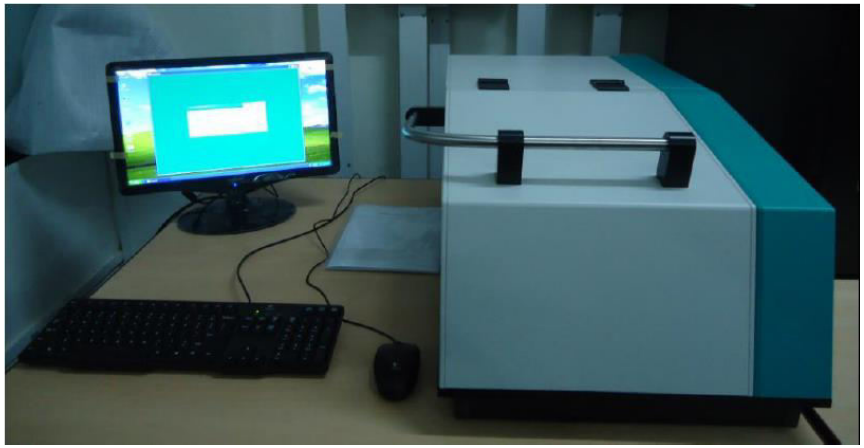
Corescan

Abstract

Corescan is an Sun Lab BV, Netherlands made solar cell characterization instrument to visualize various energy loss locations across the cell and helps in optimization of various process parameters.

System Specifications:

Solar cell dimensions: 5 - 21.5 cm
Solar cell shapes: round, semi-square, and rectangular
Maximum probe speed: 20 mm/s
Special resolution: 0.1 mm
Probe dimension: 0.2 mm (diameter)
Lamp intensity: 150-300 mW/cm2
Lamp homogeneity: > 95%
Voltage range: 0-1000 mV
Voltage measurement accuracy: 1 mV
Output in 1D, 2D, 3D graphs
Output files in ASCII



System capabilities:

- ❑ Core (contact resistance) scan: full surface measurement of contact resistance of front side metallization
- ❑ Shunt scan: locates shunts on solar cells and finds out about their nature.
- ❑ Open circuit voltage (Voc) scan: finds the locations of increased recombination.
- ❑ LBIC (Light Beam Induced Current) scan: finds the regions on a solar cell with reduced short-circuit current density or lower bulk lifetime.

Location: NCPRE Characterization Lab

Overview

1. ***Corescan ?***
2. ***Working principle***
3. ***Applications***
4. ***Specifications***
5. ***Company profile***
6. ***Publications***

Corescan ?

- CORE_The central, innermost, or most essential part of anything

- SCAN_To examine closely

➔ GEOlogik Corescan System provides precise, high quality results for geoscience - exploration, production and documentation since 1990.

➔ DMT Corescan System is a portable digital drill-core imaging system in the field of geosciences.

➔ Corias Corescan System is core scanning machine makes it possible to record and calibrate sections of drilling core of 4 to 15 cm diameter up to one meter in length in a single operation in field of geo-exploration.

➔ **Sun Lab BV** Corescan System is the instrument **reveals energy loss locations** in **solar cells** having four scan methods for four different types of energy loss-

1. **Corescan** (Contact resistance scan) to locate regions of increased contact resistance of the front side metallization.

2. **Shuntscan** to locate shunts.

3. **V_{oc} scan** (Open-circuit voltage scan) to locate recombination losses on test cells without front side metallization.

4. **LBIC scan** (Light Beam Induced Current scan) to locate positions with reduced short-circuit current density.

In reference to solar cells

Corescan

is the name devised

By

SunLab BV

to publicise

Its

Products

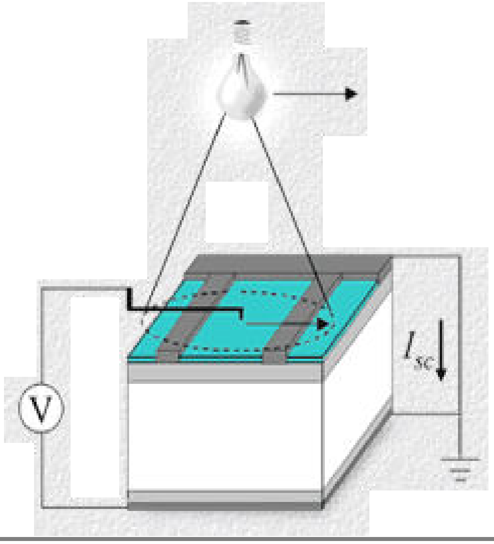
Working principle

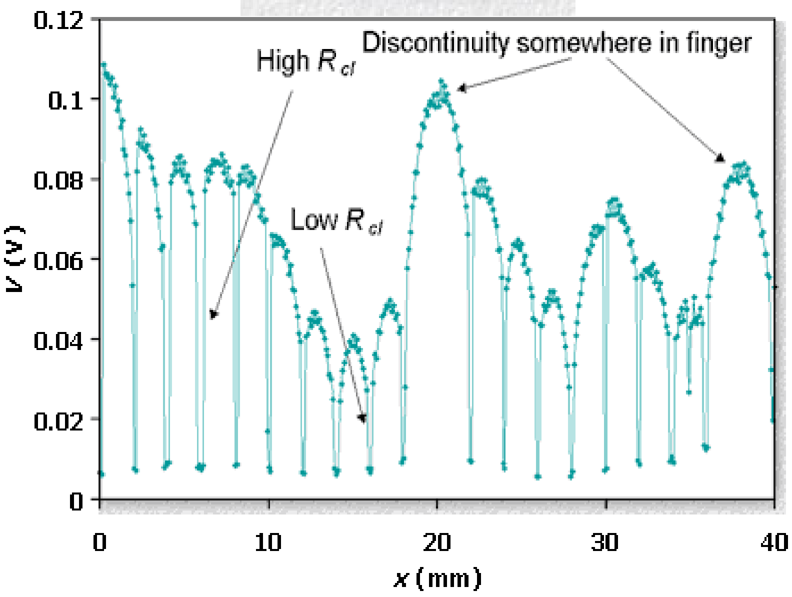
- Basic principle for all Corescan methods is almost same.
- It is the **measurement of the potential distribution on front surface of a solar cell**.
- The only **difference** between these methods is the **condition** at which the cell is operated

- for Corescan, it is <u>short circuited</u> and <u>locally illuminated</u>
- for Shuntscan, it is operated at <u>~300 mV forward bias in the dark</u>
- for Voc scan, it is <u>open circuited and locally illuminated</u>
- for LBIC scan, it is not based on potential mapping and it existed already long before the Corescan instrument was developed.

1. Corescan (Contact resistance scan)

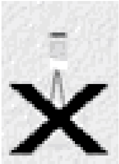
1. Based on measurement of the potential jump at the boundary between a metal line and the silicon adjacent to it, while a current flows from the silicon into the metal line.
2. Line contact resistance can be calculated by dividing this potential jump by the current flow into the line (per unit length of line).
2. light current is locally generated by a small light beam, current flow is enabled by short-circuiting the cell externally.
3. A potential probe centred in the beam measures the local potential and moves together with the beam over the cell, while being continuously in contact with the surface.
4. The probe is always scanned perpendicular to the metal lines, an example of a scan line measured in this way is shown below; R_{cl} means line contact resistance
5. By making parallel scan lines the potential can be determined on the entire cell, and these data are presented within the Corescan software by 2D colour graphs or 3D graphs

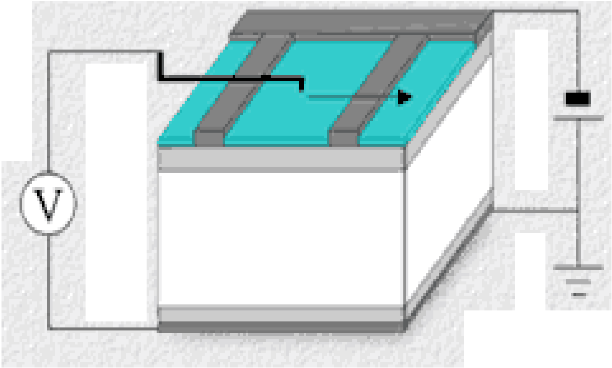




2. Shuntscan

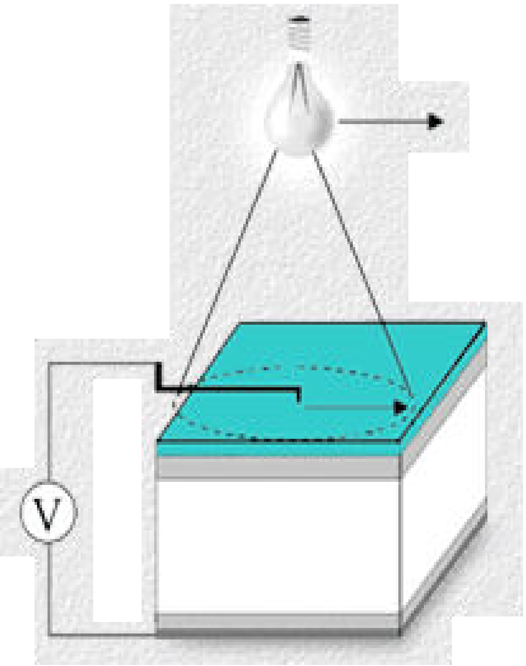
1. Here the cell is not illuminated and current flow is induced at shunt locations in the cell by applying an (adjustable) bias potential across the cell.
2. Because the emitter has a relatively high resistance, the current flow from the adjacent silicon to a shunt will induce a potential gradient in the direction of the shunt in the silicon
3. This is detected by the potential probe. In the Shuntscan maps,
4. The absolute difference between the applied bias potential and the locally measured potential can be plotted
5. So that shunts are represented by spikes in the graph.
6. By scanning at different bias potentials, it is also possible to investigate the (non-)linearity of individual shunts.





4. Voc scan

1. During a Voc scan, the local potential is measured in the centre of a scanning light beam while the cell is open-circuited.
2. In this way, it is possible to measure a kind of local Voc, provided that the cell has no front side metallisation (otherwise the potential differences across the cell are smeared out).
3. Although the resistance of the emitter is considerable, there will certainly be current flow to the dark regions of the cell, due to the fact that the illumination is local.
4. This causes the measured potentials to be lower than the Voc value at one sun intensity, despite the fact that the light beam is adjusted to one sun.
5. With this method, the local current leakage through the p-n junction can be measured, shunts can be located in cells without the necessity for a front side metallisation,
6. Also non-visible cracks can be detected and also the absence of a BSF on some locations could be detected.
7. The interpretation of the results of this method is still under investigation.



4. LBIC scan (Light Beam Induced Current scan)

1. The LBIC scan method is not a real member of the Corescan methods family for two reasons.

First , it is not based on potential mapping like the other methods

Second, the LBIC method was already widely used before the Corescan was developed.

2. The LBIC scan method is scanning of a light beam over a cell while measuring the resulting short-circuit current for each position.
3. The usual LBIC set-ups measure LBIC with a very small beam (down to 0.1 mm) to obtain a high spatial resolution.
4. The Corescan LBIC is a low resolution LBIC, since the beam diameter is fixed at 9 mm. It is therefore only meant as a relatively coarse method to find good and bad regions on a solar cell.
5. An advantage of the large beam diameter is that the scan time is relatively short (5-10 min).
6. In principle, we could even make an LBIC scan and a Corescan simultaneously,

But since a Corescan damages the surface somewhat and reduces Isc by a few %, it is better to separate the scan methods.

Applications

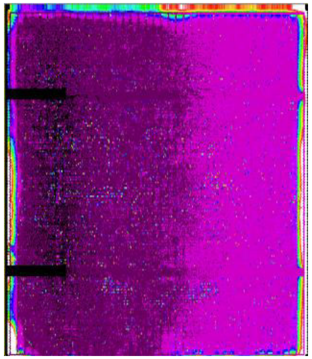
- Corescan

- To map the contact resistance of the front side metallisation
- Optimise the metallisation process.
- To optimise firing temperature
- To study the effect of crystal orientation on contact resistance
- To study the effect of supports below a cell
- To study the effect of a non-uniform emitter

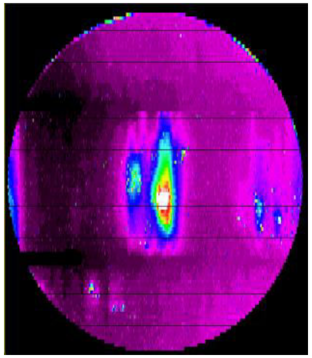
- # Shuntscan

- Locate shunts on solar cells and find out about their nature.
- **Examples**

1.The shunts are located at the edges of the cell due to a poor edge shunt removal method.



2.This Shuntscan shows a strong shunt at the centre of the cell either due to poor emitter formation or an impurity in the wafer material.



- V_{OC} Scan

- Find the locations of increased recombination (on research cells without front side metallisation).

- **Examples**

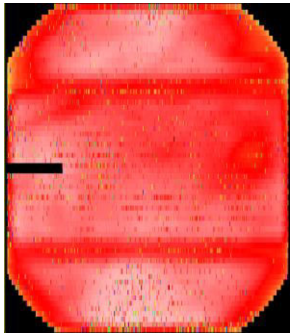
1.The Voc scan on this mono-crystalline cell clearly shows the influence of the absence of the BSF below the silver rear busbars

❑The V_{oc}'s measured at the corresponding positions on the front side are lower than on the rest of the cell.

❑Some edge shunts can be seen on the upper left edge and the upper right edge.

❑It is to be noted that the Voc is quite constant when compared with the multi-crystalline cell.

❑This is probably due to the absence of grain boundaries in the mono material.

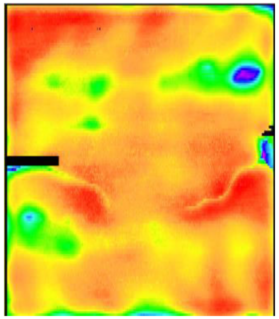


2.This multi-crystalline cell shows a much different Voc's than on the mono-crystalline cell

❑This material contains more grain boundaries and defects;

❑Two cracks show up on locations that were not visible on the cell.

❑On the right hand side of the wafer there is an edge shunt.



• LBIC Scan

➢ Find the regions on a solar cell with lower bulk lifetime, optimise gettering and hydrogen passivation.

➢ **Example**

❑LBIC scans on three cells made from wafers that were adjacent in a Si ingot are shown here.

❑The measured short-circuit current in mA is indicated on the colour scale on the right.

❑The light beam and the scan resolution were the same as used for the Corescan

❑It is clear that the cells have the same distribution of relatively good and bad regions, as expected.

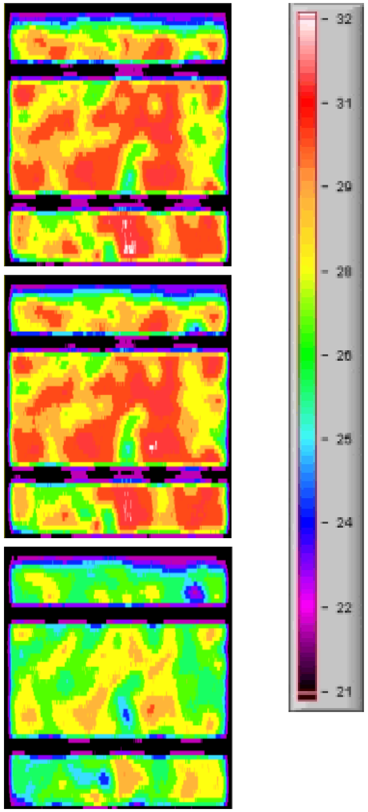
❑The LBIC scan on the right was performed after a Corescan had been made, showing that the local short-circuit currents have decreased somewhat due to the scratching of the Corescan potential probe.

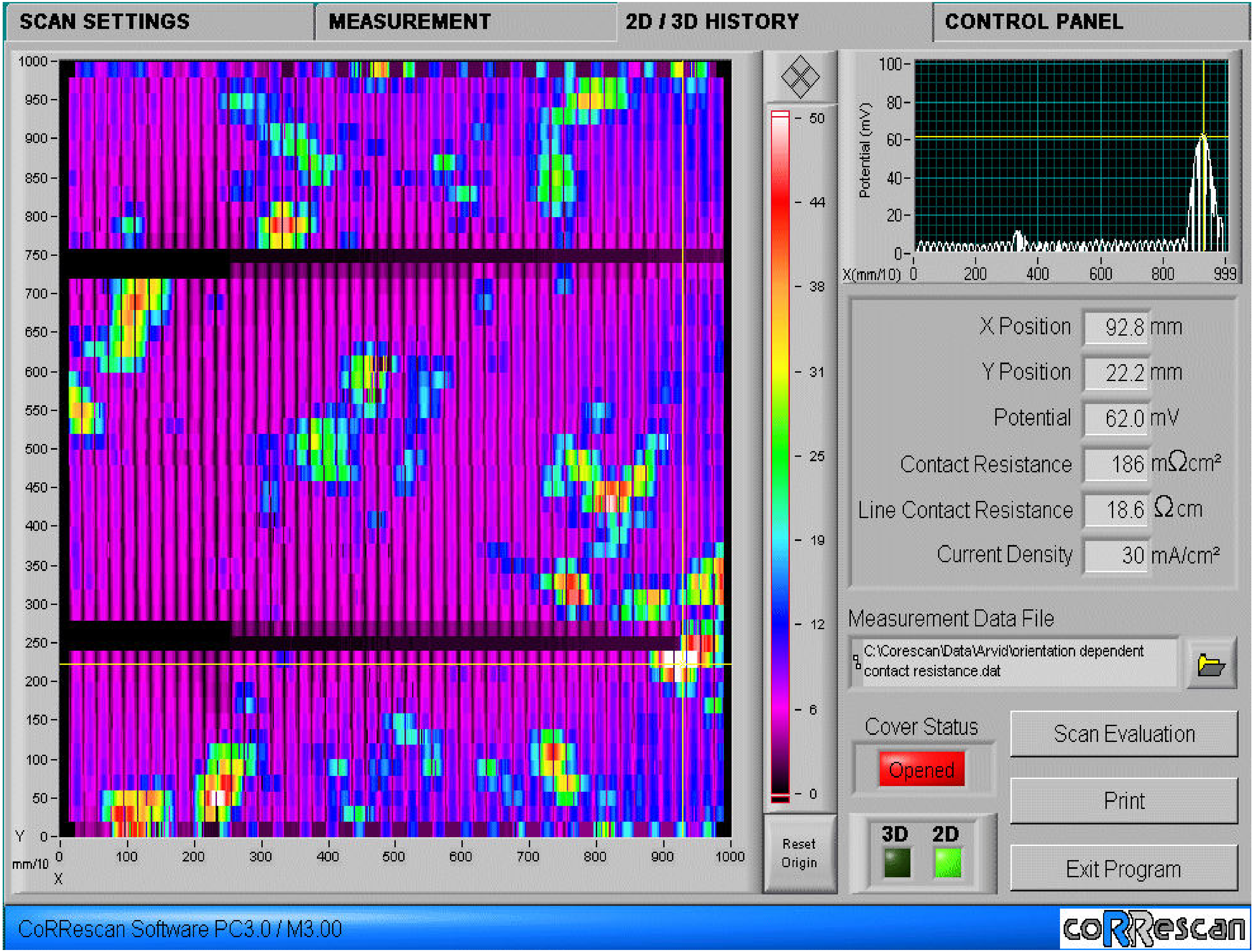
❑However, when looking at the colour scale the current loss is seen to be < 10 % so that the Corescan results have not been influenced very much.

❑Although the lateral resolution of the LBIC scan of the Corescan is not as high as usual for LBIC

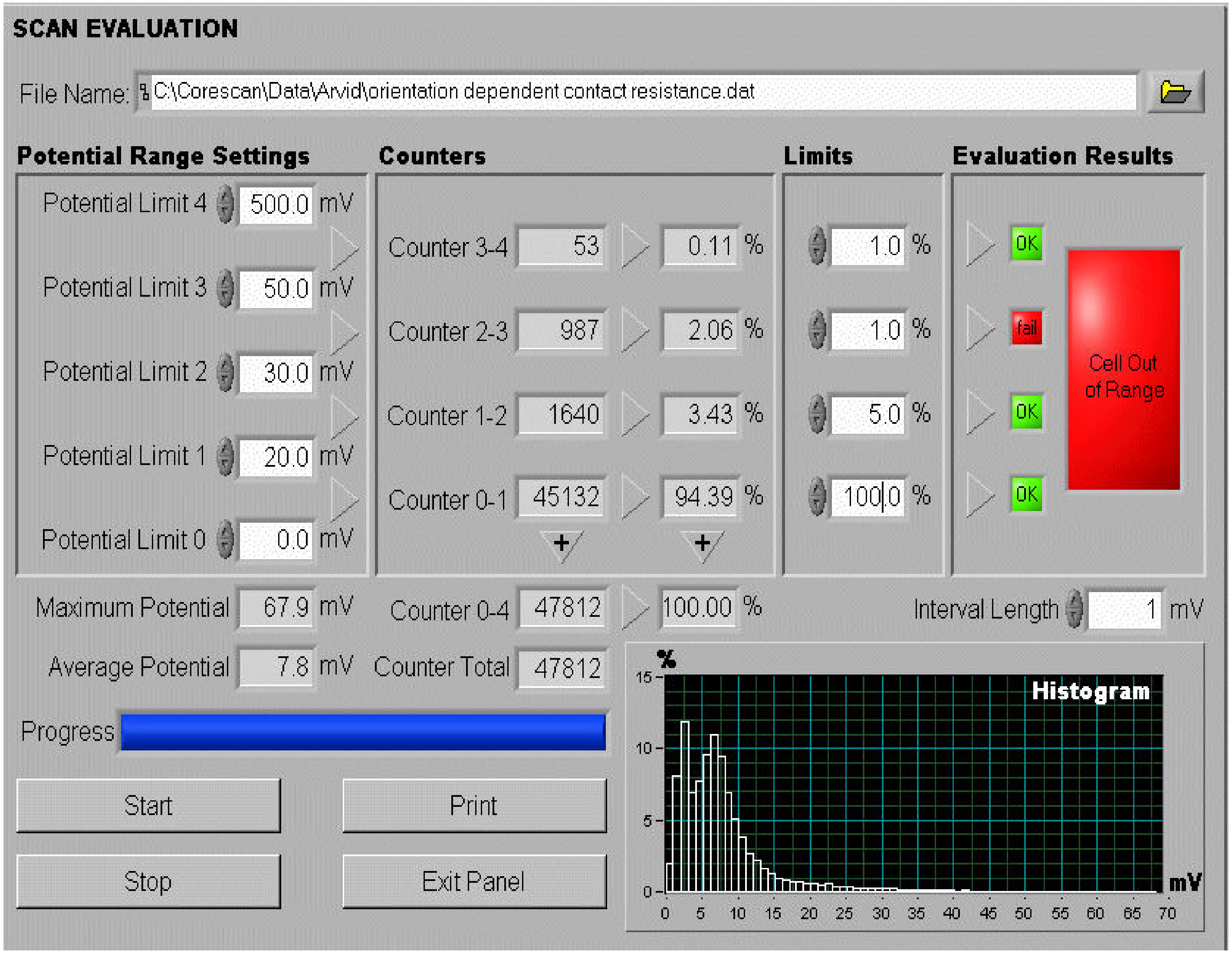
❑An advantage of the lower resolution is the shorter measurement time (6 min for 10 cm x 10 cm).

❑The method is still very useful to look at the **spread in material quality and the influence of gettering and hydrogen bulk passivation**.





SCAN SETTINGS
MEASUREMENT
2D / 3D HISTORY
CONTROL PANEL
Reset Origin
Potential (mV)
X(mm/10)
X Position 92.8 mm
Y Position 22.2 mm
Potential 62.0 mV
Contact Resistance 186 mΩcm²
Line Contact Resistance 18.6 Ωcm
Current Density 30 mA/cm²
Measurement Data File
C:\Corescan\Data\Arvid\orientation dependent contact resistance.dat
Cover Status
Opened
Scan Evaluation
Print
Exit Program
3D
2D
CoRRescan Software PC3.0 / M3.00


SCAN EVALUATION
File Name: C:\Corescan\Data\Arvid\orientation dependent contact resistance.dat
Potential Range Settings
Potential Limit 4 500.0 mV
Potential Limit 3 50.0 mV
Potential Limit 2 30.0 mV
Potential Limit 1 20.0 mV
Potential Limit 0 0.0 mV
Counters
Counter 3-4 53 0.11 %
Counter 2-3 987 2.06 %
Counter 1-2 1640 3.43 %
Counter 0-1 45132 94.39 %
Limits
1.0 %
1.0 %
5.0 %
100.0 %
Evaluation Results
OK
fail
OK
OK
Cell Out of Range
Maximum Potential 67.9 mV
Average Potential 7.8 mV
Counter 0-4 47812 100.00 %
Counter Total 47812
Interval Length 1 mV
Progress
Start
Print
Stop
Exit Panel
Histogram
%
mV

Specifications

Corescan specifications			
	Mains supply		230/115 V AC, 50-60 Hz
	Power consumption		130 VA
	Fuse (20x5 mm)	For 230 V	1.6 A (slow blow)
		For 115 V	3.15 A (slow blow)
	Measuring environment	Temperature	15-30 °C
		Humidity level	80%
		Vibration free	...
	Interface		Serial, 9 pin SUB D
	Measuring probe	Diameter	0.2 mm
	Overall dimensions	Width	809 mm
		Height	350 mm
		Depth	515 mm
	Total weight		28 kg
	Min. table size	Width (Including monitor)	800 mm (1200 mm)
		Depth	600 mm
	Solar cell size	Thickness	200-1000 µm
		Length (X-axis)	50-205 mm
		Width (Y-axis)	50-205 mm
		Cell shape	Square, semi-square, rectangle, circle
	Light source	Light intensity	0-200 mW/cm²
		Light homogeneity	± 5 %
		Light stability	± 5 %
		Light spectrum	white light, wavelengths ~ 350-1200 nm
		Light beam diameter	9 mm
	X, Y axis	X,Y range	0-215 mm (for the older versions it was 0-205 mm)
		X,Y speed	10-20 mm/s (adjustable)
		X resolution	0.1 mm (fixed)
		Y resolution	0.5-200 mm (adjustable)

Corescan operating software	1.The Corescan instrument comes with operating software on a CD.
	2.No additional software or hardware is needed.
	3.It is also possible to download the software for free.

Required computer specifications	Processor	Pentium 1 GHz minimum
	Internal memory	256 MB or more
	CD drive	
	Hard disk	50 MB minimum
	Keyboard	
	Mouse	
	Communication	Serial port COM1 or COM2, baud rate 57600 bps. USB also possible with USB to serial converter
	Operating system	Windows 98 or newer
	Display resolution	1024 x 768 pixels minimum

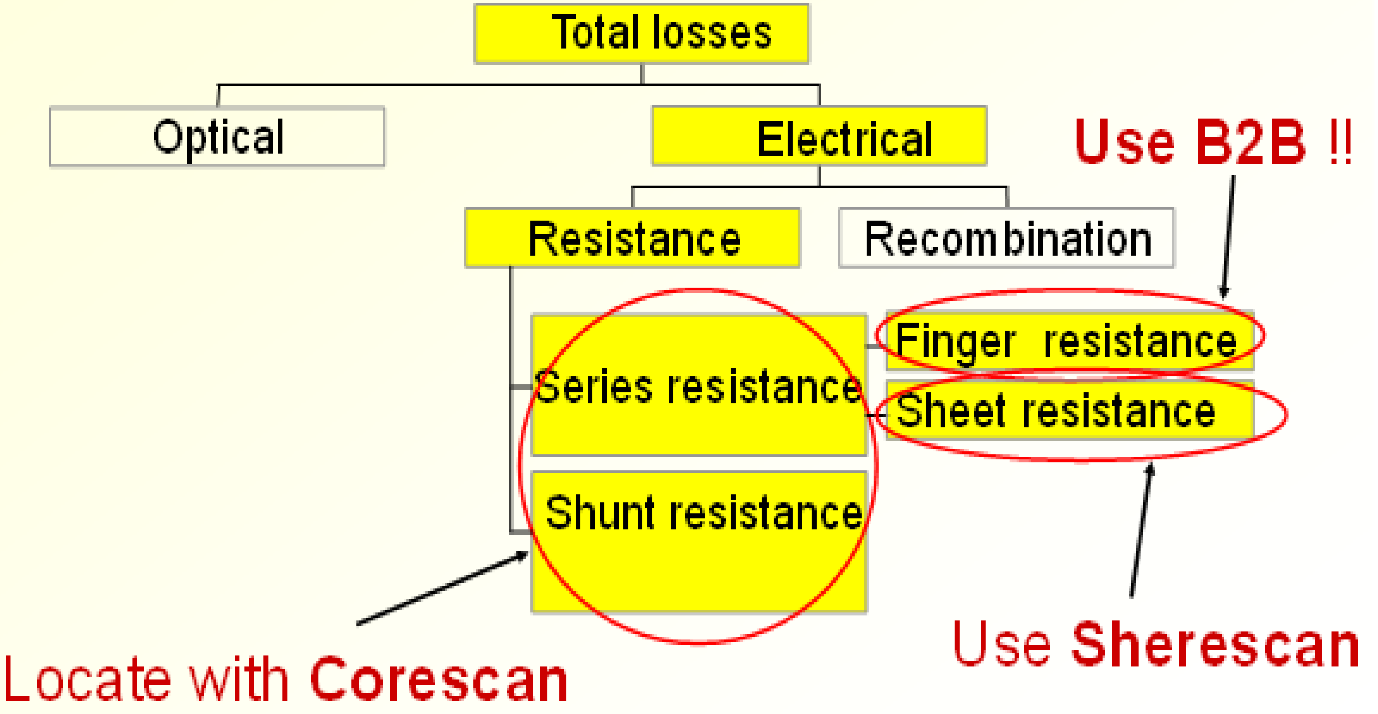
Company profile

- ❑Sun Lab BV is a daughter company of Energy Research Centre of the Netherlands.

- ❑Founded in 1999 to commercialize special products of ECN solar energy.

- ❑Offers three instruments:
    - ❑Corescan _brought to the market in 2000
    - ❑Sherescan_…………………………. in 2005
    - ❑SunLab B2B _the latest instrument, and available since 2010.

Losses in solar cell covered by SunLab instruments



Corescan

- Detailed surface mapping
- Contact resistance between the emitter and the metallization grid of solar cells
- Shunt resistance
- Short circuit current (LBIC)
- Open circuit voltage (Voc)

Sherescan

- Measure the emitter sheet resistance across the surface of a single wafer
- P/N recognition
- Metal conductivity
- Useful in optimizing the emitter diffusion process

SunLab B2B

- Measure the resistance of all fingers between two busbars on an H-pattern solar cell
- Can be used to optimize finger patterning

Publications based on the instrument

1. Mapping of contact resistance and locating shunts on solar cells using Resistance Analysis by Mapping of Potential (RAMP) techniques - Proceedings 16th European Photovoltaic Solar Energy Conference, Glasgow (United Kingdom), page 1438 (2000).
2. Error diagnosis and optimisation of c-Si solar cell processing using contact resistances determined with the Corescanner - Proceedings 12th Photovoltaic Science and Engineering Conference, Jeju (Korea), page 591 (2001).
3. Error diagnosis and optimisation of c-Si solar cell processing using contact resistances determined with the Corescanner - Solar Energy Materials & Solar Cells 74, page 43 (2002). This is a pre-print version; submitted 2001 at the 12th PVSEC in Jeju, Korea (see above). The original paper is available via Elsevier Science Direct.
4. Contact resistance scanning for process optimization: the Corescanner method - 11th NREL workshop on crystalline silicon solar cell materials and processes, Estes Park (Colorado, USA), page 293 (2001).
5. Shunt detection in solar cells with the Corescanner and lock-in thermography: a comparison - 11th NREL workshop on crystalline silicon solar cell materials and processes, Estes Park (Colorado, USA), page 253 (2001).
6. Contact resistances measured using the Corescan: relations with cell processing - Proceedings 17th European Photovoltaic Solar Energy Conference, Munich (Germany), page 1531 (2001).
7. Optimizing the front side metallization process using the Corescan - Proceedings 29th IEEE Photovoltaic Specialists Conference, New Orleans (Louisiana, USA), page 340 (2002).
8. Locating losses due to contact resistance, shunts and recombination by potential mapping with the Corescan - 12th NREL workshop on crystalline silicon solar cell materials and processes, Breckenridge (Colorado, USA), page 117 (2002).
9. Simple, detailed & fast firing furnace temperature profiling for improved efficiency - Proceedings of the conference PV in Europe - From PV technology to energy solutions, Rome (Italy), page 276 (2002).
10. Influence of grain orientation on contact resistance at higher emitter sheet resistances, investigated for alkaline and acid saw damage removal - Proceedings 3rd World Conference on Photovoltaic Energy Conversion, Osaka (Japan), page 1036 (2003).
11. Explanation of high solar cell diode factors by non-uniform contact resistance - Progress in Photovoltaics 13, page 3 (2005). This PDF is a preprint version, the original paper is available at Wiley Inter Science.
12.New approach for firing optimisation in crystalline silicon cell technology - Proceedings 19th European Photovoltaic Solar Energy Conference, Paris (France), page 1044 (2004).
13. Contact optimisation on lowly doped emitters using the Corescan on non-uniform emitter cells - Proceedings 19th European Photovoltaic Solar Energy Conference, Paris (France), page 701 (2004).
14. Lead free metallisation paste for crystalline silicon solar cells: from model to results - Proceedings 31st IEEE Photovoltaic Specialists Conference, Orlando (Florida, USA), to be published.

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http://www.sunlab.nl

Thank you!