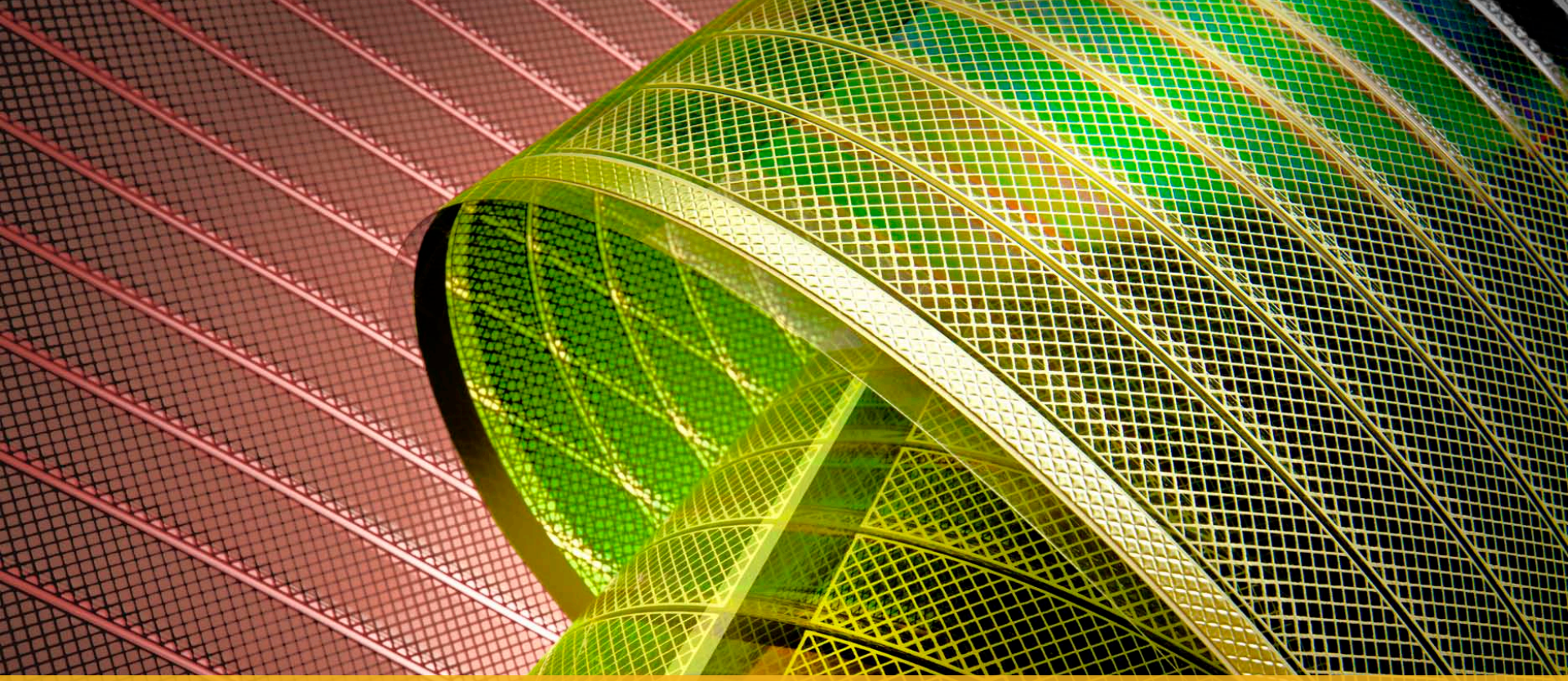


Meeting IEC 61646 Climatic Chamber Test Requirements w/OPV

NREL Photovoltaic Modules Reliability Workshop (PVMRW, February 2012)

Yan, Fadong; Peltola, Jorma; Wicks, Stephen; Balasubramanian, Srini; Kam-Lum, Elsa

KONARKA®

Summary

- A historical milestone for OPV technology worldwide has been achieved.
- A press announcement on 2/15/2012 by Konarka stated that OPV modules laminated in glass passed the IEC 61646 climatic chamber tests.
- This facilitates Konarka's Power Plastic integration into BIPV glass applications.
- The key 61646 test results are presented:
  - for laminated glass products – results by TUV Rheinland
  - for flexible products – Internal results by Konarka. TUV testing is in progress
- Lessons learned are discussed

International Standard IEC 61646

Thin-film terrestrial photovoltaic (PV) modules
Design qualification and type approval

TUV Declaration

Product: PV Modules
Type: Konarka PP120- G/G

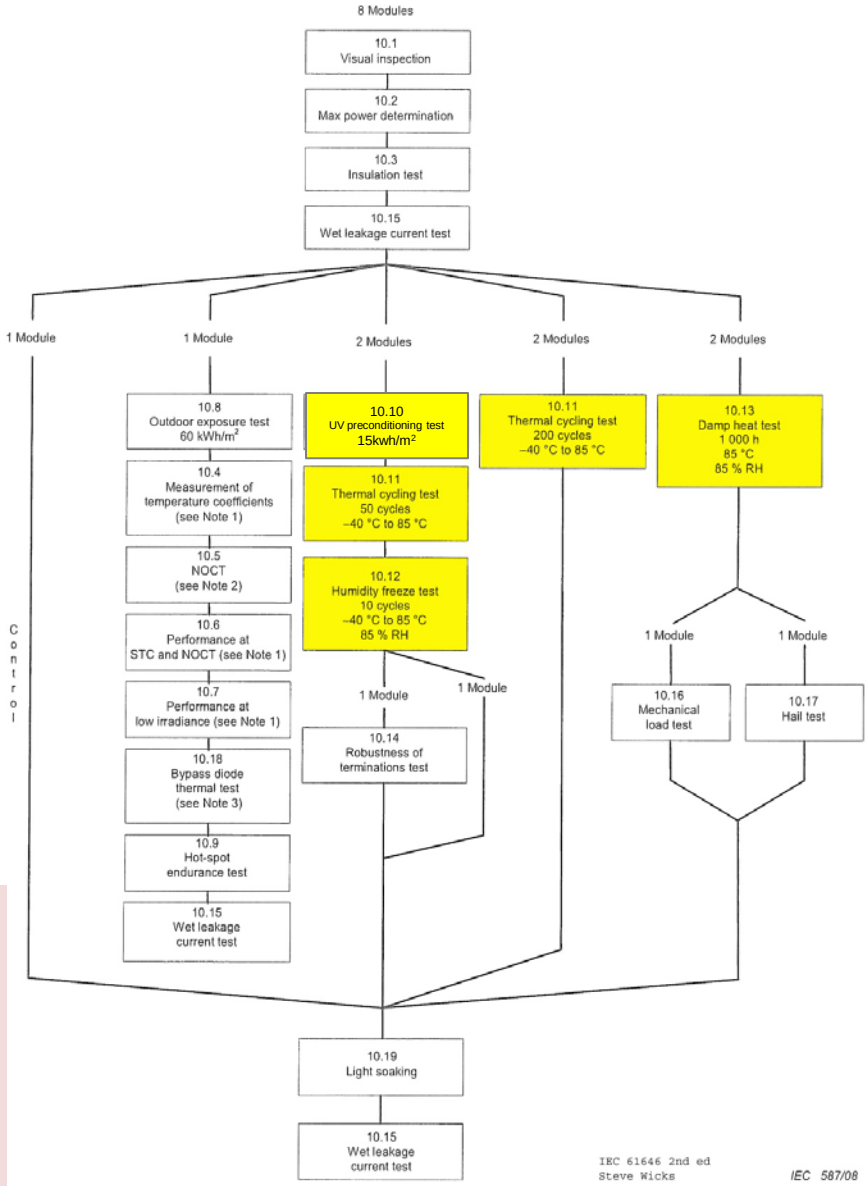
Carbon Neutral Company

Herewith we declare that for the above listed module type
- the UV test sequence (including UV preconditioning, Thermal Cycling Test (50 cycles) and Humidity Freeze Test),
- a Thermal Cycling Test (200 cycles) and
- a Damp Heat Test

acc. to EN IEC 61646:2008 were performed (three modules per test) and that after these tests
- a visual inspection and
- a relative output power measurement

were successfully performed. The determined maximum power degradation caused by the above listed environmental stress tests is 4 %.

Business Field Solar Energy

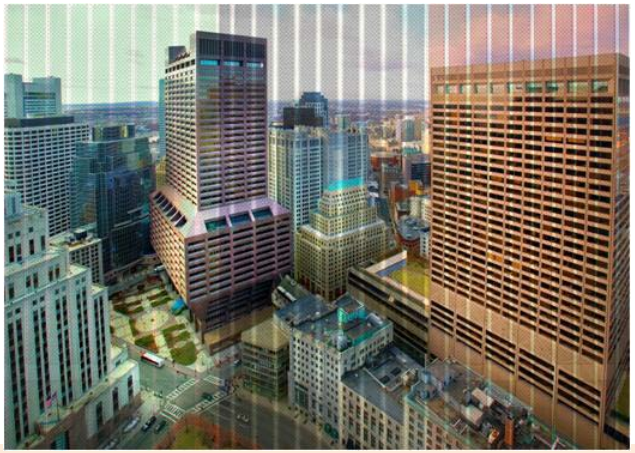


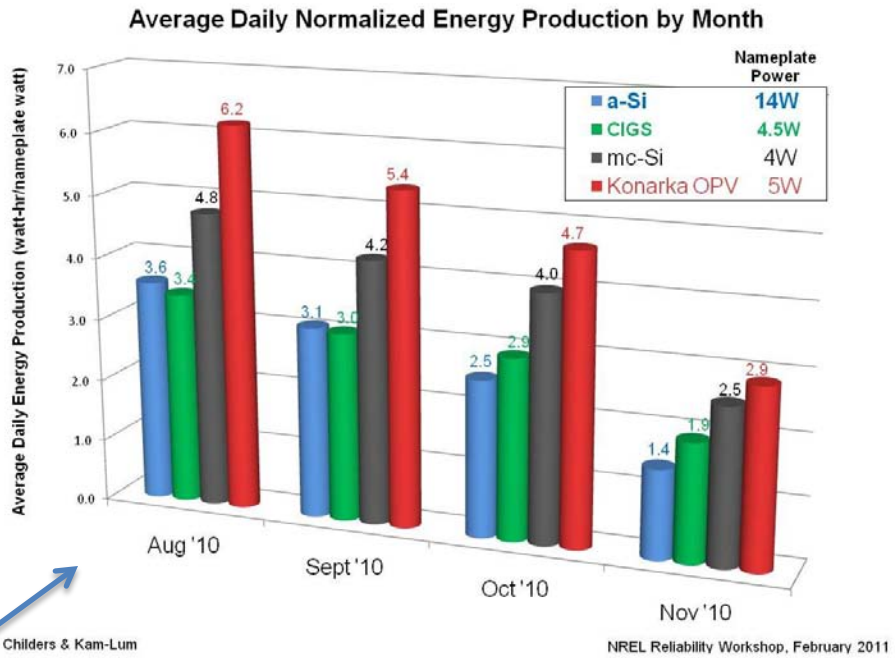
Reported Data Include:

- Rigid Glass/Power Plastic Laminates TUV Rheinland, Cologne, Germany
- Flexible Power Plastic Laminates, Preliminary Internal test results by Konarka Technologies, Lowell, MA

Power Plastic™ Enables Glass, Polymer and Flexible Component Constructions

KONARKA®





Advantages:

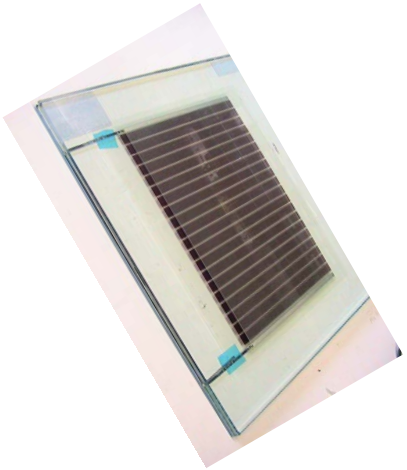
- Flexible, thin, lightweight- portable
- Low light sensitivity, indoor and outdoor
- Off angle performance
- Collects energy up to 70 off axis
- Sunrise to sunset power generation
- Can be used on vertical surfaces
- Transparent version in multiple colors
- Low cost manufacturing/printable
- Customizable by voltage requirements
- Tunable cell chemistry can absorb specific wavelengths of light
- Positive thermal coefficient

Rigid Laminations Feasible by Industry Standard Process Methods

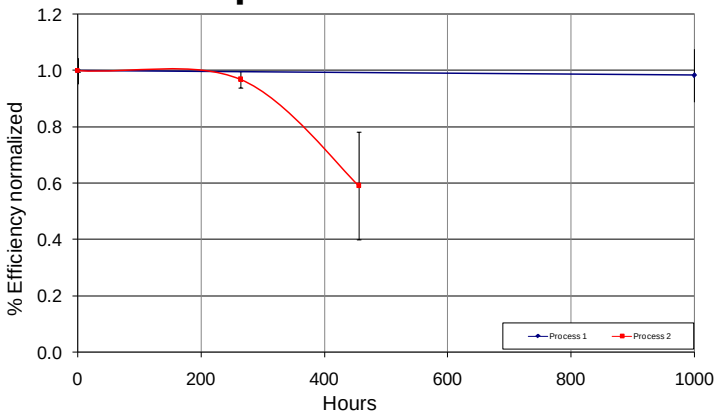
Vacuum Laminator

Vacuum Oven

Autoclave



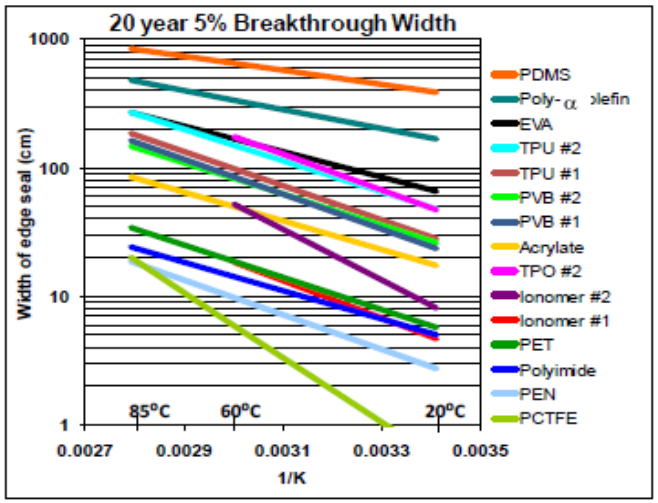
Comparison of Process 1 & 2
Damp Heat 85C/85%RH



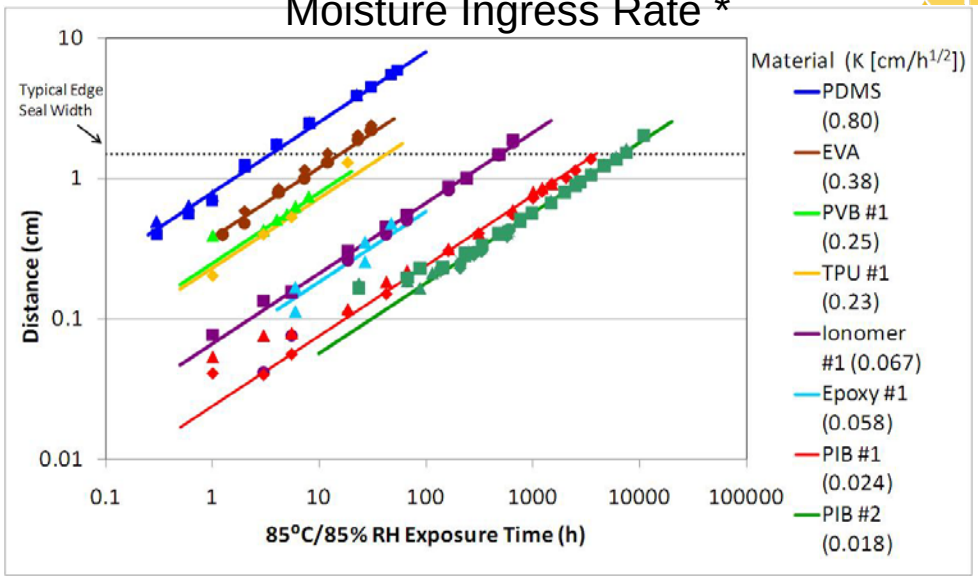
Manufacturing versatility for the fabrication of flat and non-flat rigid glass, polycarbonate and acrylic laminates

Process technology & development optimization required.

Effect of Interlayer in Glass Laminates DH Performance

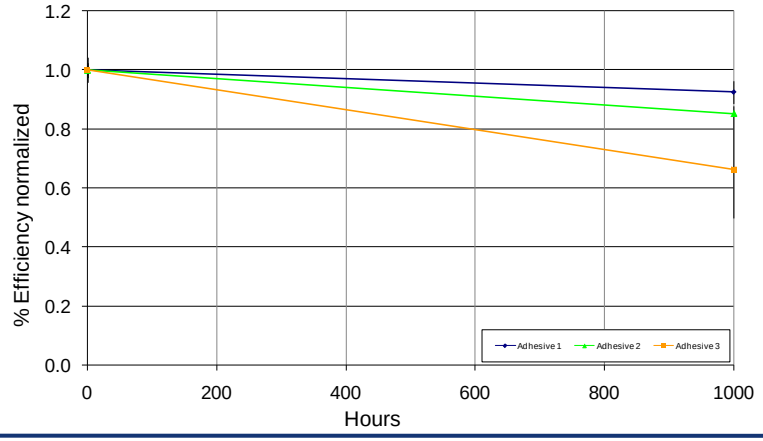


**Width of edge seal made from different materials that would be necessary to keep moisture below 5% of equilibrium values at a given temperature*



Penetration depth of moisture between glass plates laminated with different materials as measured by oxidation of a 100nm film of Ca *

Comparison of Adhesives 1, 2, 3 in Damp Heat, 85C/85%RH

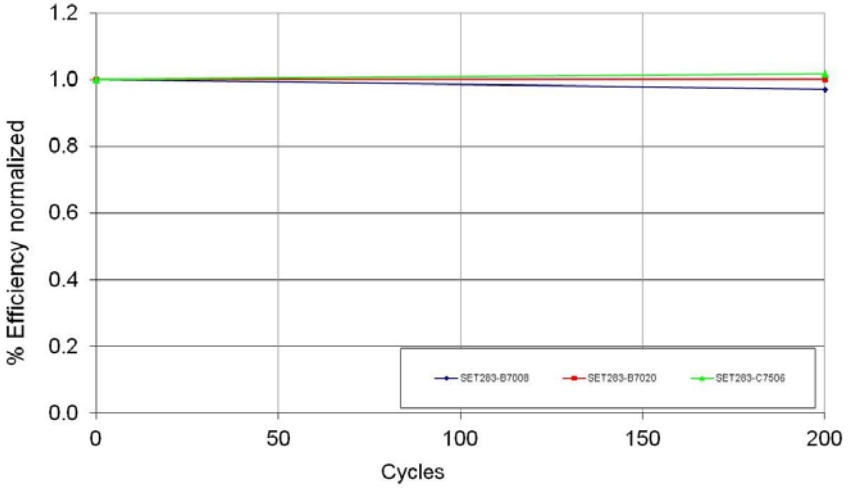


Interlayer Type	Supplier WVTR, g/day/m2 (ASTM F1249)	Average % weight loss @100 oC/30 min by TGA
Type 1	20	2.7
Type 2	40	1.7
Type 3	20	0.6
Type 4	<1.0	<0.01
Type 5	<1.0	0.3

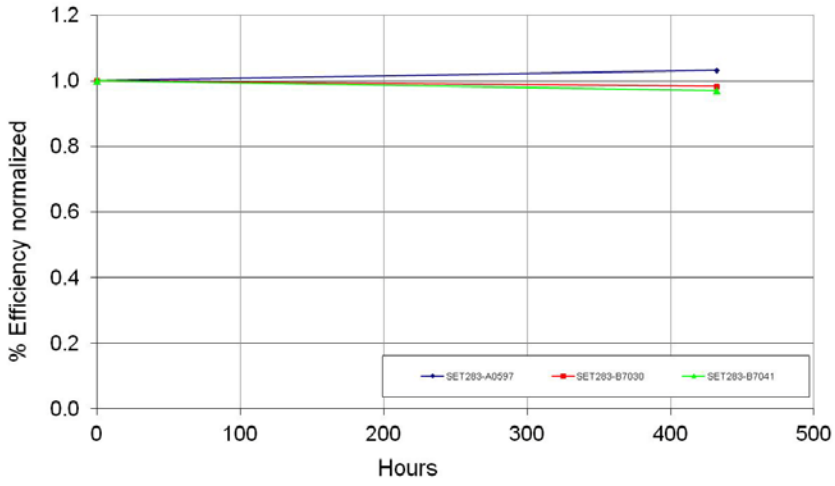
*Kempe, M., "Overview of Scientific Issues Involved in Selection of Polymers for PV Applications", 37th IEEE Photovoltaic Specialists Conference, Seattle, WA June 19-24, 2011

Flexible OPV Modules Laminated in Glass. IEC 61646 – results by TUV Rheinland

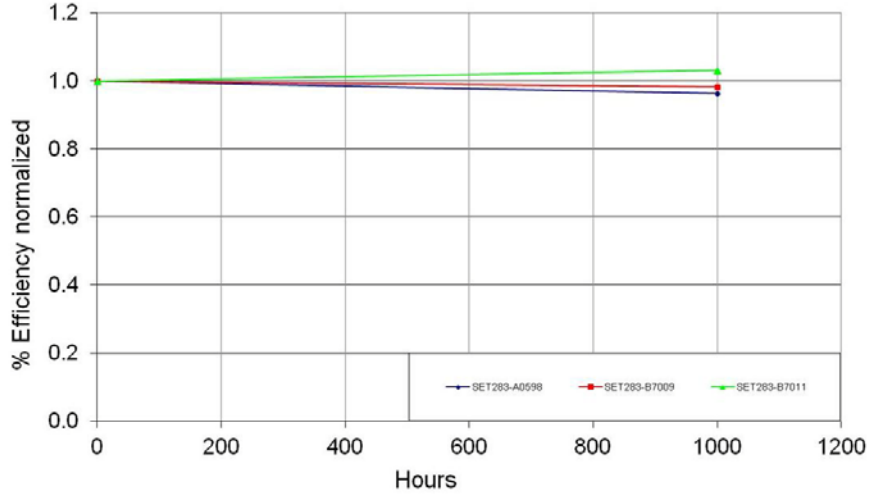
IEC 61646 10.11 TC 200 cycles



IEC 61646, 10.10 UV + 10.11 TC50 + 10.12 HF10

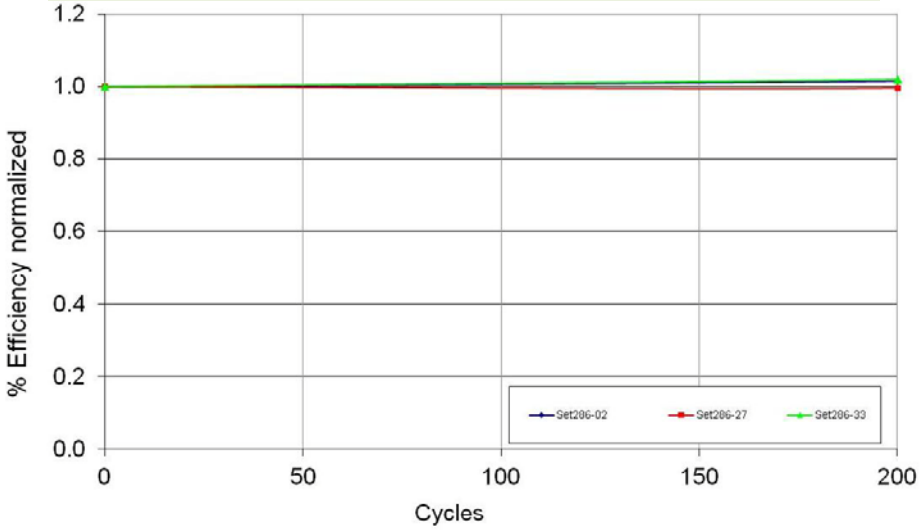


IEC 61646 10.13 DH 1000 hrs 85C/85%RH

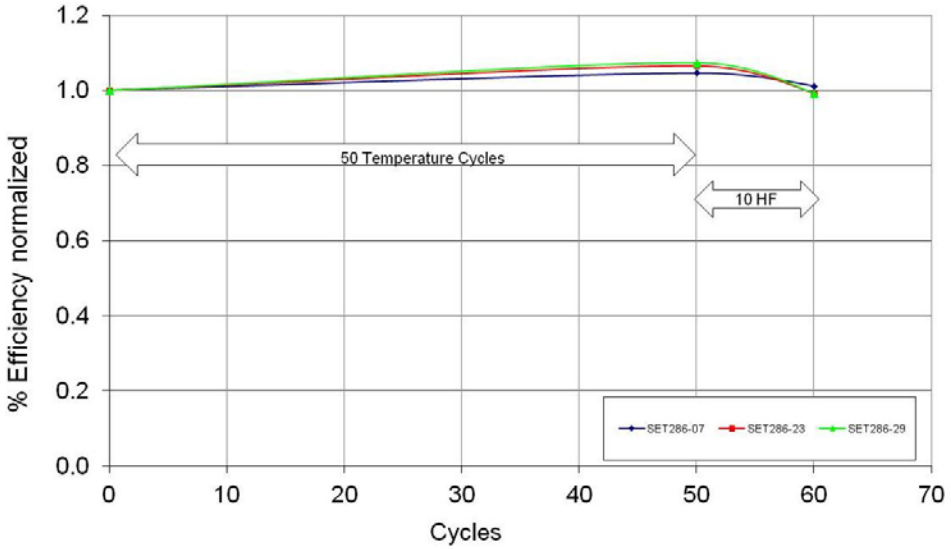


Flexible OPV Modules. IEC 61646 - Konarka Internal Results

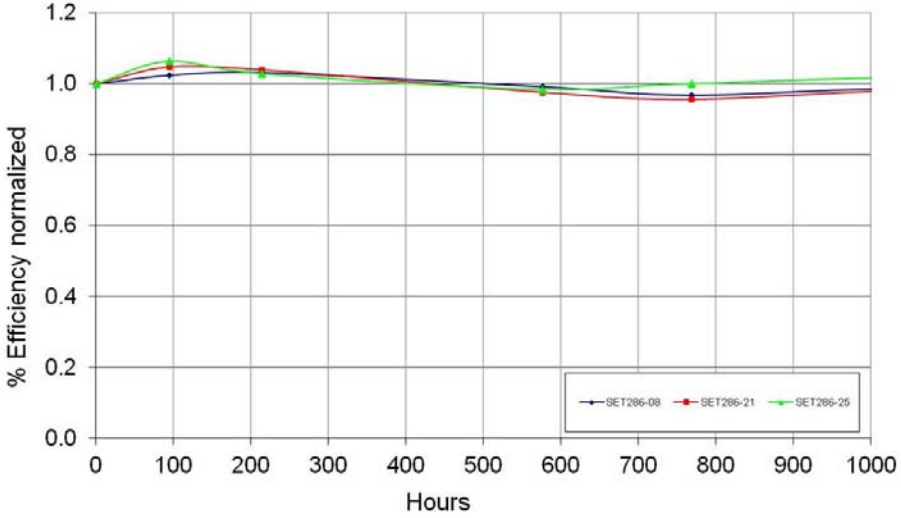
IEC 61646 10.11
TC 200 cycles, -40 C to 85 C



IEC 61646 10.11 TC50 + 10.12 HF10

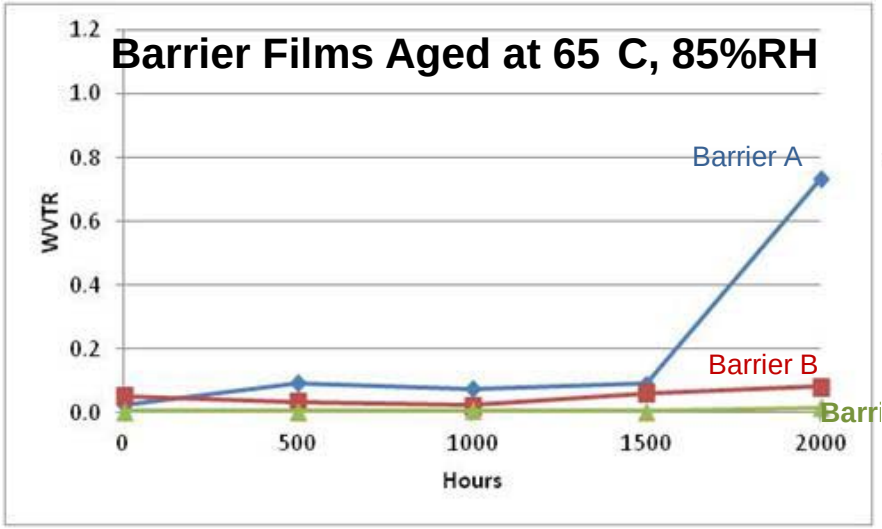


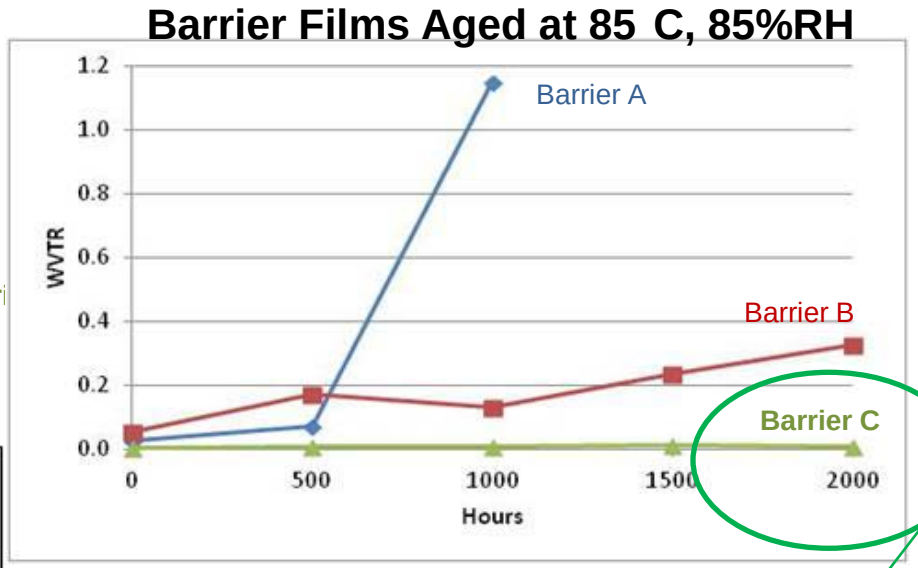
IEC 61646 10.13 DH 1000 hrs 85C/85%RH

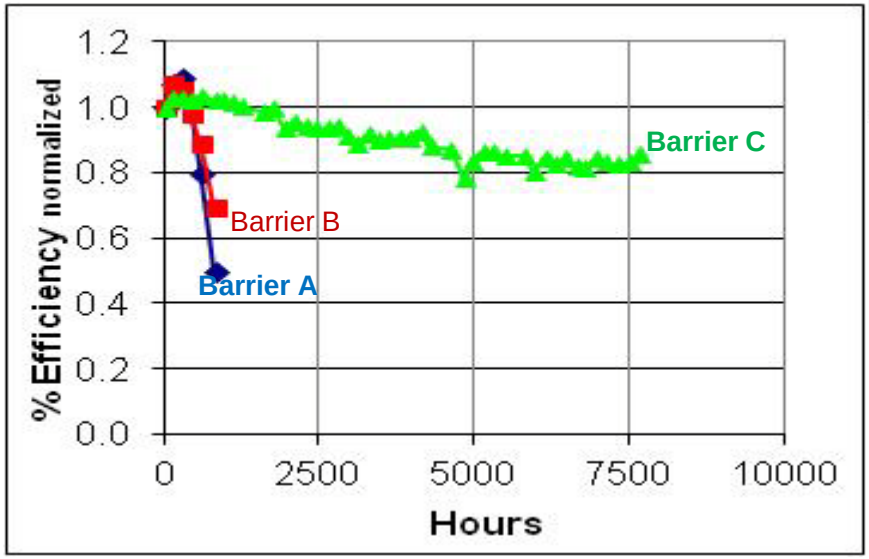


To Pass IEC 61646, Flexible OPV Modules

Require Excellent WVTR Barriers that are Stable Over Long Exposure Time







Modules Performance @65 C/85% RH

Barrier C necessary to pass IEC 61646, 10. 13: 1000 hours @85C/85% RH

Barriers Initial WVTR*

Barrier A: 4 x 10^{-2} g/m²/day

Barrier B: 5 x 10^{-2} g/m²/day

Barrier C: 5 x 10^{-3} g/m²/day

** WVTR derived from internal calcium test conducted at 65 C, 85%RH. Not MOCON WVTR test at 38 C/ 100%RH*

Conclusions

- OPV modules can pass IEC 61646 climatic chamber test requirements with the appropriate outside barrier. For glass laminated modules one combination of optimized layers tested by TUV Rheinland passed. Optimization of the layers and lamination process are necessary.
- OPV modules encased in glass can be manufactured by industry standard process methods
- For flexible OPV modules, internal tests indicate good probability of passing with a stable barrier with WVTR* of $\leq$ $5x\ 10^{-3}$ $g/m^2/day$. Tests are in progress at TUV.

** WVTR derived from internal calcium test conducted at 65 C, 85%RH. Not MOCON WVTR test at 38 C/ 100%RH*