DISTANCE THROUGH INSULATION (DTI) – A MUST FOR THE SAFETY OF BACKSHEETS

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I. Introduction

So far, there was no requirement in the safety PV module standard of a certain thickness of backsheets for insulation. The partial discharge test in air (not oil) somehow regulated the thickness of backsheets in the range of 300 µm for 1000 V systems. Due to the new edition of 61730 and the removal of partial discharge testing the insulation thickness was incorporated. The thickness is defined as shortest distance between a live part and the outside of the module. The allowed distances through insulation (DTI) are dependent of the system voltage (SV) and have to be assigned as relied upon insulation (RUI). The RUI is defined by the requirement of RTI and the di-electric strength (2kV + 4x SV).[1]

DC system voltage	0 - 300 V	600 V	1000 V	1500 V
Thickness of thin layers	10 µm	60 µm	150 µm	300 µm

Table 1: DTI for different system voltages defined by 61730-1.

III. Approaching the test design

The test was designed in several steps, e. g. with a plate on which steel tips were fixed. The first trials lacked the possibilities to find the right minimum position during a cross-cut or lead to unrealistic results (e.g. piercing of PET by steel tips). In order to overcome these issues a wire approach was chosen. The wire consisting of soft solder material has a diameter of 800 µm. It is laminated with glass, release film and one layer of encapsulant in order to simulate the situation behind a solar cell in a module. After removal of the glass the laminate can be sectioned (w/ or w/o wire). The wire geometry allows to find the position of the shortest distance (DTI) easily by cutting perpendicular to it. Suitable cross-cut methods are e.g. grinding section and microtome cutting (e.g. via hammer method) The assessment of the cross-cut can be done via different optical methods.

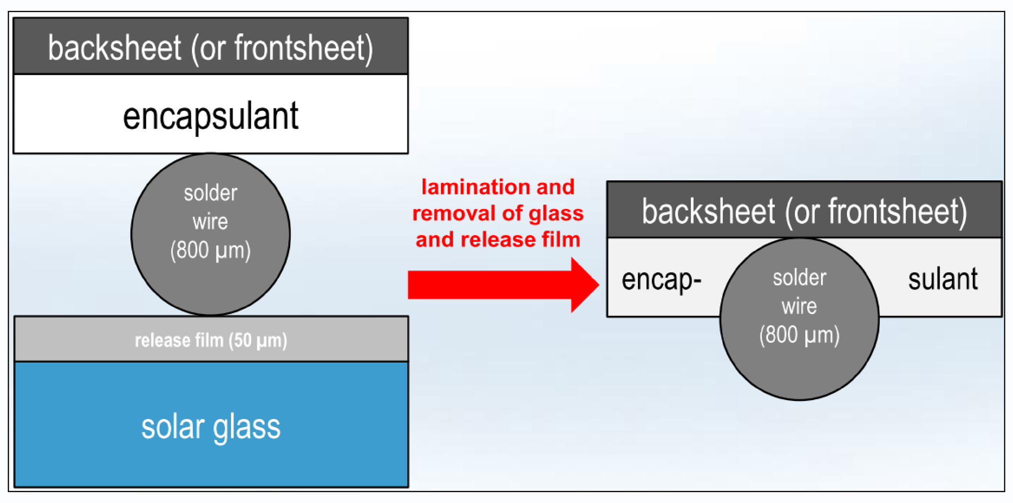

Figure 2: Scheme for composition of lamination with solder wire.

Figure 3: Microtome blade for hammer method.

V. Prequalification of a backsheet

The uncertainty of the measurement has to be added to the measured DTI value in terms of safety reasons (typical value ≈ 5 %). The result for DTI on component level prequalifies for other PV designs with the same type of encapsulant, when the lamination conditions are less harsh than performed on component level (T, p, t, etc.).

FERON used harsh lamination conditions, even without using a layer of encapsulant during the test. Although simulating conditions much harsher than practical laminations, in all cases the required DTI was achieved. A comparison @ softer conditions with a competitor fluorine coated CPE showed that too much of the backsheet is displaced.

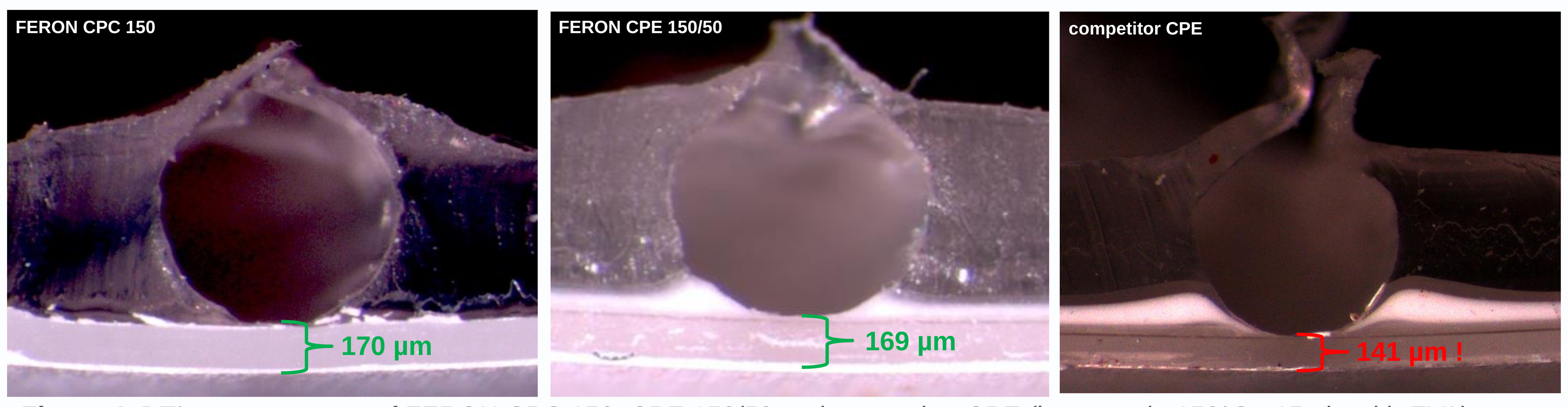

Figure 4: DTI measurements of FERON CPC 150, CPE 150/50 and competitor CPE (lam. cond.: 150°C - 15min with EVA).

VII. Acknowledgement

This work was developed in cooperation with Rene Eugen (Isovoltaic AG), Takao Amioka (Toray Industries, Inc.), Jürgen Jung (Agfa-Gevaert N.V.), Kiyoteru Miyake (Fujifilm Corporation), Bernt-Ake Sultan (Borealis AB), Jörg Althaus (TÜV Rheinland GmbH), Keita Arihara (Dai Nippon Printing Co., Ltd), Karlheinz Brust (Krempel GmbH).

II. Situation @ module level and the need for a component prequalification

The IEC safety standard 61730-2 requires an insulation thickness test (MST 04) at three locations on the PV module.[2] In terms of minimum distances through insulation it is sensible to observe solder connections, edges of frameless PV modules, laminator membrane incidents, etc..

An investigation of real soldering tips resulted in a broad range of different geometries, even in the same batch. The heights of the tips were up to 900 µm.

In order to ensure a certain minimum thickness of a backsheet, it is necessary to perform a worst-case scenario on component level. With this method it is possible to evaluate materials, especially which are not form stable during practical lamination cycles. It gives the certification bodies the option to decide whether to check on module level (e.g. in case of doubts of poor craftsmanship) or component level (e.g. for known designs).

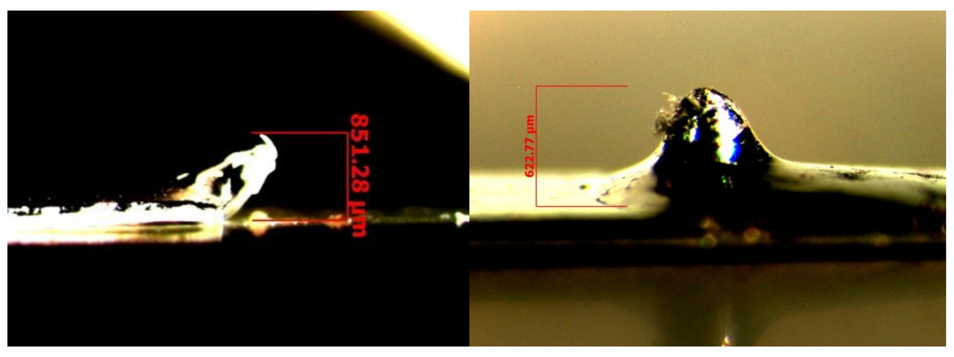

Figure 1: Soldering tips from PV module productions.

IV. Reproducibility of the solder wire testing

The reproducibility of the wire testing was checked via a round-robin test in the DTI group (WG2 - group bs&fs). Several participants conducted the test with three different backsheet materials (PET, TPT, TPE) The results of the cross-cut quality was checked by comparison with the caliper method of the non-laminated materials. The position of DTI (yellow arrow in Fig.1) was determined exactly under the position of the wire.

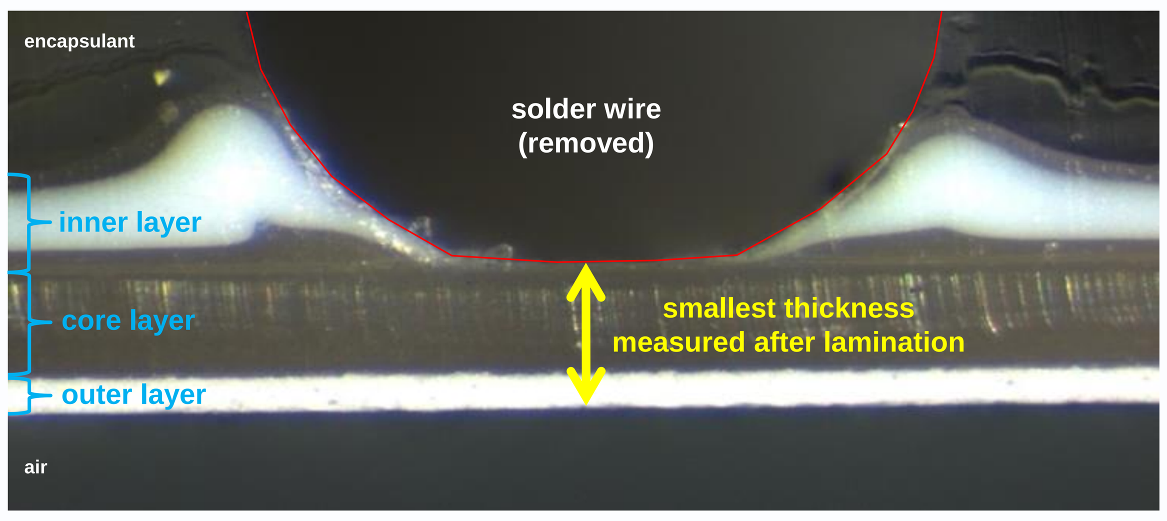

Figure 1: Cross-cut of a TPE backsheet after removal of the solder wire.

participants sample-No.	cross-cut-method	measurement method	thickness [µm] PET 150µm non-laminated bs caliper overall	PET 150µm non-laminated bs cross-cut overall	PET 150µm laminated stack cross-cut overall	TPT (37/75/37) non-laminated bs caliper overall	TPT (37/75/37) non-laminated bs cross-cut overall	TPT (37/75/37) laminated stack cross-cut overall	TPE (37/125/100) non-laminated bs caliper overall	TPE (37/125/100) non-laminated bs cross-cut overall	TPE (37/125/100) laminated stack cross-cut overall
FERON1	microtome (w/o wire)	optical	148	153	154	169	171	172	279	278	183
FERON2	hammer metod	microscope	149	155	150	169	173	165	280	288	179
FERON3	Leica 818	(Zeiss)	149	153	156	169	170	165	280	286	179
TORAY1	microtome (w/o wire)	laser microscope	153	153	153	166	165	167	272	272	176
TORAY2	Thermo scientific, HM325		151	151	154	168	162	168	274	267	176
TORAY3	steel		151	151	151	169	162	167	274	264	176
ISOVOLTAIC1	microtome (w/o wire)	optical microscope	148	158	150	173	165	167	277	277	176
ISOVOLTAIC2	hammer metod		151	161	148	171	167	162	276	276	170
ISOVOLTAIC3	Leica 818		149	162	142	172	167	163	275	274	170
BOREALIS1	microtome (w/o wire)	optical microscope	150	166	163	170	170	170	278	281	186
BOREALIS2	hammer metod		151	157	160	170	170	173	276	281	188
BOREALIS3	Leica 818		151	144	173	170	168	169	277	280	180
DNP1	microtome (w/o wire) blade	SEM	151	153	152	167	164	180	272	273	175
DNP2			150	151	154	169	161	178	270	267	175
DNP3			151	152	152	168	167	181	271	271	178
Fuji1	microtome (w/o wire)	optical	151	151	149	158	165	163	259	277	178
Fuji2	rotary	microscope	151	150	152	158	162	159	258	277	181
Fuji3	Leica RM2165	and SEM	151	151	152	160	162	165	261	274	175
TÜV1	polished section (with	optical	-	-	150	-	-	161	-	-	176
TÜV2	wire)	microscope	-	-	153	-	-	170	-	-	191
		average	150,3	154,0	153,4	167,6	166,1	168,2	272,7	275,7	178,4
		standard deviation	1,3	5,2	6,3	4,4	3,7	6,2	6,8	6,3	5,4
		CV (%)	0,9%	3,4%	4,1%	2,6%	2,2%	3,7%	2,5%	2,3%	3,0%

Table 2: DTI results of round-robin test.

The method gave very reproducible results for all materials, although the participants followed different strategies in terms of cross-cutting and measurement. The coefficient of variation was below 5 %.

VI. Conclusion

The work presented will be published as test method in IEC TS 62788-2 and will be referred in 61730 through an amendment.[3] It should be up to the certification bodies to decide if MST 04 is necessary to perform or if the test parameters on component level already simulate the module level. The test method shows clearly if a backsheet adds enough thickness for a relied upon insulation. Furthermore, the DTI test is very important as an entry test for the determination of the DC breakdown voltage testing and the comparative tracking index (CTI) of a backsheet.

[1] IEC 61730-1:2016 - Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction.
[2] IEC 61730-2:2016 - Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing.
[3] IEC/TS 62788-2 Ed. 1.0 - Measurement procedures for materials used in photovoltaic modules - Part 2: Polymeric materials used for frontsheets and backsheets.