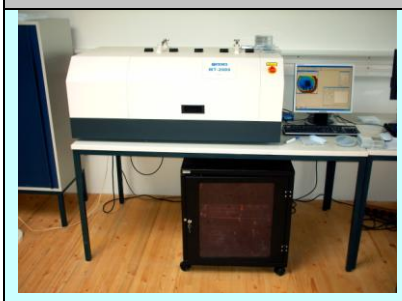
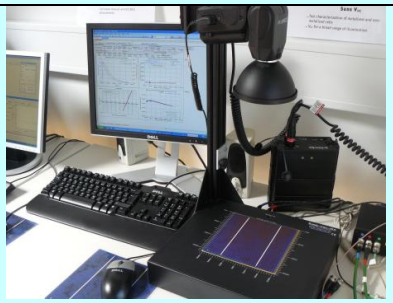
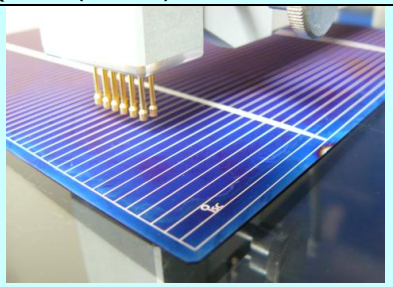
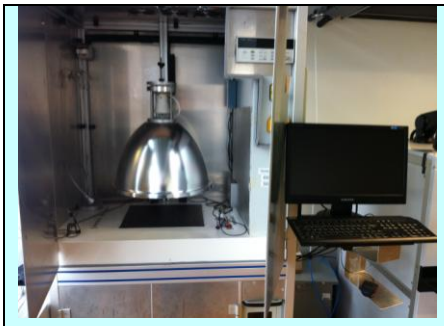
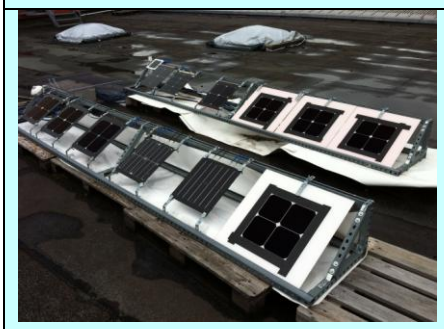
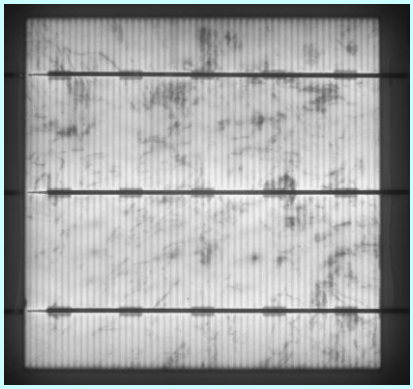
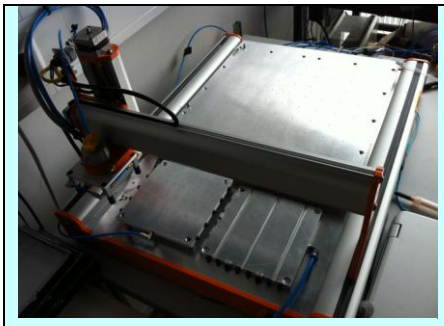
Listing and specification of **characterization** equipment at ISC Konstanz

30.05.2016

Electrical Characterization

 µW-PCD (Semilab)	- spatially resolved minority charge carrier lifetime	- wafer size up to 210 x 210 mm^2 - as-cut measurement of bricks - high resolution lifetime maps (62.5 µm) - SHR (sheet resistance mapping) - LBIC (current, IQE mapping) - Eddy current resistivity mapping of wafers and bricks
 PV2000 (Semilab)	-diffusion length mapping via surface photo voltage method -Fe concentration and B-O distribution mapping using internal accelerated-LID chuck -QSS-uPCD for minority charge carrier lifetime mapping @ defined injection levels -corona charging for evaluation of passivating layers	-fully automated measurement of up to 100 wafers/cells -measurement of wafers at various production stages -
 QSSPC (Sinton) + suns Voc	- injection level resolved minority charge carrier lifetime - illumination-dependent Voc measurements - contactless resistivity measurement	- fast lifetime measurements - Voc for metalized and non-front-side- metalized cells - Voc for a broad range of illumination
 4-point tester (GP-solar)	measurement of: - wafer resistivity - sheet-resistance - line resistance - contact resistance	- exchangeable measuring-heads - measurement of wafer, half processed cell and cell properties - contact resistance for finger spacing of about 2,6mm

	- Light induced degradation test - Solar cell regeneration & annealing - In-situ V_{OC} measurement	- capable of four solar cells in one run - chuck with controllable temperature (10-230°C, active heating & cooling) - 1000 W/m² halogen light source - UV light source available - Individual programmable recipes for free experiment configuration - Data logging in text file
 module measuring syst. (ISC Konstanz)	- outside testing field for 16 modules	- outside IV-measurement for up to 16 modules (configuration may be one-cell up to four-cell mini modules) - measurement interval flexible (smallest step is every 1 minute) - light intensity measurement with pyranometer - temperature tracking with thermocouple
	- outside testing field for 4 large modules	- outside IV-measurement for up to 5 - measurement interval flexible (smallest step is every 1 minute) - light intensity measurement with pyranometer - temperature tracking with thermocouple
  EL, PL (ISC Konstanz)	- imaging of recombination in as-textured wafers - analysis of gettering/hydrogenation in mc-Si material - imaging of surface recombination - series resistance imaging, particularly useful for firing optimization/paste evaluation - shunt imaging - detection of processing induced issues like tweezers marks, finger prints etc - detection of cracks during module fabrication	- non-destructive characterization of solar cells in all process-stages - very fast measurement, ca 1 second per image
 Modul EL	- electroluminescence imaging of solar modules up to the size of 6 x 12 = 72 cells (6 inch) - measurement of half-cell modules - measurement of low current EL images (0.5A)	- 3 cameras - single cell measurement - resolution ~200µm/pixel = ~1 MP/cell - excitation current 0...25 A (0...220V) - typ. measurement time ~30s/module

 back contact minim-module line	- Semi automated assembly of back contact modules (one to four cells) - Dispensing of ECA or similar materials on solar cells (both sides possible)	- Dispensing unit can execute custom made CAD dispenser layouts - Pick and place of solar cells - Operating space 40x60 cm - Alignment pins for placement of conductive backsheet and rear encapsulation - Xyz-stepper motors with +- 50 micron accuracy
 ECV	- Electrochemical capacitance-voltage (ECV) profile allows the extraction of the active doping concentration of doped semiconductors. - ECV use in R&D PV industry to measure the phosphorus or boron doping profile of silicon wafer solar cells and silicon thin-film solar cells.	- Active dopant densities in the range of 10^{12} - 10^{21} cm^{-3} can be detected with a depth resolution of 1 nm.
	- Peel tester for simultaneous peel testing of up to 3 interconnected ribbon to determine the adhesion between ribbon and solar cell - Mechanical measurement and evaluation module integrated to determine mechanical properties of solar ribbon (e.g. max. elongation and yield strength)	- Highly sensitive force sensors to determine peel force with accuracy in mNewton range - Force-displacement measurement - High accuracy yield strength determination of solar ribbon
Optical Characterization		
 flasher (Berger)	- Illuminated and dark IV measurement at RT - Suitable for bifacial cells - Suitable for mini-modules - Reconfigurable depending on busbar positions	- Lamp AM 1.5G (0.2 – 1 Suns) - Flash pulse 18 ms - Cell load & measurement time < 30 s - Temperature and irradiance corrections - Built-in module for cell parameters extraction (series and shunt resistances, power)
	- Illuminated and dark IV measurement at room temperature - Suitable for bifacial cells - Suitable for mini-modules (single cell) - Reconfigurable for measuring IBC solar cells (e.g. Zebra)	- Lamp AM 1.5G (0.2 – 1.2 Suns) - Flash pulse 120 ms - Cell load & measurement time < 30 s - Temperature and irradiance corrections - Built-in modules for cell parameters extraction (series and shunt resistances, power, grid resistance, pseudo fill factor, etc)

flasher (Halm)		
 spectroscopic ellipsometer	- Optical and dielectric layer properties (thickness, refractive index) - Ellipsometry is a very sensitive measurement technique that uses polarized light to characterize thin films, surfaces, and material microstructure. Usually the polarization of light changes upon reflection. These changes are measured by an ellipsometer and interpreted on the basis of model calculations. The change in the state of polarization is the direct consequence of the interference within the layer system, that is captured by the so called ellipsometry angles Δ and Ψ and results by modelling for example in optical n(λ), k(λ) and dielectric properties expressed by ε_1, ε_2.	- UV-Vis wavelength range (280-920 nm) - default wavelength window: □□□□300 – 850nm - standard sample size few mm < □ < 20cm - fast measurement (< 1 min) - thickness measurement down to 0.5 nm - double-layer evaluation - large number of fitting models available Development or adaption of fitting models to layer structures and internal materials structure and morphology (e. g. heterogeneous material structure) possible - measurements of flat, polished and also on textured surfaces of mono- and multi-crystalline samples (e.g. random pyramids, iso-texture)
 SR	- EQE, reflexion measurements on solar cells - Measurement of finger widths and calculation of metal fraction of solar cells - Automated wafer thickness measurement - Quantum efficiency mapping	- spot size can be changed - scanning of the entire surface of the solar cell - loss analysis
 spectral photometer	- Measurement of the diffuse as well as directed optical reflectivity R and the transmission T vs. wave length; □calculation of absorption A=100-R-T	- standard sample size about 1cm < □ < 15cm, but larger ones possible by adaption Size of illuminated spot from 0.5cmx3cm down to 0.1cmx0.1cm - wave length window: □=180nm – 3200nm - adaption of measurement set-up and proceeding is straight forward possible - Sample sizes ranging from 2cm in diameter up to the size of large modules - X-Y table with scanning area of 200 x 200 mm²
module flasher	- Illuminated and dark IV measurement at room temperature - Suitable for modules of different sizes, up 210 x 140 cm²	- Lamp AM 1.5G (0.2 – 1.2 Suns) - Flash pulse 100 ms - Flexibility in contacting - Temperature and irradiance corrections - Advanced measuring and analysis methods

		- High precision measuring
IR thermography 	- Mapping of shunts, bad edge insulation, short-circuits due to printing - Suitable for cells and mini-modules (single-cell)	- IR camera (~2000 nm) - Operating in reverse polarization at -10V
 3D Microscope	- determination of width and height of screen printed finger-grid - characterization of isotropic and anisotropic textures - roughness analysis	- 5fold, 10fold, 20fold, 50fold and 100fold objective - resolution down to 120nm (x/y-direction) and 10 nm (z-direction) - slope detection capability up to 85° - motor-driven - programmable optical table
 RTP oven	- Thermal processing for single solar cells - In-situ measurement of temperature and resistance (developed at ISC Konstanz)	- up to 156x156mm² wafers - up to 1000°C - heating with 75K/s - cooling with up to 100K/s (>700°C) - Gas inlet for forming gas, N2, O2, air - water cooled - custom software for data collection available
FTIR	Collaboration contract with IPE of University of Stuttgart	
spectral Photometer		
SIMS		