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Backsheet cracking – a global phenomenon

14 November 2023

9:00 am – 10:00 am | EST, New York City
3:00 pm – 4:00 pm | CET, Berlin
6:00 pm -7:00 pm | GST, Dubai

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PROBLEM OF BACKSHEET CRACKING OVERVIEW OF POSSIBLE REPAIR SOLUTIONS

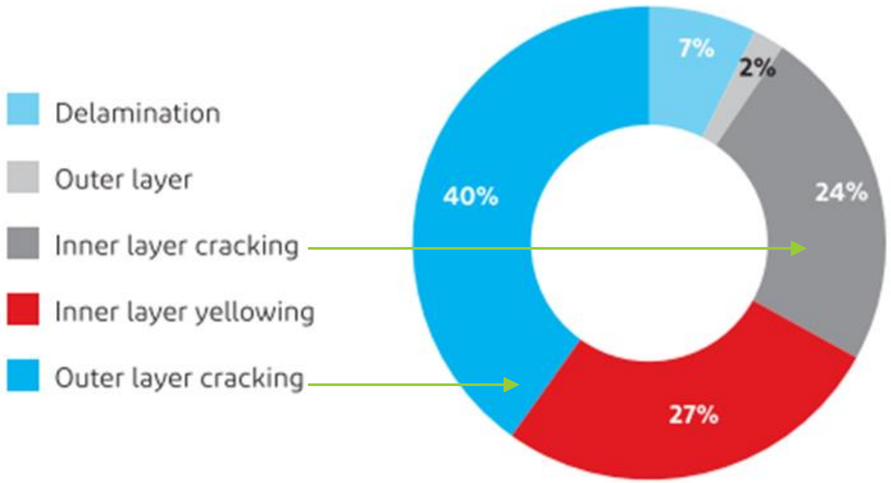
Gabriele C. Eder & Yuliya Voronko - OFI, Austria

Global field data analysis (performed by DuPont)

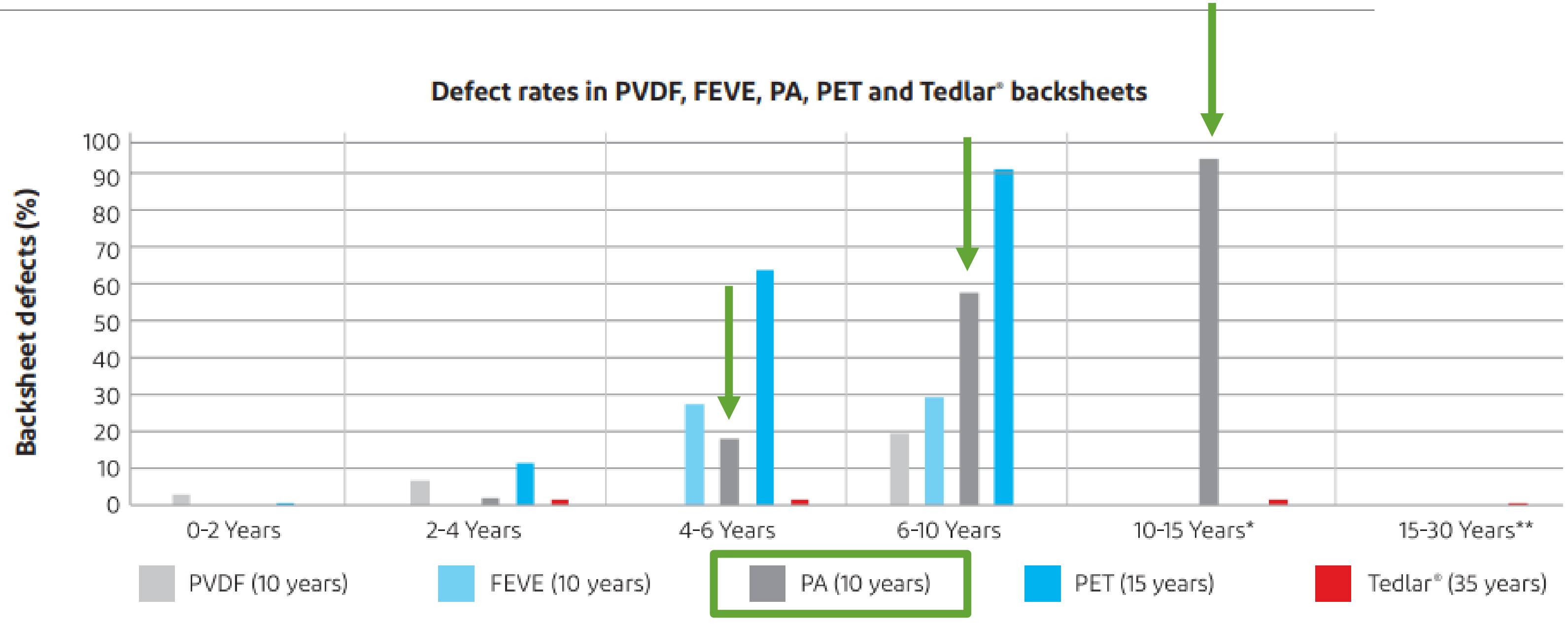
Inspection observations based on 3GW of fields:

- Total module defects: 30%
- Total backsheet defects: 16%
- Total cell/interconnect defects: 14%
- Cracking comprises 64% of all backsheet defects

Backsheet defects by degradation mode



Defect rates in PVDF, FEVE, PA, PET and Tedlar® backsheets



PA = Polyamide
PET = Polyethylene terephthalate

PVDF = Polyvinylidene fluoride
FEVE = Fluoroethylene vinyl ether

*No PVDF, FEVE or PA backsheets in this age range exist in the field.

**No PVDF, FEVE, PA or PET backsheets in this age range exist in the field.

Backsheet defects in the field

Degradation and failure modes

Table I. Severity rating used to rate and rank different degradation modes.

Severity	Rating
Major effect on power and safety	10
Major effect on power	8
Moderate effect on power	5
Slight deterioration of performance	3
No effect on performance	1

Table II. Summary of degradation modes with their severity rankings.

Mode	Severity
Encapsulant discoloration	3
Major delamination	5
Minor delamination	1
Backsheet insulation compromise	10
Backsheet other	1
Internal circuitry discoloration, series resistance increase	5
Internal circuitry failure, solder bond failure	8
Hot spots	10
Fractured cells	5
Diode/J-box problem	5
Glass breakage	5
Permanent soiling	2
Potential induced degradation	8
Frame deformation	3

around 11-12 GW of PV with PA-backsheets installed (2010-2015)

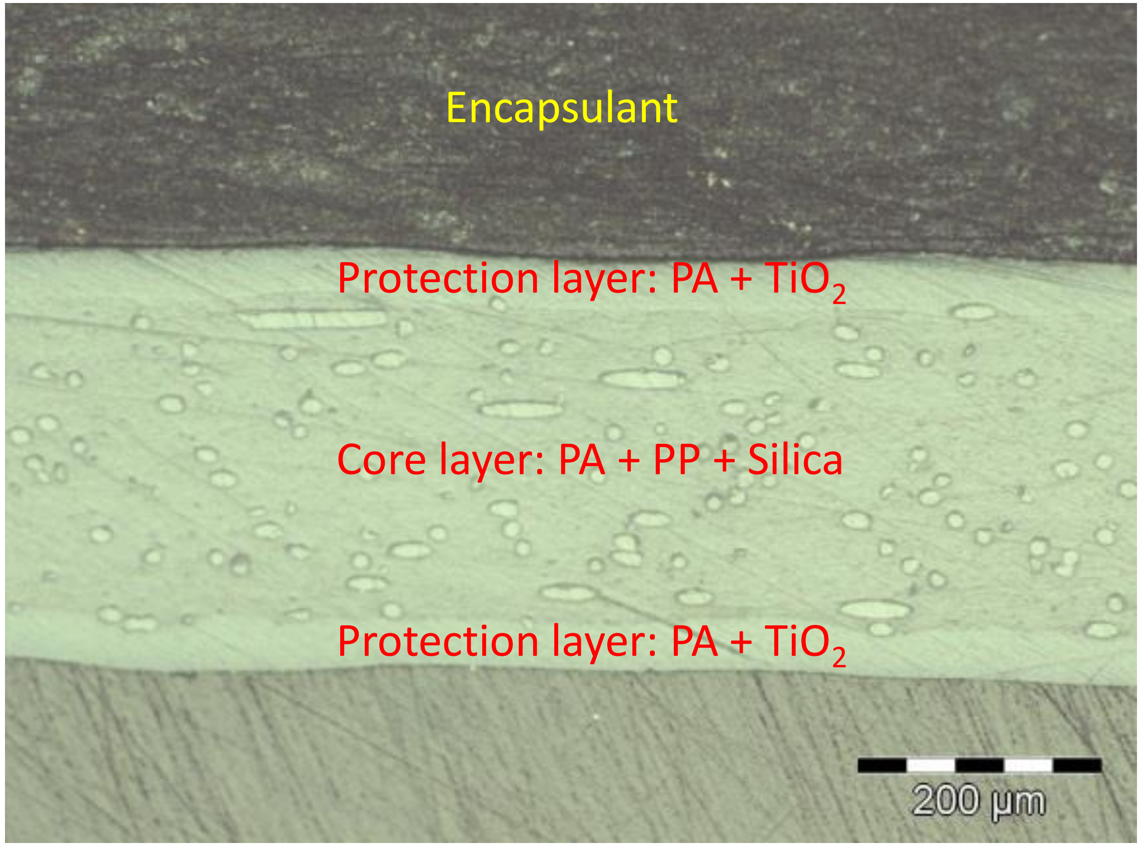
Photovoltaic failure and degradation modes
D. C. Jordan, T. J. Silverman, J. H. Wohlgemuth, S. R. Kurtz, K. T. VanSant; *Prog Photovolt Res Appl*, vol. 25, pp. 318-326, April 2017.

PA-Backsheet structure

Light microscopy

Polyamide-Backsheet:

Cross-section of co-extruded backsheet



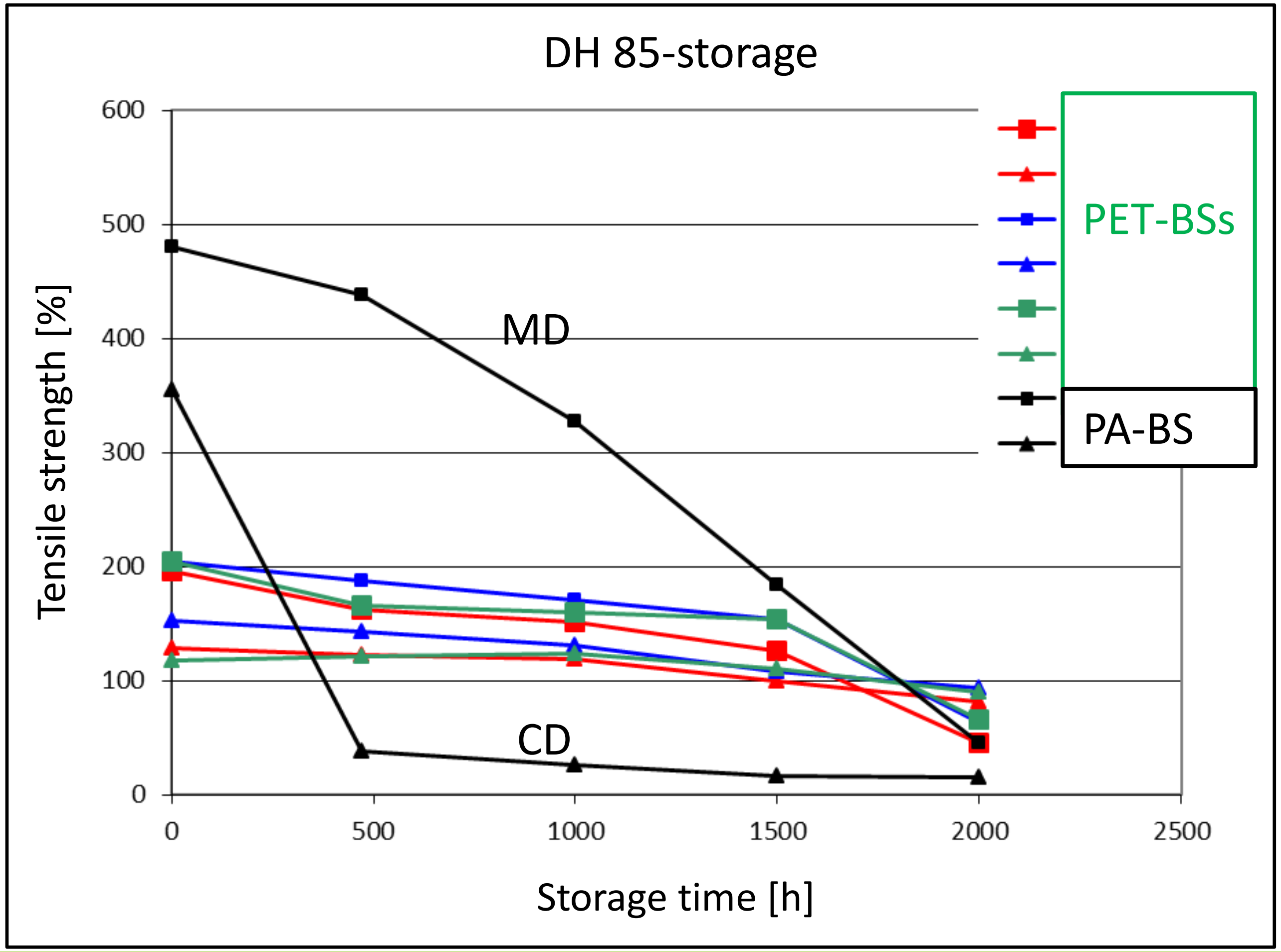
PA-Backsheet -mechanical characteristics

Tensile testing

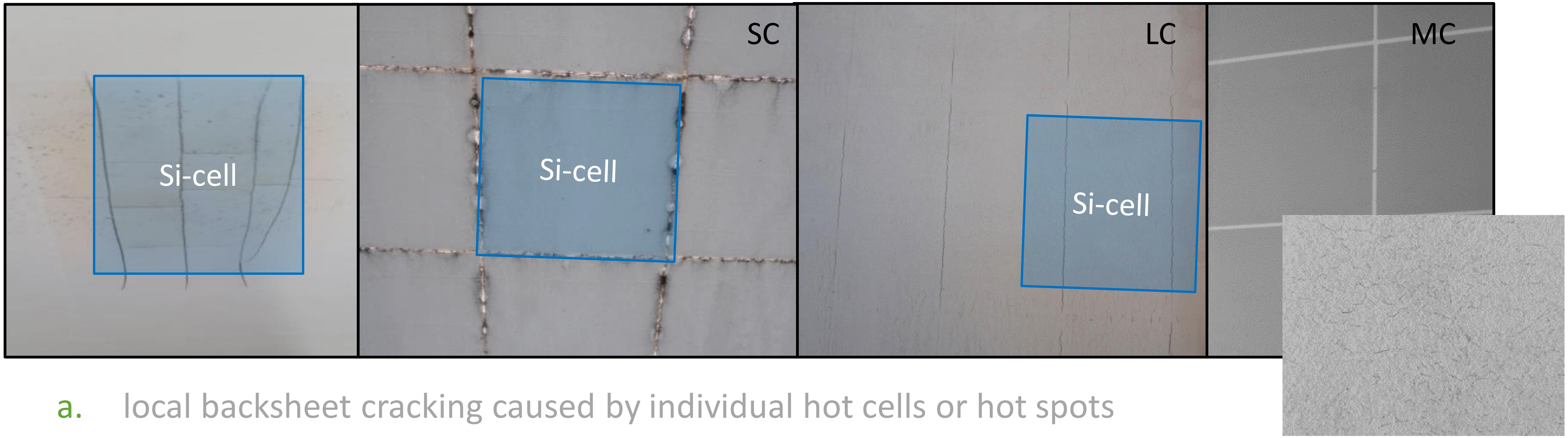
High anisotropy:
machine (MD) : cross (CD) direction of PA-backsheet

after accelerated aging:

- DH 85 -storage
- UV-irradiation



PA-Backsheet cracking



a. local backsheet cracking caused by individual hot cells or hot spots
b. Tile-shaped, square cracks – between cell areas; SC
c. Longitudinal cracks (along the busbars of the cells); LC
d. Microcracks in the outer layer; MC

Impact on electrical output & safety

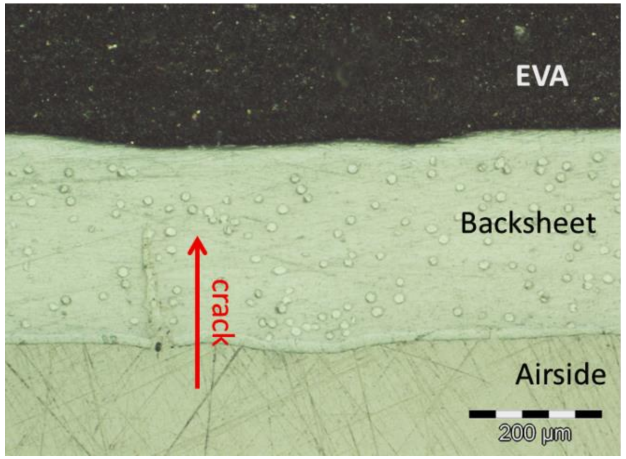
- Backsheet defects such as chalking and microcracks have no immediate impact on electrical output, but are precursors to further backsheet deterioration/cracks and
- in the initial state, longitudinal and square cracks have no effect on the electrical performance

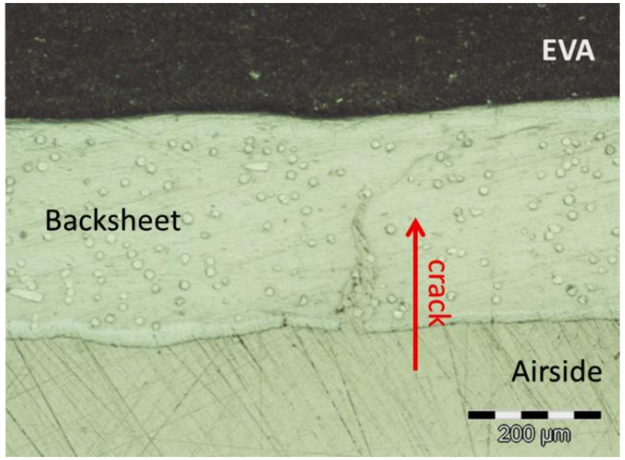
  BUT deep SC and LC can pose a safety issue due to a reduction in insulation resistance (when wet) (has to be > 40 MΩ.m^2 according to a wet leakage current test MQT 15, IEC 61215-2); Operational problems (inverter failure) can also occur

- with increasing operational time incoming moisture and oxygen lead to oxidation and corrosion effects

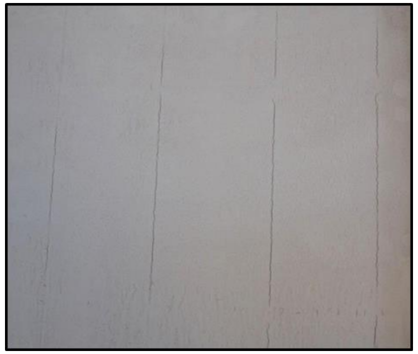
Visualisation : Longitudinal and micro cracks

LC, MC, CH

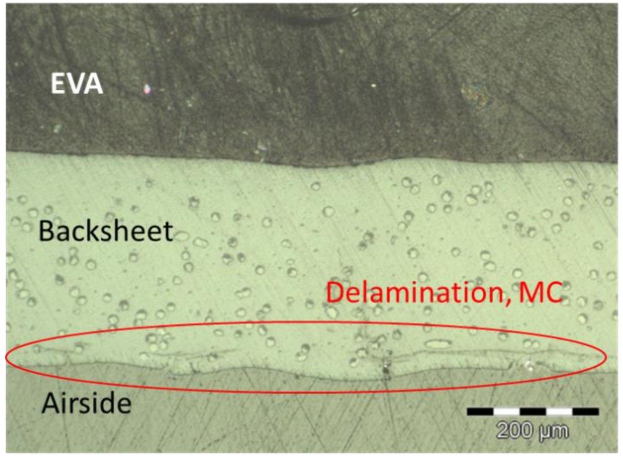


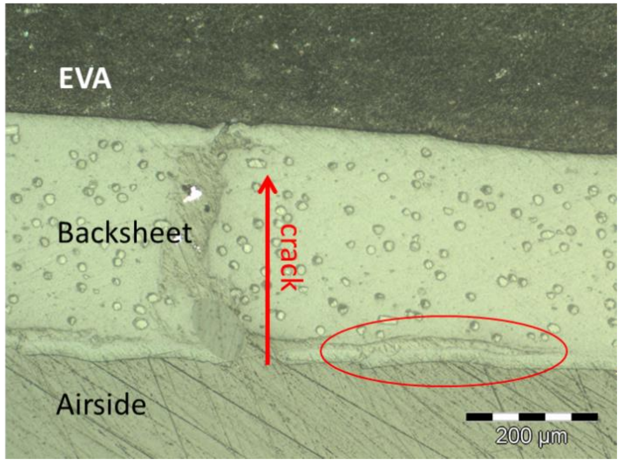


physical cracks in PA outer layer and core layer



LC, MC

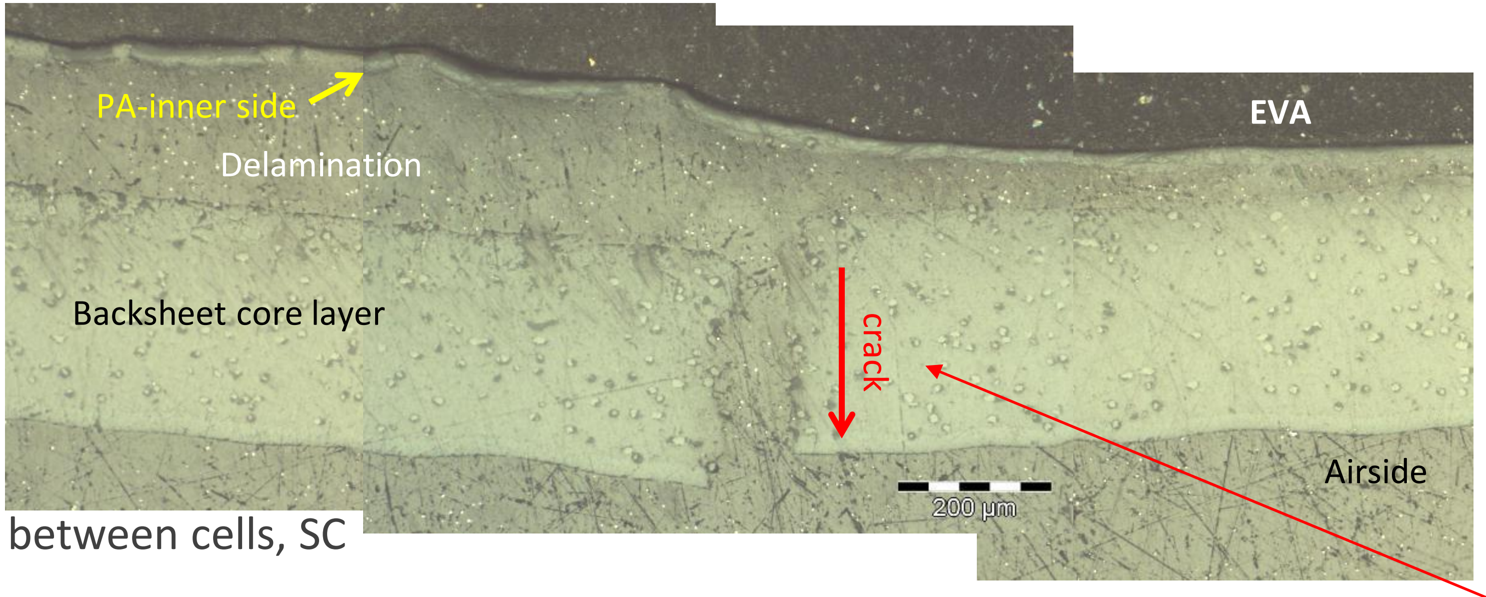




delamination of PA outer layer,
cracks in PA outer layer and core layer
no chemical degradation

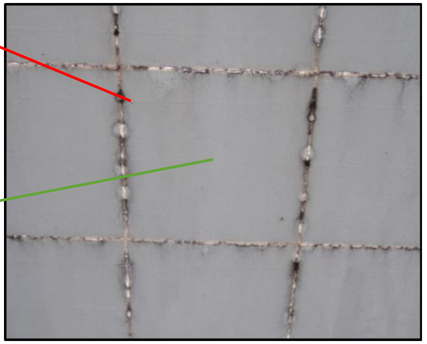
ERROR ANALYSIS OF AGED MODULES WITH CRACKED POLYAMIDE BACKSHEETS; Gabriele C. Eder, Yuliya Voronko, Gernot Oreski, Wolfgang Mühleisen, Marlene Knausz, Antonia Omazic, Alois Rainer, Christina Hirschl and Horst Sonnleitner, Solar Energy Materials & Solar Cells 203 (2019) 110194, DOI: 10.1016/j.solmat.2019.110194

Visualisation : squared cracks

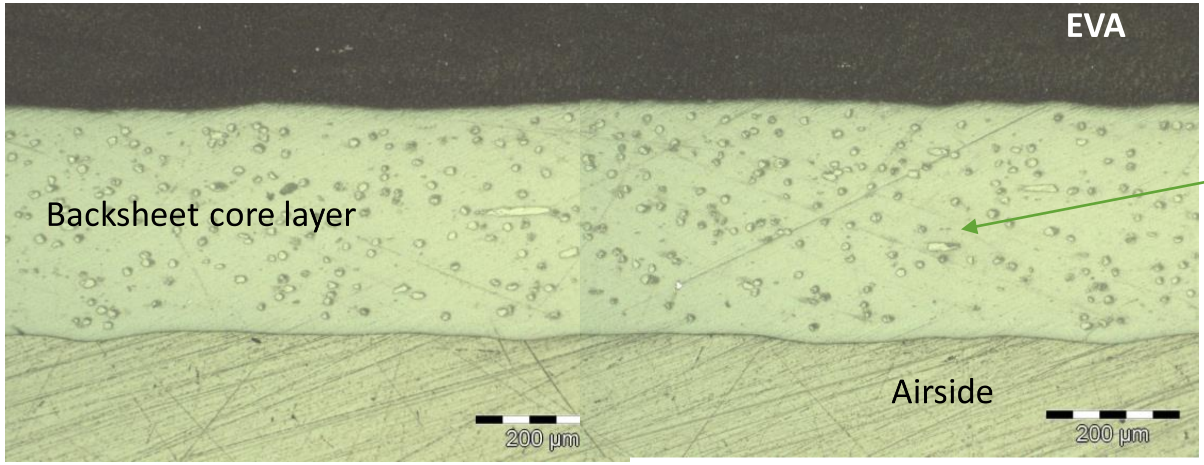


between cells, SC

- Delamination inner layer / core layer + chemical degradation
- crack in core layer + chemical degradation

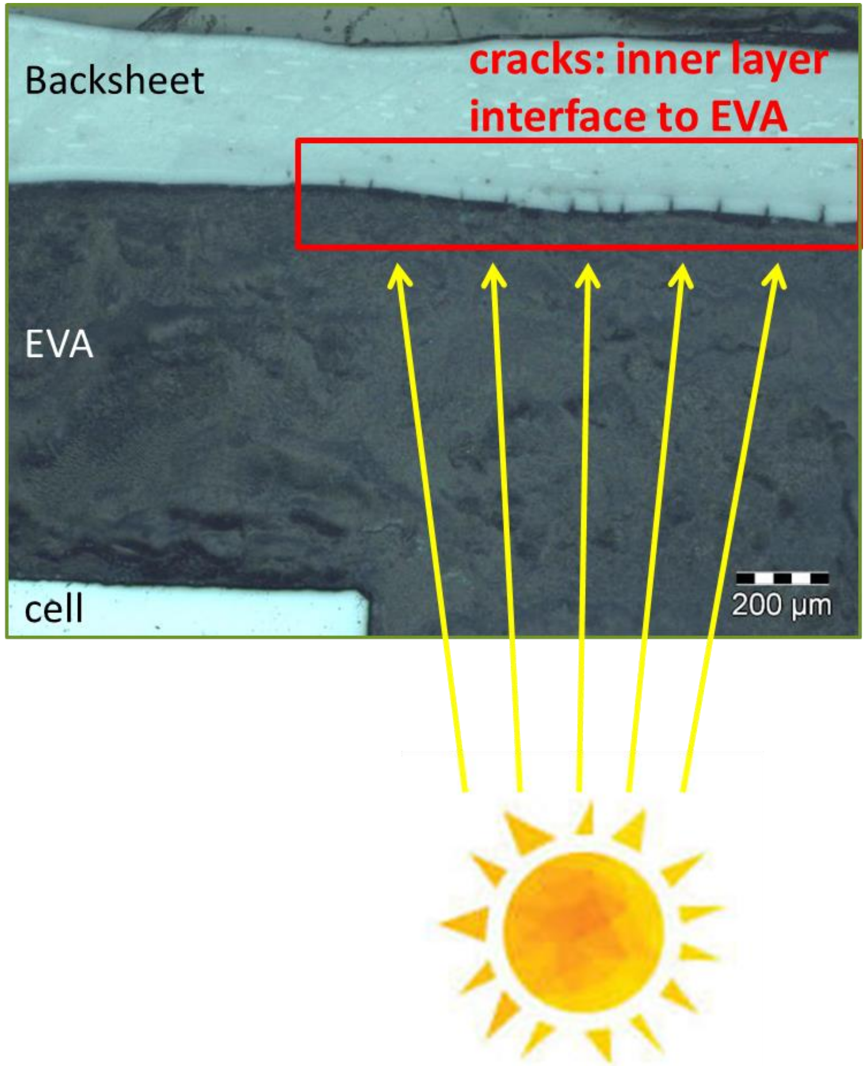


below cells, SC



BUT: below the cells, all backsheet layers are intact

ERROR ANALYSIS OF AGED MODULES WITH CRACKED POLYAMIDE BACKSHEETS; Gabriele C. Eder, Yuliya Voronko, Gernot Oreski, Wolfgang Mühleisen, Marlene Knausz, Antonia Omazic, Alois Rainer, Christina Hirschl and Horst Sonnleitner, Solar Energy Materials & Solar Cells 203 (2019) 110194, DOI: 10.1016/j.solmat.2019.110194



EVA-grade is important!

Problem: if EVA is without UV-stabiliser is used

SC: Cracks in the inner PA-layer / EVA-interface

ERROR ANALYSIS OF AGED MODULES WITH CRACKED POLYAMIDE BACKSHEETS; Gabriele C. Eder, Yuliya Voronko, Gernot Oreski, Wolfgang Mühleisen, Marlene Knausz, Antonia Omazic, Alois Rainer, Christina Hirschl and Horst Sonnleitner, Solar Energy Materials & Solar Cells 203 (2019) 110194, DOI: 10.1016/j.solmat.2019.110194

Summary of failure analysis

	Square cracks	Longitudinal cracks	Micro cracks	Chalking
Change in BS-Thickness	no	no	yes, when delamination	Yes
Crack propagation	from inner PA layer into core layer	from outer PA-layer into corelayer	in outer PA-layer	-
Oxidative degradation	starting from EVA/PA interface -> into crack	only outer PA-surface layer (weathering)	only outer PA-layer	outer PA-surface
Influence EVA-quality	yes (UV-stabilisation)	no	no	no

Possible repair strategies

→ Repair instead of exchange

Investigations on different failure modes

Identify suitable materials

optimize application solutions

Repair process (with/without dismounting)

Aim:

Restoring of electrical insulation and safe operation in the field
(? reliability testing of repaired modules ?)

Y. Voronko, G. Eder, C. Breitwieser, W. Mühleisen, L. Neumaier, S. Feldbacher and G. Oreski, Repair options for PV modules with cracked polyamide backsheets, in 37th EU PVSEC (online, 2020) and Energy Sci Eng. 2021; 9: 1583– 1595. https://doi.org/10.1002/ese3.936

Identification of suitable materials

<u>System requirements:</u>

- Clean and water-free surface/crack

1. Filler
   - ✓ Low viscosity: easy to enter pores/penetrate
   - ✓ form a water vapour barrier

2. Coating
   - diffusion barrier
   - electrically insolating
   - mechanically stable
   - weathering resistant

MATERIAL COMPATIBILITY

<u>Possible solutions for coating:</u>

- 1-K-system, air or humidity drying
- 2-K coating systems (curing via mobil UV or thermal dryer)

Suitable application solutions

Application for coating solution:

- Avoid solvents and dangerous substances
- Coating with brush, roller, spraying, spatula, squeegee…..
- Curing: preferably under ambient conditions; otherwise thermally or via irradiation

Application of tapes or foils via an adhesive system:

- Surface pretreatment might be neccessary
- Adhesive has to have good wetting ability of the weathered surface
- PSA or solvent based adhesives

Repair strategies

	Tape		BS-foil		Adhesive or Coating (fill and coat)	
	lab	field	lab	field	lab	field
local	x	x	-	-	x	x
continous deck	-	-	x	?x	x	x

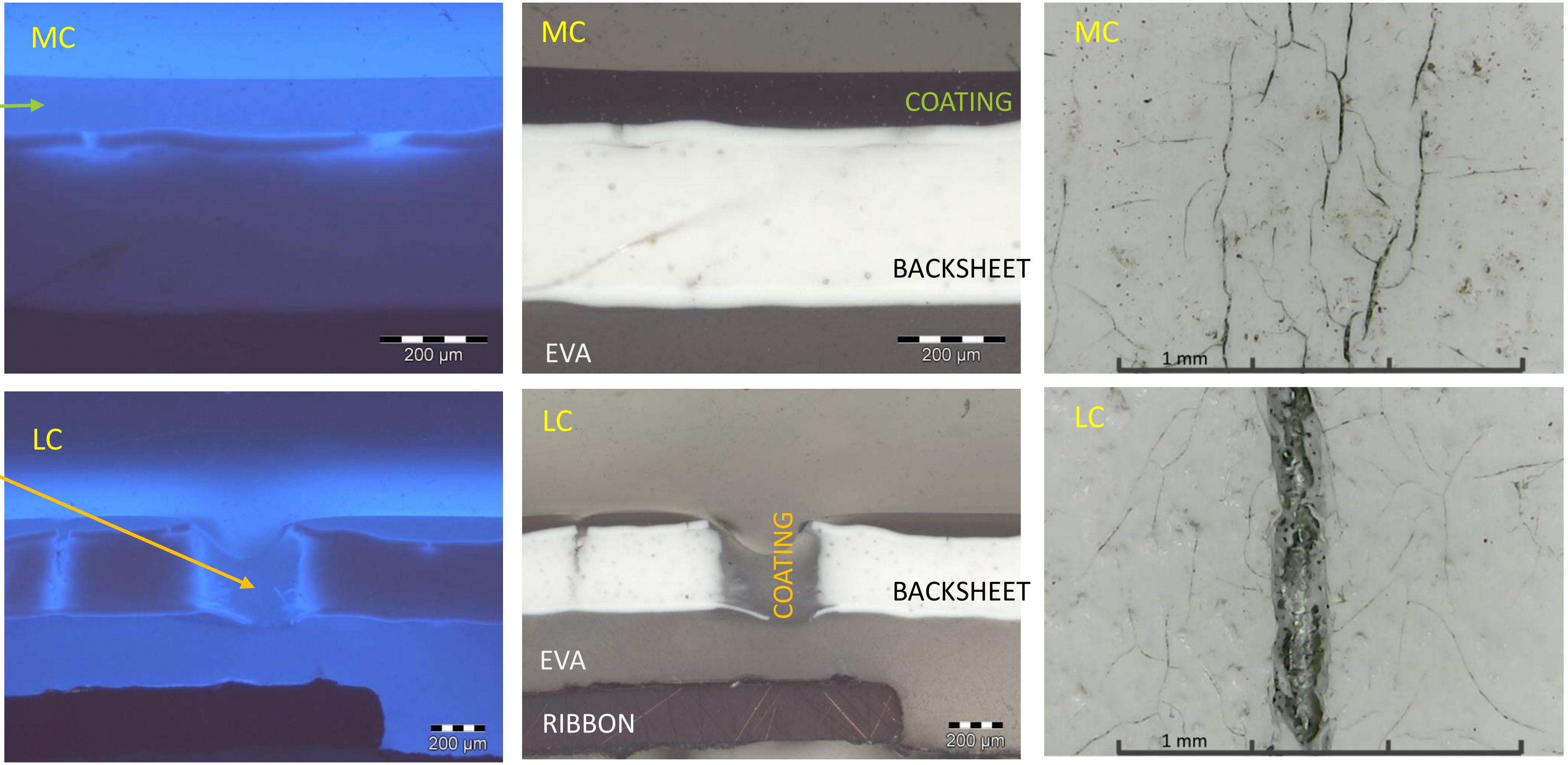
Multi-step process:

1. Cleaning
2. Filling of cracks + drying
3. Barrier layer of weather-resistant coating

Successful repair

Sealing /protection barrier layer

Crack filling (no voids)



Microscopic images:
cross-sections
BS surface/airside

Y. Voronko, G. Eder, C. Breitwieser, W. Mühleisen, L. Neumaier, S. Feldbacher and G. Oreski, Repair options for PV modules with cracked polyamide backsheets, in 37th EU PVSEC (online, 2020) and Energy Sci Eng. 2021; 9: 1583– 1595. https://doi.org/10.1002/ese3.936

Summary: repair process & application solutions

Multi-step process

1. cleaning (mechanical wipping with wet towel)
2. pre-treatment (only for synthetic rubber coating)
3. coating (crack filling and continuous deck=protection layer)

   or tapes / foils

→ repair process in horizontal position preferred (in the field: with module dismounted)

Coating materials tested

- epoxy (1K)
- + mod. polyurethan (2K)
- + silicone adhesive
- + flowable silicone*
- synthetic rubber

→ best results with layer thicknesses of at least 100 µm

Tapes tested

Application

with

- brush
- + spatula / wipper / squeegee
- spray-coating

→ Applicable in one or two-step (with solvent) process

*Repair and Preventive Maintenance of PV Modules with Degrading Backsheets Using Flowable Silicone Sealant; Guy Beaucarne, Gabriele Eder, Emmanuel Jadot, Yuliya Voronko, Wolfgang Mühleisen, EU PVSEC 2021 5.DO.2.6. and PIP3492; DOI: 10.1002/pip.3492

Y. Voronko, G. Eder, C. Breitwieser, W. Mühleisen, L. Neumaier, S. Feldbacher and G. Oreski, Repair options for PV modules with cracked polyamide backsheets, in 37th EU PVSEC (online, 2020) and Energy Sci Eng. 2021; 9: 1583– 1595. DOI: 10.1002/ese3.936

Acknowledgment

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ENERGY RESEARCH 4th CALL TOPIC 5 . 5 PHOTOVOLTAICS

Backsheet repair
with DOWSIL™ PV-9001 Backsheet Coating

This is Dow

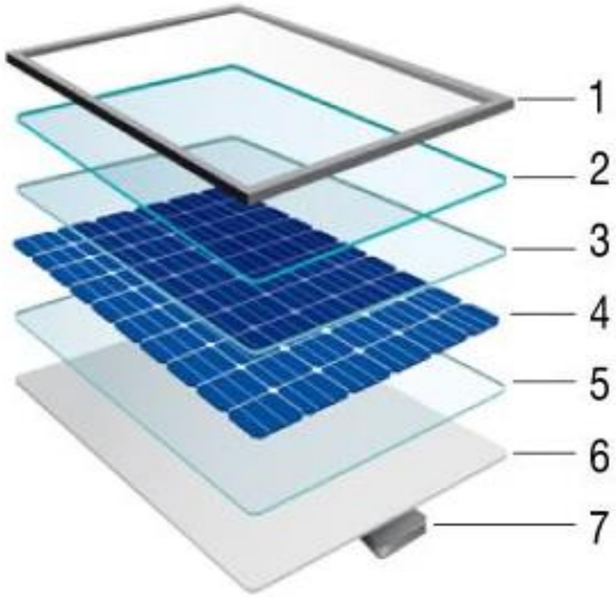
Every answer starts with asking the right question.

At Dow, these questions and the pursuit of solutions for the world's toughest challenges inspire us to collaborate and use our materials science expertise to create innovative solutions that transform our world and deliver a sustainable future.

2022 NET SALES	EMPLOYEES	MANUFACTURING SITES	GLOBAL REACH
$57B	**~37,800**	**104**	**31 countries** in which Dow manufactures products

Note: All data as of December 31, 2022

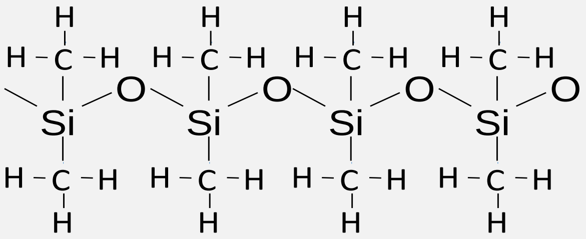
Dow materials for Photovoltaics



1. **Frame or rails**
   DOWSIL™ frame sealants and rail bonding adhesives
2. **Glass**
3. **Encapsulant**
   ENGAGE™ PV and DOWSIL™ encapsulants
4. **Solar cells**
5. **Encapsulant**
   ENGAGE™ PV and DOWSIL™ encapsulants
6. **Backsheet**
   DOWSIL™ coatings, ADCOTE™ adhesives, and DOW™ curing agents
7. **Junction box/power optimizer/microinverter**
   DOWSIL™ adhesives, potting agents, and electronics encapsulants

SILICONE COATING MATERIAL FOR BACKSHEETS

- Silicones:
  - polymer with Si – O backbone
  - Very stable and durable
  - Used in demanding applications (facades, automotive,…)
- For this application: DOWSIL™ PV-9001 Backsheet Coating
  - Single component material, which cross-links using ambient moisture into elastomer
  - Sufficiently liquid to be applied as coating, but viscous enough to resist flowing off surfaces



Material property	Value
before cure	
Viscosity	28000 mPa s
after cure	
Cure time for 0.20 mm thick layer	45 min
Hardness	19 shore A
Tensile strength	1.2 MPa
Elongation at break	400%
Resistivity	4.8×10^{15} Ω cm
Dielectric strength	20 kV/mm

These are typical properties, not to be construed as specifications.

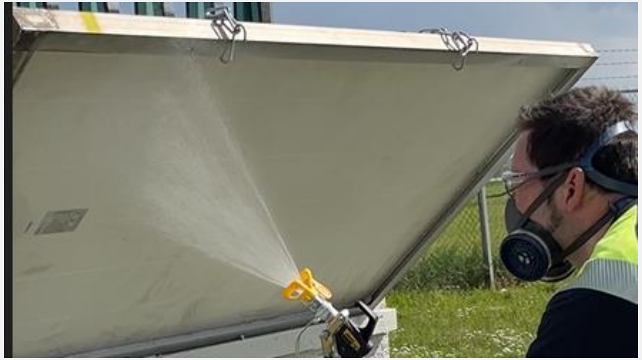
Application

- Several applications possible, each with pros and cons
- Two of those:

'Squeegee method'

- Simple method, no equipment
- Requires temporarily dismounting the module and mounting it again
- Can be done in the workshop or in the field

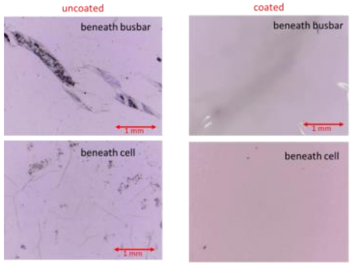
'In field spray method'

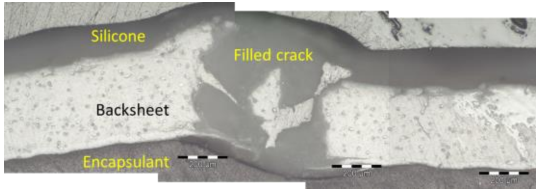


- No dismounting
- Requires specific pumping/spraying equipment
- Masking/shielding might be needed

First repair and durability study

- Test modules:
  - PV modules with AAA backsheets
  - Had operated in PV plant in Southern Europe for 7 years
  - Deep longitudinal cracks, causing leakage currents and decommissioning
- Coating
  - Module horizontal, backsheet facing up
  - Spreading and smoothing with spatula





- R_{iso} in wet leakage (IEC 61215 MQT 15= IEC 61730 MST 17) before repair, after repair, after 1000 h damp heat

The graphic representations are presented here for illustrative purposes only and should not be construed as product specifications

Before repair		After repair	
'Dry' R_{iso}: (no water immersion)	Wet leakage R_{iso}	Wet leakage R_{iso}	Wet leakage R_{iso} after Damp Heat 85/85
> 1000 MΩ	Failed R_{iso}= 0 MΩ	Passed R_{iso}**>1000 MΩ**	Passed R_{iso}= **254 MΩ**

Presented at **EUPVSEC 2021**
'Repair and preventative maintenance of photovoltaic modules with degrading backsheets using flowable silicone sealant', **Progress in Photovoltaics** 2022, Guy Beaucarne, Gabriele Eder, Emmanuel Jadot, Yuliya Voronko, Wolfgang Mühleisen

DOW®

RECENT REPAIR AND DURABILITY STUDY

- Modules of 245 W nominal power, Tier 1 manufacturer
- Operated 8-10y in a solar park, now decommissioned
- Severe degradation observed:
  Deep cracks in checkered pattern, signs of corrosion
- Worst case scenario of repairable backsheet
- Applied DOWSIL™ PV-9001 Backsheet Coating (Spray / Spread).
  Nominal coating thickness 400 µm
- Modules sent to independent testing lab (AIT, Austria)

Results presented in part **at EUPVSEC 2023**
'Accelerated aging study of backsheet repair with flowable silicone sealant'.
Joint contribution with OFI
Guy Beaucarne, Jorge Lima Garcia, Emmanuel Jadot, Kayla Kenney, Anika Gassner, Gabriele Eder

Illuminated I-V measurements

Modules exhibit surprisingly good performance in dry conditions, considering the advanced degradation stage of backsheet and cells and the years of operation on the field

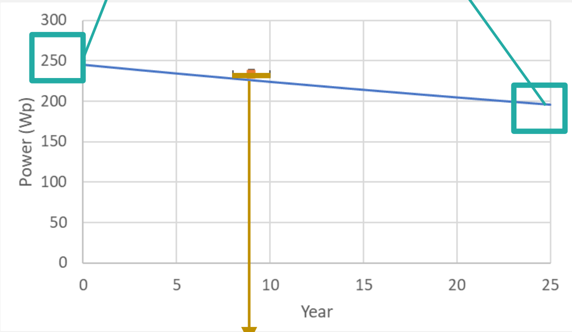
Power decrease during field aging, in line with expectations

Sample #	Isc (A)	Voc (V)	Imp (A)	Vmp (V)	Pmp (W)	FF (%)
1	8.45	36.88	7.98	29.53	235.79	75.64
2	8.58	36.80	7.97	29.33	233.74	74.06
3	8.54	36.92	7.93	29.58	234.63	74.43
4	8.53	36.82	7.99	29.37	234.61	74.67
5	8.46	36.68	7.79	29.45	229.26	73.86
6	8.43	36.53	7.29	28.45	207.36	67.37

Module 6 cells cracked due to impact during transport, significant power drop to be expected

Initial nominal power (245 W_p)

Warranted end-of-life power : 80% of initial power after 25 years



Average measured power (Mod. 1-5)

Initial measurements (after field aging, after repair)

Insulation resistance (R_{iso}) in wet leakage tests

Modules immersed in water, with 1000V applied between cells and frame (IEC 61730 MST 17)

Sample #	R_{iso} (MΩ)	Results
1	360	> 25 MΩ, Pass
2	287	> 25 MΩ, Pass
3	311	> 25 MΩ, Pass
4	340	> 25 MΩ, Pass
5	381	> 25 MΩ, Pass
6	350	> 25 MΩ, Pass

All modules exceed the minimum resistance requirement of 25MΩ, as per IEC 61730 MST 17

Restoration of panel insulation was successful thanks to DOWSIL™ PV-9001 Backsheet Coating.

Discarded modules have a second chance of use

These are typical properties, not to be construed as specifications.

Aging sequence

All existing standards are designed to evaluate brand new PV modules. <u>There is no standard</u> to evaluate aged or repaired modules, which accommodates for endured field exposure.

- In absence of dedicated standard, IEC 61730-2 sequence B was selected:
  - Sequence introduced in IEC 61730-2: 2016 edition to include a multiple-stress sequence to help detect backsheet problems
  - Better suited than other sequences in IEC standards as backsheet cracking has been proved to be the result of combined stresses
  - Uses standard equipment available and commonly performed in test labs
- Two modules (1, 6) were selected for full aging sequence
- Module 4 was selected for aging sequence except UV cycles

IEC 61730-2 sequence B

DH 200

UV front ($60\ kWh/m^2$)

HF 10

UV back ($60\ kWh/m^2$)

HF 10

Final results: observations

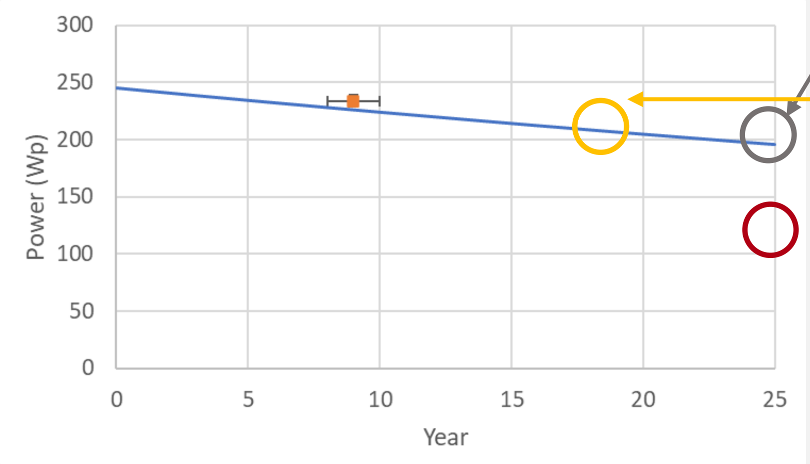
- The aging sequence significantly worsened damage level of the modules
- Types of degradation observed:
  - Yellowing of backsheet (inner side)
  - Local delamination of encapsulant
  - Further corrosion of metal leads and metallization
  - Further opening of cracks in backsheet (under repair layer)
  - Appearance of some new cracks in backsheet (under repair layer)
  - Some damage to repair layer, yet still functional
- Learning: do not wait for the module to be badly degraded to repair it

FINAL RESULTS: ILLUMINATED IV (AFTER IEC 61730-2 SEQUENCE B AGING)

Illuminated I-V measurements

Sample #	Isc (A)	Voc (V)	Imp (A)	Vmp (V)	Pmp (W)	FF (%)
1	8.284	36.659	7.134	28.077	200.3	66.0
4	8.417	36.616	7.420	28.484	211.3	68.6
6	7.310	35.665	4.955	25.414	125.9	48.3

Starting Pmp (W)	Δ (W)
235.75	-35.45
234.61	-23.31
207.36	-81.46



Power decrease for modules 1 and 4 after Sequence B aging falls within expected range for field-aged modules.

Module with impact damage during transportation : Severe power decrease as expected for broken cells, due to further cell cracking during thermal cycles

Final results: Insulation resistance (after IEC 61730-2 Sequence B aging)

Insulation resistance (R_{iso}) in wet leakage tests

Modules immersed in water, with 1000V applied between cells and frame (IEC 61730 MST 17)

Sample #	R_{iso} (MΩ)	Results	Initial R_{iso} (MΩ)
1	344	> 25 MΩ, Pass	360
4	236	> 25 MΩ, Pass	340
6	307	> 25 MΩ, Pass	350

Complete results of tests carried out at AIT are available in the test report, which can be obtained upon request from Dow authors

All modules exceed the minimum resistance requirement of 25MΩ, as per IEC-61730 MST 17

Slight decrease in R_{iso} observed, still well above limit

DOWSIL™ PV- 9001 Backsheet Coating offers durable insulation resistance restoration, even in severely damaged PV modules

Carbon footprint of repair substantially lower than replacement

- Internal LCA for DOWSIL™ PV-9001 Backsheet Coating + carbon footprint calculation based on IEA PVPS Task 12 PV sustainability reports
- Scope: cradle to grave
- Assumptions:
  - Initial module power: 250 W. Replacement module power 335 W
  - Replacement with 1.6 m^2 modules, no change to mounting system
  - Repair with 400 µm DOWSIL™ PV-9001 Backsheet Coating, 20 % material loss
  - Carbon footprint of module transport and installation/repair neglected
  - 30 years system lifetime
- Different scenarios, both assuming 30 years of system life

Scenario 1: PV module **replaced** by new module after 10 years of operation		**Scenario 2**: PV module **repaired** with DOWSIL™ PV-9001 Backsheet Coating after 10 years of operation
107 g CO_2 eq./kWh	- 24.6 % →	**80.6** g CO_2 eq./kWh

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Certification and warranty

- **No standards available** on module repair today
- Standards might emerge in the future from standards working groups, e.g. IEC TC 82 WG2 Re-use of PV Modules
- In the meantime, entities repairing modules need to establish their own test procedures and certification programs to provide evidence to customers

- Dow contributes to offering a trustworthy repair through product warranty
  - Covers silicone coating material
  - Does not cover whole PV module or other PV module components
  - Warranty program uses Dow's established Building & Infrastructure warranty practices

Conclusions

- DOWSIL™ PV-9001 Backsheet Coating can restore electrical insulation of PV modules with cracked backsheet
- Demonstrated on PV modules with degraded AAA backsheets
- Insulation resistance restored even for modules with extensive backsheet cracking
- Repair effectiveness is maintained after applying Sequence B of IEC 61730-2:2016, which includes multiple environmental stresses
- Carbon footprint of repair substantially lower than replacement
- Dow offers durable coating material

THANK YOU

For additional information, please check out our website:

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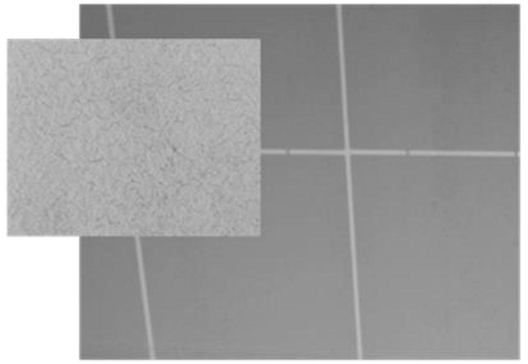
FIELD TESTING OF REPAIRED MODULES – RELIABILITY

<u>Gabriele C. Eder</u> & Anika Gassner - OFI, Austria

Timeline of crack-formation with PA-backsheets (AAA)

Backsheets (AAA) without noticeable problems

Strong chalking, Filler (TiO_2) was set free



Chalking & beginning detection of micro-cracks

Microcracks & first indication for beginning of longitudinal cracks

Detection of deep longitudinal & micro-cracks

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Production	Start Operation											

PV System I (ITA)

C warm temperate, s summer dry, a hot summer [Csa]

- annual GHI: **1649** kWh/m²
- average annual T: 17,6 °C; highest T (average in August): 27,0 °C

PV System II (DEU)

C warm temperate, f fully humid, b warm summer [Cfb]

- annual GHI: 1138 kWh/m²
- average annual T: 9,6 °C; highest T (average in July): 19,4°C

all modules dismantled and replaced

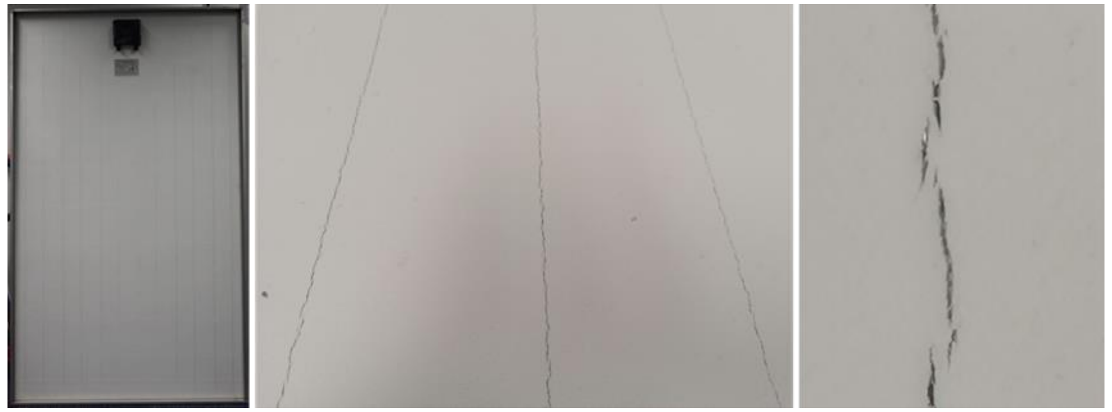
PV System III (AUT)

D cold temperate/snow, f fully humid, b warm summer [Dfb]

- annual GHI: 1307 kWh/m²
- average annual T: 8,4 °C; highest T (average in July): 18,4 °C

Backsheet Cracking

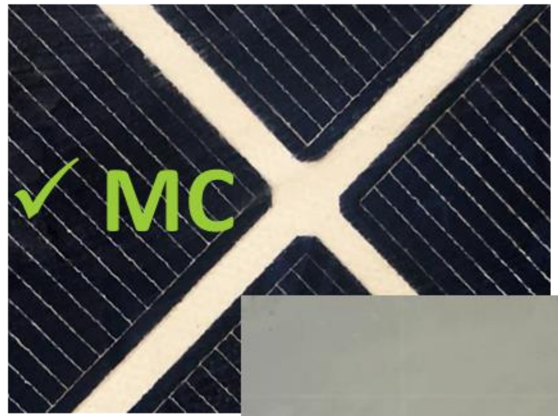
- after 4 to 7 years operational time → enhanced occurrence of backsheet chalking and cracking was observed for PA-based backsheets
- around 11-12 GW of PV with PA-backsheets (AAA) installed (2010-2015)

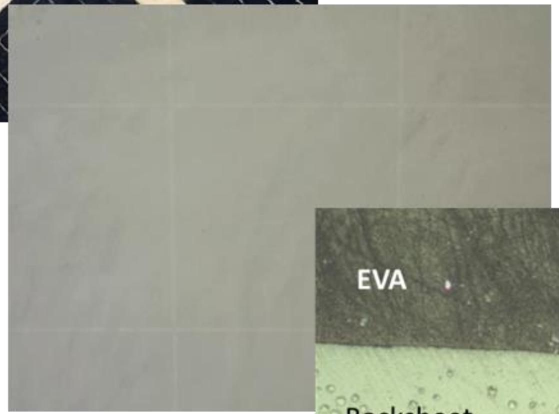


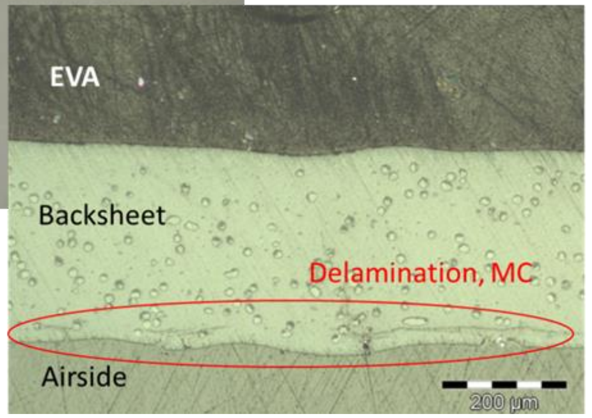
Microcracks (MC)

Prevention:

Stop material degradation / crack propagation



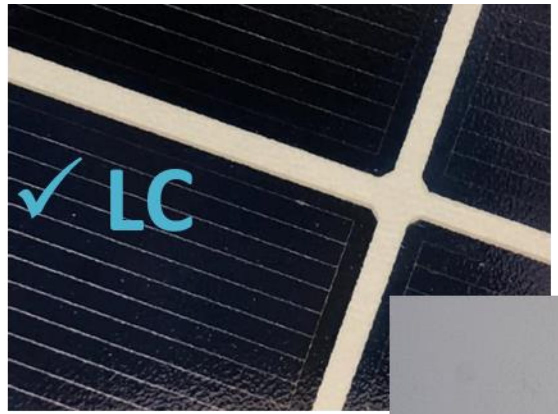


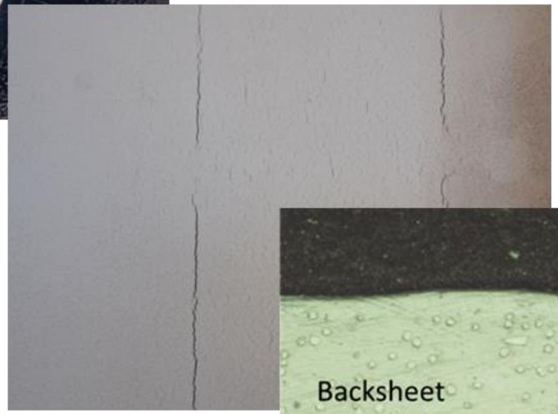


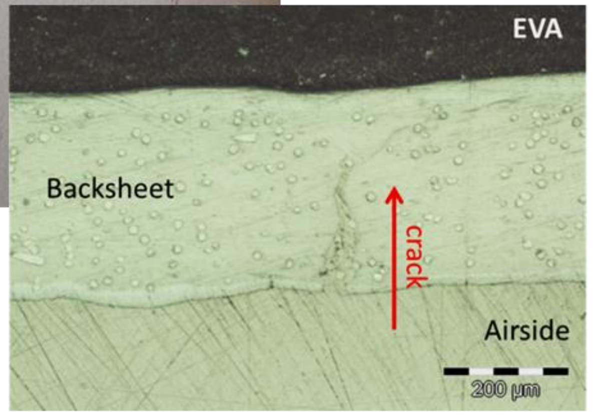
Longitudinal cracks (LC)

Damage Repair:

Restore electrical insulation and safe operation in the field







objective:

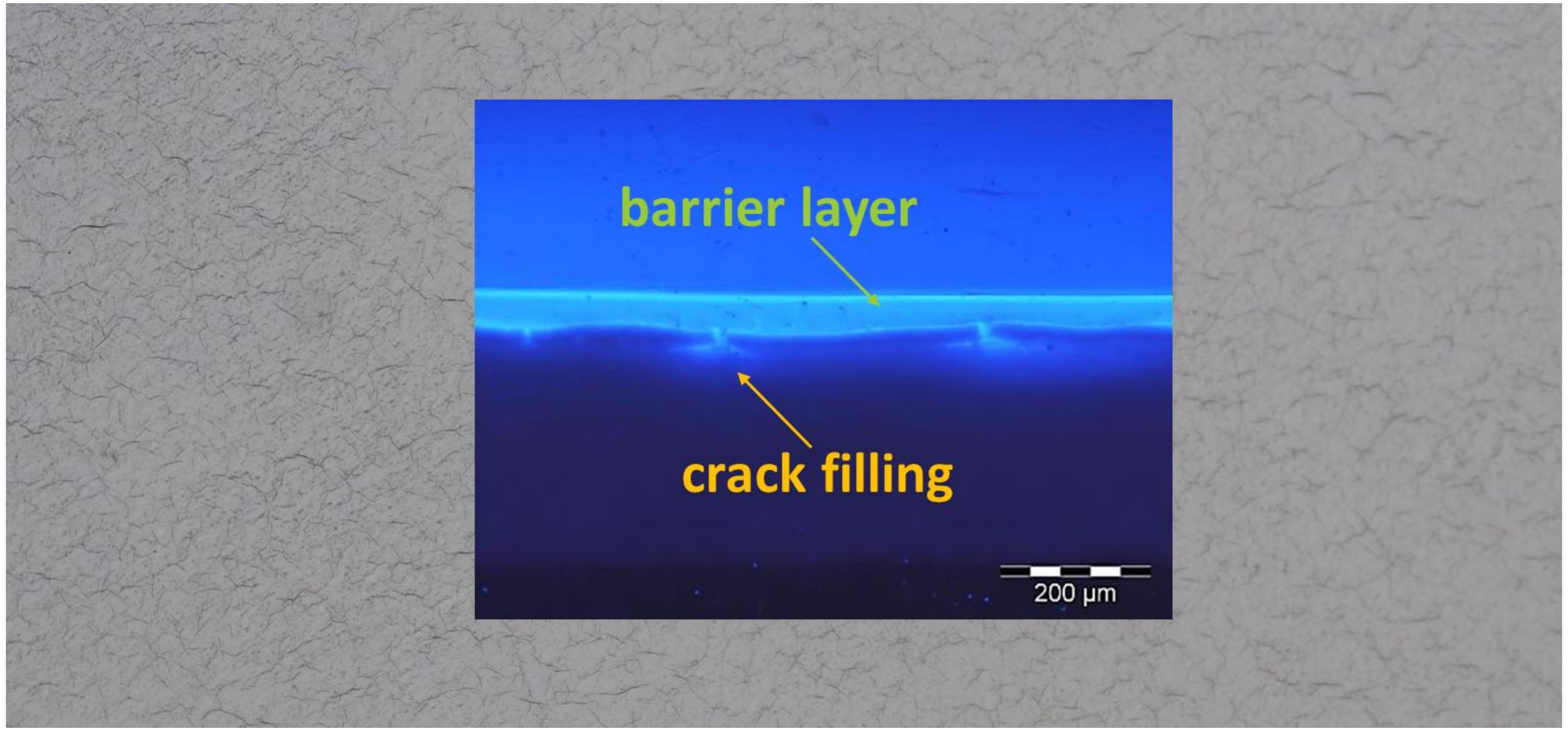
→develop possible strategies for the repair of cracked backsheets

→monitor the long-term stability of the repaired backsheets

→increase operational lifetime of the modules

G. Eder, Y. Voronko, G. Oreski, W. Mühleisen, M. Knausz, A. Omazic, A. Rainer, C. Hirschl and H. Sonnleitner, ***Error analysis of aged modules with cracked polyamide backsheets***, Solar Energy Materials and Solar Cells, 203, 110194 (2019). https://doi.org/10.1016/j.solmat.2019.110194

Long-term stability of repaired PV-modules with microcracks MC



Minimizing crack propagation in cracked PV backsheets through repair coatings;
Yuliya Voronko, Gabriele Eder, Wolfgang Mühleisen, Lukas Neumaier, Christian Breitwieser, Sonja Feldbacher, Gernot Oreski, Markus Feichtner, Tudior, Dobra; September 2022; WCPEC 8 Milano 09.2022

Long-term reliability of repaired PV-modules with MC

Repair of microcracked backsheets + reliability testing (AUT, Dfb) installed in 2012

Coating in the field + natural weathering (start 06.2020; ongoing) **→3,3 Years (40 M)**

Before repair process @2020:

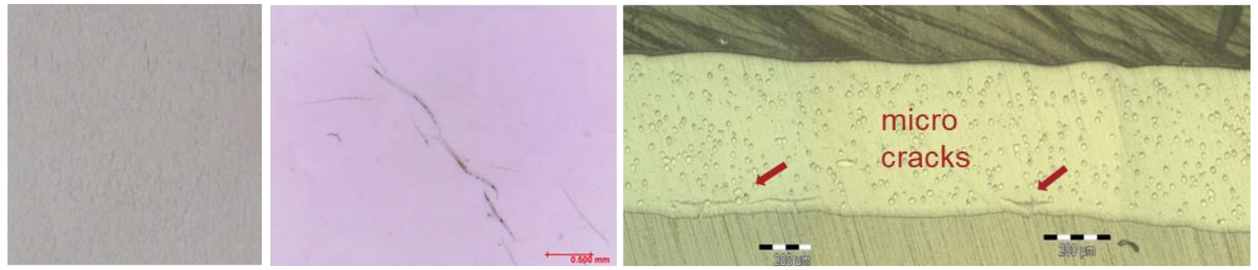
- NO electrical performance degradation, NO insulation problems under wet conditions;
- Material degradation -> chalking and micro-cracking of outer backsheet layer (polyamide)

The aim to prevent further growth of surface near MC and their evolution to LC could be achieved

After 40 M natural weathering:

→ good adhesion and material stability of 3 types of coatings

→ no changes in electrical characteristics of the coated modules

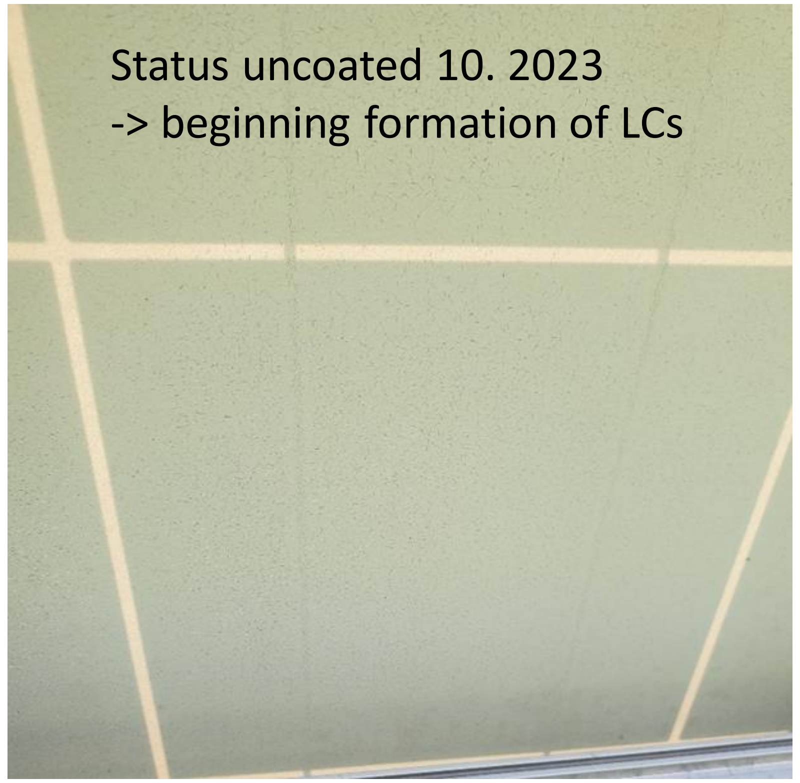


Repair options for PV modules with cracked polyamide backsheets, Y. Voronko, G. Eder, C. Breitwieser, W. Mühleisen, L. Neumaier, S. Feldbacher and G. Oreski, in 37th EU PVSEC (online, 2020) and Energy Sci Eng. 2021; 9: 1583– 1595. https://doi.org/10.1002/ese3.936

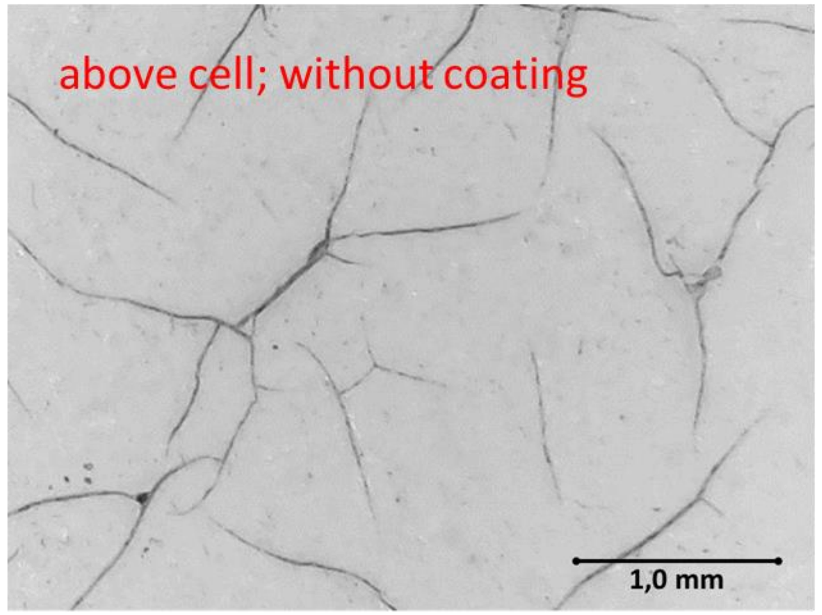
Long-term reliability of repaired PV-modules with MC

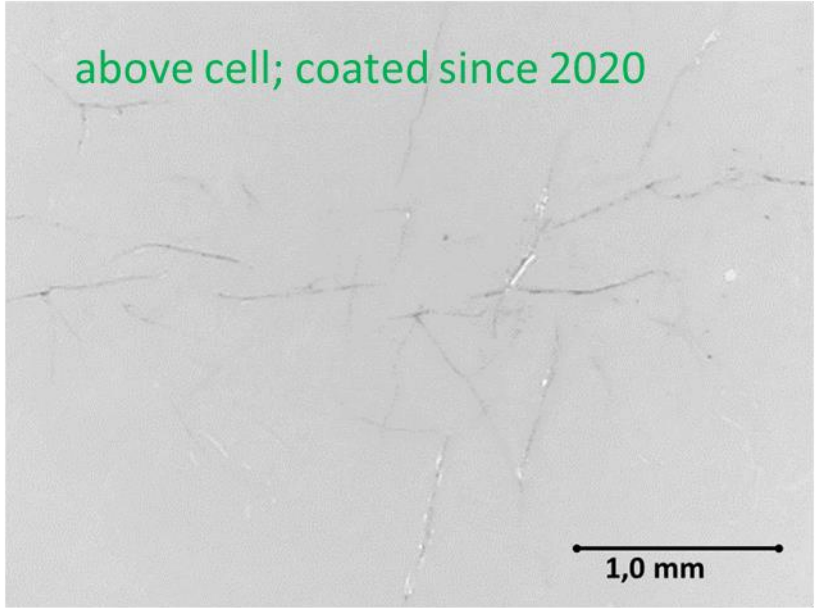
Repair in the field

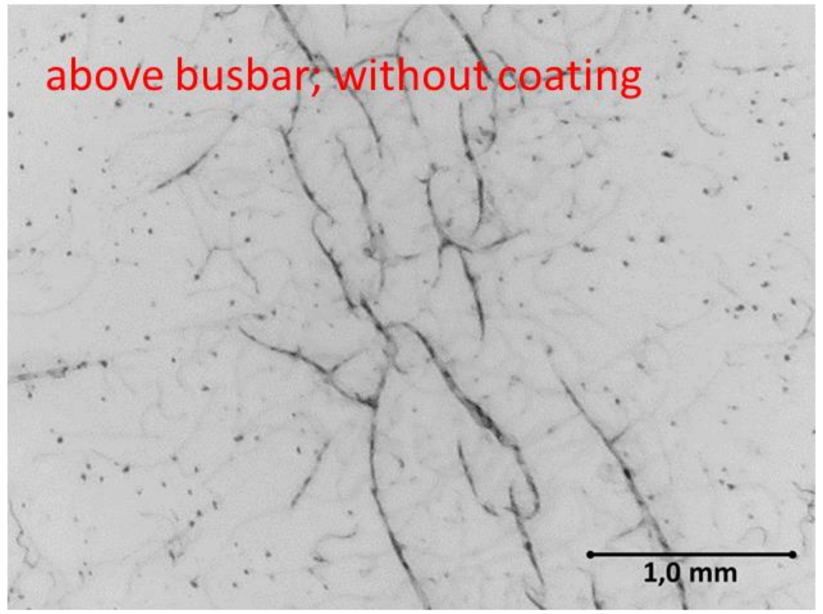
- Various repair coatings tested
- Characterisation-methods:
  - visually/USB-microscope: crack formation and propagation
  - FTIR-spectroscopy: potential chemical degradation of coating
  - colour-measuring instrument: discolouration (chem. degradation)
  - tape peel test: adhesion of coating to BS-surface
  - electrical characterization (IV-curve, EL-images)

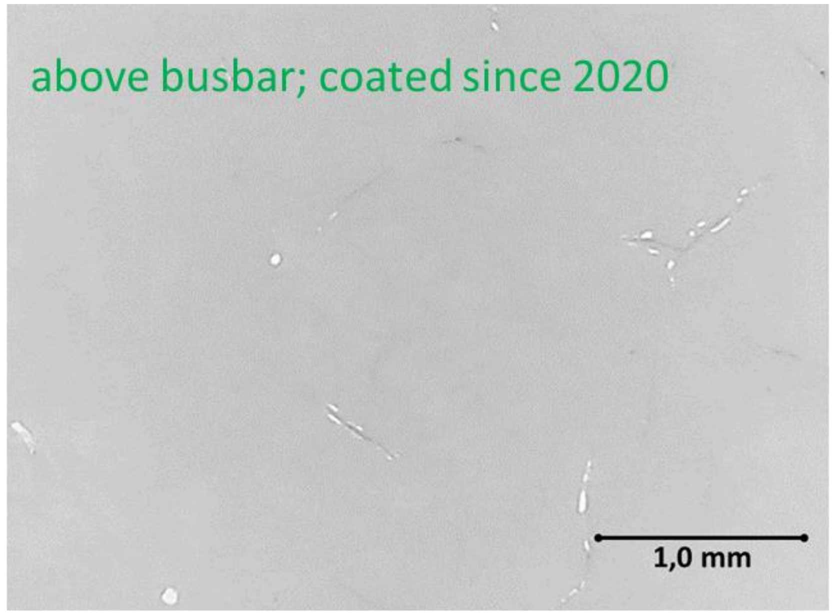


Evaluation (non-destructive) of repaired modules after 40M in the field (natural weathering) – Status 10.2023

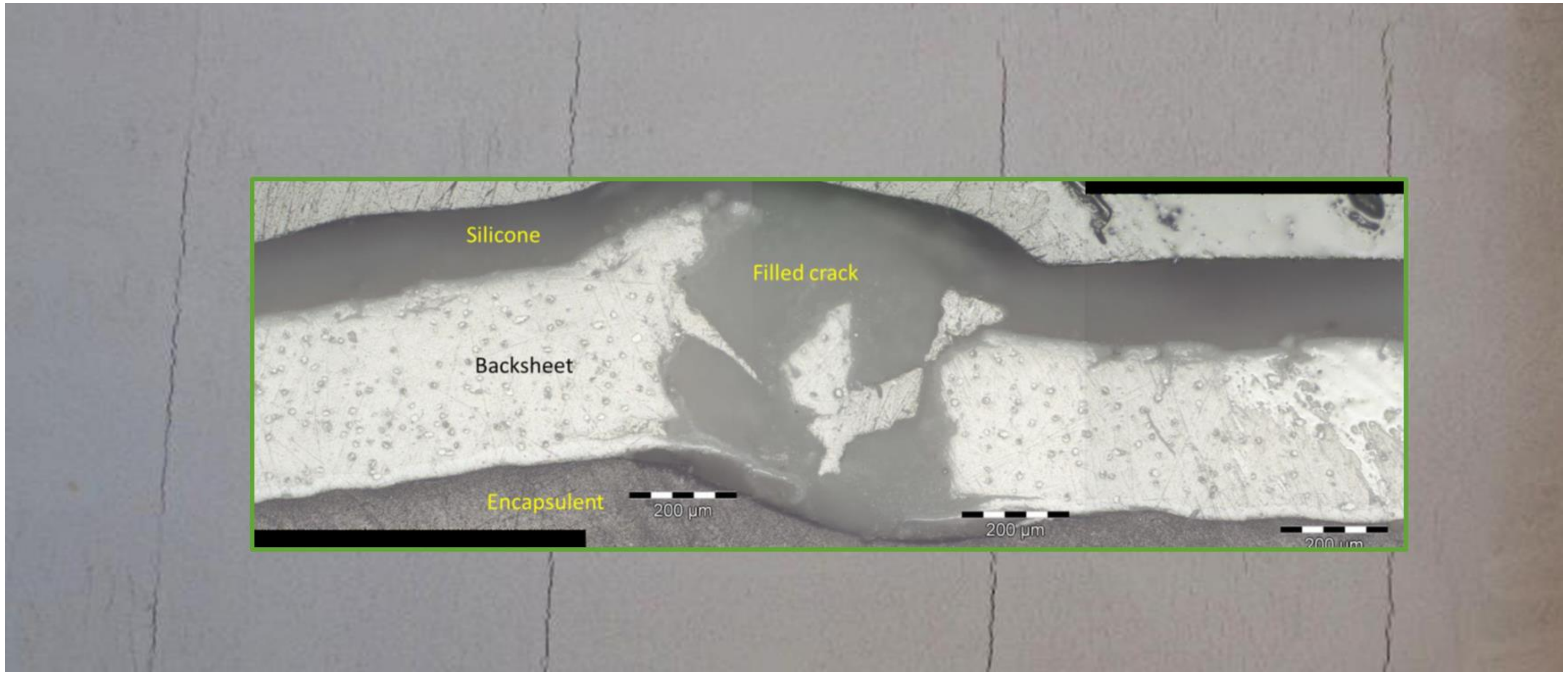








Long-term stability of repaired PV-modules with longitudinal cracks LC



Repair and preventive maintenance of PV modules with degrading backsheets using flowable silicone sealant
Guy Beaucarne, Gabriele Eder, Emmanuel Jadot, Yuliya Voronko, Wolfgang Mühleisen; EU PVSEC 2021 5.DO.2.6. and PIP3492; DOI: 10.1002/pip.3492

Long-term reliability of repaired PV-modules with LC

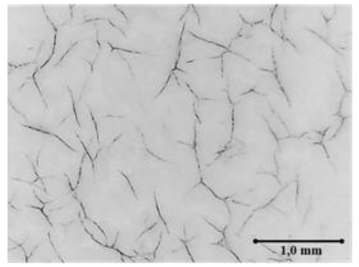
PVRe²

Repair of BSs with deep LC cracks + reliability testing (DEU, Cfb) installed 2012

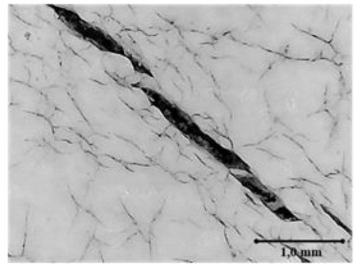
Coating in the field (6 modules) + coating in the lab (12 modules)

→ test-plant in Vienna in operation since 07.2021 **→2,25 Years (27 M)**

Microcracks between busbars



Longitudinal cracks along busbars



Before repair process @2021:

- Safety and operation problems: insulation resistance under wet conditions broke down; no pronounced power degradation
- material degradation -> chalking and deep longitudinal cracks (whole PA-backsheet affected)
  → repowering of PV-plant / insurance claim (safety issue)

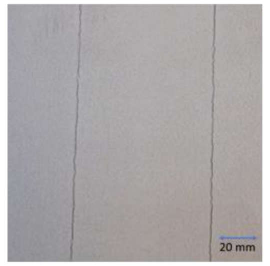
The aim to restore the required insulation resistance of the aged modules
→ extension of operational lifetime could be achieved

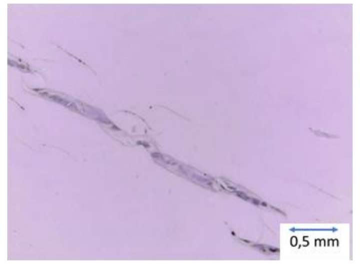
After coating and 27 M natural weathering:

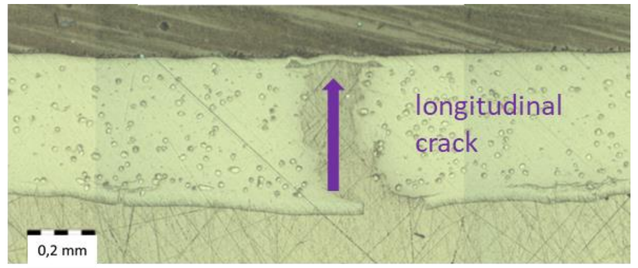
→ no changes in electrical characteristics

→ no inverter tripping events due to leakage current

→ good adhesion and material stability of coatings; cracks filled







Thank you for your attention !

....and to all PVRe^2 project partners for their good cooperation!

If you have any questions, please contact:
gabriele.eder@ofi.at

ENERGY RESEARCH 4th CALL TOPIC 5 . 5 PHOTOVOLTAICS
This work was conducted as part of the Austrian "Energy Research Program" project "PV Re^2 - Sustainable Photovoltaics" (FFG No. 867267) funded by the Austrian Climate and Energy Fund and the Austrian Research Promotion Agency (FFG).

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Backsheet cracking – a global phenomenon

Q&A

14 November 2023

9:00 am – 10:00 am | EST, New York City
3:00 pm – 4:00 pm | CET, Berlin
6:00 pm -7:00 pm | GST, Dubai

Mark Hutchins
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Guy Beaucarne
TS&D Fellow
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Wednesday, 15 November 2023
11:00 am – 12:00 pm EST, New York City
5:00 pm - 6:00 pm CET, Berlin

Sizing fuses to protect BESS power circuit from overcurrents

Friday, 17 November 2023
8:00 am – 9:00 am EST, New York City
2:00 pm – 3:00 pm CET, Berlin

Mounted PV: Steel foundations explored

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