PvFoundry®

Semi-Flexible Lightweight Module (Flex)

for Contour-shape roof, Aged-fragile roof, Weight-sensitive structure, high wind-load scenarios, for enabling and to improve Project IRR%

13 APRIL 2021

Contact: info@pvfoundry.com
Website: www.pvfoundry.com

Enterprise Singapore

PvFoundry®
Fabless Module Technology Company

Photovoltaic Foundry Pte. Ltd. (PvFoundry®) is an Invent-and-Build solar technology company headquartered in Singapore since 2016. PvFoundry® specialises in solar module design & customization, offer full suite of turnkey solutions which includes project design, engineering, supply, installation, maintenance & asset management for rooftop solar system as well as mass scale solar asset development.

PvFoundry® leverages its self-proprietary patented technologies and capabilities into solar asset development to achieve client's objectives and to attain higher-than-average project returns of investment. Our innovations are designed and engineered in Singapore. Among our product portfolio is the High-Power Density low-glare module (GMD series), 3-in-1 Building-Integrated solar roof materials (BiPV series), Bi-Facial double glass Fire Test Class A modules (DG series), and Ultra-lightweight bendable flexible module (FLEX series).

PvFoundry® has established market presence in Singapore, Malaysia, Hongkong, Sri Lanka and is determined to promote Singapore Brand abroad as a regional solar tech-based asset developer, which is in-line with our institutional investor Enterprise Singapore (ESG) vision.

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PvFoundry® Semi-Flexible Lightweight Solar Module Technology

① **Ultra-low Weight**： **-62%** lower module weight/sqm. **-27%** Less Transportation Cost.

② **Semi-Flexible Physical Property**： Bendability up to **30°**

③ **Extra Material Safety**： Fluoride Composite Materials provides excellent reliability over ultraviolet exposures, anti corrosive features, low water penetration rate, good thermal conductivity, lower temperature causes for hot spot formation, etc.

④ **Higher Power Density**： PvFoundry® GMD High Power Density Solar Cell Pattern technologies enable **+9%** extra power for the same space available (Effective Module Efficiency, EFE%). **+245%** higher watt/kg compare conventional solar panel.

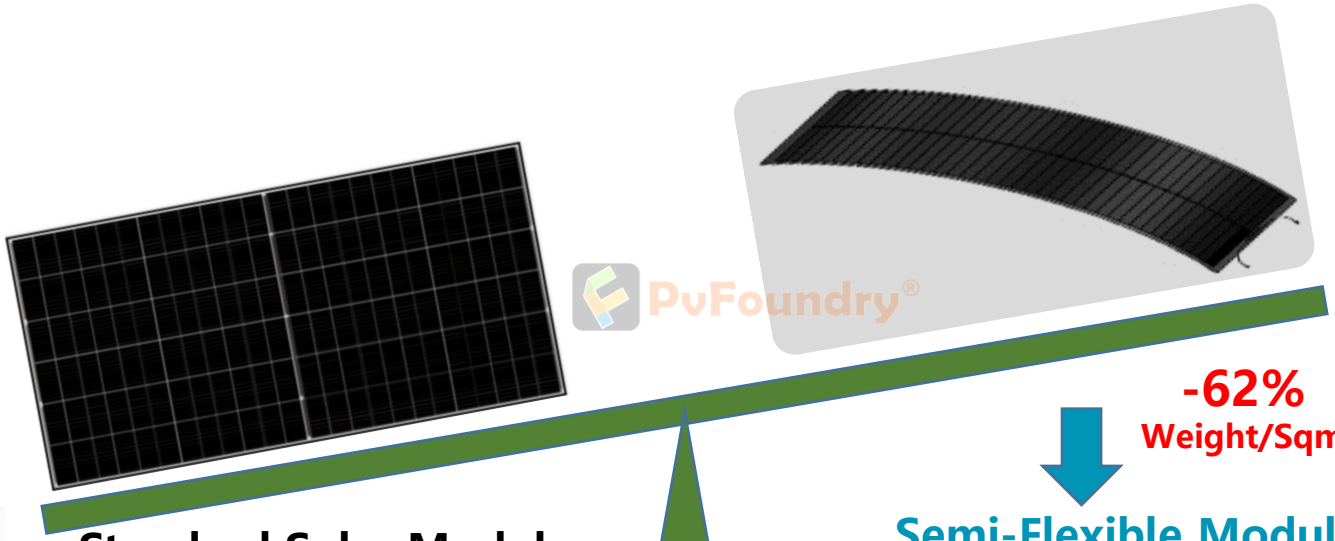
⑤ **Higher Energy Yield**: Better energy generation performance in shading scenarios.

⑥ **Better Module Reliability**： Higher wind load design, IP68 grade water tightness module junction box, etc.

⑦ **Ease of Installation**: Solar Module comes with pre-stick double-sided tape with construction grade glue, enable simplicity in various tapes of rooftop, eg. contour-shape roof, aged-fragile roof, low mechanical strength structure roof, etc.

	Module Technical Index	Unit	Tier 1 Conventional Module	PvFoundry Semi-FLEX Module	Comparison	Remarks
Power Density (Watt per Sqm installed)	Module Power	Watt	375	325	-	
	Dimensions (L, W, H)	mm	1756 x 1039 x 30 (height include Jbox &	1750 x 990 x 20 (height without Jbox 4mm)	-	-
	Module Efficiency (ME)	%	20.55%	18.76%	*-1.79% lower in ME*	**FLEX losses ME due to Jbox extra space occupation at module sunny side. This white space wastage enable module rear side to achieve 100% flat contact to mounting surface**
	Module Bendability	degree	NA	up to 30 degree		**Shingle Cell technology & advance encapsulation materials enable bending & prevent micro cracks**
	Normal Roof Surface Unitlization (RSU)	%	80%-85%	80%-85%		**Edge clerance is required by default (SCDF)**
	Curvature Roof Surface Unitlization (RSU)	%	70%-80%	>90%	*>10% higher in RSU*	**FLEX does not require structure & fixtures**
	Effective Module Efficiency (EME = ME x RSU)	**%**	**15.41%**	**16.88%**	*+1.47% higher EME* *(+9% power density)*	**FLEX unable higher capacity installed in curvature, special shape, weak structure roof**
Weight per Sqm installed	Net Module Weight	kg	21.0	7.4	-	**pre-installation module weight perspectives**
	Module Power per kg	**Watt/kg**	**17.9**	**43.9**	*+245% higher Watt/kg*	**pre-installation module power per weight**
	Pre-install Module weight per square meter	kg/sqm	11.5	4.3	*-62% weight in kg/sqm*	**pre-installation module weight per sqm**
	Post-installation total weight per square meter	**kg/sqm**	**~14.5** (panel + structure + fixture)	**~4.8** (panel + cable tray)	*-67% weight in kg/sqm*	**post-installation total system weight on roof surface per sqm**
	Weak Mechanical Structure RSU	-	Require additional structure upgrade before install	Direct installation without need to strengthen structure		**Onwer savings on building structure upgrade cost, lead time for solar system installation**
	Gap between solar module and surface installed	mm	100 - 300	zero gap		**Zero gap in between solar module and mounting surface enable system to withstand stronger wind load scenarios, eg. seaside, typhoon region**
Warranty	Manufacturing Warranty	Years	10	10	*Comparable*	-
	Linear Power Warranty	Years	25	25	*Comparable*	-
	First year power degradation	% p.a.	2.00%	2.00%	*Comparable*	-
	Subsequent year power degradation	% p.a.	0.55%	0.55%	*Comparable*	-
	Maximum System Voltage	VDC	1500VDC	1000VDC	*lower VDC*	**FLEX target application is rooftop (not solar farm)**
EPC Cost	Trasportation Cost - Capacity in 40HQ Container	watts/ctn	36pcs/pallet, 864pcs/ctn (319,680 watts/container)	56pcs/pallet, 1344pcs/ctn (436,800 watts/container)	*+38% more watt (40HQ)*	**More watts can be shipped within the same container thus obvious $/w savings cross ocean**
	Trasportation Weight - 40HQ Container truck	T/ctn	8.6T (20ft), 22.5T (40HQ)	3.3T (20ft), 13.3T (40HQ)	*-45% less weight (40HQ)*	**Obvious transportation cost savings at lack of access area where last miles cost is high**

[1] Ultra-low Weight : -62% weight reduction will boost Project cost benefits in packaging, international shipment, last miles land transportation, warehouse fees, site installation man hour savings, etc.



-62%
Weight/Sqm

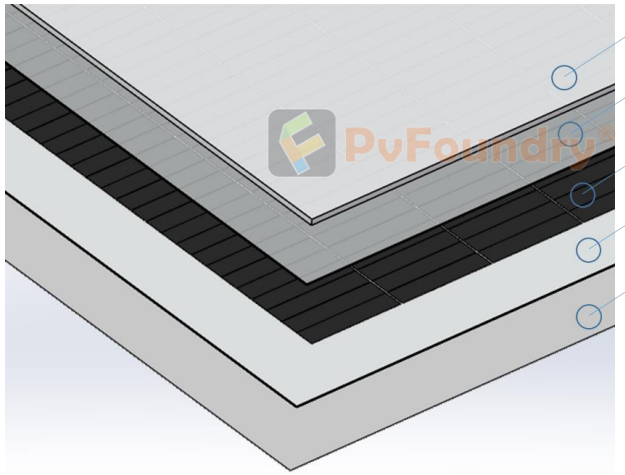
Standard Solar Module
375W, 1.8244sqm, 21.0kg
= 205W/sqm
= 17.9W/kg
= 11.5kg/sqm

Semi-Flexible Module
325W, 1.7325sqm, 7.4kg
= 187W/sqm (-8.7%)
= 43.9W/kg (+245%)
= 4.3kg/sqm (-60%)

-27%
Less Transportation Cost

Module Type	Dimension (mm)	Power (Watt/pcs)	40ft Ctn (pcs)	Max Load (watts)	Land Transport Cost (400km distance per truck)	Freight Cost (USD/kW)
Semi-Flexible Module (56pcs/ctn, 24ctn/40ft container, 13.3T)	1750*990*4.0	325	1344	436,800	USD 1000	**USD2.29/kW**
Conventional Module (36pcs/ctn, 24ctn/40ft container, 22.5T)	1792*1048*30	375	620	319,680	USD 1000	USD3.13/kW

[2] Semi-Flexible Physical Property : Bendability up to 30° will enable aplenty installation scenario which is not possible by conventional rigid panel become possible. Eliminate dependency on structure, brackets, clamps.



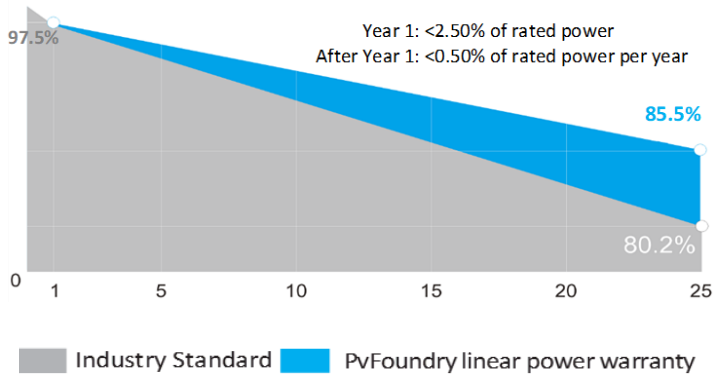
Lightweight
Optimized composite materials, up to 70% lighter than standard panels

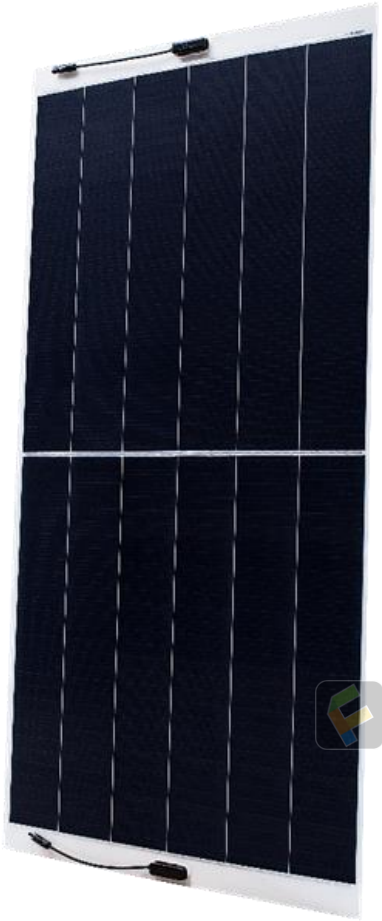
Flexibility
Flexible encapsulant, combined with shingled cell interconnection technology

Shingled Cell Technology
Series-Parallel-Series interconnection
Low operating current and resistive loss

Extensive Application
Vertical installation, Curved surface installation, Floating systems, etc.

Low Operating Temperature
Higher energy generation capability





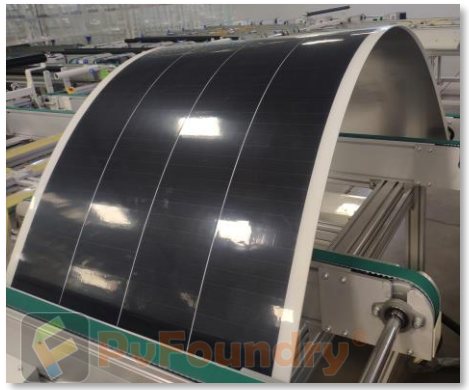
Product and Quality Certifications
- ✓ IEC 61215, 61730 certification by TUV SUD

Manufacturing Site Certifications
- ✓ ISO 9001 Quality Management System
- ✓ ISO 14001 Environmental Management System
- ✓ ISO 45001 EHS Management System

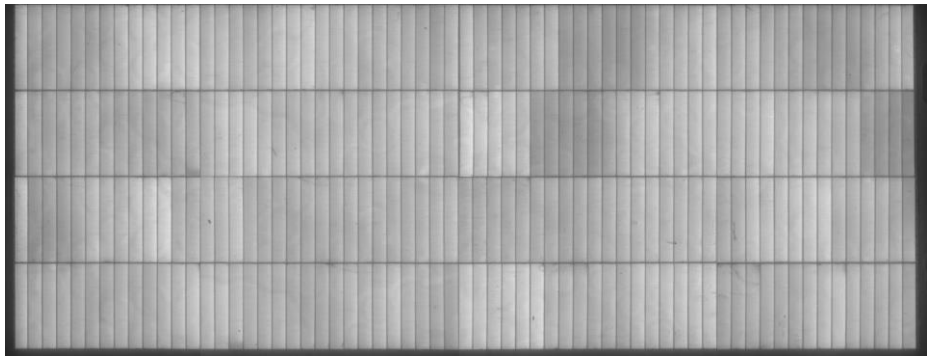
25 Year
Linear Power Warranty

10 Year
Material and Workmanship Warranty

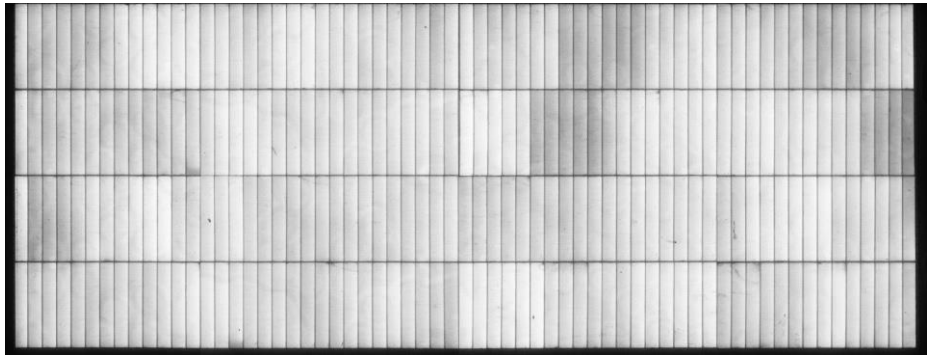
[2] Semi-Flexible Physical Property : Bendability up to 30° will enable aplenty installation scenario which is not possible by conventional rigid panel become possible. Eliminate dependency on structure, brackets, clamps.




Electroluminescence Test
Before bending



Electroluminescence Test
After 12hrs bending



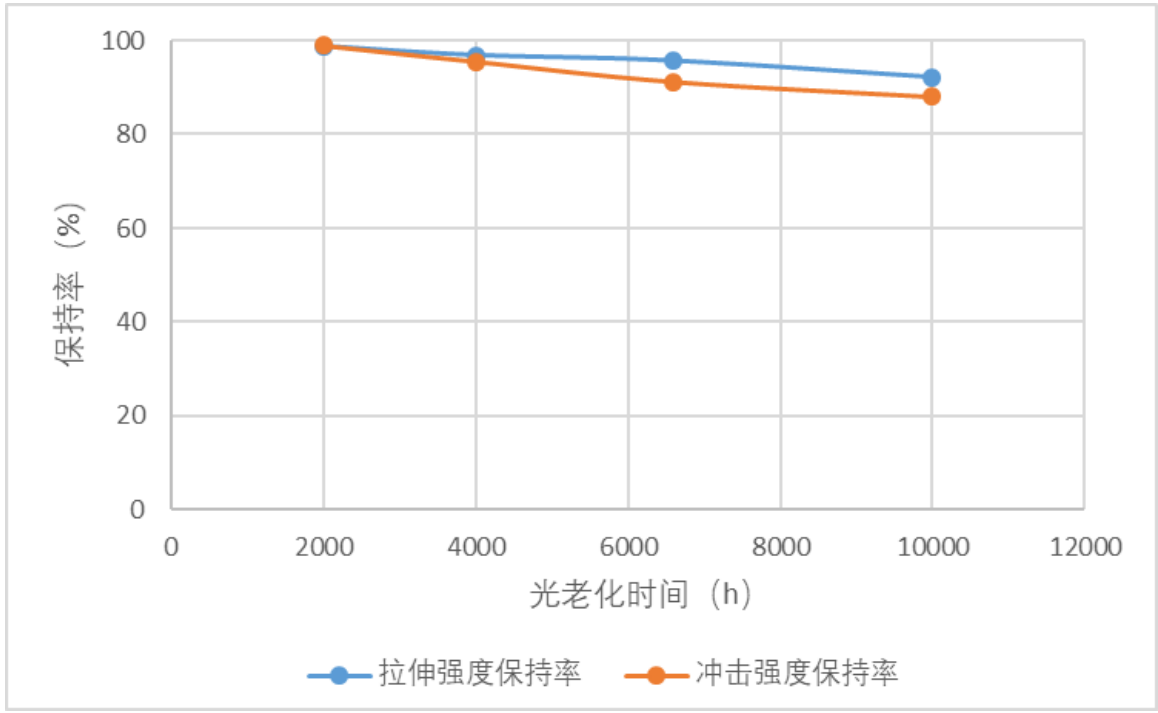
- ✓ **Bending radius： 400mm**
- ✓ **No micro cracks occurrence**
- ✓ **Power degradation within IEC61215 spec**

[3] Extra Material Safety: UV Resistivity & Sunlight Exposure Reliability

测试项目	测试条件	单位	技术指标	测试结果		平均值	判定
光老化测试	测试标准：ASTM G154 测试周期：0 小时、2000 小时、4000h、6000 小时、10000 小时和 12000 共 7 个周期。 黑板温度：60±3℃；辐照度： 0.89W/m²/nm@340nm	/	试样表面不出现粉化、龟裂、变形等异常现象	试样表面未出现粉化、龟裂、变形等异常现象		合格	合格
拉伸强度	光老化前进行测试 测试标准：ISO 527-1/2 测试速率：50mm/min 测试温度：23℃	MPa	/	15.2 16.3 16.2		15.9	合格
悬臂梁冲击强度	光老化前进行测试 测试标准：ISO 180 测试温度：23℃	kJ/m²	/	55.9 55.2 55.7		55.6	合格
拉伸强度保持率	光老化后进行测试 测试标准：ISO 527-1/2 测试速率：50mm/min 测试温度：23℃	%	≥70	2000h 4000h 6600h 10000h	98.7 96.8 95.6 92.1	合格	合格
悬臂梁冲击强度保持率	光老化后进行测试 测试标准：ISO 180 测试温度：23℃	%	≥70	2000h 4000h 6600h 10000h	98.9 95.5 91.2 88.0	合格	合格

Test Method: ASTM G154

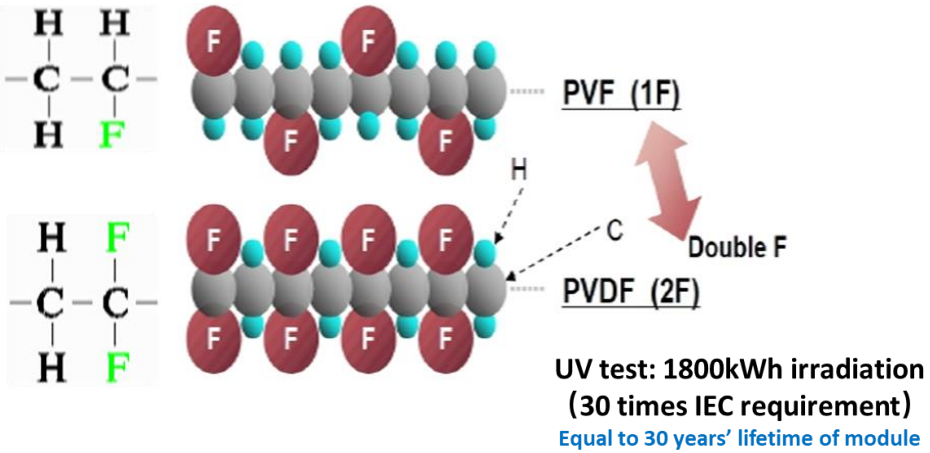
Test Method: Irradiance 0.89W/m² @340nm； Board Temp 60 ±3℃

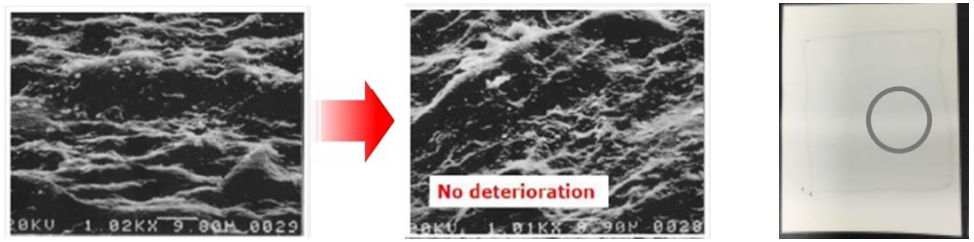


Singapore Irradiation approx. 5706MJ/m². Assume UV constitute 5% of total Irradiation, and test laboratory can simulate 1% of representation, local UV lights annual exposure is estimated at 5706/(0.89*3600*100)=943.4h

Total 10,000 Test Hours represent Outdoor exposure of 10000/943.4=**10.5 years**

[3] Extra Material Safety: Fluoride Polymer Film Front Sheet



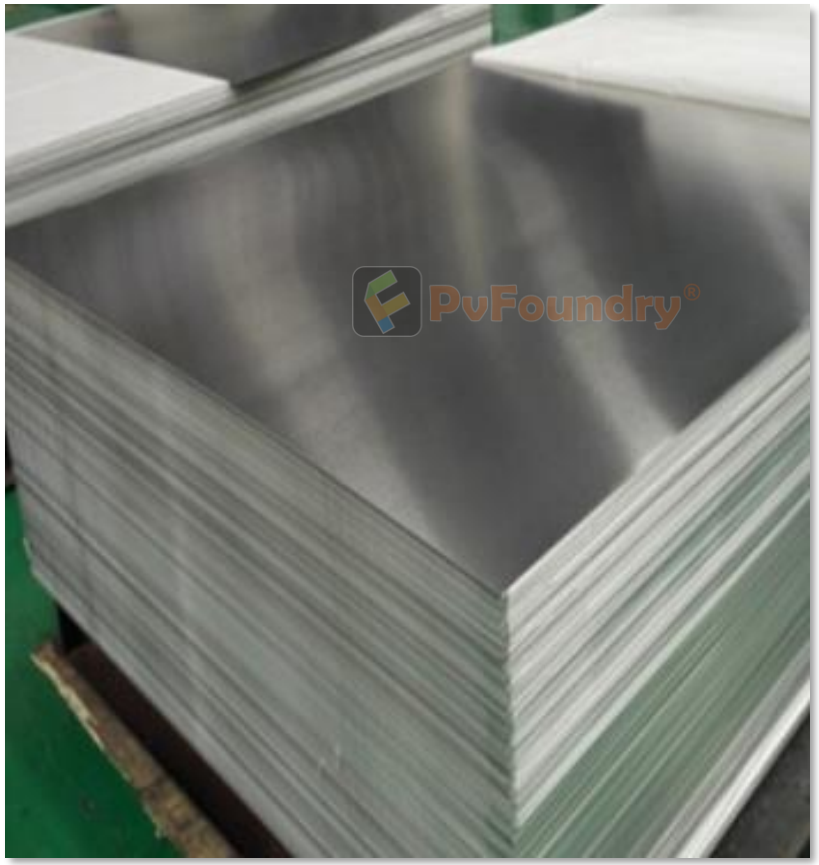


Fluoride film, such as PVDF is used, which has C-F bond and high resistance to UV light.

- ✓ No crack
- ✓ No yellowing
- ✓ No chalking

- **Excellent UV resistance**: C-F bond energy is up to 485KJ/mol, only light with wavelength less than 220nm could deteriorate C-F bond. The sunlight wavelength is 290nm~5300nm, above this threshold.
- **Excellent anti-corrosive ability**: Resistance to chemical agent, acid, alkaline, high humidity.
- **Excellent mechanical property**: Tensile strength 28~41MPa, temperature resistance in the range of 150℃ (High) and -70℃ (Low). Excellent mechanical performance.
- **Excellent insulation property**: Dielectric strength of 15KV
- **Low water vapor transmission rate**: Less than 2.5g/m2/day;
- **Excellent self-clean ability**: Fluoride film has natural non-adhesion properties against soiling and these surface soiling could be self-cleaned after rain.

[3] Extra Material Safety: Water-proof Substrate Back Sheet



Material Properties & Characteristics		
No.	Specialty	Description
1	**High Water-resistance**	Back side fully covered by PET & Al foil, Zero moisture ingress into the module
2	**Excellent heat conduction**	Al alloy thermal conductivity: 234W/(m*k) (at 25℃)
3	**Anti-corrosion**	Al content surpasses 99.6%

[4] High Power Density : PvFoundry® GMD High Power Density (GMD) Self-Proprietary Solar Module Product Technology & Intellectual Properties.

	IP	PvFoundry Patent	Technology Relevancy	Priority Filing	International Filing	International Publication	National Level Entry Phase	Fcst Patent Grant
PvFoundry®	1	PV Cell Design for PV Modules with Shingled Cells (USPTO#62398653) (IPOS#10201704556R) (PCT/US17/51289) (MY: PI2019001629)	[A] [B] [C]	23-09-2016 USPTO	13-09-2017 WIPO-PCT	29-03-2018 WIPO-PCT	Singapore : 12-06-2019 Malaysia : 22-03-2019	Singapore : Q4' 2021 Malaysia : Q3' 2021
	2	Electrode Design for PV Modules with Shingled Cells (USPTO#62431118)	[A] [B] [C] [D] [E]	07-12-2016 USPTO	-	-	-	-
	3	Method of Interconnecting Shingled PV Cells (USPTO#62431644) (PCT/US17/64625) (CN:201780075292.7) (IPOS: 11201904019W) (MY: PI2019002650) (EPO:17879474.9)	[A] [B] [C] [D] [E]	08-12-2016 USPTO	05-12-2017 WIPO-PCT	14-06-2018 WIPO-PCT	Singapore : 03-05-2019 Malaysia : 09-05-2019 Europe (EPO) : 04-07-2019 China : 05-06-2019	Singapore : Q4' 2021 Malaysia : Q2' 2022 Europe (EPO) : Q2' 2022 China : Q3' 2022
	4	PV Module Construction Method (IPOS#10201705346W), (PCT/SG2018/050300) (MY: PI2019007850) (SIPO 201721352681.3 , 210710975465.2)	[A] [D] [E]	29-06-2017 IPOS	19-06-2018 WIPO-PCT	03-01-2019 WIPO-PCT	Malaysia : 27-12-2019 China : 01-05-2018	Malaysia : Q4' 2022 China : Q3' 2022
	5	PV Cell (IPOS#10201708021P), (PCT/SG2018/050482)	[A] [B] [C] [D] [E]	28-09-2017 IPOS	20-09-2018 WIPO-PCT	04-04-2019 WIPO-PCT	*Ongoing*	
	6	Rework Procedure for Shingled PV Modules	[A] [B] [C] [D] [E]					
	7	Silicone Encapsulation Method & Process know-how	[C] [D] [E]					
	8	Silicone Encapsulation Method & Process know-how	[C] [D] [E]					
	9	DGSE module design	[C] [D] [E]					
	10	Bi-Facial Cell Design	[D] [E]					
	11	Diode-less, Inter-string module design with bi-facial cells	[A] [B] [C] [D] [E]					
	12	String construction with Multi + 2 end mono cells	[A] [B] [C] [D] [E]					
		Collaborative Patent						
PvFoundry Collaborate IP's with Partners	13	Preparation method of solar cell sheet unit and solar cell assembly Application #: [illegible]	[A] [B] [C] [D] [E]	Application : 31-Dec-2015, Priority : 22-May-2015 Current Status : Granted, 17-Oct-2017				
	14	Solar cell sheet, solar cell assembly, cell sheet unit and preparation method. Application #: [illegible]	[A] [B] [C] [D] [E]	Application : 31-Dec-2015, Priority : 22-May-2015 Current Status : Granted, 29-Aug-2017				

- [A] Cell Stack-Up @ High Power Density Technology
- [B] Double Glass + EVA Technology
- [C] Double Glass + Silicone Encapsulation Technology (DGSE)
- [D] DGSE + N-Type Bifacial Technology
- [E] DGSE + HIT Bifacial Technology

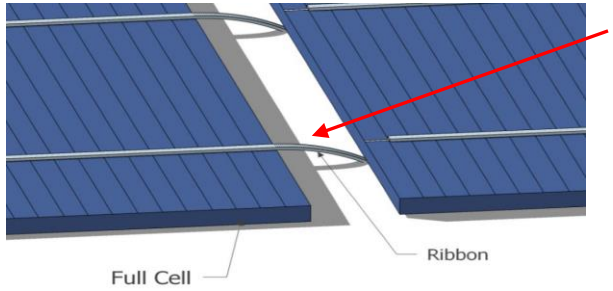
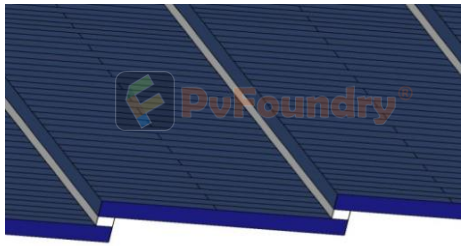
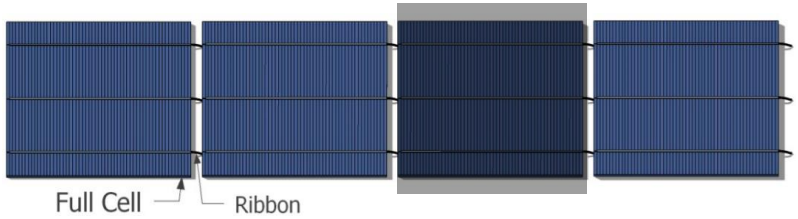
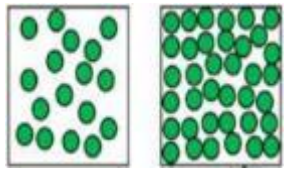
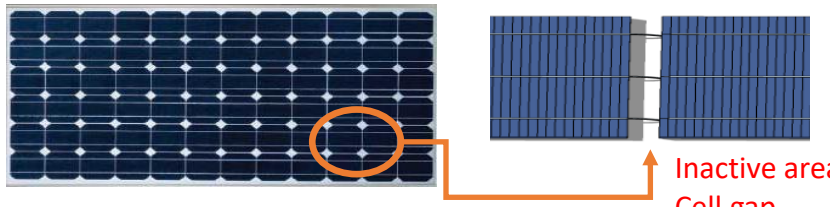
SPORE IP granted 29/May/2020

5 International + National Patent Filing Completed

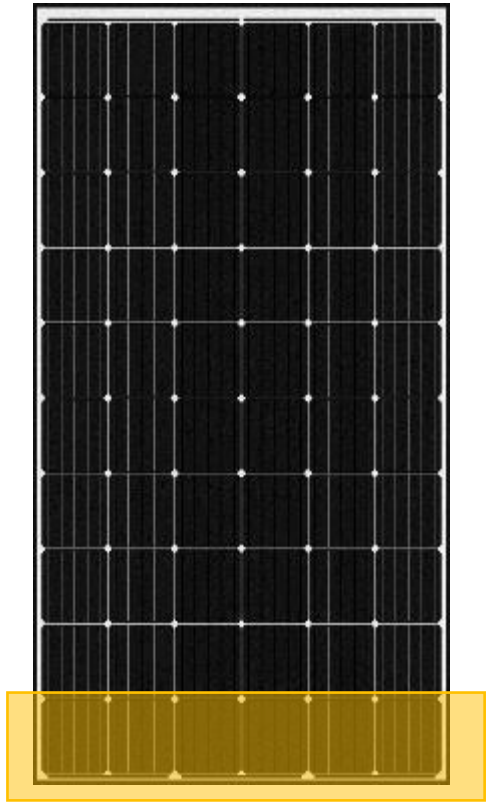
7 Technologies in preparation for filing

Granted in PRC, National Phase filing in other countries

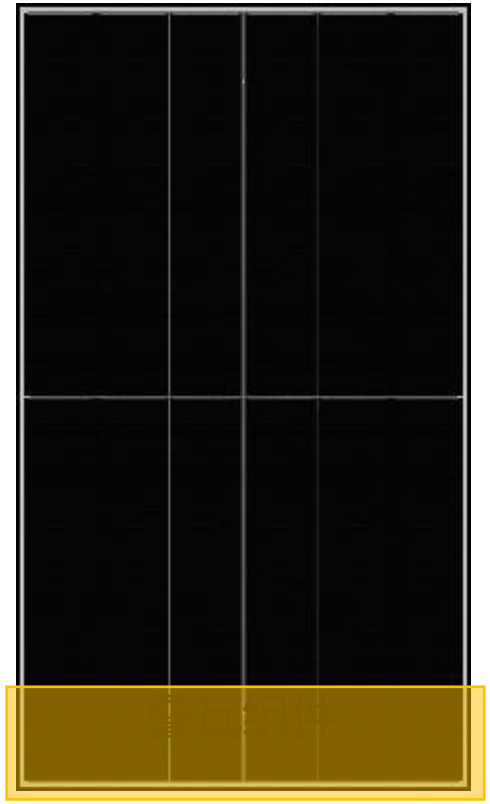
[4] High Power Density : PvFoundry® GMD High Power Density (GMD) Self-Proprietary Solar Module Product Technology & Intellectual Properties.

	Conventional Module	PvFoundry High Power Density (GMD) Module
Resistivity Loss	 Power loss in module caused by ribbon resistive loss	 **Direct contact** between cell busbars. Resistive loss minimized **Power Gain** +13% per module
Hot Spot	 When 1 cell shaded, **9.0A** forward current flows in reverse and heats cell up. Heat is contained within same cell. Long term reliability impact	 **Reliability Gain** -80% lesser current pass through single shaded cell Smaller strips produce lesser current **~1.8A**. Hotspot heat generating capability is suppressed (50%). Shingle design also allows heat to migrate across string
Power Density	  A 72c module with 3mm cell spacing have a total inactive area of 0.031m2	 **Higher Density** +7% more cells packed in the same equivalent space No Cell-Cell gap Inactive area is eliminated, **with more cells packed in,** module density, power & efficiency increase

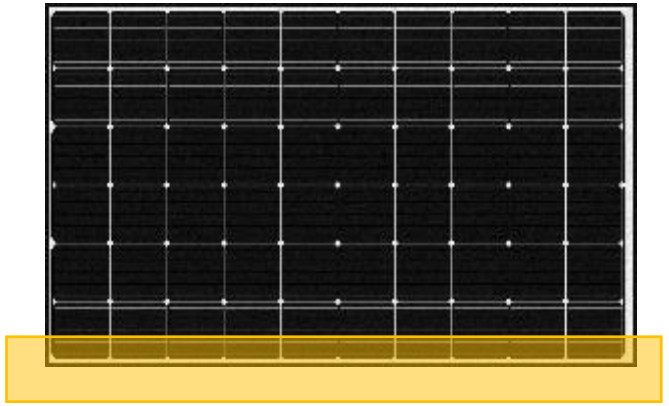
[5] Higher Energy Yield: Better Energy Generation Yield Performance at Sun Shading Scenarios



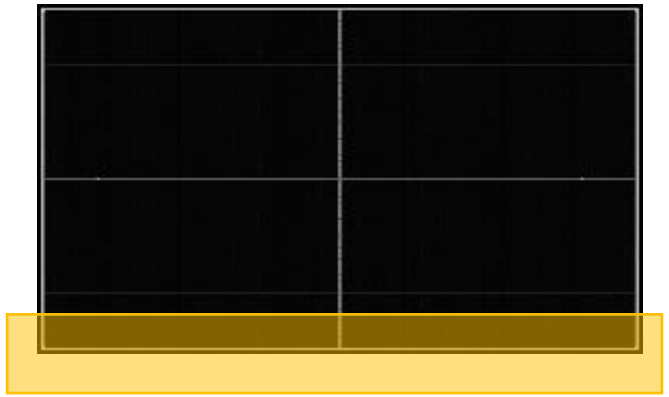
0% output
Conventional Modules



50% output
Shingled Modules (GMD)

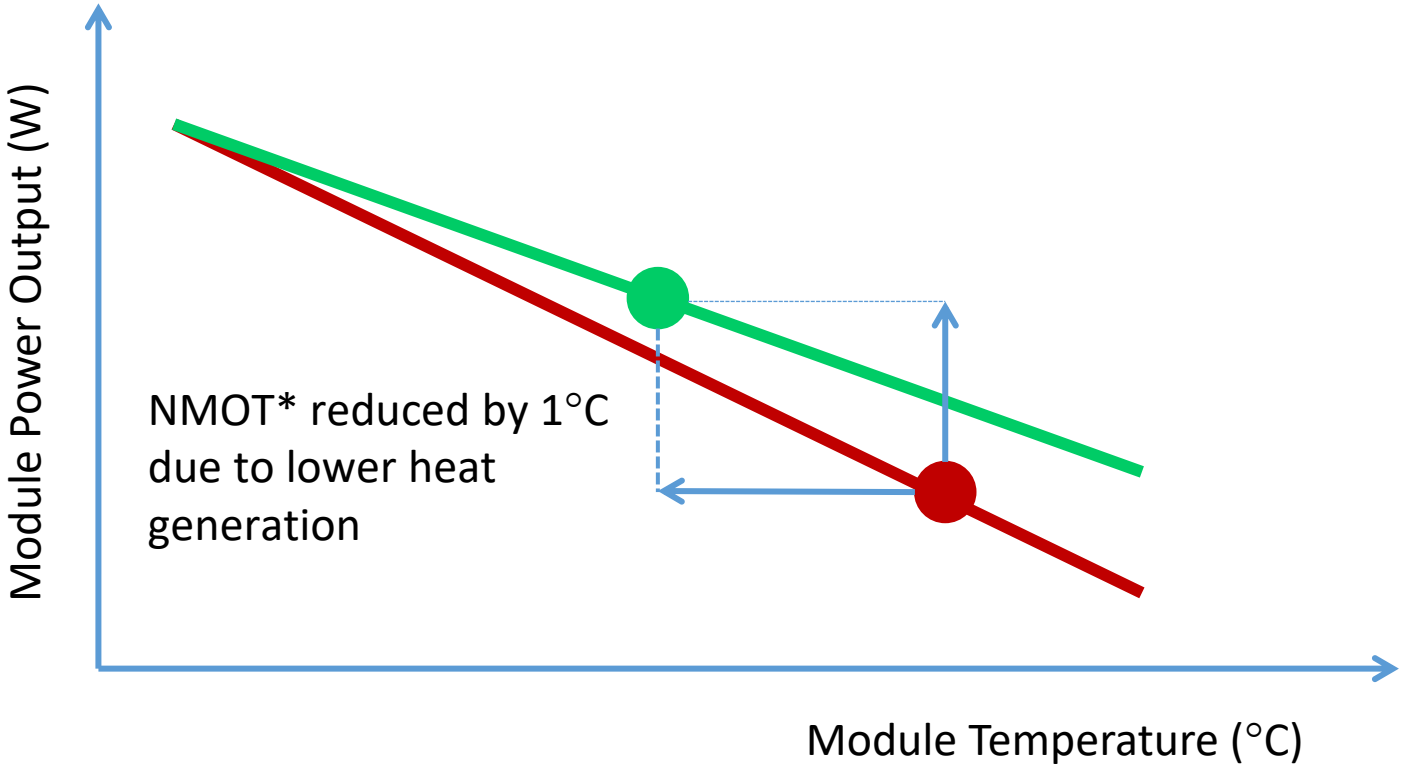


67% output
Conventional Modules



83% output
Shingled Modules (GMD)

[5] Higher Energy Yield: Lower Nominal Module Operating Temperature (NMOT)

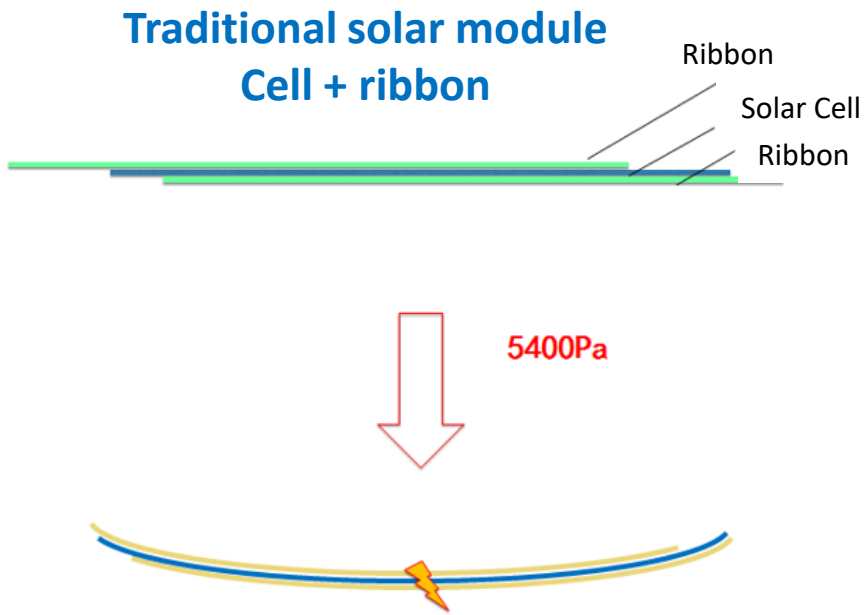


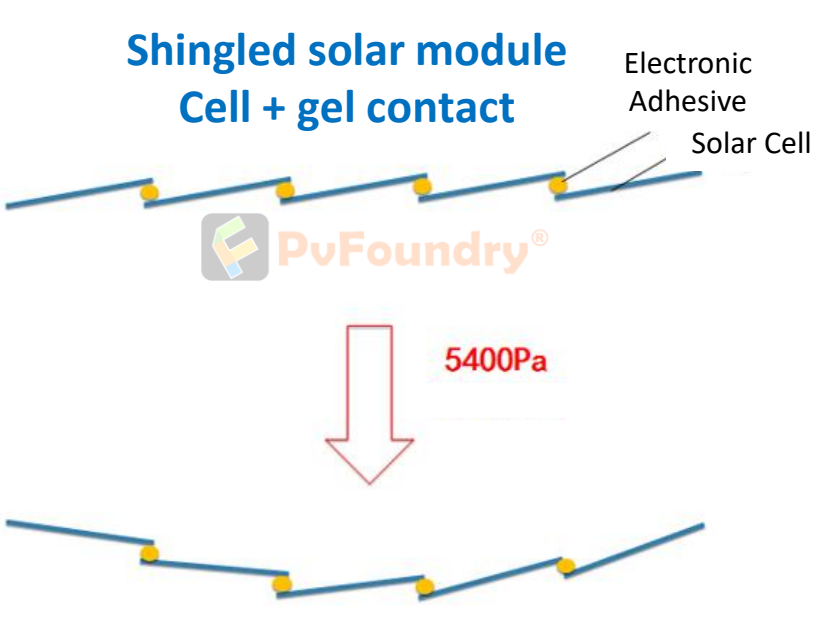
NMOT of shingled module is lower than full cell module due to;

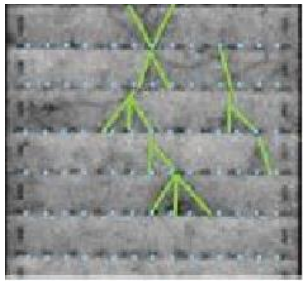
- **Lower operating current :** The current of shingled module is 1/6th of full cell module
- **Excellent heat migration :** The local heat generation within cells are dissipated with neighboring cells more efficiently due to direct surface contact between cells, unlike via interconnecting ribbons in conventional full cell module which is ineffective.

*NMOT: Nominal Module Operating Temperature

[6] Better Module Reliability : Higher Mechanical Load & Lower Micro-Crack Risk







Cell Size : 158.75mm (Full Cell)
Cell Thickness : 200um

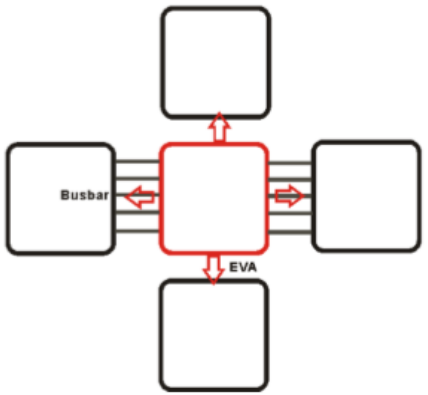
Cell Size : 26.45mm (1/6th)
Cell Thickness : 200um

- When stress is applied across traditional full cell, the tendency of cracks and micro cracks is high as these silicon cells are rigid and are not designed to flex under load

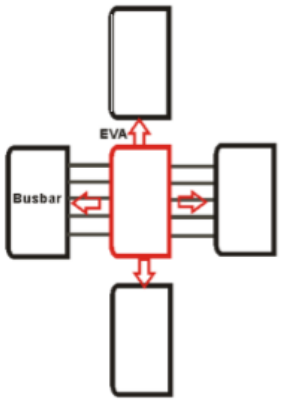
- **On a shingled module, cells are laser cut, singulated into 1/6th size and interconnected using conductive adhesives. The flexural strength is significantly increased**

[6] Better Module Reliability : Hotspot Temperature Suppressed By Up To 50%

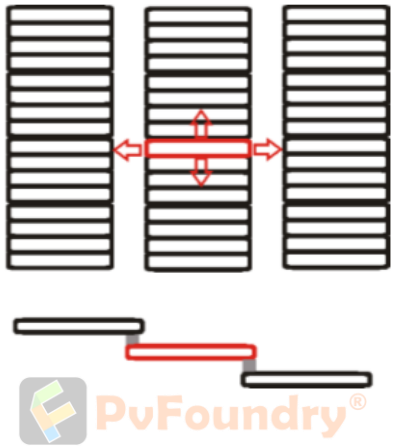
Schematic diagram of horizontal heat dissipation of cell



1 full cell



2 half cells

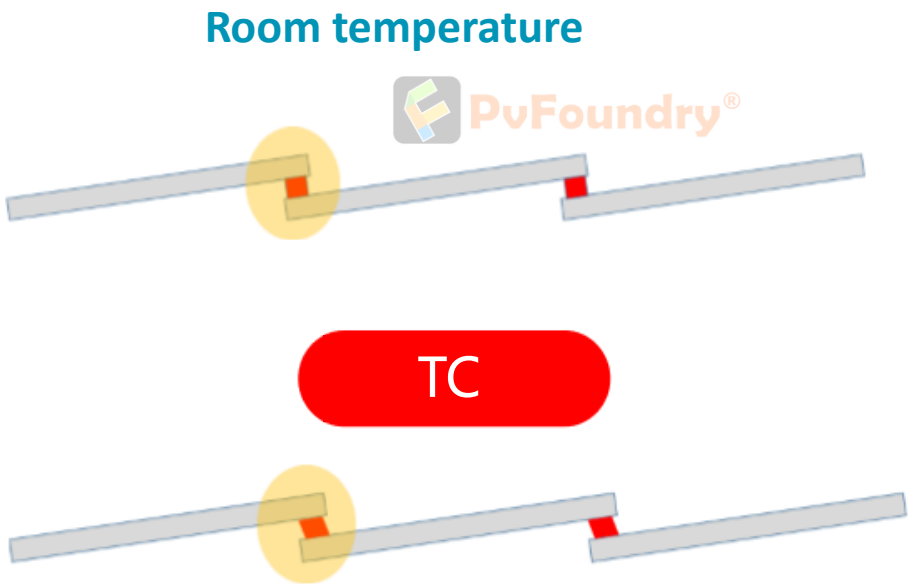


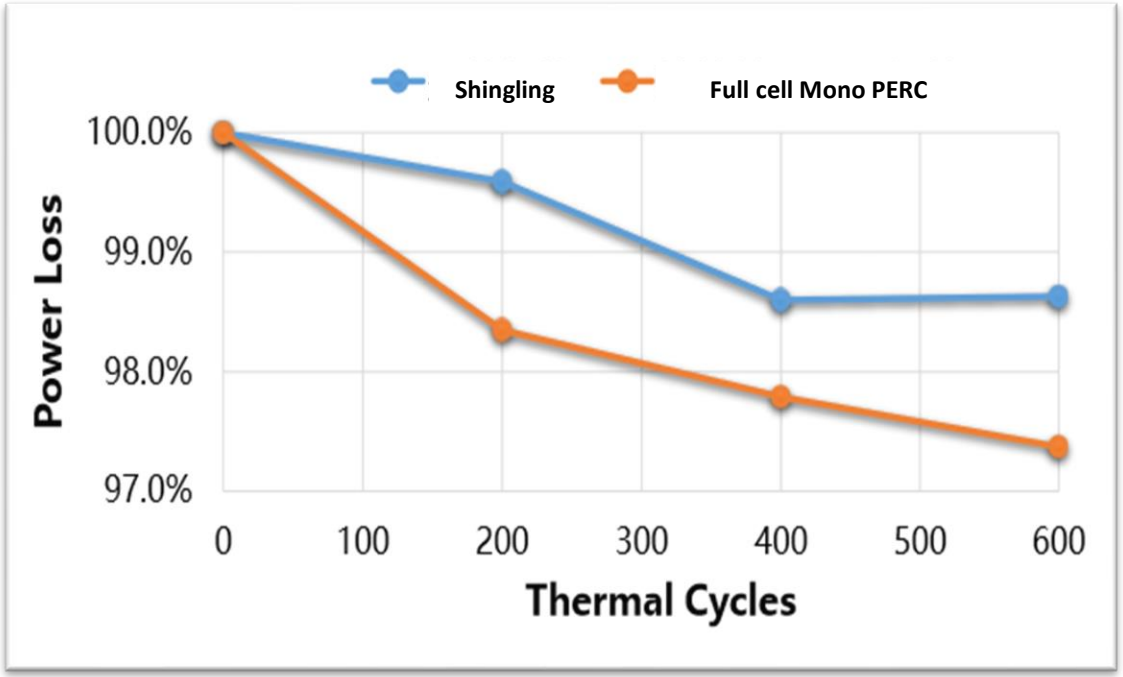
Shingled cells

- In the event of partial shading, solar cells turns into a resistive load and this increases the cell temperature. The full cells gets hotter at a much higher rate due to 6x higher operating current. Heat migration rate to next neighboring cells is poor as these cells are typically arranged in a “silo” layout.

- **When similar shading scenario happens to shingled modules, the hotspot heat generation impact is much lower due to 1/6th lower operating current and the local hotspot heat generation within cells are dissipated with neighboring cells more efficiently due to direct surface contact between cells. This leads to improved long term module reliability.**

[6] Better Module Reliability : Better Thermal Cycle Performance





- The deformation of flexible conductive gel makes up for the difference of thermal expansion coefficient between the cell and the ribbon and other materials. Therefore, shingled module has better Temperature Cycle performance, which allows module adaptation to various temperature environments.

[6] Better Module Reliability : High Insulation Characteristics

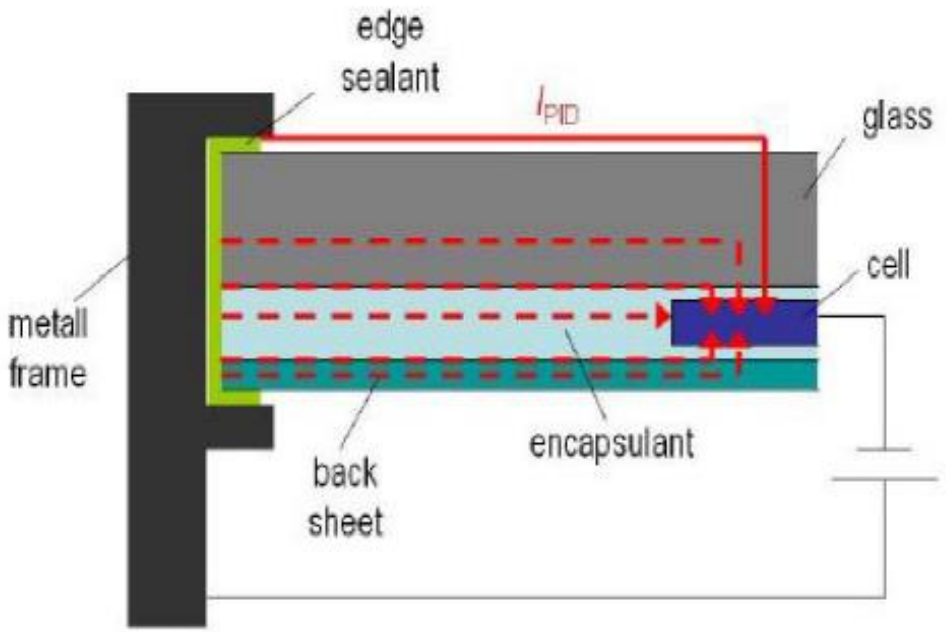
1000V

1500V

Wet leakage test：

- ❑ Test Procedure： IEC61215, immersed in water, apply 1000V or 1500V voltage
- ❑ Conclusion: Insulation resistance > 50GΩ·㎡, much bigger than 40MΩ·㎡, which is IEC61215 requirement.

[6] Better Module Reliability : PID Free



Semi-Flexible modules are PID free

- No metal ions in the front side polymer cover
- No metal frame

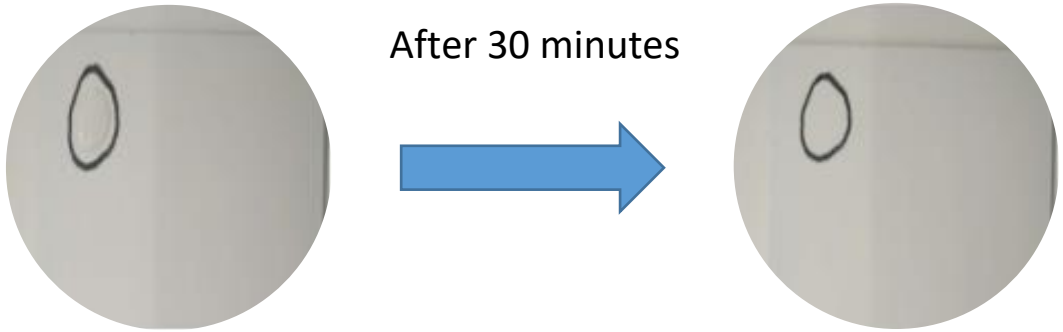
- PID (Potential Induced Degradation), are caused by high negative voltage between module surface and the solar cells inside which could drive the metal ions (such as Na+,K+ etc) inside the glass to degrade the cells.

[6] Better Module Reliability : Fire Resistance Test

- Burning brand test: No occurrence of “burnt through "when 20 pieces of burning block was used for this test
- Spread-of-flame test: Flame temperature 704±28℃， air velocity 5.2-5.3m/s， no burnt block drop for 4 minutes.

[6] Better Module Reliability : Anti-Corrosion

Test: 98% concentration sulfuric acid drop test on fluoride material

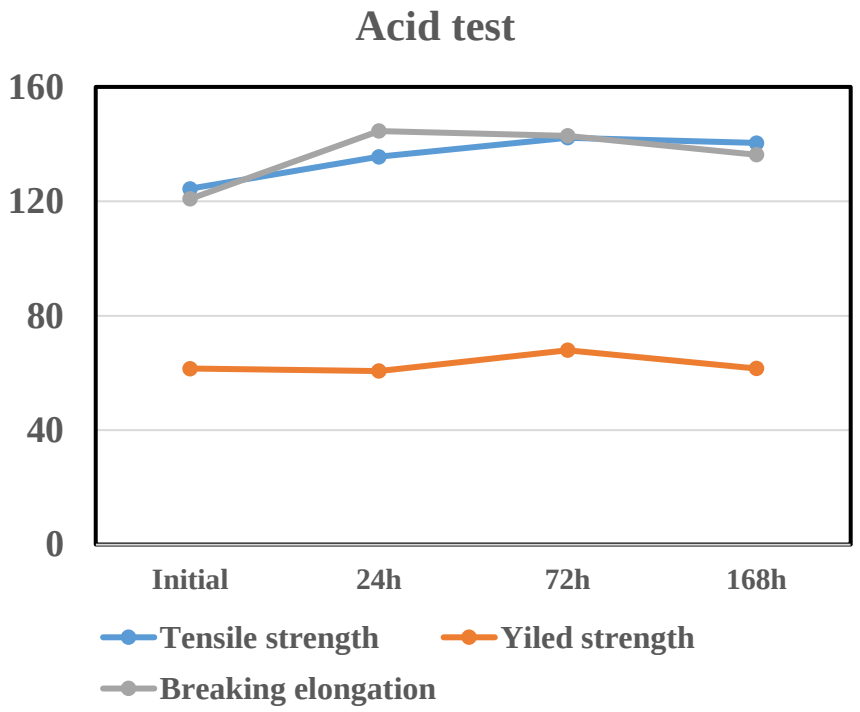


The film is still intact and no damage is shown

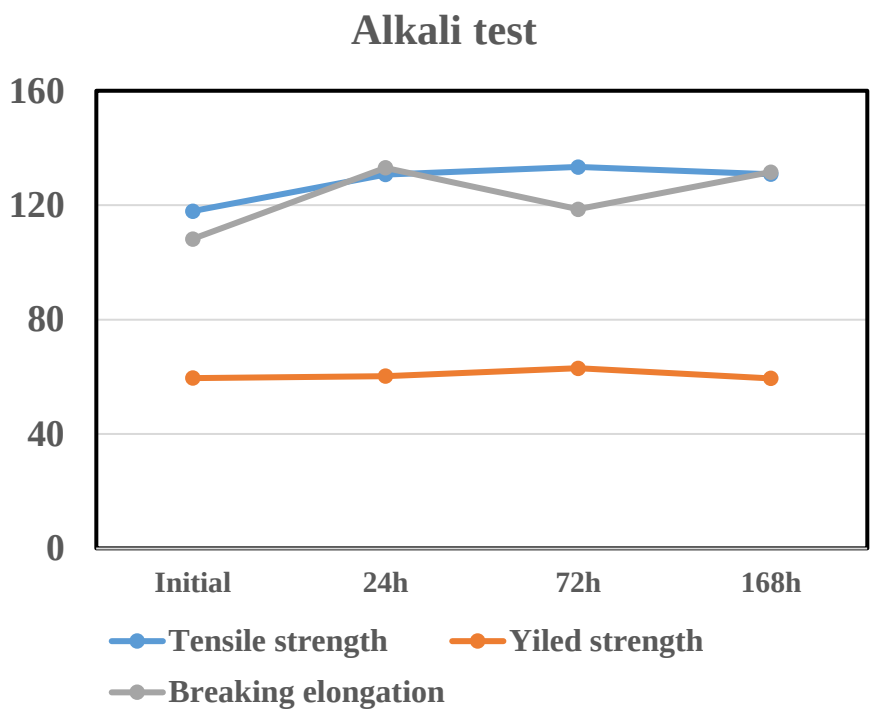
SN	Test item	Result
1	cupping test,8 mm	Pass, no peel of and crack
2	5% content hydrochloric acid for 24 h	Pass: No damage
3	5% sodium hydroxide for 24 h	Pass: No damage
4	Thermal cycle, 50 cycles	Pass: No damage
5	Slat mist test 1000h, class 1	Pass
6	UV irradiation, 1800h	Pass: $\triangle$E=0.8(0 Level)
7	Nitric acid for 30 minutes	Pass: No bubble, chalk and crack
8	Saturated methyl ethyl ketone solvent, wipe 200 times	Pass: base film is not shown
9	Stain resistance， ≤5%	1%
10	Fire rating	A_2

[6] Better Module Reliability : Acid and Alkaline test

Acid test: PH 2-3, sealed immersion environment



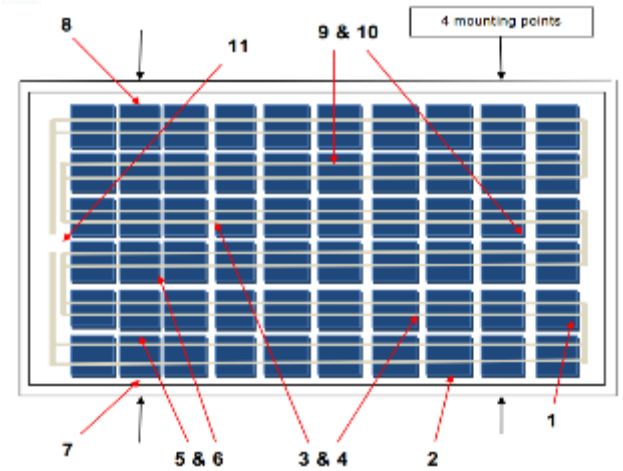
Alkaline test: PH 11-12, sealed immersion environment



After acid and alkali test, tensile strength, yield strength and breaking elongation do not show obvious deration.

[6] Better Module Reliability : Hail Impact Test

Item		Pmax (W)					
		1	2	3	Av.(W)	Degradation(W)	Degradation(%)
	Initial Pmax (W)	195.1641	195.1988	195.2151	195.1927	/	/
Height (mm)	200	195.0336	195.0092	195.0087	195.0172	0.1755	0.09%
	400	194.5226	194.5866	194.5447	194.5513	0.4659	0.24%
	600	194.0071	194.0782	194.0249	194.0367	0.5146	0.26%
	800	193.3704	193.3469	193.2878	193.3350	0.7017	0.36%
	900	192.5447	192.5629	192.5447	192.5508	0.7843	0.41%



Drop Testing

In this test, 227 g steel ball is used to drop at 900mm max height, according to IEC standards.

Degradation < 5%, Pass IEC standards

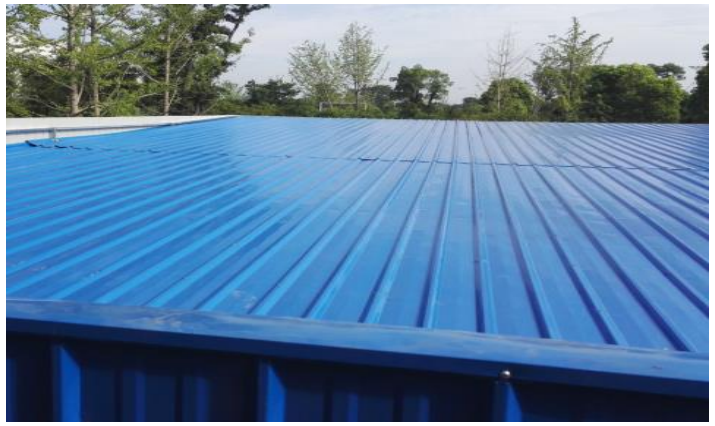
[7] Ease of Installation : Wider applications, Reduce labor cost & skill required

Easy to Install - As easy as to “paste posters”

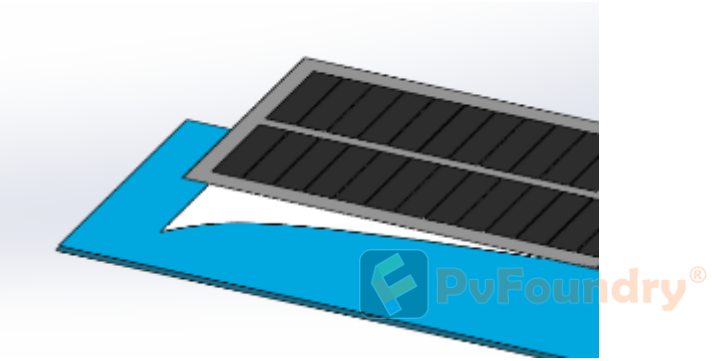
Fast to Install – Just require normal skill worker to install, average 2.0 minutes installation per piece for a two-man team on site.

Cheap to Install – Able to reduce -50% installation labor cost on site

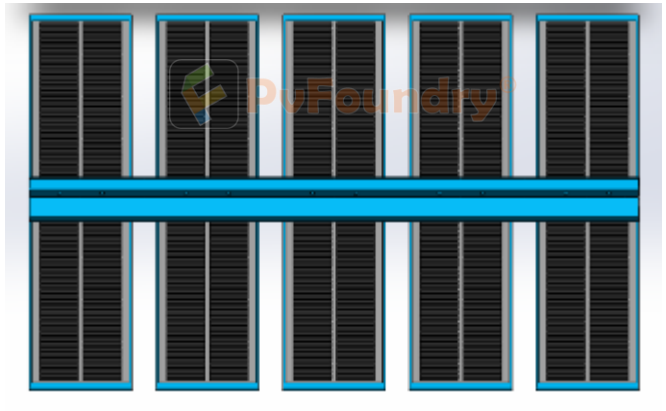
[7] Ease of Installation : Wider applications, Reduce labor cost & skill required



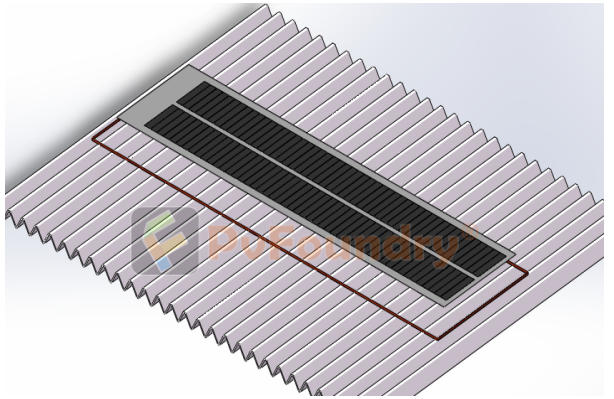
Surface Cleaning



Remove Double-sided tape



Installation Complete



Module Positioning & Install

Semi Flexible Module Applications – Vertical Solar, Low Weight, Contour Roof