2017 太阳能电池校准规范：光电性能

测试环境条件及地点 Testing place and environment:

温 度 Temperature: $(22\pm3)^{\circ}\text{C}$ 地 点 江苏省苏州市吴中区木渎镇下李塔路 1 号

湿 度 Humidity: $(43\pm2)\%\text{RH}$ 其 它 Others: /

测试使用的计量基（标）准装置（含标准物质）/主要仪器

Reference Standards (Including Reference Material) /Instruments used

名 称 Name	测量范围 Measurement Range	不确定度/ 准确度等级 Uncertainty/ Accuracy	报告编号 Certificate No.	证书有效期至 Due Date (YYYY-MM-DD)
标准太阳能电池 Reference solar cell	$I_{sc}:(1-200)\text{ mA}$	$U_{rel}=0.9\%(k=2)$	GXgf2024-07457	2025-11-29
稳态太阳模拟器 Steady solar simulator	$(200-1000)\text{ W/m}^2$	AAA+级	GXgf2024-07729	2025-12-20
直流电子负载 Electronic load	电流: $(0.1-30)\text{ A}$ 电压: $(0.1-500)\text{ V}$	$U_{rel}=0.05\%(k=2)$ $U_{rel}=0.03\%(k=2)$	241003000015507	2025-08-27

2019-cs-R0520

测试结果

Test Results

1. 测试条件 Test Conditions:

扫描方向: 反扫和正扫 Scan Direction: Reverse and Forward

扫描时间 Scan Time: 84 秒 (钙钛矿 Perovskite); 56 秒 (晶硅 Silicon)

样品温度: $(25 \pm 5)^\circ\text{C}$ Sample temperature: $(25 \pm 5)^\circ\text{C}$ 光阑 Mask (Y/N): Y

2. I-V 特性曲线和参数 I-V Characteristic curves and parameters:

以标准太阳能电池标定太阳模拟器辐照度至 1000 W/m^2 , 标定过程引入光谱失配修正, 光谱失配修正因子为 0.998 (钙钛矿)、0.988 (晶硅)。被测光伏电池 I-V 特性曲线和参数测量结果如下:

Use the reference solar cell to calibrate the solar simulator's irradiance to 1000 W/m^2 . The calibration process takes into account spectral mismatch correction. The spectral mismatch correction factor is 0.998 for perovskite and 0.988 for silicon. I-V characteristic curves and parameters of the sample are as follows.

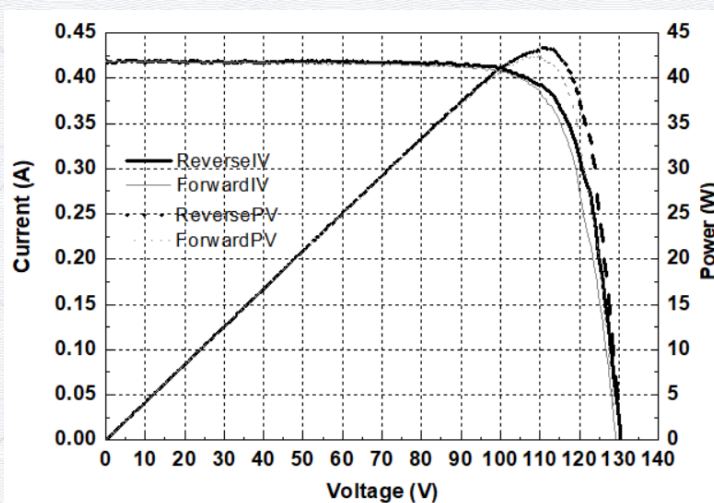


图 1 钙钛矿层样品 I-V 曲线图 Perovskite I-V Characteristic curves

电池类型 Type	扫描方向 Scanning Direction	有效面积 (m^2)	短路电流 $I_{\text{sc}}(\text{A})$	开路电压 $V_{\text{oc}}(\text{V})$
钙钛矿 Perovskite	反扫 Reverse	0.2048	0.421	130.2
最大功率 $P_{\text{max}}(\text{W})$	最大功率电流 $I_{\text{max}}(\text{A})$	最大功率电压 $V_{\text{max}}(\text{V})$	填充因子 FF (%)	转换效率 η (%)
43.37	0.391	111.0	79.04	21.18



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电池类型 Type	扫描方向 Scanning Direction	有效面积 (m ²)	短路电流 <i>I</i> _{sc} (A)	开路电压 <i>V</i> _{oc} (V)
钙钛矿 Perovskite	正扫 Forward	0.2048	0.419	129.2
最大功率 <i>P</i> _{max} (W)	最大功率电流 <i>I</i> _{max} (A)	最大功率电压 <i>V</i> _{max} (V)	填充因子 FF (%)	转换效率 η (%)
42.48	0.387	109.8	78.46	20.74

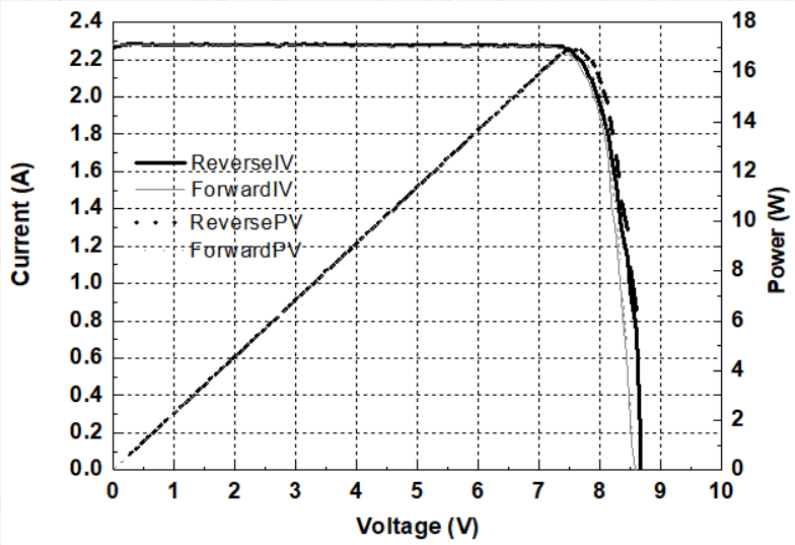


图 2 晶硅层样品 I-V 曲线图 Silicon I-V Characteristic curves

电池类型 Type	扫描方向 Scanning Direction	有效面积 (m ²)	短路电流 <i>I</i> _{sc} (A)	开路电压 <i>V</i> _{oc} (V)
晶硅 Silicon	反扫 Reverse	0.2048	2.287	8.668
最大功率 <i>P</i> _{max} (W)	最大功率电流 <i>I</i> _{max} (A)	最大功率电压 <i>V</i> _{max} (V)	填充因子 FF (%)	转换效率 η (%)
17.07	2.266	7.534	86.12	8.33

测 试 结 果

Test Results

电池类型 Type	扫描方向 Scanning Direction	有效面积 (m ²)	短路电流 I_{sc} (A)	开路电压 V_{oc} (V)
晶硅 Silicon	正扫 Forward	0.2048	2.304	8.611
最大功率 P_{max} (W)	最大功率电流 I_{max} (A)	最大功率电压 V_{max} (V)	填充因子 FF (%)	转换效率 η (%)
16.87	2.229	7.570	85.06	8.24

3. 最大功率点跟踪 Maximum Power Point Tracking:

采用最大功率点跟踪法 (MPPT)，对样品最大功率进行持续扫描 5 min，前 0.5 min 最大功率平均值为 42.42 W，最后 0.5 min 最大功率平均值为 42.14 W。钙钛矿层样品最大功率点跟踪曲线如下：

Using the MPPT measurement method, continuously scan the maximum power of the sample for 5 min. The average maximum power of the sample is 42.42 W for the first 0.5 min and 42.14 W for the last 0.5 min. The Perovskite MPPT curve is as follows.

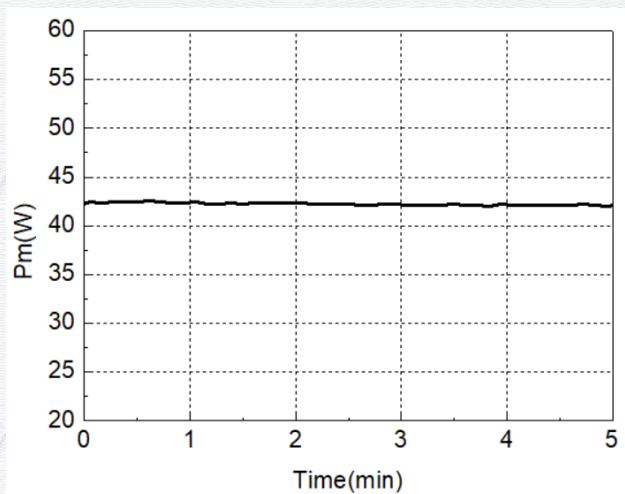


图 3 钙钛矿层样品最大功率点跟踪图 Perovskite Maximum Power Point Tracking curve

注 Note:

1. 光伏组件样品面积为 0.2048 m² (证书编号: 802293035)。

The area of the sample is 0.2048 m² (Certificate No. 802293035).

2. 此数据仅对被测样品当时状态有效。

The data apply only at the time of the test for the sample.

3. 英文证书摘要见附录。

Summary of certificate in English is attached in the appendix.



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声明 Statement:

1. 我院仅对加盖“中国计量科学研究测试专用章”的完整报告负责。
NIM is ONLY responsible for the complete report with the test stamp of NIM.
2. 本报告的测试结果仅对所测试的样品有效。
The report is ONLY valid for the tested sample or instrument.
3. 本报告用中英文两种语言表达，准确含义以中文为准。
The report is expressed in both English and Chinese, with the Chinese version as standard.

测试员:

蔡川

Tested by

核验员:

张俊超

Checked by



Appendix: Summary of the Report

Report No.: GXgf2025-00297

Client: Kunshan GCL Optoelectronic Material Co.,Ltd.

Sample: Perovskite-Silicon tandem PV module

Type/Model: Perovskite-Silicon tandem DUT S/N: Q40#

Manufacturer:Kunshan GCL Optoelectronic Material Co.,Ltd.

Sample temperature: (25±5)°C Date of Test: 01/21/2025

Environmental conditions: (22±3) °C, RH (43±2) %

Scan Time: 84 s (Perovskite) ; 56 s (Silicon)

Mask (Y/N) : Y Sample area: 0.2048 m² (Certificate No. 802293035)

The test has been conducted by the PV Metrology Lab of NIM (National Institute of Metrology, China). Measurement of irradiance intensity and all other measurements are traceable to the International System of Units (SI). Data in this report apply only at the time of the test for the sample. For more details, please refer to the text of the report.

Type	Scanning direction	Area (m ²)	I _{sc} (A)	V _{oc} (V)
Perovskite	Reverse	0.2048	0.421	130.2
P _{max} (W)	I _{max} (A)	V _{max} (V)	FF (%)	η (%)
43.37	0.391	111.0	79.04	21.18

Type	Scanning direction	Area (m ²)	I _{sc} (A)	V _{oc} (V)
Silicon	Reverse	0.2048	2.287	8.668
P _{max} (W)	I _{max} (A)	V _{max} (V)	FF (%)	η (%)
17.07	2.266	7.534	86.12	8.33

Type	Scanning direction	Area (m ²)	I _{sc} (A)	V _{oc} (V)
Perovskite	Forward	0.2048	0.419	129.2
P _{max} (W)	I _{max} (A)	V _{max} (V)	FF (%)	η (%)
42.48	0.387	109.8	78.46	20.74



Type	Scanning direction	Area (m ²)	$I_{sc}(A)$	$V_{oc}(V)$
Silicon	Forward	0.2048	2.304	8.611
$P_{max}(W)$	$I_{max}(A)$	$V_{max}(V)$	FF (%)	η (%)
16.87	2.229	7.570	85.06	8.24

I-V Characterization Methods:

JJF 1622-2017: Calibration Specification of Solar Cells: Photoelectric Properties

Reference Solar Cell:

Type: Mono-Si (with spectral mismatch correction)

Solar Simulator:

Classification: AAA+;

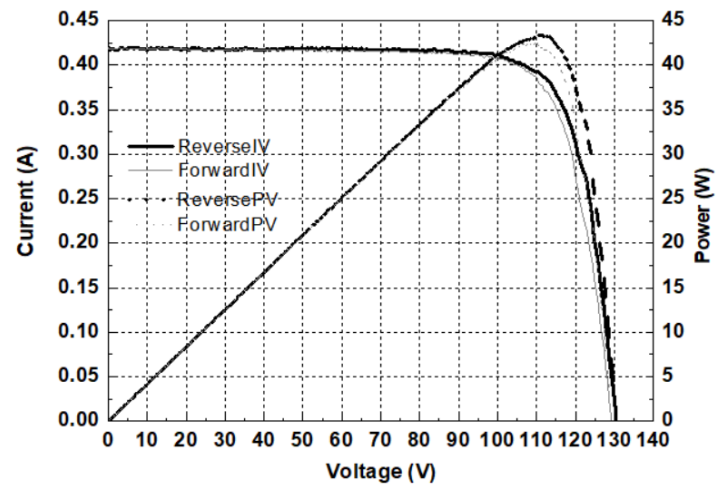
Total irradiance: 1000 W/m² based on I_{sc} of the above Reference Solar Cell.



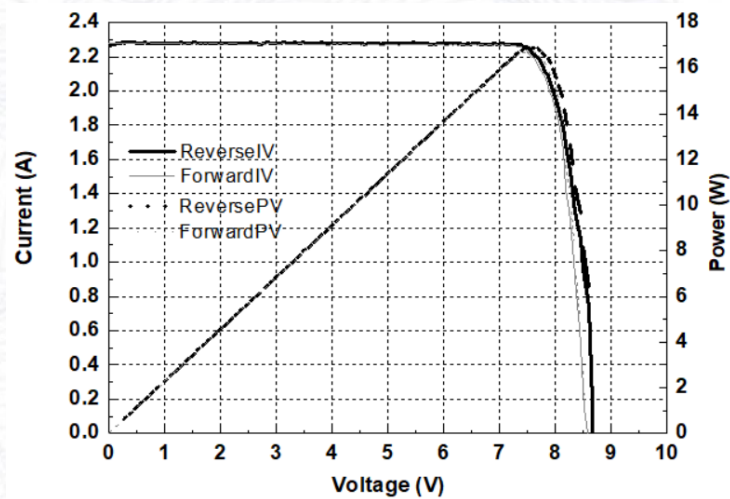
Report No.: GXgf2025-00297

DUT S/N: Q40#

Perovskite I-V Characteristic curves (Reverse& Forward)



Silicon I-V Characteristic curves (Reverse& Forward)

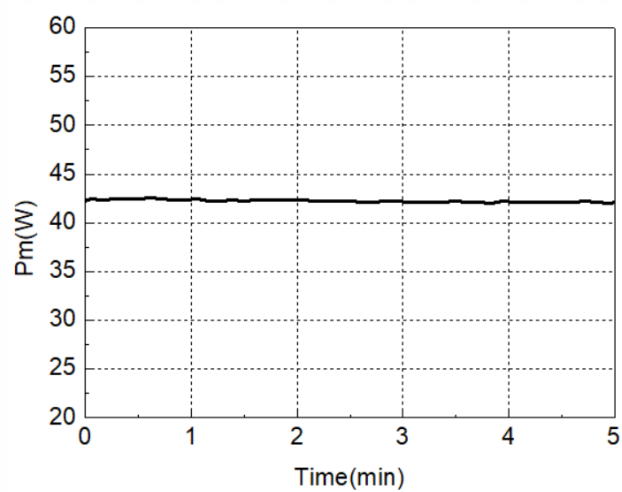




Report No.: GXgf2025-00297

DUT S/N: Q40#

Perovskite Maximum Power Point Tracking curve



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