

Leading the Future of PV



Heraeus Photovoltaics
Value Added Total Solutions

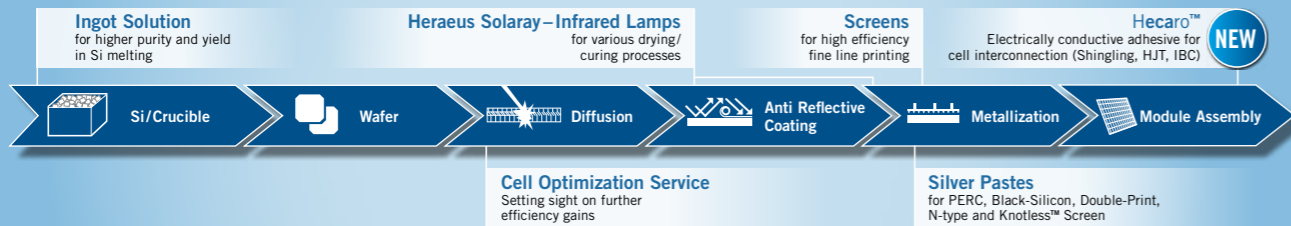
Heraeus Photovoltaic Total Solutions

Providing our customers the edge in this dynamic industry

Heraeus. Technology delivered. All around the world.

- Family owned technology group, headquartered in Hanau, Germany, founded 1851
- One of the biggest, family owned businesses in Germany
- More than 160 years of experience in Precious Metal Management
- 13.000 employees and more than 100 sites in 40 countries worldwide
- Products for environmental, health, electronics, mobility and industrial applications

OUR VALUE CHAIN



With over 160 years of experience in precious metal processing, Heraeus strives to provide customers with the most cutting edge materials and solutions to aid them in the effort to maximize performance.

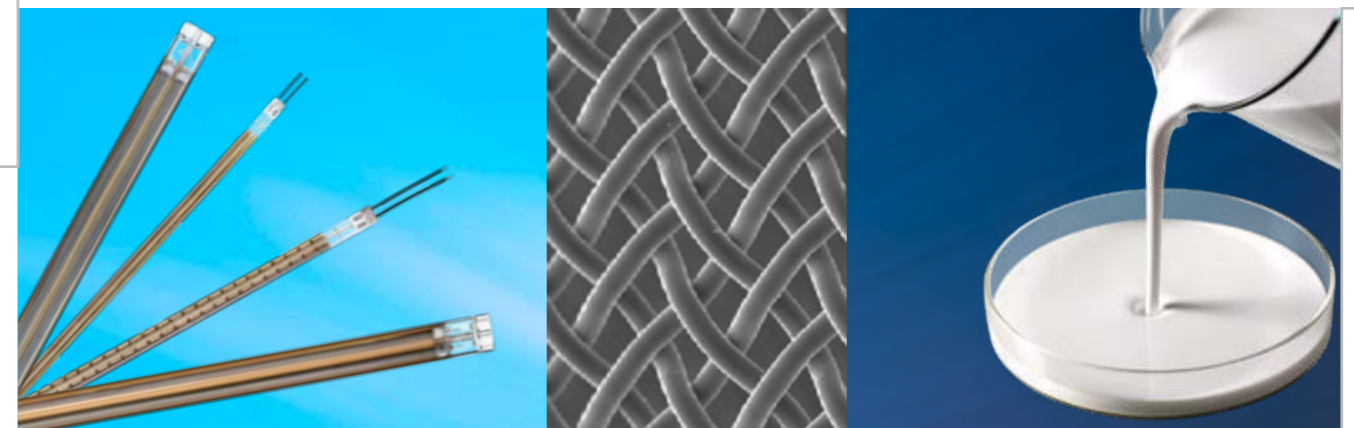
Having established firm leadership position in the photovoltaic conductive silver paste sector, Heraeus Photovoltaics now offers beyond paste solutions. The goal is to provide synergistic solution bundles that together can elevate our customer's efficiency and yield.

In the solar industry, Heraeus Photovoltaics' R&D efforts aim primarily for optimizing solar cells, the key link in the photovoltaic value chain. By developing new applications and solutions for photovoltaic solar energy, Heraeus Photovoltaics contributes to reduce solar cell production costs. Furthermore, Heraeus Photovoltaics provides a photovoltaic total solution in order to improve customer's solar cell efficiency and yield.

This includes various beyond paste products: Ingot Solution – for higher purity and yield in Si melting, Heraeus Solaray – Infrared Lamps for various drying and curing processes, Cell Optimization Services – to set sight on further efficiency gains, Paste/Screen bundle service – for high efficiency fine line printing and Hecaro™ – our new electrically conductive adhesive for cell interconnection.

WHAT WE CAN OFFER YOU:

- High-quality product bundles for high cell efficiencies
- Expertise on advanced solar cell analysis and process optimization
- Unparalleled expertise in leading cell technologies like PERC



Ingot Solution

Higher purity and yield in Si melting

HeraGlaze®: High purity SiO₂ diffusion barrier coating

- Increased yield per ingot and higher cell efficiencies
- For multi-Si and mono-like solar cells
- Up to 4% more yield per ingot

The innovative HeraGlaze® coating is a leap in quality and yield for integrated PV-manufacturers. It enhances crucible performance for up to 4% more wafers per ingot and significantly higher cell efficiencies.

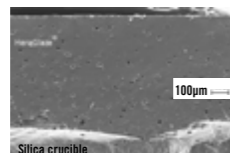
HeraGlaze® is a high purity, high density SiO₂-barrier coating, which prevents thermally induced impurity transfers from the crucible surface into the Si-melt/ingot without increase of oxygen permeation during the crystallization process. The enhanced quality of the Si-melt/ingot results in improved carrier lifetime leading to significantly higher cell efficiencies.

HeraGlaze® is in-situ applicable for all commercially available crucibles thus it eliminates the need for additional capital expenditures. Please contact our local technical service teams for detailed product information.

KEY BENEFITS:

- Enhances crucible performance in multi-silicon solar wafer production
- Up to 4% higher yield per ingot
- Enhanced cell efficiency by improved carrier lifetime
- In-situ applicability, no CAPEX required
- Fits to all commercially available crucibles

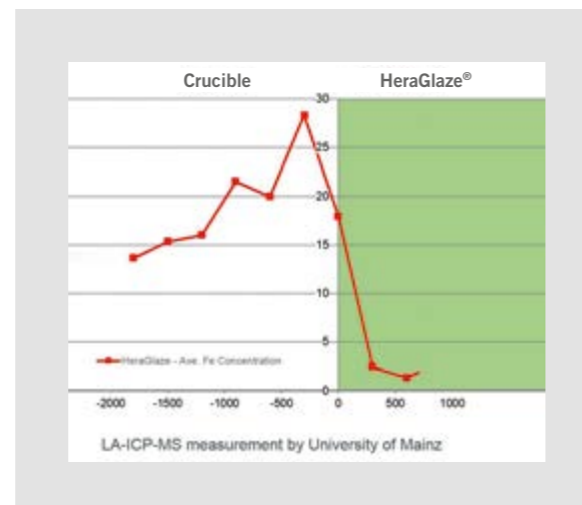
Microstructure of densified, vitreous HeraGlaze® layer



FUNCTIONAL LAYER

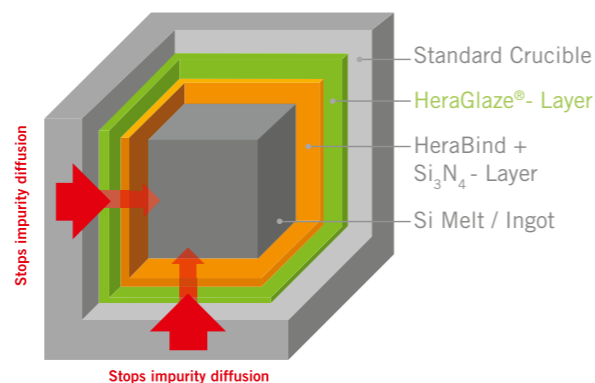
In standard wafer production processes, it comes to thermal interactions between the porous silica surface of the crucible and the molten silicon. Impurities like Fe contaminate the Si-melt/ingot, negatively affecting ingot yield and cell efficiency.

PREVENT IMPURITY DIFFUSION



HeraGlaze® effectively prevents the diffusion of impurities by forming a highly densified layer thus creating a diffusion barrier on the crucibles surface. Applied as a dispersion of micro- / nanoscale SiO₂ particles it sinters in-situ to create a glass-like layer.

HERAGLAZE® WORKING PRINCIPLE



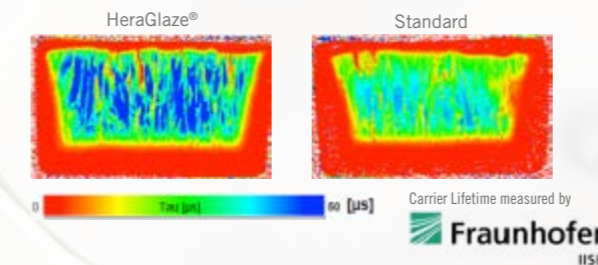
HERABIND: HIGH PURITY SiO₂ BINDER

HeraBind could help to densify SiN layer and enhance the performance of HeraGlaze®.



BETTER YIELD, HIGHER CELL EFFICIENCIES

HeraGlaze® reduces the red-zone in the outer volume of the ingot and enables up to 4% more wafer volume yield.



The overall impurity level in the ingot bulk material is reduced by the HeraGlaze® barrier coating, resulting in an improved carrier lifetime which contributes to significantly higher cell efficiencies.

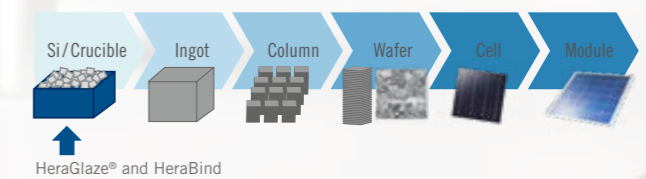
HERABIND PARAMETERS AND SPECIFICATIONS

Parameter	Units	Typical Values
Appearance	–	white, fluffy powder
Silicon dioxide content (dried material)	wt. %	> 99,99
Crystal structure	–	amorphous
Property in contact with water/moisture	–	hydrophilic
Bulk density	g/l	approx. 200
Residue from sieving (referring to DIN EN ISO 787-7)	wt. %	< 0,1
BET-surface area	m ² /g	30 ± 5
Average size of primary particles	nm	approx. 94
pH of substance dispersed in water (4 %)	–	4,8 ± 0,3
Loss on drying (2 h at 105 °C)	wt. %	0,2 ± 0,1
Loss on ignition (2 h at 1000 °C)	wt. %	0,7 ± 0,1
Density of silanol groups ¹⁾	SiOH/nm ²	approx. 8

PURITY: THE VALUE PROPOSITION OF HERAGLAZE® AND HERABIND

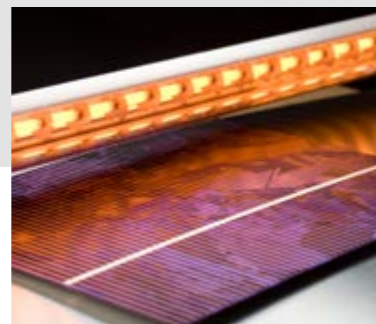
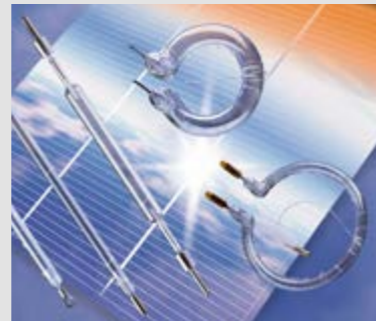
By HeraGlaze® the purity of the silicon is ensured already at the first step of the solar cell and module production process.

This provides a real value-add to all integrated PV-manufacturers, which can enhance yield and cell efficiencies simultaneously.



Heraeus Solaray – Infrared Lamp

for sintering furnace of high cost performance



OPTIMIZING SINTERING PROCESS TO IMPROVE BATTERY EFFICIENCY

While the competition within the photovoltaic industry is getting much more fierce, manufacturers of silicon ingot, wafer, cell and modules are focusing on both - cost and efficiency. As a result, it is necessary for the upstream manufacturers to understand customer's requirements and to provide customized solutions which is also known as one-stop service. As the leading solar cell silver paste supplier, Heraeus continued to grow rapidly in recent years. Meanwhile, Heraeus invested a lot in its research and development and technical personnel, in order to provide quick and accurate customized services and products to its customers.

In the printing process of solar cells, and sintering are the key steps. The heating element in sintering furnace has important influence on the printing effect of the solar cell and even the efficiency of the final solar cell, both in the stability of the spectrum, the heating efficiency and the stability of the thermal field.

Heraeus Noblelight is the technology and market leader in the field of specialty light source as well as one of the most recognized brand in the industry. Through intensive R&D, production and promotion, Heraeus UV lamps are widely used in fields such as manufacturing, processing, environmental protection, pharmaceutical, chemical, research and analysis.



First choice worldwide for reliable UV process solutions



Stable analytical lamps support precise analysis



High performance arc and flash lamps customized for reliable processes



Intelligent heating solutions save energy

Heraeus Photovoltaics and Heraeus Noblelight joined forces and launched Heraeus Solaray – Infrared Lamps for cost effective sintering furnace.

Heraeus Solaray - Infrared Lamp, through the employment of high quality quartz tube and heating material, as well as stringent control of the material properties and processing technology, provides a more stable optimization of sintering process for solar cell and brings potential efficiency benefit for the customer.

Heraeus Solaray provides not only ordinary lamps, but also can be matched with Heraeus silver paste and provides cell with smoother optimization of sintering process and brings higher efficiency for customers.

KEY BENEFITS:

- Stable IR lamp performance
- Uniform filament temperature
- Provide a corresponding wavelength IR lamp for matching with the sintering process

Heraeus Solaray – Infrared Lamp

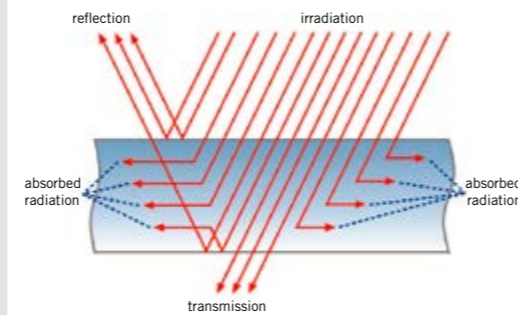
for sintering furnace of high cost performance

REFERENCE LINKS:

1. What is infrared radiation tube heating?

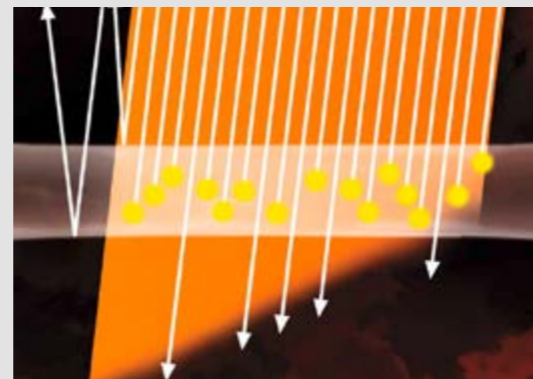
All objects can absorb infrared radiation. A part of the infrared radiation is reflected by the surface. The part of the infrared radiation can pass through the surface of the object, the other part of the infrared radiation will be absorbed and converted into heat. Perfectly matched Heraeus Solaray – Infrared Lamp will make the heating process more efficient and more precise.

IR-absorption/reflection and transmission



2. Heating advantages of Heraeus Solaray – Infrared Lamp

- 1) Through rapid response, IR lamp power can be controlled and adjusted smoothly
- 2) It can be heated in a specific area and according to the required time
- 3) The production speed is higher, the occupation area is smaller, therefore a better heating effect can be achieved
- 4) Quartz infrared heating energy consumption is lower



3. Correct choice: Heraeus Solaray – Infrared Lamp

The critical parameters for sintering are the heating element's uniformity in terms of wavelength, spacial and with time. With Heraeus Solaray, the wavelength and heating profile is controlled so that the heat transfer to the solar cell is optimized.

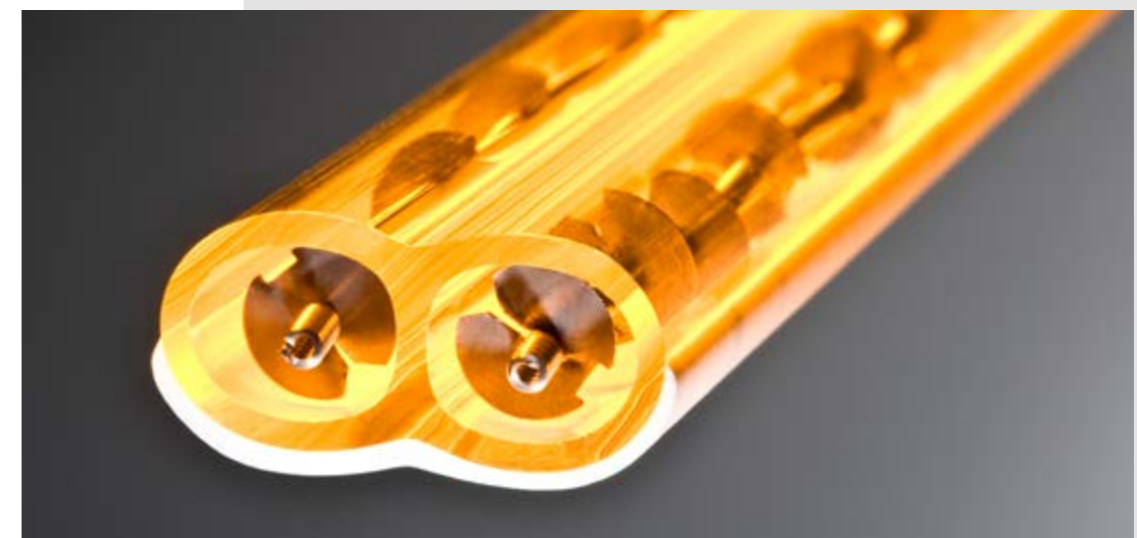
- 1) Filament material (noble metal): High performance filament material can provide infrared radiation with strong spectral matching and uniform heating capabilities. Other advantages include high radiation intensity and durability
- 2) Quartz material: High quality quartz material with high purity, light penetration and excellent heat resistance characteristics



WHAT WE CAN OFFER YOU:

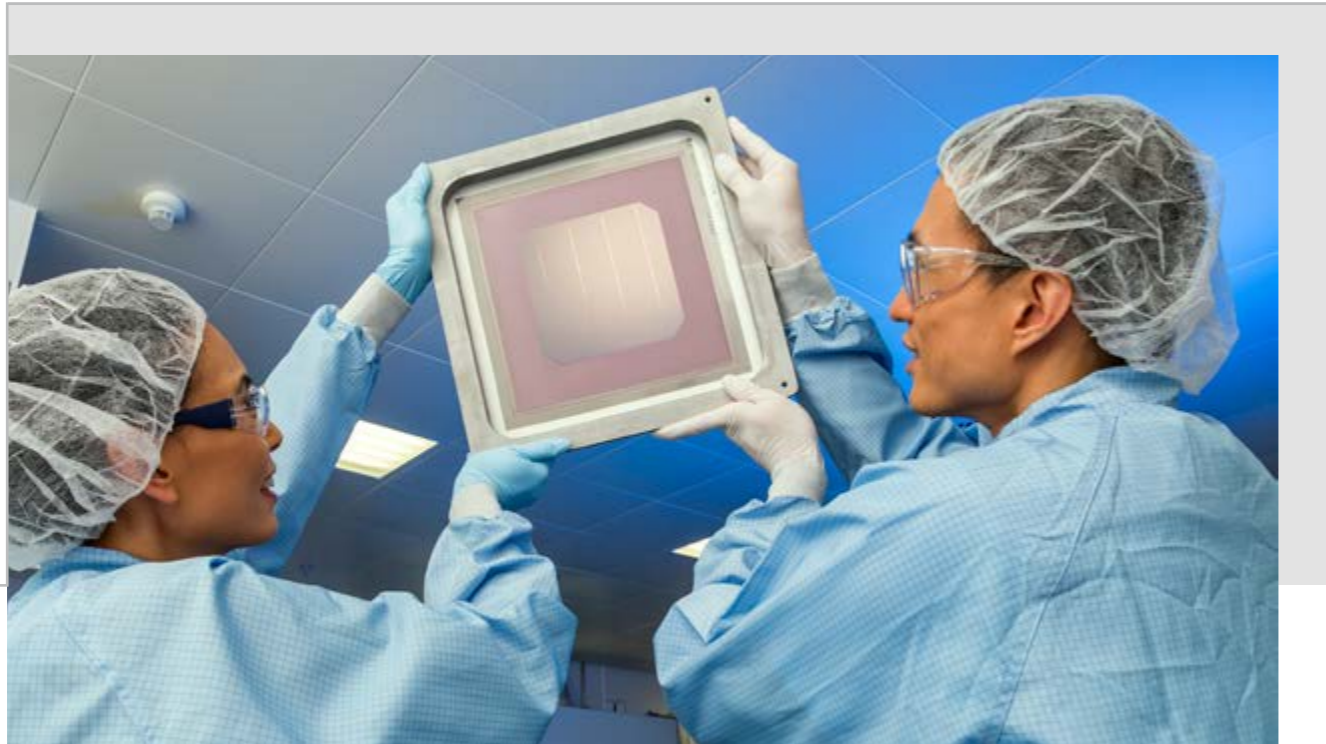
- We provide cost-effective products with international quality at a reasonable price
- We provide professional online technical support for customers to supply optimal sintering process
- We optimize the supply process to support customers with faster delivery
- We offer free warranty for two months and we will provide free replacement in case of problems
- We are responsible for each customer and will track each customer's service condition

Looking to the future, the PV industry will never stop the pace of product and service optimization. Instead it will be more prevailing. As the leading material supplier, Heraeus will focus on developing more diversified products and services, in order to provide more total solutions for PV Industry.



Heraeus Screen Bundle Services

Provide paste/screen total solution for photovoltaic customers



Heraeus provides one-stop solution for solar customers with paste and screen bundle, which shorten the test time and reduce production cost, effectively optimize the metallization process in solar cell production lines.

ALL KINDS OF STAINLESS SCREENS IN THE MARKET ARE AVAILABLE BY HERAEUS, INCLUDING:

Conventional screen:
360/16,380/14 and 430/13

Knot-free screen:
325/16,360/16 and 380/14

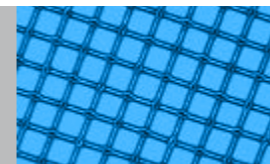
Knot-free 380/14 and high mesh screens of conventional 430/13 are supplied. Tailored material design ensures the high compatibility between pastes and screens, which can provide advantages of fine-line printing and meet the high efficiency and stability requirements.

KEY BENEFITS OF HERAEUS CONVENTIONAL 430/13 SCREEN:

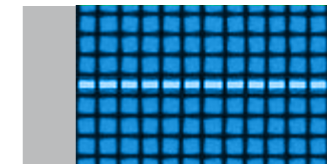
- Fine line printing, printing opening below 27 μm
- Flat emulsion edge, small particle size and excellent Line shape control
- Efficiency gain
- Laydown saving
- Cost-effective bundle solution with Heraeus paste

KEY BENEFITS OF HERAEUS KNOT-FREE 380/14 SCREEN:

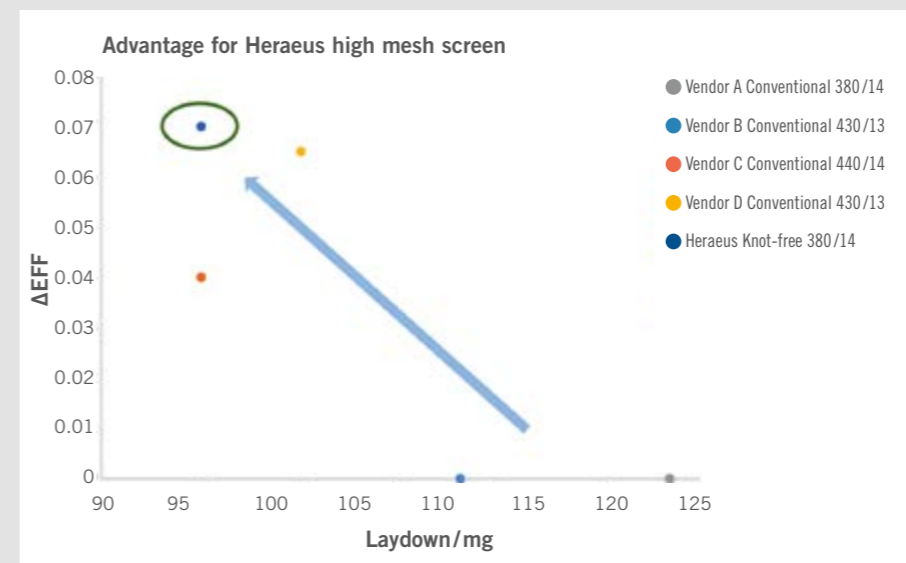
- Fine line printing, printing opening below 24 μm
- Efficiency gain
- Competitive laydown
- Strong corrosion resistance, long printing life time
- Cost-effective bundle solution with Heraeus paste

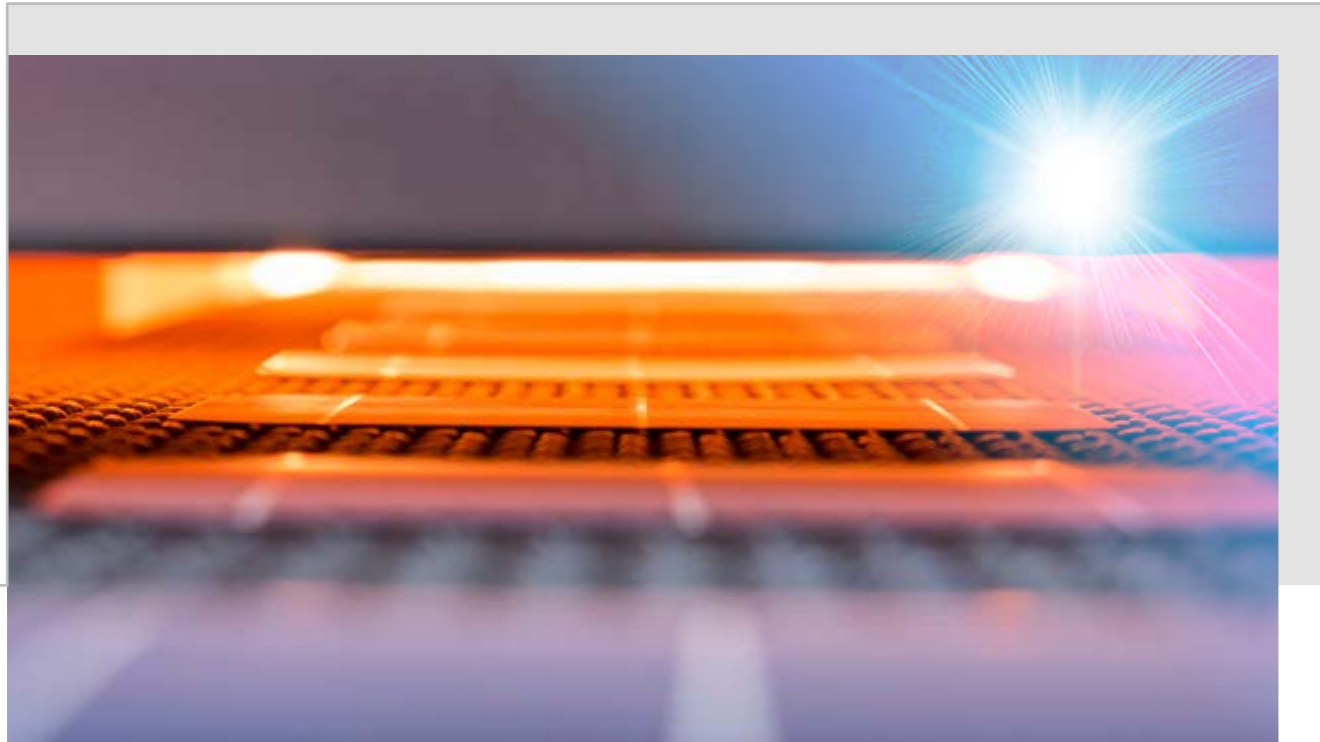


Conventional Screen



Knot-Free Screen





Setting Sight on Further Efficiency Gains

- Applicable to PERC, BSF and n-type bifacial cells
- Adaptable to customer's current processes
- Up to 0.2% efficiency gain

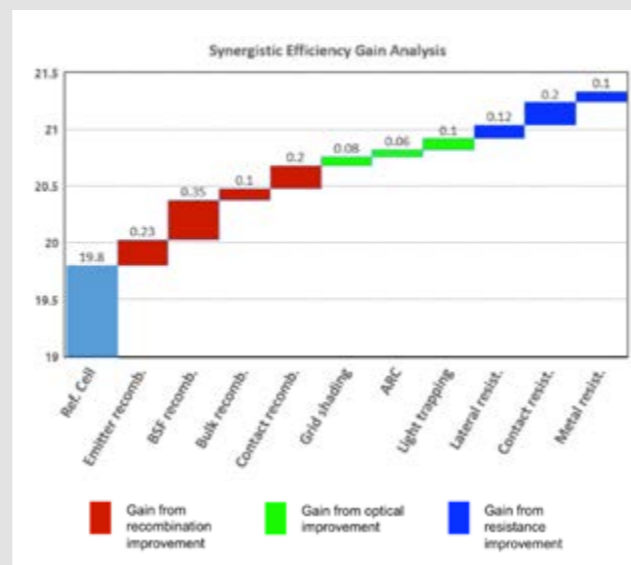
ANALYSIS AND CELL LINE OPTIMIZATION

Having firmly established itself as the industry leader in providing high performance screen printed front and rear silver pastes for multiple applications, Heraeus now extends its service to beyond the printing and firing processes.

Collaborating with world class research institutions, Heraeus offers a complete solar cell analysis, simulation and process optimization framework to identify and implement the optimal processes for the customer's production and machine conditions.

SOLAR CELL SIMULATION

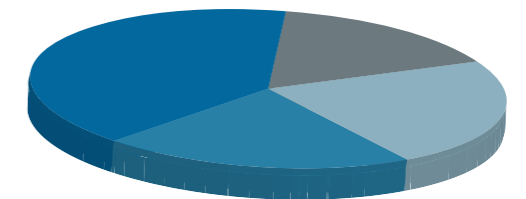
Efficiency improvement Scenario



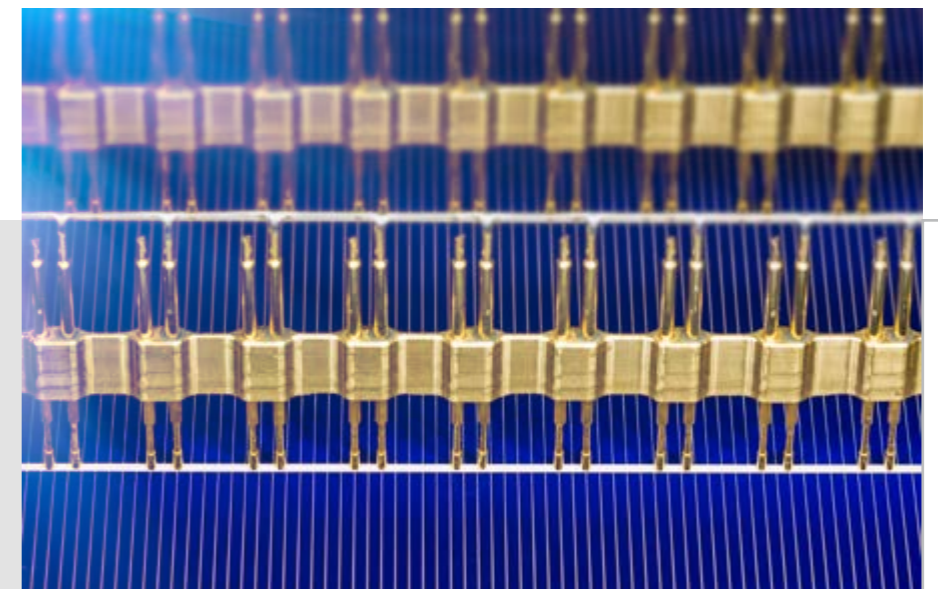
This service aims to reduce the customer's experiment loading by reducing the trial and error iteration process. This systematic process thus makes the experimental procedure more efficient and avoid excess down time in mass production due to experimentation. The requirement for comprehensive metrology lab setup at each of the customer's production sites can also be reduced.

With the analysis and optimization framework, the customer can gain in depth understanding of the areas for greatest potential efficiency gain in a quantified fashion. Heraeus team then combines silver paste design expertise and solar cell process optimization know-how to give the customer the potential for the highest possible efficiency gain through process tuning.

VOLTAGE LOSS COMPONENT



- front metal 40%
- front passivated emitter 23%
- rear LBSF 16%
- rear passivation 21%



OUR STRENGTH

Mass production experience and deep engineering know-how for process optimization:

- Conducting paste design expertise
- Process tuning know-how

Abundance in available resources:

- Close cooperation with renowned research and industry partners
- In depth BKM on processes and materials

Leader in tailoring paste to customer's individual process:

- Industry leading R&D organization
- Largest technical service team in the industry

HOW IT WORKS

Sample preparation:

Depending on the cell type under investigation, the customer will be asked to provide samples in various stages in their production process.

Loss mechanism analysis:

World class solar cell analysis laboratory fully equipped with advanced solar cell characterization tools.

Measurement match to simulation mode:

The parameters uncovered in the loss analysis can be used to build up simulation models.

Adjust model to find optimum parameter:

The cell parameters can be adjusted within the model to find the optimized condition for the current processes and materials used.

Adjust process recipe to fit parameter:

The optimized model can then be implemented in the production through process recipe tuning.

KEY BENEFITS:

- Outstanding efficiency gain possible
- Provide insight to your processes
- Quantify loss mechanisms
- Reduce trial and error experiments
- Save cost on analysis equipment and software packages
- Optimized cell process conditions through mass production expertise

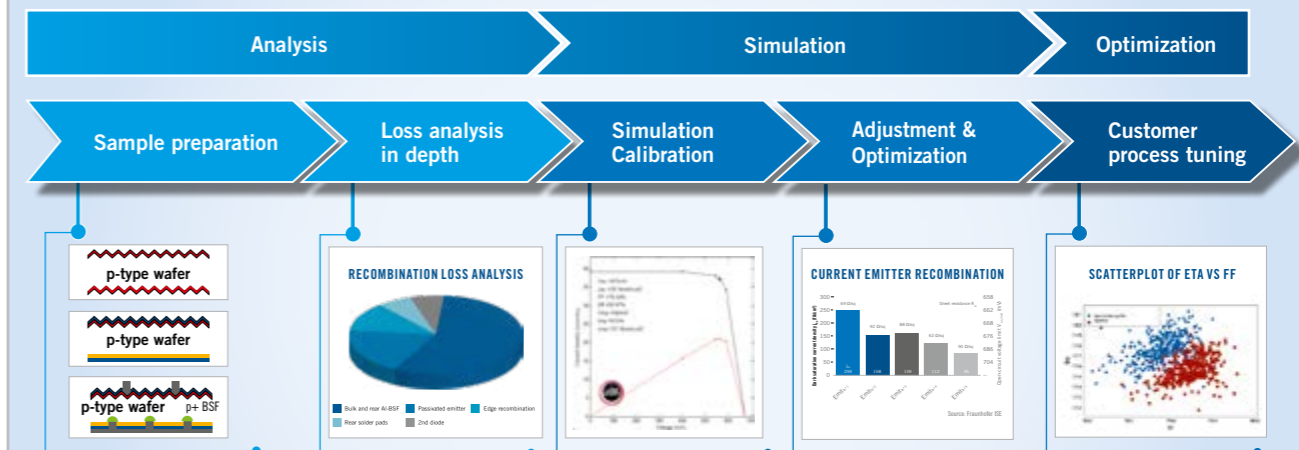
The Cell Optimization Service involves taking various measurements on customer samples at different stages of production.

The measured parameters are then fed into the loss mechanism analysis model to identify areas of greatest possible efficiency improvement.

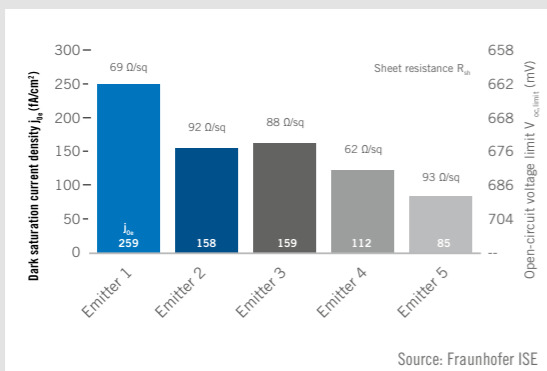
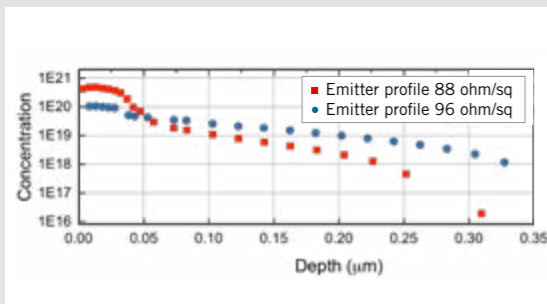
We then utilize 1D and 2D modeling to simulate the optimum process parameters that will yield the identified efficiency improvement areas.

Finally, the customer's process recipes can be fine-tuned to fit that of the simulated profile, ultimately resulting in a possible increase in production cell efficiency.

CELL OPTIMIZATION SERVICE PROCEDURE



EMITTER ANALYSIS:



EUROPE (GERMANY)

**Heraeus Deutschland
GmbH & Co. KG**

63450 Hanau
Phone +49 6181 35 5051
pv.hde@heraeus.com

ASIA (CHINA)

**Heraeus Materials Technology
Shanghai Ltd.**

201108 Shanghai
Phone + 86 21 3357 5688
pv.hmts@heraeus.com

AMERICA (USA)

**Heraeus Precious Metals North America
Conshohocken LLC/Heraeus Incorporated**

19428 W. Conshohocken
Phone +1 610 825-6050
pv.hpmc@heraeus.com

ASIA (JAPAN)

Heraeus K. K.

112-0012 Tokyo
Phone +81 3 6902 6564
pv.hkk@heraeus.com

ASIA (TAIWAN)

**Heraeus Materials Technology
Taiwan Ltd.**

33855 Luzhu (Taoyuan)
Phone +886 3 321 9937
pv.hmtt@heraeus.com

ASIA (SINGAPORE)

**Heraeus Materials Singapore
Pte. Ltd.**

639335 Singapore
Phone +65 6571 7888
pv.hmsl@heraeus.com

ASIA (KOREA)

Heraeus Korea Corporation

16506 Suwon-si (Gyeonggi-do)
Phone +82 31 270 9428
pv.hmk@heraeus.com

Visit us online:

www.heraeus-photovoltaics.com
www.heraeus-renewables.com
www.heraeus-photovoltaics.cn
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