The Reliability and Durability of Novel Silicone Materials for Photovoltaic Encapsulation

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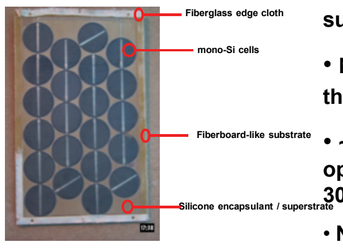
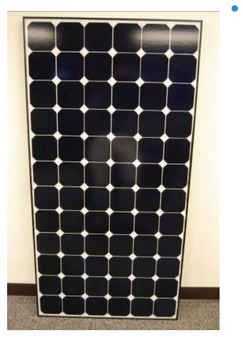


- Module encapsulated by Silicone rubber as superstrate, fiberglass as substrate with potted junction box.
- Modules operated over 27+ years in the hot desert condition.
- ~70% of modules still functional operating, average power drop about 30% from its power rating.
- No notable delamination of the superstrate and busbar corrosion observed even after additional stress tests applied.

- Module from solar array at BP Solar in Frederick, Maryland.
- These modules were encapsulated with silicone only without backsheet.
- Modules still delivery > 90% of nameplate rating after 15 years operating and 10 years storage.
- No evidences show corrosion and yellowing.

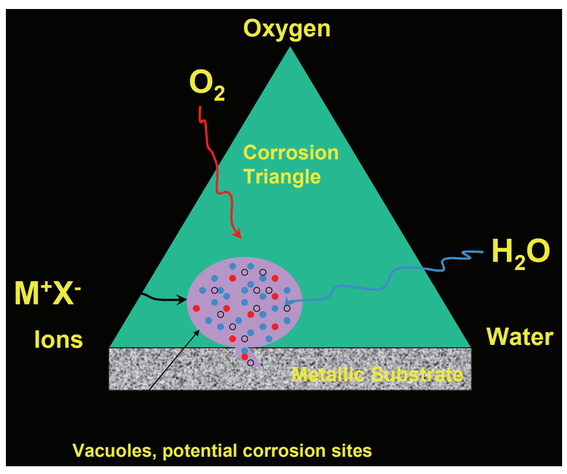


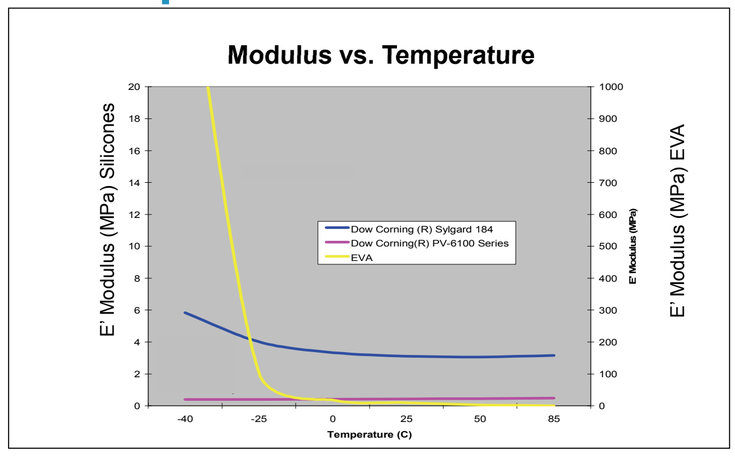
- SunPower Module with PV-6100 Series encapsulant made by 2009
- Fully-automated dispensing & cell-placement

Silicone properties make them ideal candidates as encapsulants for photovoltaic modules

General Silicone Composition and Optical Properties

- Excellent UV-visible transmittance 250 to 900 nm
- Good near-IR transmittance 1000 to 1600 nm
- Tunable refractive index 1.38 to 1.58
- Range of dn/dT –2 … –5×10^{-4} °C
- Low modulus/Low T_g
- Variety of cure chemistries available
  - Addition cure, Pt catalyzed
  - Condensation cure
- Excellent environmental stability, no change in properties:
  - High temperature stability (150 °C continuous)
  - Low moisture pick-up (<0.05%)





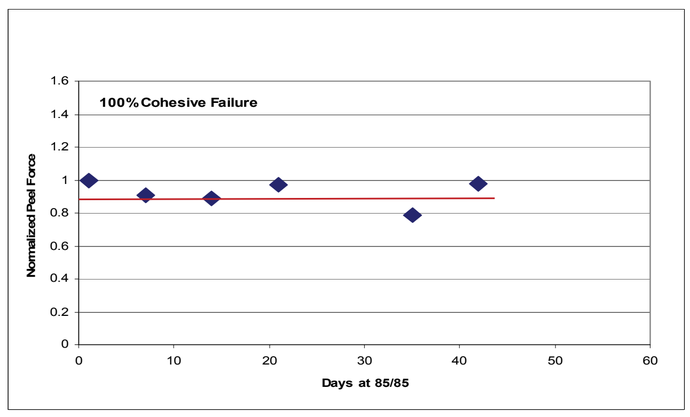
Silicones can be formulated to be low modulus over a very wide temperature range due to the very low T_g. Whereas EVA and other organic polymers have higher modulus at low temperatures.
Low modulus promotes stress relief in encapsulation applications.

Dielectric Properties-Silicones are known for having good electrical insulating properties

Material	Dielectric strength, V/mil	Thickness, mils (mm)	Break through voltage, kV
PV-6100 Series	720	21 (0.53)	15.1
EVA	907	17 (0.43)	15.4

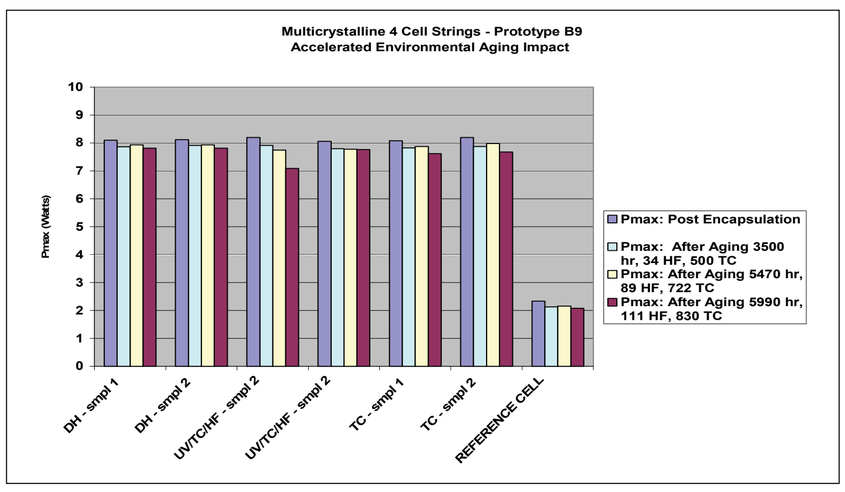
Partial Discharge Test For Silicone Encapsulation

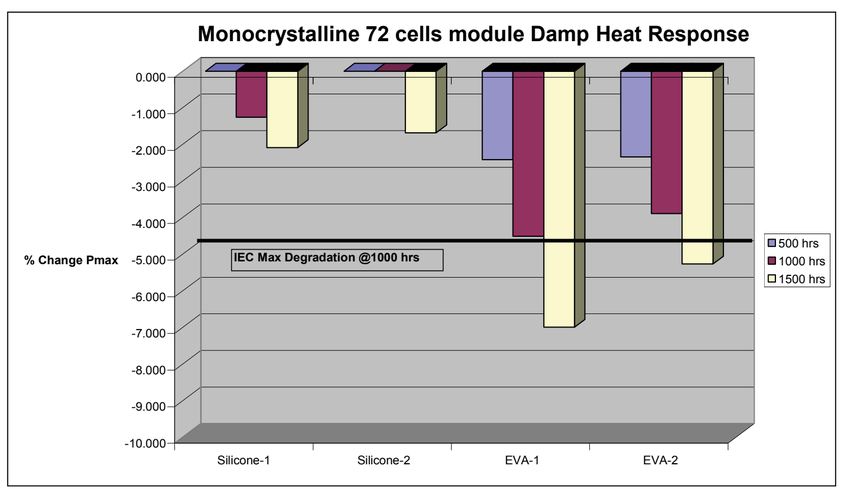
Sample	Corrected Extinction Voltage	Results
Tedler (25 micro) /Polyester(15mil)/Silicone #1	1220	> EU Rated
Tedler (25 micro) /Polyester(15mil)/Silicone #2	1058	> EU Rated
PET Backsheet (50 micro)/Polyester(15mil)/Silicone #1	1098	> EU Rated
PET Backsheet (50 micro)/Polyester(15mil)/Silicone #2	1165	> EU Rated
Silicone #3/Polyester (15mil)	1019	> EU Rated
Silicone #3 (30mil)	No Break Down	> EU Rated
Silicone #2 (30mil)	No Break Down	> EU Rated

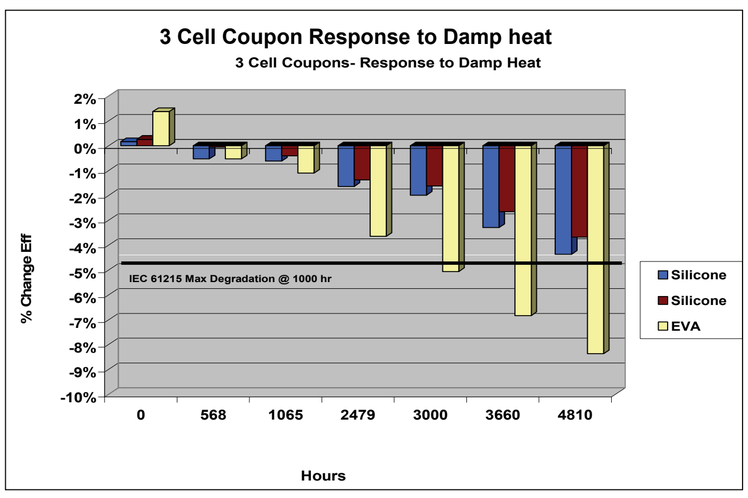


Silicones can be formulated to show only cohesive failure after 1000 hours of 85/85 exposure, no drop in peel force

Silicones encapsulant has better reliability and durability over EVA







Dow Corning INTERNAL

IEC 61215 Certification

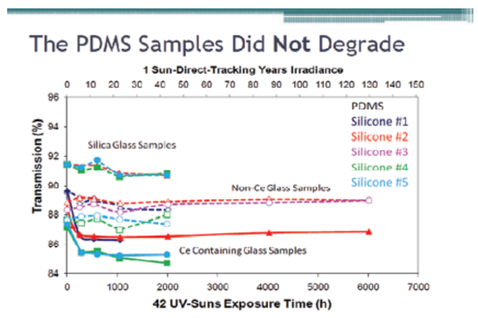
- Passed UV Exposure/Temperature Cycling 50/ Humility Freeze 10 in TUV-PTL.
- Passed Damp Heat (85C/85%) 1000 hours in TUV-PTL.
- Passed Mechanical load after DH1000 test in TUV-PTL.
- Passed Thermal Cycling 200 cycles internally.
- Passed Outdoor exposure/ Hot spot tests in TUV-PTL.
- Passed Fire Test (Class C) in Western Fire Center Inc.
- Full IEC 61215/61730/UL1703 engineering evaluation on going in TUV-PTL.

Dow Corning INTERNAL

Extended Aging Beyond Certification

- The Dow Corning® PV-6100 Encapsulant Series has passed IEC 61215 specifications even up to 500 Thermal Cycles on full size modules.
- The Silicone encapsulant has been approved under "Fast thermal cycling (-30C ~ 60C)" test up to 2000 cycles on 2 cells coupons and will continue to end.
- Silicone encapsulated PV modules have been passed up to 4800 hours damp heat (85C/85%) on 3 cells coupons and passed 1500 hours on full size modules.

•Two Silicone encapsulated PV systems are operation in Michigan's four season climate. Other installations are planned in other regions.

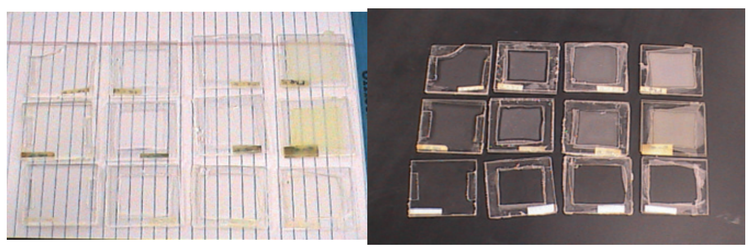


* By Michael Kempe's (NREL) presentation at ATLAS conference

41 hr DH

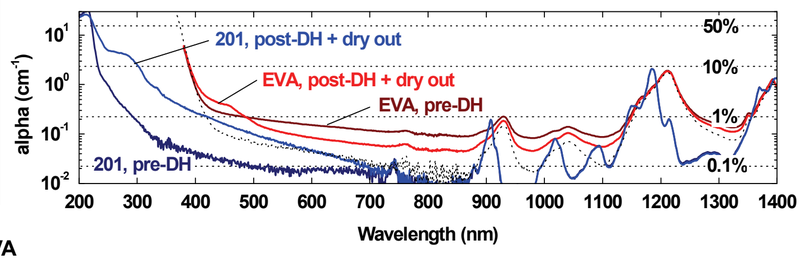
740 hr DH

833 hr UV

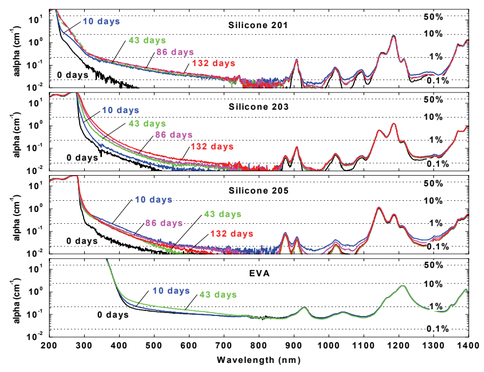


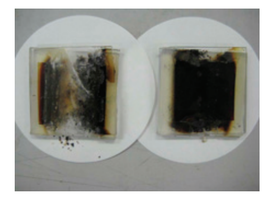
Silicone A Silicone B Silicone C EVA Silicone A Silicone B Silicone C EVA

Comparison of alpha before and after damp heat aging



Alpha Response to 30X roof top concentrator @ ANU





EVA charred after 86 days on 30X tracker

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