

TEMPERATURE MEASUREMENT FOR SOLAR

Non-contact temperature control in the production of photovoltaic cells and modules



Improving Solar Cell Quality and Yield

The solar industry is a growing market with ever expanding demands on the quality and performance of its products. Producers of solar cells are pushing to reduce the cost of solar energy to the level of traditional energy sources.

Reducing PV cost/watt by improving product performance and increasing production throughput is a constant industry demand. High quality temperature measurement is essential in improving process control and optimization and enabling producers to meet tighter tolerances.

Versatile Monitoring Options

With more than 60 years of experience, Advanced Energy offers two types of non-contact temperature sensors:

- Pyrometers
- Thermal imagers

Our measurement instruments are suitable for virtually every step in the manufacturing of solar cells.

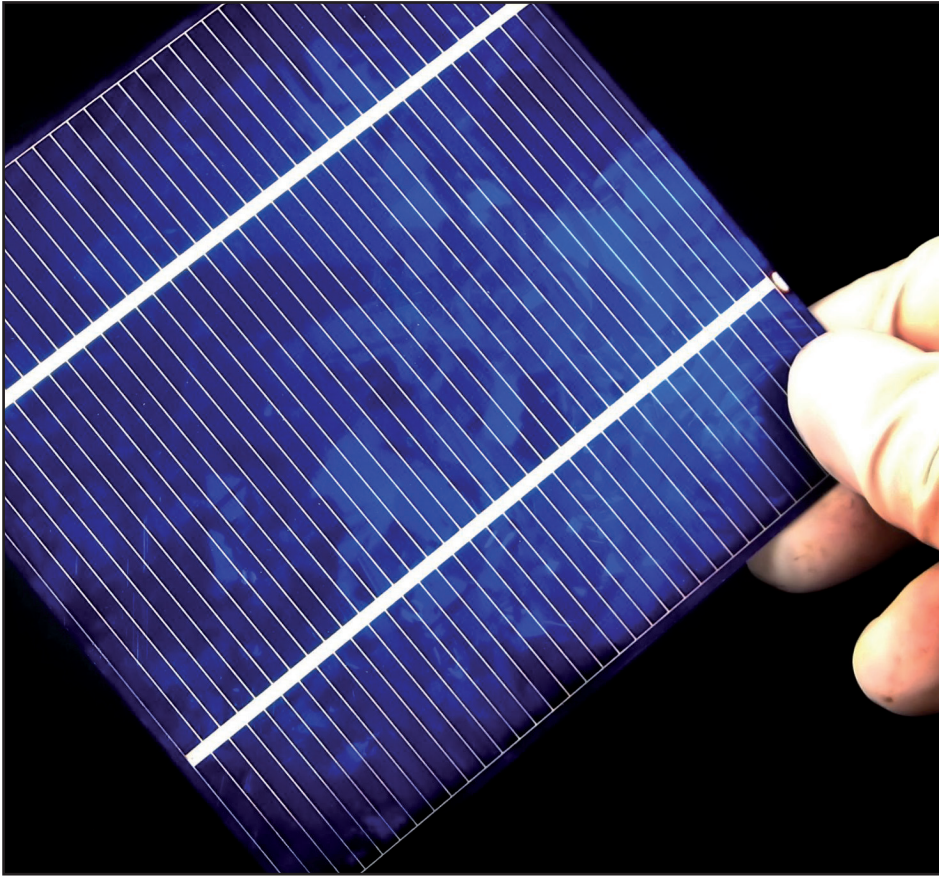
Solar Application Experience

Advanced Energy understands how critical precise temperature measurement is to the production of solar cells, and we offer you:

- Long standing experience with solar applications
- A broad range of high quality instruments for non-contact temperature measurement
- Extensive consultation to solve your specific measurement needs
- Worldwide support on-site via our network of Advanced Energy offices, subsidiaries, and sales representations



Solutions



Non-Contact Temperature Control

Advanced Energy solutions represent rugged, modern, and reliable technologies. We have more than 60 years of experience integrating temperature measurement sensors into production processes.

Our solutions also include first class support and consultation. Advanced Energy works with you to understand your specific measurement needs and unique challenges.

Our experience enables manufacturers to quickly improve their process control and to avoid production losses.

Controlling the production process of:

- Ingots and Wafers
- Photovoltaic Cells
- Photovoltaic Modules



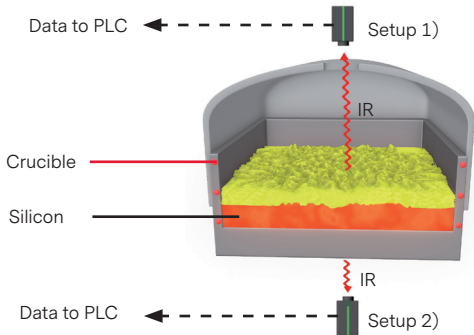
Monocrystalline, Polycrystalline, and Thin Film Cells for the Solar Industry

The Advanced Energy's Impac® and Mikron® product lines provide non-contact temperature measurement for process control during the production of monocrystalline, polycrystalline, and thin film cells.

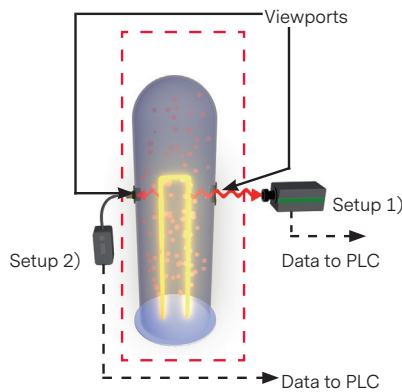
Our infrared temperature measurement solutions enable both an improvement in product quality as well as a more effective process control for all current manufacturing processes in the solar industry. The figures below illustrate varying applications using our wide range of instruments for the optimum solution for your measurement task.



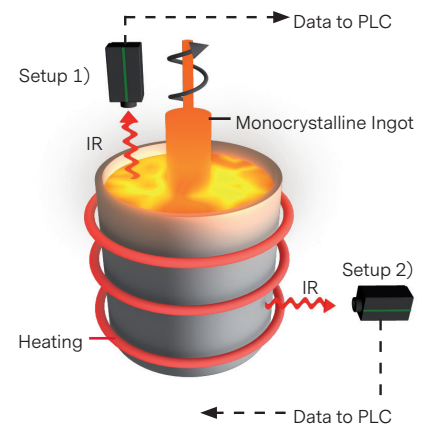
1 Multicrystalline Silicon Directional Solidification Process



2 CVD Reactor (SIEMENS Process)

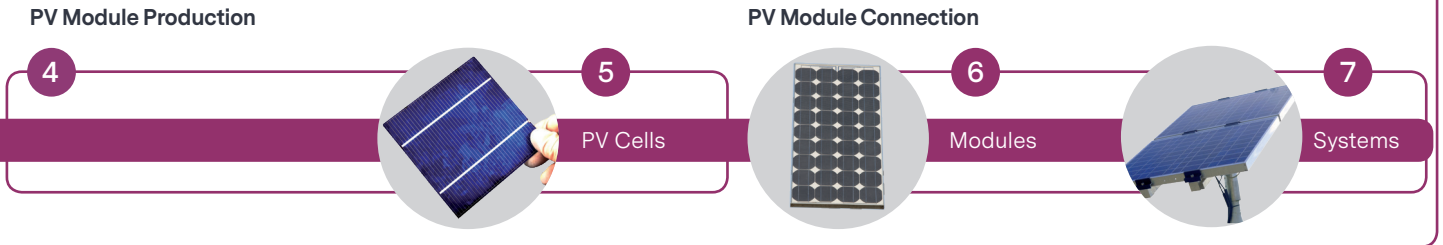


3 Monocrystalline Silicon (Czochralski Process)

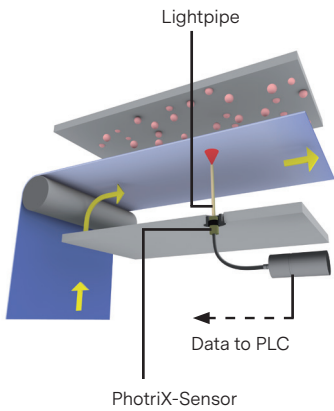


Application Details			
Process Step	Multicrystalline Silicon	Polysilicon Rod "CVD / Siemens Process"	Silicon Crystal Pulling "Czochralski Process"
Process Task	Meticulous control during solidification of the molten silicon into the polycrystalline silicon cast is critical to achieve the desired crystal size and homogeneity.	Temperature of deposition surfaces must be measured precisely to control the growth process and the uniformity of growth inside the reactor.	1) Determine silicon melt temperature and assure correct crystallization process. 2) Control of heating system to optimize energy efficiency and crystallization process.
Advanced Energy Solution	Highly accurate narrow band or 2-color infrared thermometer with optional video output for fast, repeatable temperature measurements. Setup 1) Measuring the melt temperature Solution: Series 5 and Series 6 pyrometers Setup 2) Control crystallization process Solution: Series 5 and Series 6 pyrometers	Stable 2-color infrared thermometers in explosion-proof housings for process safety. Setup 1) For easily accessible objects Solution: Series 6 pyrometer Setup 2) For hard to access objects Solution: Series 50 pyrometers	Highly accurate narrow band or 2-color infrared thermometer with optional video output for fast temperature measurement. Setup 1) Measurement of melt temperature Solutions: Series 5 and Series 6 pyrometers Reliable and easy to integrate infrared thermometer for temperature monitoring and PLC control. Setup 2) Control of heating system Solution: Series 200 pyrometers
Customer Benefits	Accurate temperature readings for material crystallization. Optimum process monitoring based on fully digital sensor architecture.	Accurate, fast silicon temperature measurement combined with process safety. Restricted mechanical sensor integration solved by robust fiber optics.	Accurate, reliable temperature readings for material crystallization. Optimal application monitoring based on fully digital sensor architecture. Rapid, non-contact temperature control of the heating system. Compact, low cost sensor for easy device integration.

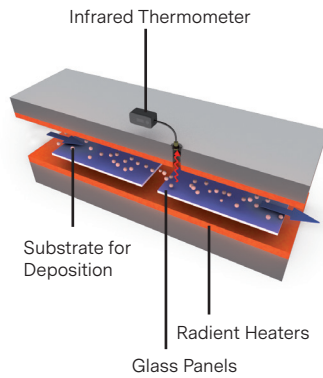
Steps in Photovoltaic Manufacturing



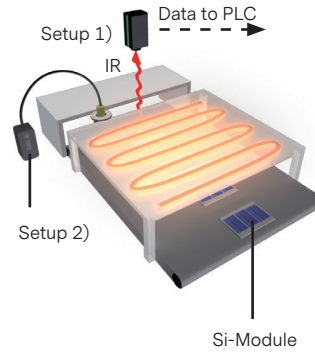
4 Thin Film Deposition for CIGS Cells



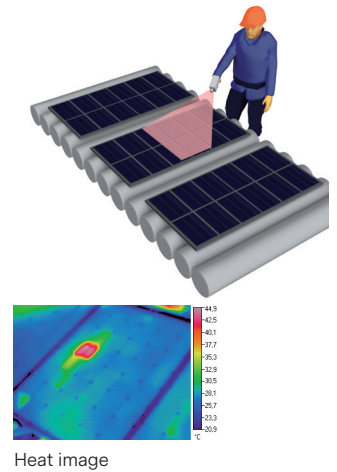
5 Thin Film Deposition



6 Soldering



7 Quality Control Before Laminating

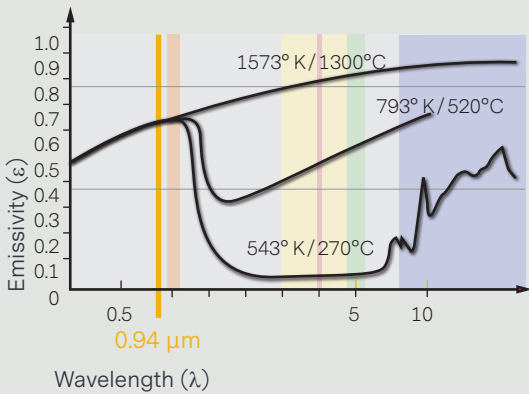


Application Details			
Thin Film Deposition for CIGS Cells	Thin Film Deposition for CdTe Cells	Soldering by Radiant Heating	Quality Control Before Laminating
Process temperature control on low emissivity surface at low or moderate temperature.	Accurately measure and control temperatures during deposition onto glass substrates. Process must be repeatable in vacuum reactor and support high-volume production.	Reduce cycle times and minimize thermal exposure of the photovoltaic cell.	Screening for any faulty areas/spots that either result in bad product or result in pre-matured failure in the field.
Provide accurate, non-contact temperature measurement of shiny, low emissivity metals or polymer webs on which the material is deposited. Solutions: Series PhotriX for metals. Series 5 or Series 6 and Series 140 pyrometers for polymers.	Pyrometers with different penetration depths into the glass to suit different needs at different stages in the process and integration accessories (windows and vacuum flanges) designed for and proven in glass measurements. Solutions: Series 200, Series 5, Series 6, or Series 140 pyrometers	A standard infrared thermometer and excellent PID controller package to assure fast feedback loop control. Setup 1) For easy to access objects Solution: Series 140 pyrometer with PI 6000 controller Setup 2) For difficult to access objects Solution: Series 140 pyrometer with fiber optics and PI 6000 controller	Radiometric imager for hot spots/areas detection. Solution: Thermal Imaging Supply thermal imaging components and system packages for online process control. Solution: Thermal Imaging
Accurate, reliable measurement and control of temperatures on low emissivity materials. Continuously assure product quality and process stability.	Ensures consistent quality and desired film thickness by leveraging production proven solutions from the glass industry.	Fast, automated process control. Tuned application package with essential PID controller from single source supplier.	Prompt and easy recognition of defective modules to improve quality management. Uncooled measurement systems with appropriate functionality. A wide variety of thermal imagers with protective enclosures.

Product Examples

Advanced Energy offers hundreds of different non-contact temperature measurement instruments for virtually every industrial application. Through our long standing experience in the field, we have developed a wide portfolio of high quality products for the solar industry.

Silicon Emissivity Over The Infrared Spectrum



The “silicon” wavelength: 0.94 μm

Silicon is one of the most difficult materials for non-contact temperature measurements. Not only does the emissivity curve strongly vary over the infrared spectrum, but each curve intensity depends on the silicon temperature.

To achieve accurate, repeatable temperature readings, LumaSense sensors incorporate 0.94 μm narrow-bandpass filters and calibrate them into the device.

At this particular wavelength the emissivity of silicon is constantly high and independent of the material temperature.



Series 5

Two-color ratio infrared thermometer for emissivity-independent temperature measurement

- Temperature Ranges: 600 to 3000°C
- Wavelength: 0.97 μm and 1.05 μm
- Exposure Time (t₉₀): < 10 ms
- Target sighting by built-in laser targeting or through lens sighting



Series 6

Digital two-color ratio infrared thermometer for emissivity-independent temperature measurement

- Temperature Ranges: 600 to 3000°C
- Wavelength: 0.9 μm and 1.05 μm
- Exposure Time (t₉₀): < 2 ms
- Target sighting by built-in laser targeting or through lens sighting



Series PhotriX

Highly accurate short wavelength infrared thermometer with unmatched low temperature capability

- Temperature Ranges: 30 to 2400°C
- Wavelength: 0.7 to 1.65 μm
- Response Time(t₉₀): 1 μs
- Lens, fiber optics and/or sapphire lightpipe



Series 200 / Series 300

Compact loop wired process sensor with linear 4 to 20 mA output

- Temperature Ranges: 650 to 2500°C
- Wavelength: 0.8 to 1.1 μm
- Response Time(t₉₀): 10 ms
- Sighting: LED targeting light



Series 140

Highly accurate and fast unit for measurement of difficult to access objects

- Temperature Ranges: 100 to 750°C
- Wavelength: 2 to 2.6 μm
- Exposure Time (t_{90}): 1.5 ms
- Fiber optics with laser targeting



Series 50

Universal temperature unit for small spot sizes

- Temperature Ranges: 400 to 1300°C
- Wavelength: 0.94 μm
- Exposure Time (t_{90}): < 1 ms
- Fiber optics with spot sizes from 0.45 mm including laser targeting



Series Impac Highspeed

Ultra high-speed sensor with built-in laser filter for small objects

- Temperature Ranges: 160 to 1000°C
- Wavelength: 1.58 to 2.5 μm
- Response Time(t_{90}): 6 μs
- LED targeting light



PI 6000 controller

Simple PID controller for digital infrared thermometer with easy, guided setup

- Programmable via PC software
- Sampling time: 250 μs
- Automatic PI self optimizing
- 9 individual controlling programs storable



Thermal Imaging

Process cameras for quality control purposes

- Temperature Ranges: -40 to 500°C, optional up to 3000°C
- Wavelength: Depending on application
- Frame rate: 5 to 60 Hz
- Reporting software or online control packages



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ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. AE designs and manufactures highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

AE's power solutions enable customer innovation in complex semiconductor and industrial thin film plasma manufacturing processes, demanding high and low voltage applications, and temperature-critical thermal processes.

With deep applications know-how and responsive service and support across the globe, AE builds collaborative partnerships to meet rapid technological developments, propel growth for its customers and power the future of technology.

PRECISION | POWER | PERFORMANCE

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