HUMAN HEALTH

ENVIRONMENTAL HEALTH

THE POWER OF THE SUN

Solar Energy Development Solutions

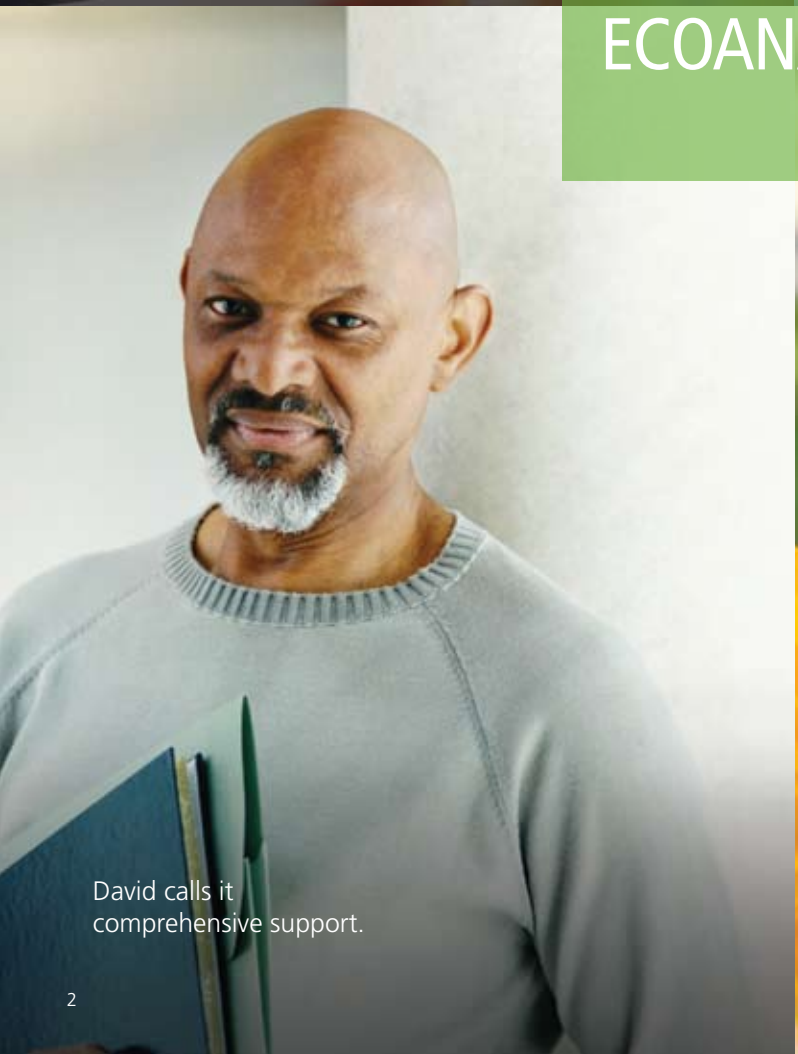
Comprehensive solutions for solar energy and a brighter tomorrow.

PerkinElmer®
For the Better

Anne calls it
simplified technologies.

Evan calls it
expert application notes.

WE CALL IT ECOANALYTIX



David calls it
comprehensive support.

Suzie calls it
a brighter tomorrow.

FEWER EMISSIONS FOR A BRIGHTER TOMORROW

Free, clean and renewable – the power of the sun has unlimited potential to not only help millions of people around the world with limited or no access to electricity, but to also greatly help solve some of our environmental challenges.

As the demand for solar power continues to grow, there needs to be a clear focus on different key issues in the life cycle of a solar cell. These issues are: efficiency, durability and cost. Coupling PerkinElmer's application knowledge and experience together with our product portfolio, we can help manufacturers overcome these obstacles. At PerkinElmer, we're taking action to ensure the quality of our environment.

Reducing the impact on our natural resources, minimizing the impurities in the air we breathe and the water we drink – all made possible by EcoAnalytix from PerkinElmer. EcoAnalytix brings together innovative technologies to meet environmental challenges; environmental stewardship through the development of environmentally smart products and processes; critical scientific knowledge and an active voice so together we can drive change for the better. EcoAnalytix – for a brighter tomorrow.

ecoanalytix™

EMPOWERING MORE OPPORTUNITY

EcoAnalytix™ from PerkinElmer provides you with a full suite of solutions that makes it easier to keep pace with an evolving industry. By combining tailored systems, standard operating procedures (SOPs) and application notes together with our OneSource® service and support, we ensure that from incoming raw material to the final product, your laboratory is ready to do more.

We enable your laboratory to maximize its prospects in solar-cell development and testing, while meeting increasing number of regulatory requirements worldwide.

You can rely on EcoAnalytix to provide your laboratory with:

- Consultation and comprehensive solutions for building your lab from the ground up
- Analytical capabilities, SOPs and application notes to perform the required methods
- Complete system support including training, validation and maintenance.

All of this means you'll know more, so your laboratory can do more. And for a world in need of renewable energy, nothing matters more.

SOLAR ENERGY DEVELOPMENT AND COMPLIANCE

EcoAnalytix from PerkinElmer offers proven leadership and a full range of solutions for your solar-cell production line, including comprehensive application notes, application support and training.

- Developing new types of photovoltaic (PV) cells by using alternative, cost-efficient and evironmentally friendly materials to make this energy source even more convenient and accessible to everyone around the globe
- Optimizing the transmission and/or emission properties of the base and cover materials to ensure the highest possible output and efficiency
- Using different types of polymers in the manufacturing process of modules and panels to improve durability and real long-term usage of high-efficiency solar cells with minimal maintenance.

So wherever you are in the development process, PerkinElmer has a solution for you.

R&D	Supplier	Process	Solar Cell	Solar Module
Improving cell efficiency and developing new materials	Purity of and impurities in raw materials and process chemicals	Efficient and process-oriented quality testing	QA/QC of final solar cell	QA/QC of solar module

SILICON-BASED PV CELLS

Silicon-based solar cells are the most common type of PV cells. As of today, about 85% of all manufactured solar cells are of this type, but this number is decreasing due to cheaper and more efficient production of thin-film cells. The average cell efficiency of these wafer-based cells is about 18% to 22%.

After slicing from a silicon ingot, the raw wafers are treated in many different steps until finally the monocrystalline or polycrystalline PV cells are combined to a single solar-cell module.

Determination of Silicon Purity by GFAA or ICP-MS

ASTM® F1724, SEMI PV1-0709, SEMI E45-1101

QA/QC of raw materials provides confidence and consistent quality during the process and ensures high quality of the final cell. PerkinElmer's long history and experience in this field of analytical technologies can help you overcome technical or application-specific challenges through a variety of solutions which include:

- The AAnalyst™ 600 and 800 Graphite Furnace Atomic Absorption spectrometers (GFAAs) meet and exceed the specifications mandated by the established ASTM® and SEMI standards and regulations.
- The NexION™ 300 ICP-MS with Universal Cell technology delivers accurate low-level data quickly and with minimal complexity of sample preparation for ultratrace, interference-free analysis of solar-grade silicon wafers. Such technology provides major benefits to a laboratory, because it can be readily and easily used without time-consuming changes in instrument configuration.
- Our selection of hyphenated technology like Laser Ablation-ICP-MS or speciation analysis with HPLC-ICP-MS or GC-ICP-MS systems delivers in-depth analysis of new material developments.

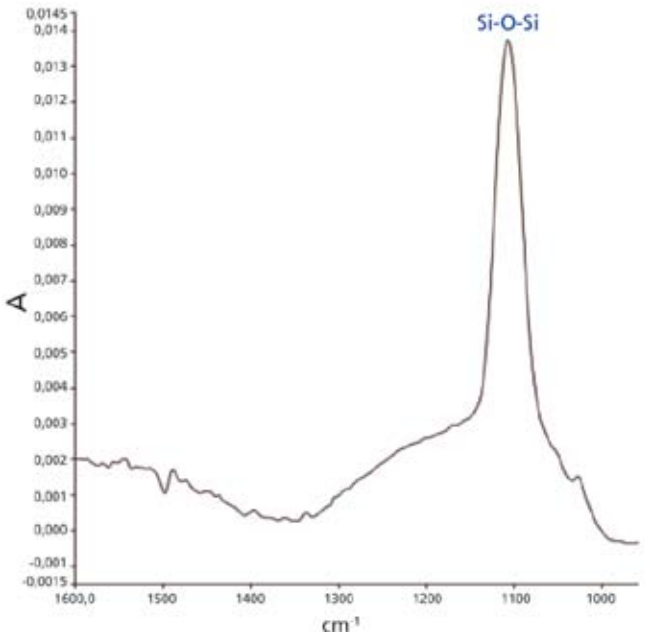
Table 1. **Solvent-related and silicon-based interferences.**

m/z	Interference	Analyte
31	^{30}SiH, $^{14}N^{16}OH$	P
39	^{38}ArH	K
47	^{28}SiF, $^{30}SiOH$	Ti, PO
48	^{29}SiF, $^{28}SiFH$	Ti
56	$^{40}Ar^{16}O$	Fe
60	$^{28}Si^{16}O_2$	Ni
63	$^{29}Si^{16}O_2H$, $^{28}Si^{16}OF$	Cu
64	$^{29}Si16OF$, $^{28}Si^{16}OFH$	Zn
65	$^{30}Si^{16}O_2H$, $^{30}Si^{16}OF$	Cu
66	$^{29}SiF_2$, $^{30}Si^{16}OFH$	Zn
68	$^{40}Ar\ ^{28}Si$, $^{30}SiF_2$	Zn

Measurement of Silicon Wafers/Cells at Ambient/ Subambient Temperatures by FT-IR

ASTM® F1391-93, ASTM® F1188, ASTM® F1630-00, ASTM® F123

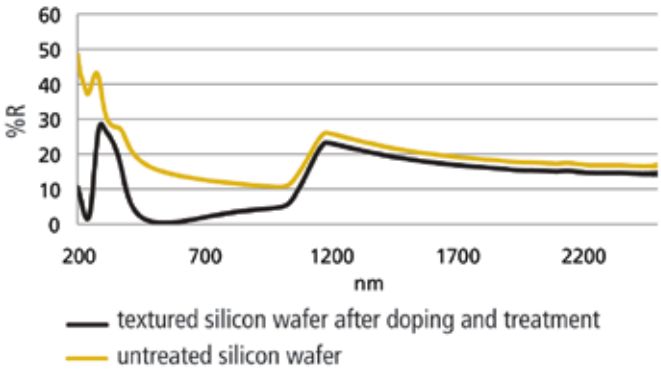
The knowledge of impurities like C, O, B, P in wafers and cells is essential and critical for the future manufacturing process and for cell efficiency. The concentration of these elements directly impacts the PV process in the semiconducting layers and therefore influences cell efficiency, most of the time negatively. The measurement of these elements takes place at ambient or more often at subambient temperatures. Infrared spectroscopy (FT-IR) is used for this application because of its ability to visualize the different types of bondings between atoms and their activity under very specific conditions. PerkinElmer's family of FT-IR spectrometers offers a full suite of solutions for this application. These include the Spectrum™ 100 or 400 Mid-IR/Far-IR and the Spotlight™ FT-IR Imaging System, accompanied by powerful software and data handling.



FT-IR spectra of silicon-based solar cell at room temperature.

Measurements for Silicon Wafers/Cells by UV/Vis/NIR Spectroscopy

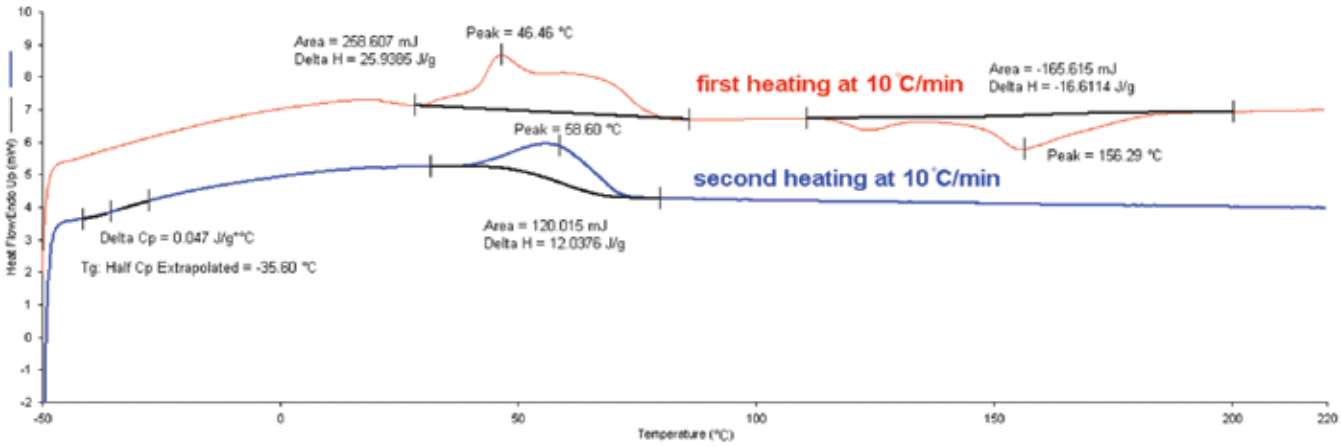
The overall efficiency of solar cells is dependent on the properties of different types of materials used in the manufacturing process. Therefore, it is essential to optimize the potential of surface textures, as well as reflective and anti-reflection coatings to obtain the necessary optical properties to ensure high cell efficiencies. UV/Vis/NIR spectroscopy is the technology of choice for these measurements. PerkinElmer offers a range of high-performance LAMBDA spectrophotometers (LAMBDA 650, 750, 850, 950 and 1050), a suite of accessories including integrating spheres and the Universal Reflectance Accessory (URA), and powerful software to ensure you can measure the reflectance, transmission and adsorption properties of raw materials and the cell at different stages of its manufacture.



% Reflection of silicon (untreated and after treatment).

Measurement of Polymer Encapsulants for Solar Cells by DSC

The polymer encapsulant needs to make a permanent and adhesive tight seal in the solar-cell system through crosslinking. After crosslinking, the encapsulant should have high optical transmittance, good adhesion to the different module materials, good dielectric and great moisture barrier properties with adequate mechanical compliance to accommodate system thermal stresses due to the different thermal expansion coefficients. Therefore, it is important to optimize the encapsulant process, including QA/QC of raw polymers, curing, weathering and stability studies on different polymers. Differential scanning calorimetry (DSC) is used to study the curing process of different types of polymers. PerkinElmer offers two types of DSCs – the heat-flux DSC 4000 for routine 24/7 analysis and the DSC 8000 and 8500 which features double-furnace power-controlled technology for most accurate energy measurement and curing kinetic studies.



The first (red) and second (blue) heating curve of raw EVA material.

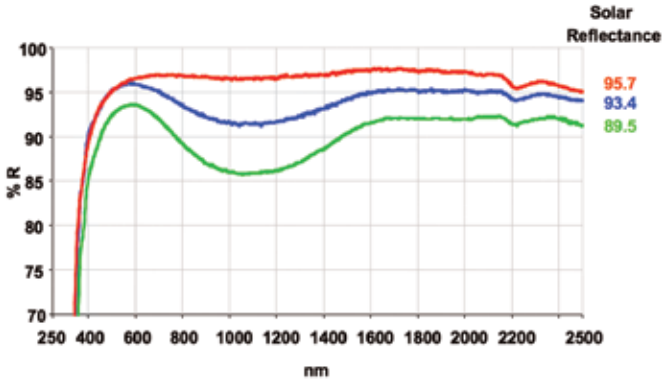
Si-BASED CELLS

THIN-FILM PV CELLS

Thin-film PV cells, either based on µ-silicon (amorphous) or on other semiconducting elements like CdTe (cadmium-telluride) or CISG (copper-indium-selenide-germanium), today comprise about 15% of the market. These cells have an average efficiency of about 12 to 15%, but can be produced much more efficiently than wafer-based PV cells. Glass or other (including flexible) materials as substrates are covered in different vapor decomposition process (VDP) steps with a variety of semiconducting materials. After printing the electrical grid and laminating the whole cell with polymer-based backsheets, the finalized solar module is ready for shipping.

Optical Characterization of Glass and Reflectors by UV/Vis/NIR

The characterization of glass and reflectors used in the construction of thin-film PV cells is important to ensure the efficiency and quality of the resulting solar panel. This is equally true for the characterization of mirrors used in solar concentrators. The high-performance LAMBDA series of UV/Vis/NIR spectrophotometers is ideal for verifying the performance of these reflective components. The unique Universal Reflectance Accessory (URA) provides automated reflectance measurement at a number of angles resulting in better characterization of your sample. Additionally, by switching to the 150 mm integrating-sphere module, the total solar reflectance (TSR) can be determined easily.



Spectra and total solar reflectance (TSR) values of silver mirrors with different levels of impurities in the glass.

Purity/Impurities of Different Materials by ICP-OES or ICP-MS

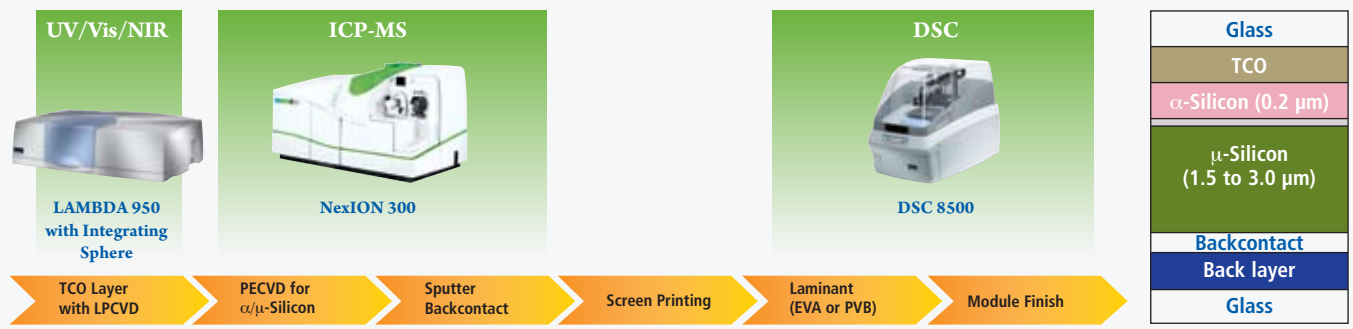
Impurities and contaminants directly impact the performance of the cell and could lead to a higher number of "junk" cells (cells that don't meet specifications). Furthermore, the recycling and reuse of broken or damaged cells is a critical part within the overall performance and success of a solar-cell manufacturer. Either ICP-OES or ICP-MS technology can be used for the QA/QC of raw materials, optimization of the VPD process and waste management (liquid, solid and gaseous emissions), and these systems also enable customers to test for other semiconducting elements, which might be used in the future.

PerkinElmer offers solutions for both of these technologies:

- The Optima™ 7300 DV ICP-OES with Dual View capabilities delivers increased range of performance, Universal Data Acquisition (UDA) collecting all spectral data to determine the concentration of elements not in the original method, and a variety of easy-to-use sample-introduction systems for increased flexibility.
- The NexION 300 ICP-MS with Universal Cell technology offers best-in-class detection sensitivity by removing spectral interferences, delivering the ultimate tool for ultratrace analysis for every matrix.

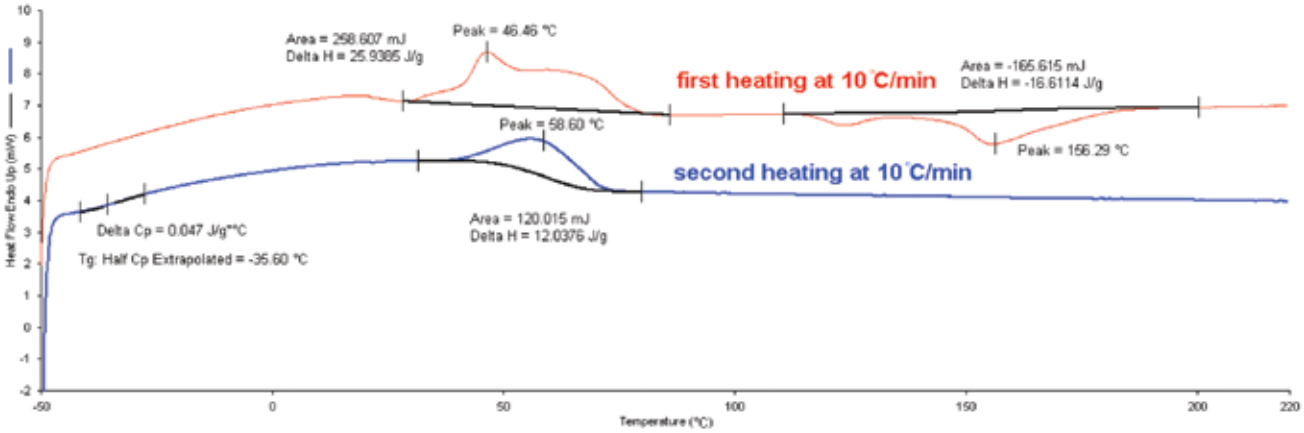
Both of these solutions are able to detect nearly all elements with excellent detection limits for impurities and contaminants. They are rugged, reliable and built to work 24/7, with additional accessories available to optimize throughput.

Si-BASED THIN-FILM CELLS



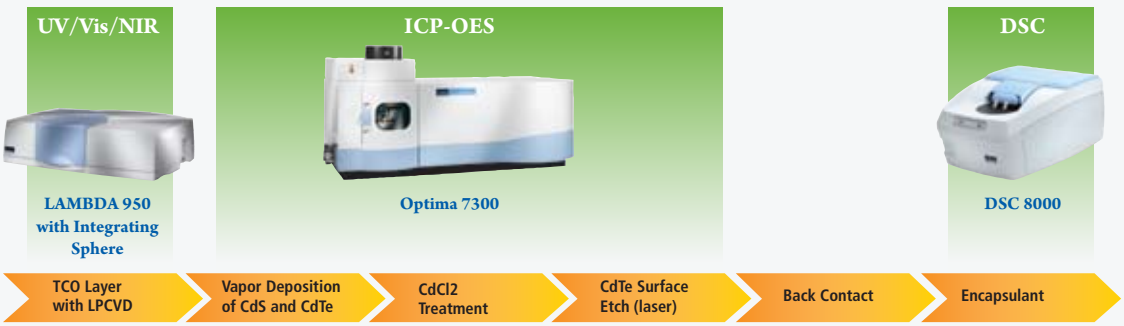
Measurement of Polymer Encapsulants for Solar Cells by DSC

As with silicon-based PV cells, also for thin-film PV cells the perfect encapsulant guarantees long-term durability of the solar cell. So it is important to optimize the encapsulating process, including QA/QC of raw polymers and curing studies on different polymers. Differential scanning calorimetry (DSC) is used for curing studies of different polymers and helps to characterize new polymers to be used as solar-cell substrates. PerkinElmer offers two types of DSCs, the heat-flux DSC 4000 for routine analysis, and the DSC 8000 and 8500 which incorporate the PerkinElmer-exclusive HyperDSC® technology for unlimited insight into the structure, properties and performance of your materials.



The first (red) and second (blue) heating curve of raw EVA material.

CdTe THIN-FILM CELLS

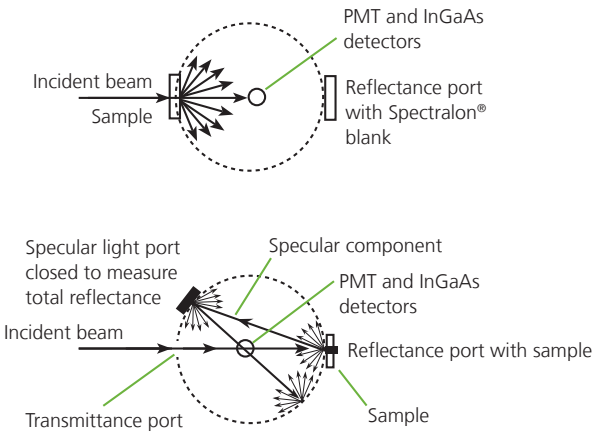


R&D AND POLYMER-BASED PV CELLS

A lot of time and effort is invested in R&D, trying to produce cheaper, but also more durable and more efficient cells with complete new ways of processing. Instead of VDP steps, the semiconducting material will be printed on flexible substrates like on film (like foils) and textile. Others will try to also incorporate organic semiconducting material into paints, so that large roof areas can be adapted to react as one large solar PV cell. The requirements and specifications for these different types of substrates and semi-conducting materials, whether organic or inorganic, are very critical and PerkinElmer can help here too.

Aging Behavior by UV/Vis/NIR

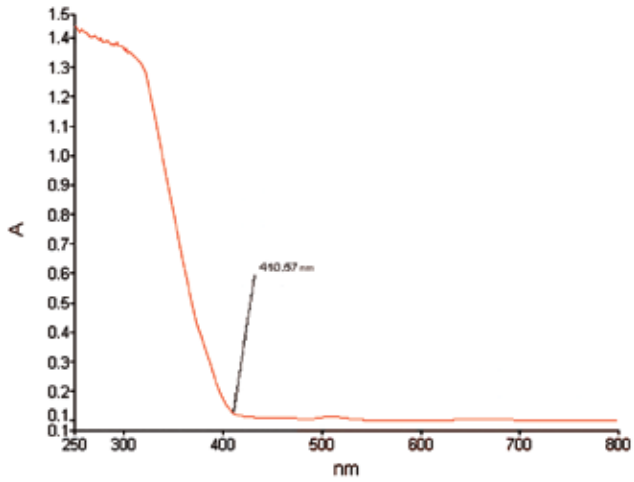
The optical characterization of glass and cell properties provides information about efficiency and quality. QA/QC of raw materials and other supplies (glass panels) will lead to manufacturing process optimization, and ultimately to a decreasing number of reject cells and better overall performance of the enterprise. PerkinElmer's full suite of high-performance LAMBDA 950 and 1050 UV/Vis/NIR spectrophotometers delivers perfect transmission and reflectance measurements, optimizing characterization of the cell. They are accompanied by a full set of accessories (integrating spheres, sample holders, detectors and also customized sample-handling parts) and powerful software, providing a complete solution.



Measurements with an integrating sphere: reflection (lower); transmission (higher).

Characterization of Nanomaterials by UV/Vis/NIR

Nanomaterials are used in the construction of polymer-based PV cells to aid the charge transfer from the light-sensitive organic material to the conducting layer of the solar cell. The efficiency of a material's charge transfer is determined by the band gap of the material. This property is also important for determining the quality of semiconducting elements used in the production of thin-film PV cells. PerkinElmer's high-performance LAMBDA UV/Vis/NIR spectrophotometers, accessories and software provide accurate measurement of key research parameters such as band gap.

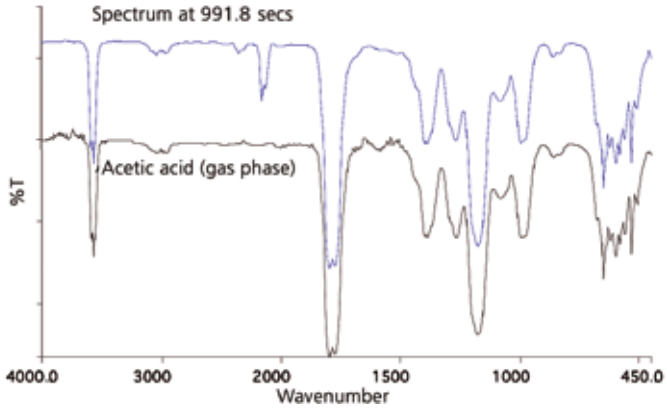


UV/Vis spectrum of TiO_2 showing a strong cutoff at 410.57 nm, which can be used to calculate the band gap of the material.

DYE-SENSITIZED SOLAR CELLS AND R&D CELLS

Development of Advanced Polymers by FT-IR/NIR

Durability and long-term use of cells is highly dependent on polymer properties – these can be tested using FT-IR and FT-IR Imaging, a perfect extension of the UV/Vis/NIR solutions, delivering additional information like spectral behavior at different temperatures. PerkinElmer's Spectrum 100/400 FT-IR/NIR and Spotlight FT-IR Imaging Systems provide ultimate flexibility and best-in-class FT-IR and FT-NIR material-characterization possibilities. Combined with high-resolution and fast-scanning imaging systems, you are able to identify surface contaminants and material degradation accurately and without extensive sample preparation.



Comparison of the infrared spectrum recorded at 991.8 s (362.3 °C) with a reference acetic-acid spectrum.

Coatings Durability and QC of Adhesives, R&D for Polymer Semiconducting Materials by TGA, DSC and Hyphenated Technologies

The advance of organic photovoltaics (OPV) relies on the development of polymer semiconducting materials. Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) have been indispensable scientific tools for polymer research. In the case of dye-sensitized solar cells, the performance degradation has been a big concern and DSC or TGA can be used to study these degradation mechanisms.

Durability and long-term weathering behavior are critical in the overall economic requirements of a solar cell, whether it is a wafer-based silicon cell or a new polymer cell based on organic semiconducting materials. Thermal Analysis and hyphenated technologies, like TGA-MS, DSC-Raman or DSC-FT-IR, provide ultimate flexibility in testing – and different types of material information can be obtained from a single measurement. All of this leads to perfect characterization of all types of materials. Thanks to PerkinElmer's extensive offering, you can obtain the entire system – whether a standalone thermal analysis instrument or hyphenated to other technologies – from a single vendor.

Global service and support

At PerkinElmer, we have manufactured and serviced laboratory instruments accross the globe for over 70 years. We have a deep understanding of your laboratory's requirements and provide you with precision-designed products, a simple ordering process and best-in-class customer service. And with 1300 service engineers and over 550 sales representatives in 125 countries, you can enjoy the peace of mind that comes with solid, reliable support. Furthermore, our OneSource® comprehensive support gives you the efficiency of one contract and one contact for all your service needs. OneSource is the only single service point with the certified expertise to repair, maintain, qualify and validate equipment from PerkinElmer and virtually any manufacturer.

From routine sample testing to moments of scientific break-through, count on PerkinElmer to supply you with the service, support, accessories and consumables you need to achieve success today and tomorrow.

Solar energy development solutions

EcoAnalytix offers expert consultation and customized solutions for your laboratory. Whether you're testing new materials or verifying existing ones to meet industry standards, we have the proven technology you need to stay in compliance from raw materials through final product. **EcoAnalytix – for a brighter tomorrow.**

A complete listing of supporting materials, including application notes and webcasts, is available on our website. Learn more at www.perkinelmer.com/solar

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