Analysis Methods and Instruments for the Production of Polysilicon Material and Crystalline Silicon Wafers

Yuepeng Wan, Dr. –Ing.

CTO, LDK Solar Co. LTD.

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PV production chain for c-Si cells

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硅矿石
Silicon ore

冶金硅料
Metallurgical silicon

高纯硅料
pure silicon raw material

硅锭
Ingot

硅块
Bricks

硅片
Wafers

LDK-R&D

电池片
solar cell

BEST Solar

电池组件
module

LDK

电池发电系统
solar system

About LDK Solar Co. LTD.

- Plant location: Xinyu, Jiangxi, PR. China
- Employee: 15000
- 2007 Sales: 0.5 billion US$
- 2008 Sales: about 1.6 billion US$
- 2008 capacity: 1.4 GW
- Products: multi- and mono-crystalline wafers, polysilicon, PV systems.
- Certificate: ISO9001-2000
- NYSE listed June 2007

Xinyu City, Jiangxi Province

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Inspection/Analysis Center in LDK Solar

The PV inspection/analysis center of LDK consists of the following labs：

- Wafer/solar cell Analysis Lab
- Chemical Analysis Lab
- GDMS/Low T-FTIR Lab
- ICP-MS Lab

The LDK inspection/analysis center is providing services to the PV industry and research institutions.

http://iac.ldksolar.com

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Inspection/analysis for polysilicon production

- To check the quality of TCS and virgin polysilicon.
- To check the effect of different processes such as purification 、deposition and so on.
- To check if there's any contamination happened in the pipe systems.

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Inspection/analysis for wafers/cells

- Physical characteristics analysis
- Appearance/edge defects inspection
- Bulk crystal defects analysis
- The carbon/oxygen content analysis
- Failure analysis of crystalline solar cells

Trace elements in MG silicon and unpurified TCS

- **ICP-OES**

  Suitable for both UMG silicon and TCS

  DL: <6N

Advantage: it is suitable for both solid and liquid samples. And it is more suitable for quantitative analysis.

Disadvantage: the sampling procedure is complicated.

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C/O content measurement in low grade silicon

Carbon analyzer

- Advantage: it is suitable for solid and convenient for use.
- Disadvantage: The detection limit is 4ppmw, which is not good enough of high purity silicon.

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C/O content measurement in low grade silicon

Oxygen analyzer

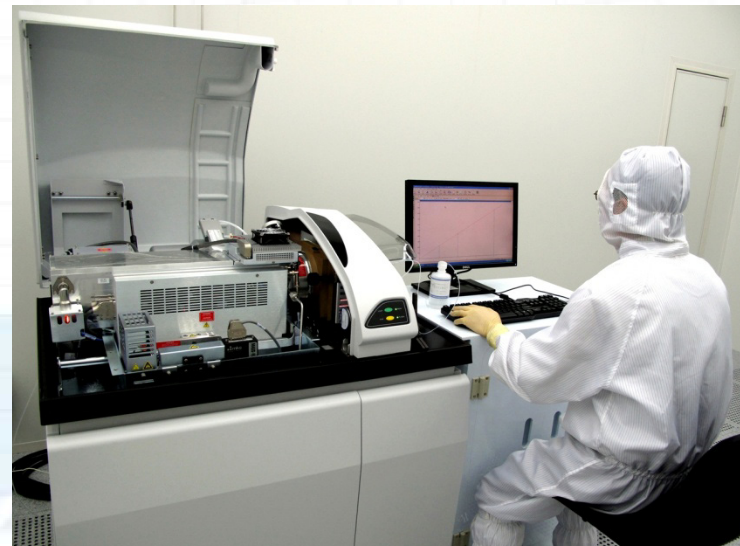
- Advantage: it is suitable for solid and convenient for use.
- Disadvantage: The detection limit is 2ppmw, which is not good enough of high purity silicon.

Trance elements for Virgin poly/high purity TCS

- **ICP-MS**

  Suitable for virgin silicon and purified TCS.

  DL ~9N



Advantage: it is suitable for both solid and liquid sample. And it is quantitative inspection technology.

Disadvantage: the treating procedure is very complicate.

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A fast analysis tool for SoG silicon (6N)

GDMS (Glow-discharge Mass Spectrometer)

- Advantage: easy to use, quick results, full range of elements.
- Disadvantage: only solid samples, semi-quantitative.

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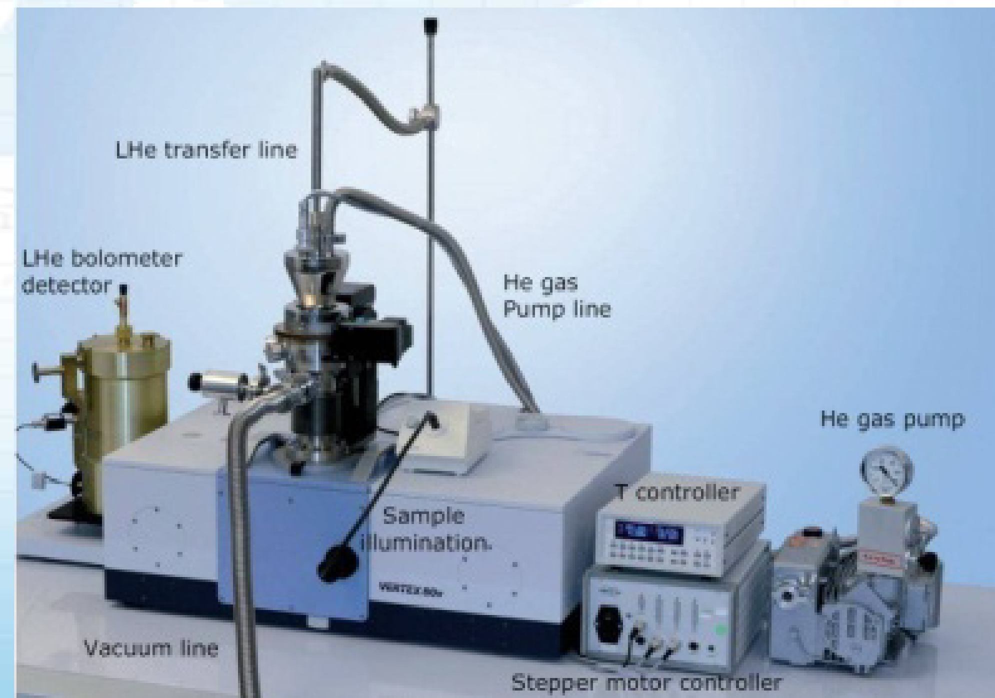
Low T-FTIR inspection for virgin polysilicon

Low Temperature FTIR

- DL of C/O is 10 ppba when sample is in 77K enviroment.
- DL of B/P is 30ppta when sample is below 8K.

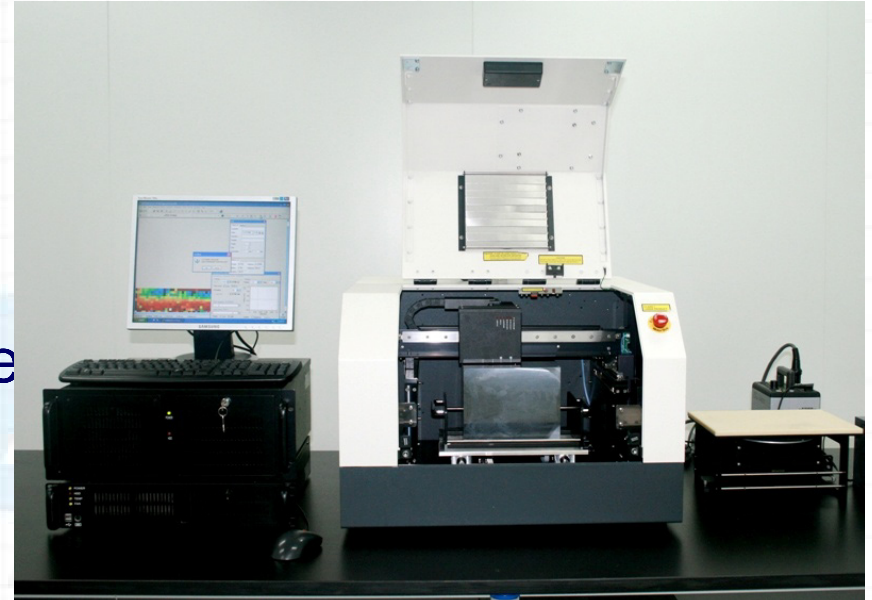


Physical characteristics of silicon wafers

Resistivity Inspection

- Four-Point Resistivity tester
- Eddy current Resistivity teste

  (contactless technology)



Minority Carrier Lifetime test

- Microwave photo conducted degradation (u-PCD) life time tester

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Appearance and defects inspection

- **Optical microscope**

  Magnification factor: 100-1000

- **SEM/EDX**

  Magnification factor: 5-300000

  EDX could be useful to study the component of the uncertain material/stain on wafer surfaces

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The concentration of C/O in silicon wafers

- FTIR

The detection limitation of FTIR is about 0.4ppma.

Mapping function is done by attached device

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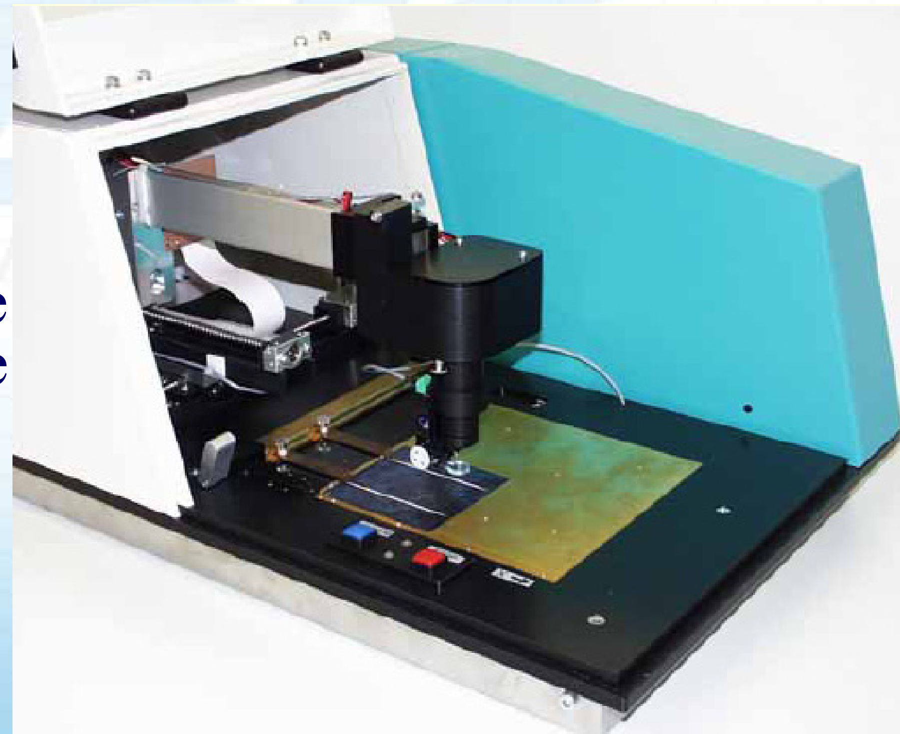
Solar cell failure analysis (CoRReScan)

- **LBIC:** Light beam induced current mapping
  To locate low efficiency area of whole cell
- **Voc Scan:** To locate low open voltage area of whole cell
- **Shunt Scan:** To locate shunting area of whole cell
- **Series resistance Scan:** To locate high contact resistance area of the whole cell



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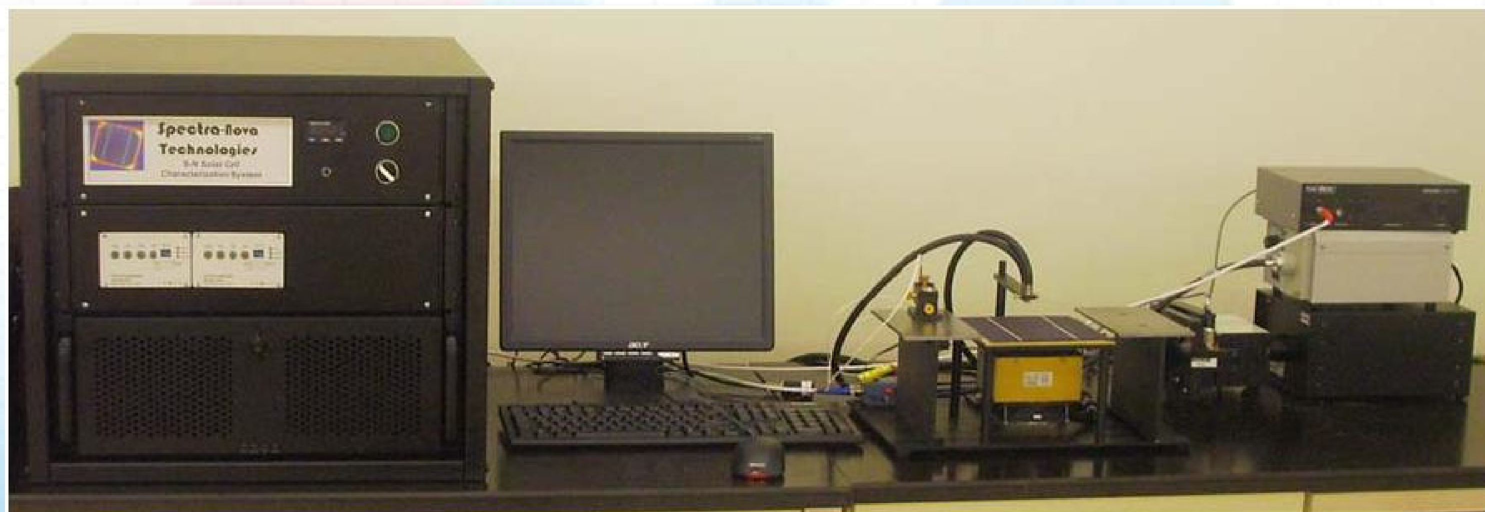
Solar cell failure analysis: -IQE/EQE/Reflectivity

- IQE-internal quantum efficiency inspection
- EQE-external quantum efficiency inspection
- Reflectivity inspection of textured wafer/solar cell



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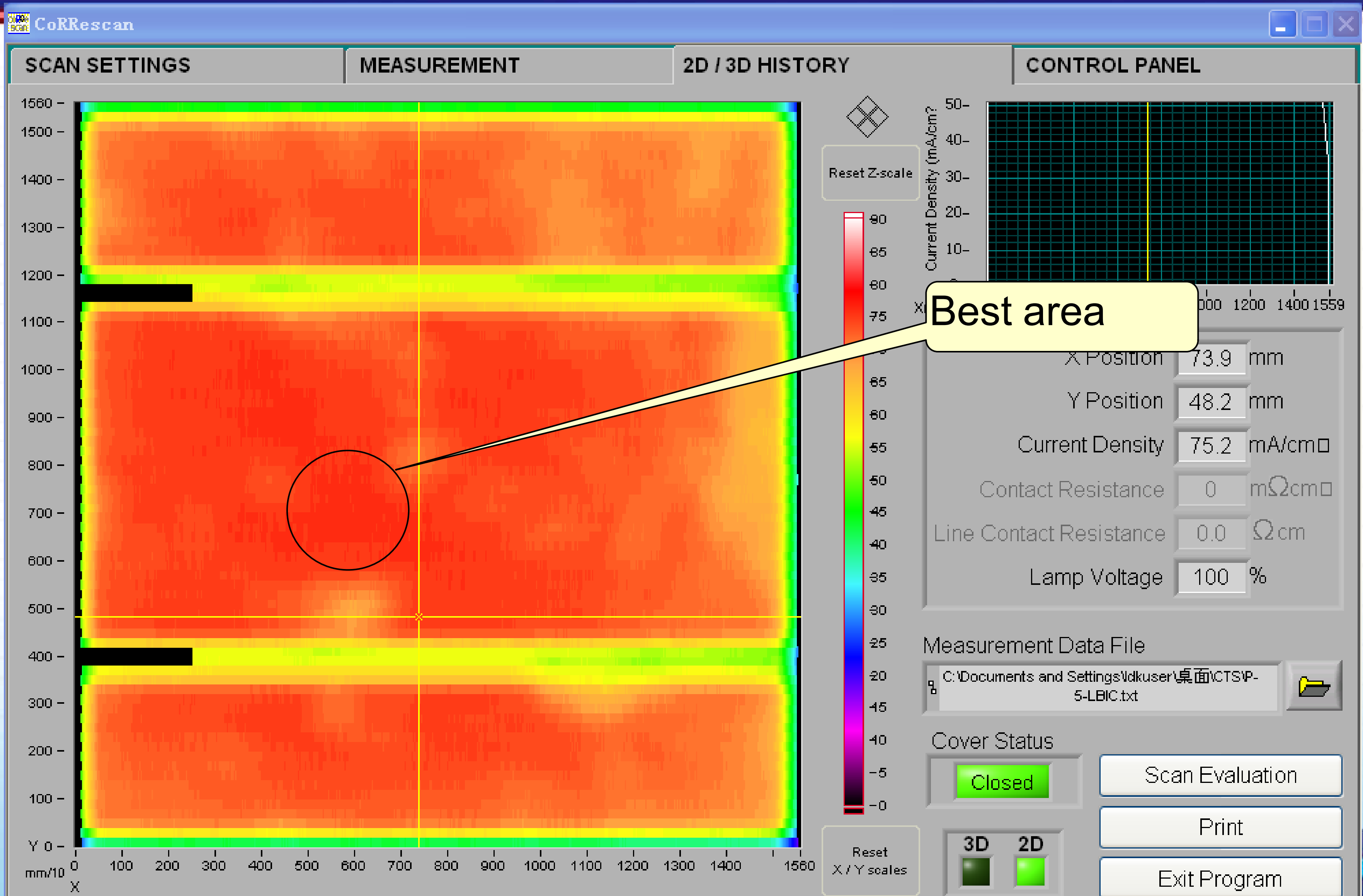
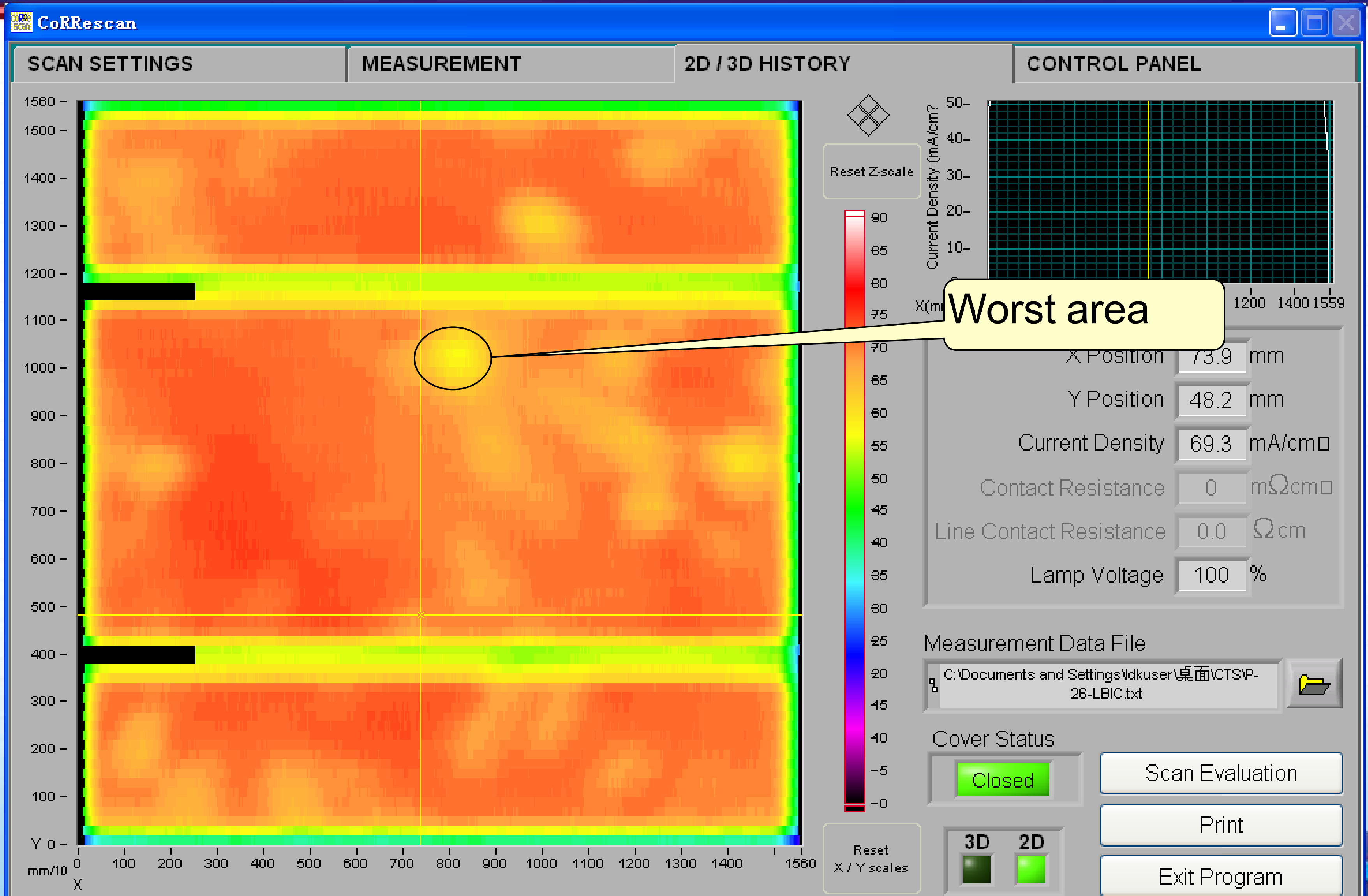
Application example 1: —low efficiency analysis



Application example 1: —low efficiency analysis



Application example 1: —low efficiency analysis

Analyte	Mass	Best area	Worst area
Na	23	**148.957**	**751.647**
Mg	24	**75.36**	**159.533**
Al	27	**287.218**	**621.468**
K	39	62.216	93.124
Ca	40	**287.449**	**825.601**
Ti	50	**-22.826**	**15.313**
V	51	-45.166	-45.22
Cr	52	**2.243**	**26.024**
Mn	55	-21.228	-18.029
Fe	56	**72.713**	**163.686**
Ni	58	48.305	79.072
Co	59	74.222	72.976
Cu	63	**42.884**	**61.484**
Zn	64	23.754	42.493
Cu	65	**3.545**	**15.279**
Zr	90	-8.876	-8.167
Nb	93	-5.15	-4.24
Mo	95	13.729	14.365
Mo	98	-3.693	-3.872
In	115	-20.897	-20.355

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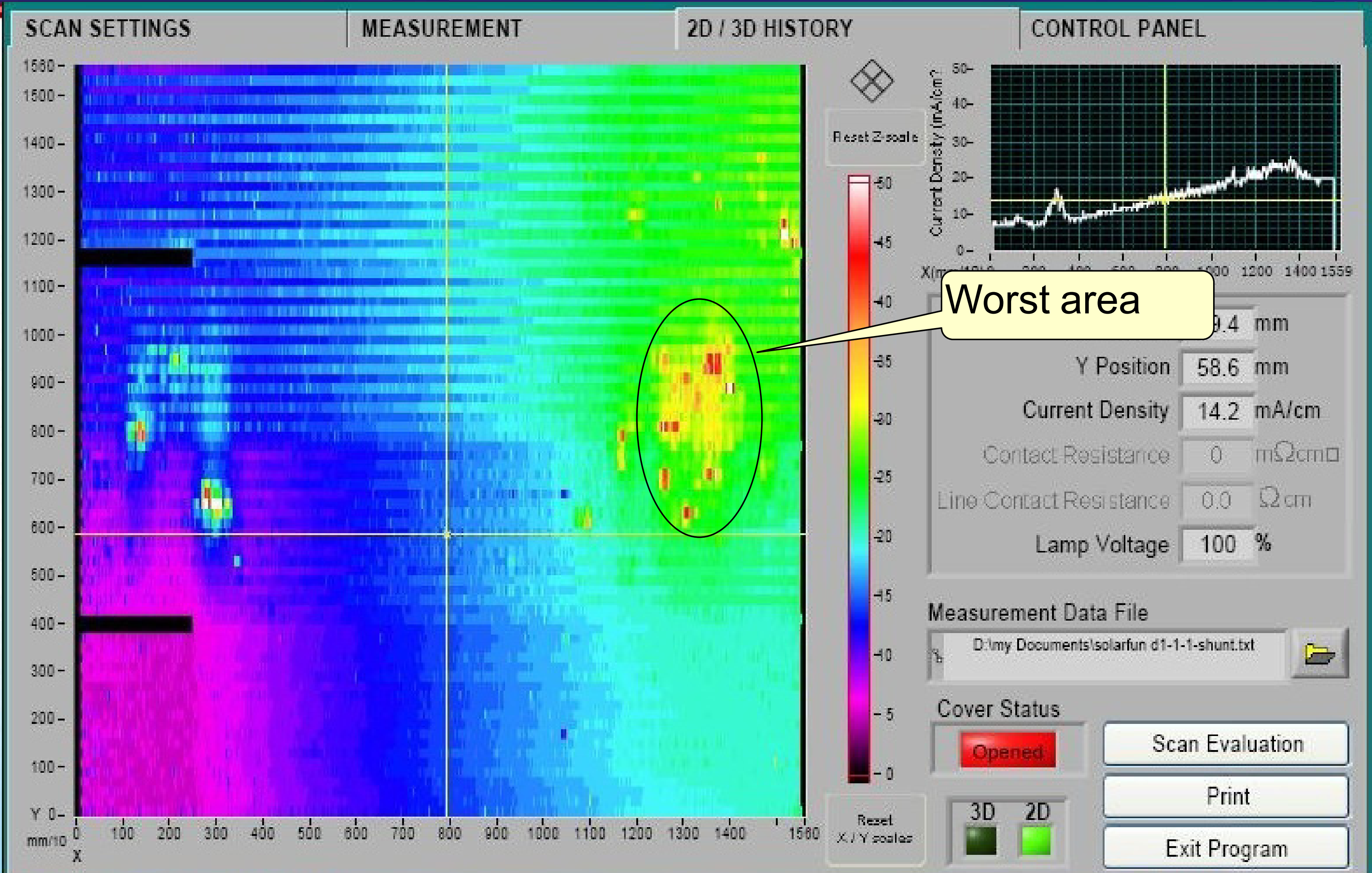
Application example 2: —shunting analysis

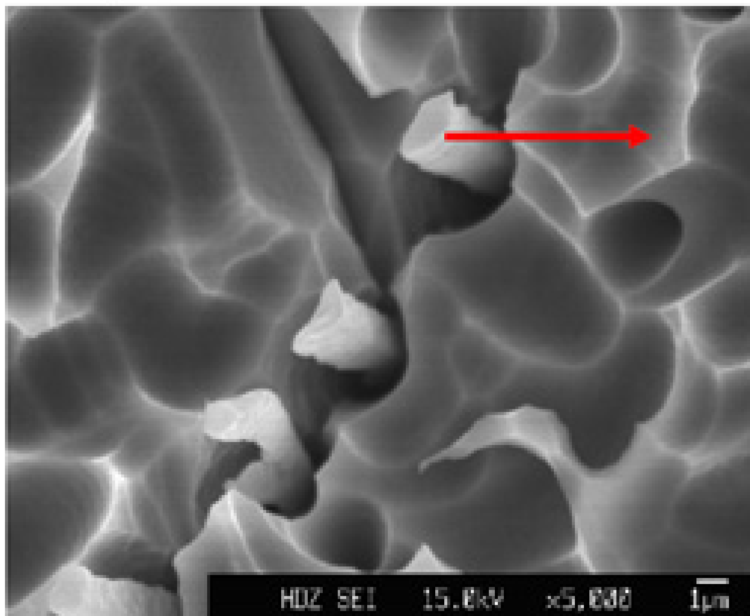


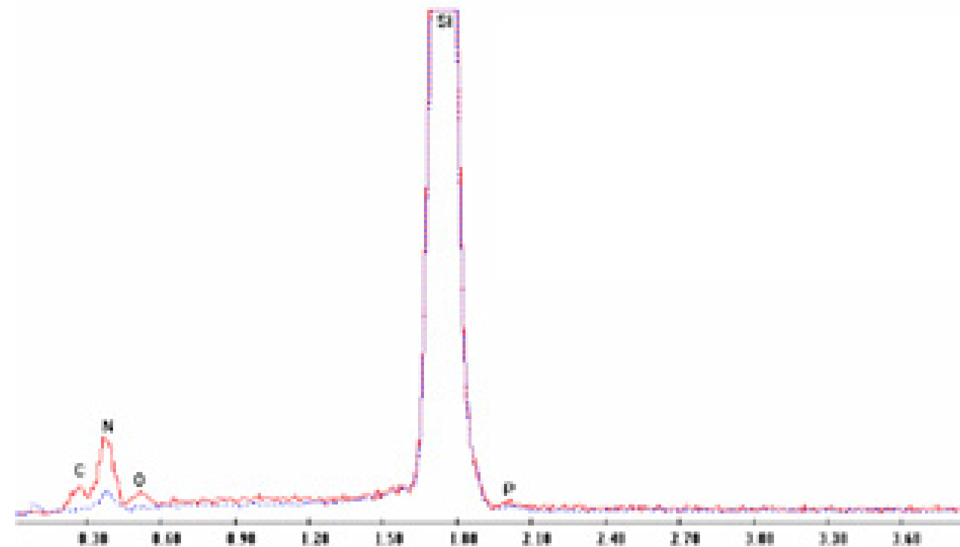
Application example 2: —shunting analysis

- **<u>Step 1. Shunt Scan:</u>** locate the shunting area.
- **<u>Step 2. SEM:</u>** showing the microstructure of the shunting area.
- **<u>Step 3. EDX:</u>** analysis the content of the micro-sticks, and it shows high C/N.

Results:

SiC crystals in the grain boundary are the causes of the shunting





Thanks for your attention!