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Measurement

Last edited by [Karl Knoebl](#) 3 years ago

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IV-Curve (Current Voltage) aka flashertest

abbreviation	IVSTC (1000 W/m ² , 25°, AM 1.5 without spectral correction) IVSTCS (1000 W/m ² , 25°, AM 1.5 with spectral correction) IVLIC (low irradi cond, 200 W/m ² , 25°, AM 1.5)	
parameter	• Conditions (near STC, computed to STC) • cell area, DUT area • calc param (α, β, κ)	
measured data	• IV-curve (current, voltage) exceeding X and Y intercept • Irradiation • Temp DUT, Temp_{CellRef}	• G_{raw} [W/m²] • V_{raw} [V] • I_{raw} [A] • Raw is valid ?
computed to	• IV-curve (current, voltage) at STC	• V_{comp} • I_{comp} • P_{comp} • computation is valid ?
aggregated to	• U_{OC} • I_{SC} • P_{MPP} • U_{MPP} • I_{MPP} • FF (fill factor) • cell efficiency • DUT efficiency • current density (J_{SC}) • R_S • R_p	• Voltage at open circuit [V] • Current at short cut [A] • Power at maximum power point [W] • Voltage at maximum power point [V] • Current at maximum power point [A] • P_{MPP} / (U_{OC} * I_{SC}) [%] • P_{MPP} / (NrOfCells * CellArea * Irrad_{STC}) [%] • P_{mpp} / (DUTArea * Irrad_{STC}) [%] • I_{SC} / cell area [mA/cm²] • Δu/Δi slope at U_{OC} (-0.1 A:+0.1A) • Δu/Δi slope at I_{SC} (-0.1 V:+0.1V)

recorded data	• IV-curve_{raw}, IV-curve_{comp} at STC • U_{OC} • I_{SC} • P_{MPP} • FF (fill factor) • cell efficiency • DUT efficiency • current density (J_{SC}) • R_S • R_P	• IV-raw[firstValidcomp:lastValidcomp] ◦ V_{raw}[firstValidcomp:lastValidcomp] ◦ I_{raw}[firstValidcomp:lastValidcomp] • IV-curve[firstValidcomp:lastValidcomp] ◦ V_{comp}[firstValidcomp:lastValidcomp] ◦ I_{comp}[firstValidcomp:lastValidcomp]
derivable information	?	
comment	only one IV-curve is recorded, effects of capacities on measurement process is eliminated by merging stable fragments of several measurements	
example input file	10-02 INFS003-5.csv	

EL Electro Luminescence

abbreviation	ELL low current 10% von Isc ELH high current ELX double current	additional info: sss[R O]cccc R O raw optimized sss= shutter time [s] cccc current [10mA] eg: 120R0900 120 sec shutter, Raw format, at 9 A
parameter	• excitation current [A] • shutter time [s]	
measured data	• monochrome picture	resolution 3000x2000 ca., raw + optimized
aggregated to		
recorded data	• monochrome picture	resolution 3000x2000 ca., raw + optimized
derivable information		
comment		shutter time of about 10s
example input file		

IIRT IR Imaging active / illuminated thermography

abbreviation	IIRT illuminated IR thermography	not frequently used
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parameter		
measured data	- monochrome picture IR - color picture VIS	resolution?
aggregated to		
recorded data	monochrome picture IR color picture VIS	
derivable information	electrical performance, inactive cells	
comment		
example input file	!! depends on camera	

DIRT IR Imaging passive / dark thermography

abbreviation	DIRT dark IR thermography	not frequently used
parameter	exciting current	
measured data	monochrome picture IR	resolution?
aggregated to		
recorded data	monochrome picture IR	
derivable information	electrical performance	
comment		
example input file	!! depends on camera	

DLIT IR Imaging passive / dark lock in thermography

abbreviation	DLITxy dark lock in IR thermography x=[A Amplitude P P Phase C Cosinus S Sinus] y = 0-4 FFT transformation order eg: DLITP3 = Phase 3 rd order	not frequently used add info: sss[R O]cccc fff nnnn sss= period time [s] [R O] Raw Optimized cccc current [10mA] fff frames per second nnnn count in 10 pictures eg: 120R09000 0 100700 = 120 seconds, Raw , 9 A, 10 frames per second , with 700 x 10 = 7000 pictures
parameter	excitation current	
measured data	monochrome picture IR colored intensity (deltaT)	resolution?
aggregated to	amplitude image (0-4), cosinus image, sinus image, phase image,	

recorded data	monochrome picture IR colored intensity (deltaT)	
derivable information	electrical performance	
comment		
example input file	!! depends on camera	

PPIT Pulse phase IR thermography

abbreviation	PPIT Puls phase IR thermography	not frequently used, only in case of failures (e.g.delamination, hot cells...)
parameter	excitation with pulsed flashlight	
measured data	monochrome picture acc. differences in thermal conductivity of different modul parts	
aggregated to	FFT transformed, monochrome picture	frequency dependent conductance image
recorded data	FFT transformed, monochrome picture	
derivable information	material characteristics, imperfections e.g. delaminations	
comment		
example input file		

PL PhotoLuminescence stimulated with LED

abbreviation	PLCG clean green PLNIR near infrared (invisible 840nm)	not frequently used additional info: sss[R O]cccc sss= shutter time [s] [R O] Raw Optimized cccc LED lamp excitation current [10mA] eg: 120R0900 = 120 seconds shutter, Raw, at 900 x 0.01 = 9 A	
parameter	excitation energy and wavelength		
measured data	monochrome picture	raw + optimized	
aggregated to			
recorded data	monochrome picture		
derivable information	connection failures, thermal irregularities (due to high resistance)		
comment			
example input file			

UV-Fluorescence Imaging

abbreviation	UVFIm1 UVFIm2 UVFIm3	several pictures of one module possible; e.g. whole modules and details of interesting parts UVFIm1= full intensity (raw) UVFIm2= half intensity (raw) UVFIm3= optimized
parameter	LEDs (380nm) -> Intensity for excitation	fotographic camera with green filter exposure time,
measured data	polychromic picture (fotographic picture of the fluorescence distribution (varying intensities) within an module)	raw and optimized picture
aggregated to		
recorded data	foto	
derivable information	UV-fluorecence pattern of the aged module; gives information about broken cells, microcracks, hot cell parts; water and oxygen permability of the backsheet	
comment	original modules do not show UV-Fluorescence; effect is developing with time and in dependence of irradiation and T	
example input file		

FTIR Spectroscopy

abbreviation	FTIR	
parameter	• resolution • range • type of measurement (transmission, reflexion ATR)	
measured data	• spectrum = transmission over wavenumber	• transmission: percentage • wavenumber: 4000: -1 : 600 [cm⁻¹]
recorded data	• spectrum = transmission over wavenumber • RESOLUTION (= 4 cm⁻¹) • type of measurement (transmission, reflection= ATR)	• transmission: percentage • wavenumber: 4000: -1 : 600 [cm⁻¹]
derivable information	chemical degradation (e.g. oxidation, hydrolysis,)	measurements on backsheet and/or encapsulation
comment	the average of multiple (S/N improving) scans is recorded only; spectra are already corrected with the background spectrum	
example input file	EVA_P004_1_k_a.ASC	

REM-EDX Scanning electron microscopy with energy-dispersive detection

abbreviation	REMX	is not frequently used; destructive method; applied only in case of discolouration of cells or ribbons or corrosion effects)
parameter	energy of excitation electron beam; magnification	
measured data	• REM: microscopic image of the surface with high magnification; current of backscattered electrons and secondary electrons • EDX: spectrum (energy dispersive intensity of x-rays)	
aggregated to	list of elements identified with concentration in % = chemical analysis of the surface (elemental distribution)	
recorded data	• list of elements identified with concentration in % • Electronmicroscopic picture	
derivable information	REM: microscopic image of the surface with high magnification EDX: chemical analysis of the surface (elemental distribution, in atom %) Mapping: distribution (prop. to conc.) of one specific element oder the sample area	
comment	destructive method; applied to single cell modules only	anorganic material analysis of cells, ribbons, electrical conductiv adhesives
example input file		

TD/GC-MS ThermoDesorption / GasChromatography - MassSpectrometry

abbreviation	REMX	is not frequently used; destructive method; applied only in case of discolouration of cells or ribbons or corrosion effects)
parameter	energy of excitation electron beam; magnification	
measured data	• REM: microscopic image of the surface with high magnification; current of backscattered electrons and secondary electrons • EDX: spectrum (energy dispersive intensity of x-rays)	
aggregated to	list of elements identified with concentration in % = chemical analysis of the surface (elemental distribution)	
recorded data	• list of elements identified with concentration in % • Electronmicroscopic picture	

derivable information	REM: microscopic image of the surface with high magnification EDX: chemical analysis of the surface (elemental distribution, in atom %) Mapping: distribution (prop. to conc.) of one specific element oder the sample area	
comment	destructive method; applied to single cell modules only	anorganic material analysis of cells, ribbons, electrical conductiv adhesives
example input file		

UV/VIS Spectroscopy

abbreviation	UVVIS	
parameter	lightsource, wavenumer range	
measured data	spectrum (percentage over wavelength)	- intensity: % - wavelength: 200:any: ~1116 nm
aggregated to		
recorded data	spectrum (percentage over wavelength)	intensity: % wavelength: 200:any: ~1116 nm
derivable information	discolouration of encapsulation and/or backsheet and or glass	
comment	transparency of materials (Glass, Glass+EVA,...) in UV+VIS range	
example input file		

UV-Fluorescence Spectroscopy

abbreviation	UVFSp	Sp
Parameter	type of UV-light source, excitation time/scan, scannumber to coadd/ spectrum	excitation via LED (380nm) or Laser (405nm)
measured data	spectrum (intensity over wavelength)	intensity: arbitrary units wavelength: 300:1100 [nm]
aggregated to		
recorded data	spectrum (intensity over wavelength)	intensity: arbitrary units wavelength: 400:800 [nm]
derivable information	degradation of encapsulant; ageing effects	
comment		
example input file		

Raman Spectroscopy

abbreviation	RAMAN	
parameter	excitation laser: 532nm, hole: 500, slit: 200, grid: 600, objective: x100 fluotar, filter: open, spectral range: 150-3300 cm ⁻¹ , integration time: 5 sec, spectra coadded: 5	
measured data	spectrum (intensity over wavenumber)	- intensity: arbitrary units - wavenumber: 3300-150 [cm⁻¹] - for calibration: e.g. Si at 521 cm⁻¹
aggregated to		
recorded data	spectrum (intensity over wavenumber)	- intensity: arbitrary units - wavenumber: 3300:150 [cm⁻¹]
derivable information	chemical degradation of polymeric materials and semiconductors Raman spectra collected of 1. encapsulant EVA and 2. backsheet	
comment	only average of multiple (S/N improving) scans is recorded	
example input file		

Colour measurement Backsheet

abbreviation	ColBS	CIE $L^*a^*b^*$ (CIELAB)
parameter	Lab color space (CIELAB): describes mathematically all perceivable colors in the three dimensions L =lightness and a and b for the color-opponents green-red and blue-yellow	measurement under standard conditions , 23 +/- 2°C and 50+/- 5 % r.H:
measured data	L^* , a^* , b^*	
aggregated to	$\Delta E = \sqrt{L.L+a.a+b.b}$	ΔE = colour change
recorded data	ΔL , Δa , Δb , ΔE	
derivable information	ageing induced colour change of backsheet	
comment		
example input file	data are aggregated in excel sheet	