Fraunhofer ITWM

Fraunhofer Institute for Industrial Mathematics ITWM

Materials Characterization and Testing

From Visible Light to Terahertz – from Layer Thickness Measurement to Material Detection

Content

Our Passion: Measurement Technology

The Department “Materials Characterization and Testing”

With our many years of experience in the field of non-destructive measurement technology, we can provide you with efficient support for measurement tasks and industrial and development projects.

Our qualified employees research on the following topics:

- Coating thickness measurement of single and multilayer samples
- Detection of structures and defects in components
- Investigation and testing of paint drying processes
- Material detection based on spectral properties

We use the entire spectrum from visible light and infrared radiation to terahertz and millimeter waves.

Our team consists of dedicated technicians, CAD designers, engineers and physicists who, with their expertise in optical measurement technology, software development and practical experience in system layout and design, offer the entire development chain of a measurement system through to integration at the company.

www.itwm.fraunhofer.de/en/mc

Application Center “TeraTec”

Services and Studies

With the “TeraTec” application center, we support you with services in the form of free preliminary investigations, feasibility studies, equipment rental and on-site measurements to solve your measurement task.

In our laboratories, we use our own measurement systems as well as commercial systems and the latest robot and camera technology. In the so-called “DigiCell”, large free-form samples are examined by first capturing the objects in 3D and then automatically aligning the robot-supported sensors precisely to the object using simulated path planning.

www.itwm.fraunhofer.de/TeraTec_en

Portfolio

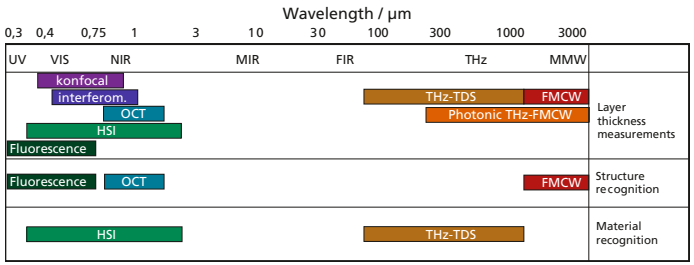
Optical Measurement Technology – the Basis of our Solutions

Our "Materials Characterization and Testing" department offers individual solutions in the following key areas:

- Coating thickness measurement
- Structure and defect detection
- Material detection

We use a wide range of measurement techniques from the entire optical spectrum – from interferometric/confocal solutions in the visible and near-infrared spectral range for transparent materials to our concepts in the millimeter and terahertz range for transparent and opaque samples.

For material detection, we use hyperspectral imaging and terahertz systems to analyze spectral properties in the appropriate wavelength range. We also assist you with the development, design and integration of the system. We provide measurement services and feasibility studies via the affiliated "TeraTec" application center.



TeraTec
Application Center for Terahertz Technology

www.itwm.fraunhofer.de/products_mc_en


Coating Thickness Measurement

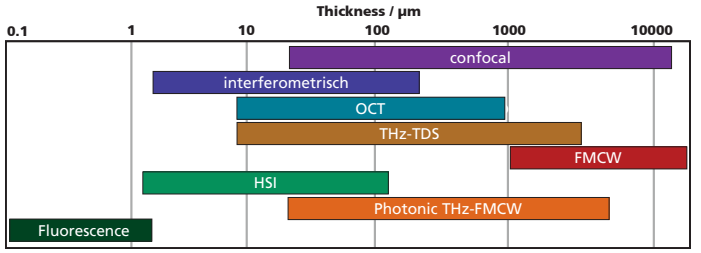
Coating Thickness Measurement

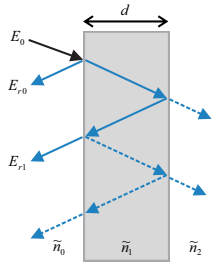
We offer a wide variety of coating thickness measurement systems, all of which have one thing in common: they are subject to the laws of optics. According to the Fresnel equations, the electromagnetic radiation used is partially reflected and transmitted at the interface between the coating and the substrate.

The measuring systems, which typically work in reflection, collect the reflected light, that contains the information of the coating system to be examined as phase or time-delay information. This information is extracted with our real-time capable software solutions and individually processed in a user-friendly way.

With our wide range of system solutions, we cover a thickness range from around one micrometer to several millimeters. We can measure the thicknesses of individual layers as well as layers in multilayer composites separately.

Depending on the measurement method, we carry out the measurements at specific points or as line and area scans in order to obtain the decisive information depending on the application.





www.itwm.fraunhofer.de/layer-thickness-measurement

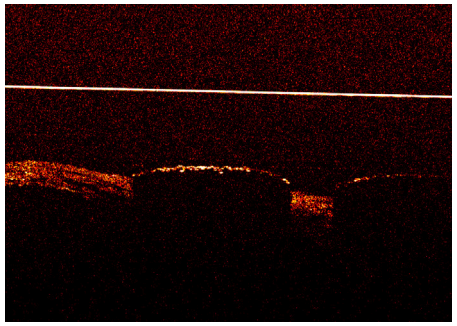
Varnishing and Coatings

Coatings are decisive quality features for many products in the automotive, aerospace, paper and furniture industries, as well as in the food and medical sectors.

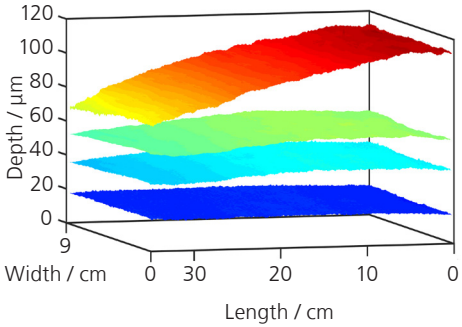
The coatings, which are available as single or multilayer systems, can be measured without contact or destruction. The techniques used for this are harmless to health and at the same time robust and stable.

The production process can be monitored and optimized by measuring the thickness of these increasingly thin coatings with micrometer resolution. The measuring heads, with supply lines of up to 20 m, can be precisely positioned by hand, linear axes or robots for inline measurement.

High measuring rates combined with excellent reproducibility of better than 1 µm allow the industrial measuring systems to be used in production. Real-time capable evaluation algorithms in combination with specific software complement the systems.



OCT measurement of a varnished wood sample. The top side of the paint and the top side of the wood are clearly visible.



Determined layer thicknesses of a four-layer paint sample with thickness gradient in the clear coat

Measurement of Single and Multilayer Coatings on

- Metal
- Plastic and composite material
- Wood
- Fired and unfired ceramics
- and other materials

Advantages

- Understand and control processes
- Increase quality
- Save material

Specifications

- Non-contact and non-destructive
- Single and multilayer samples
- Measuring range from 10 µm to 3 mm
- Reproducibility better than 1 µm
- Measuring rate up to 1600 Hz
- Dry and wet layers
- Robot-guided measurements

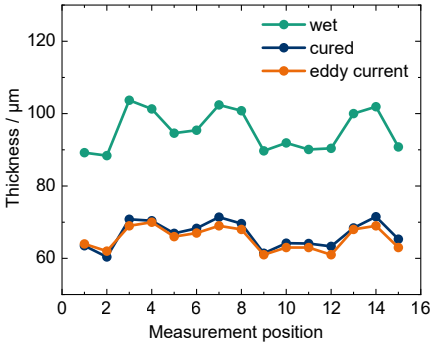
Wet Paints and Soft Coatings

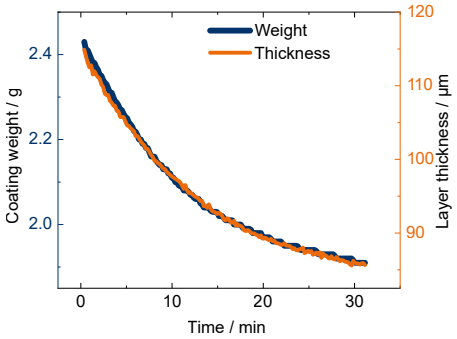
Thanks to our contactless terahertz systems, even wet or soft coatings can be examined.

This allows drying and painting processes to be better understood and monitored. This information is used to detect rejects at an early stage and thus save energy, material, time and money.

With knowledge of the exact layer thickness development during paint drying, the painting and production process can be optimized to achieve the best possible result. We also examine one- and two-component uni and metallic paints and record drying curves for these paints. The final paint thickness can then be calculated in the process immediately after application.

Our measuring systems are used reliably in industrial environments with robot guidance.



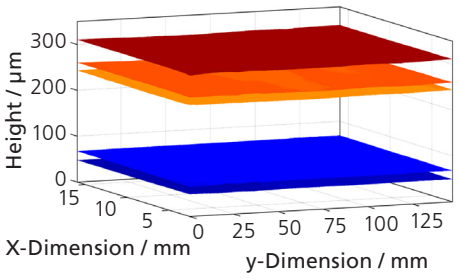


Plastic Films

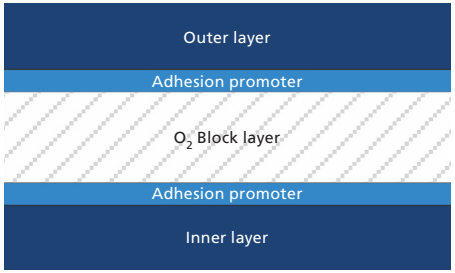
Plastic films often consist of up to seven thin individual layers, including adhesion promoter and oxygen block layer (EVOH).

Due to this complex composition, films place high demands on the measuring systems, particularly in terms of accuracy and reproducibility.

Our terahertz, OCT and hyperspectral systems are used for film analysis. They scan the samples with up to 1,600 point measurements or up to 300 line measurements per second and can continuously monitor the film thicknesses in production.



Depth representation of a film with central EVOH layer, outer and inner layer and adhesion promoter



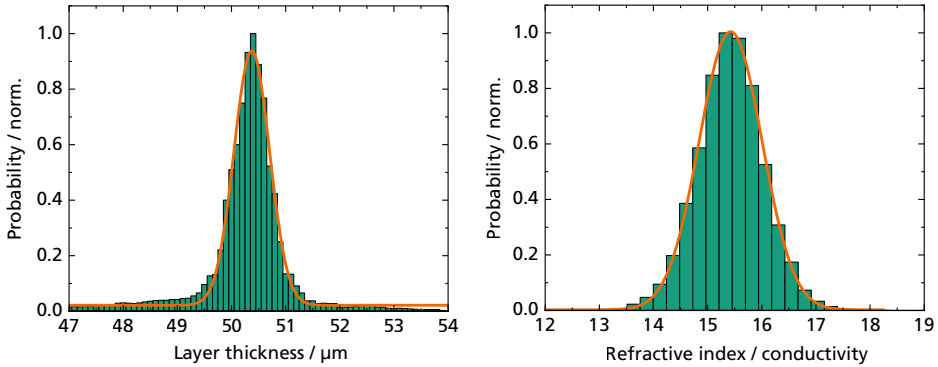
The EVOH layer can be measured with sub-micron repeatability

Battery Films

Battery films are the main components in lithium-ion battery cells. Continuous monitoring of the material parameters – layer thickness and conductivity – is crucial for product quality.

Lithium batteries – used in electric vehicles and large battery storage systems – consist of anode and cathode films, which must have different properties depending on their task. Measuring these properties, in particular conductivity and layer thickness, is essential in the development and production of efficient batteries in terms of energy density and longevity.

Cathodes are characterized by low conductivity. Anodes, on the other hand, have a significantly higher conductivity, which makes them difficult to measure. With our photonic terahertz FMCW systems, which have been specially optimized for this application, we are nevertheless able to generate precise information from the films, which are several 10 µm thick, as shown using the example of an anode film.



Coating thickness and conductivity measurements with maximum accuracy

Pilot plant for battery cells at the project partner, the Fraunhofer Research Institution for Battery Cell Production FFB

The inline-capable measuring system, with measuring speeds of up to 1,000 measuring points per second, is also scalable in terms of the number and position of the measuring heads.

Their suitability for use with reproducibilities of better than 1 µm has been successfully demonstrated on various samples and in a pilot plant.

Advantages

- Anodes and cathodes are measurable
- Continuously monitor production
- Ensure product quality

Specifications

- Non-contact and non-destructive
- Measuring range from 10 µm to 300 µm
- Measuring rate greater than 1 kHz
- Reproducibility better than 1 µm

Pipes and Hoses

Extrusion processes for plastic and rubber coatings produce continuous products. An inline-capable measuring process for checking the thickness of the products is, therefore, essential for quality control.

We reliably meet these requirements with our optical and terahertz systems, even in industrial working environments. The data is recorded at high measurement rates to achieve fine spatial resolutions, evaluated in real time and processed graphically.

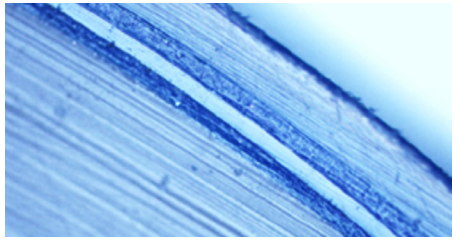
System integration into existing production facilities is also one of our areas of expertise.

Advantages

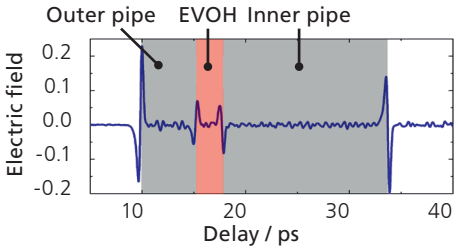
- Monitor/control the extrusion process inline
- Recognize trends in the process
- Save material

Specifications

- Non-contact and non-destructive
- Inline-capable
- Robust even in demanding environments
- Measuring range from 3 µm to several cm
- Reproducibility better than 1 µm
- Graphical representation

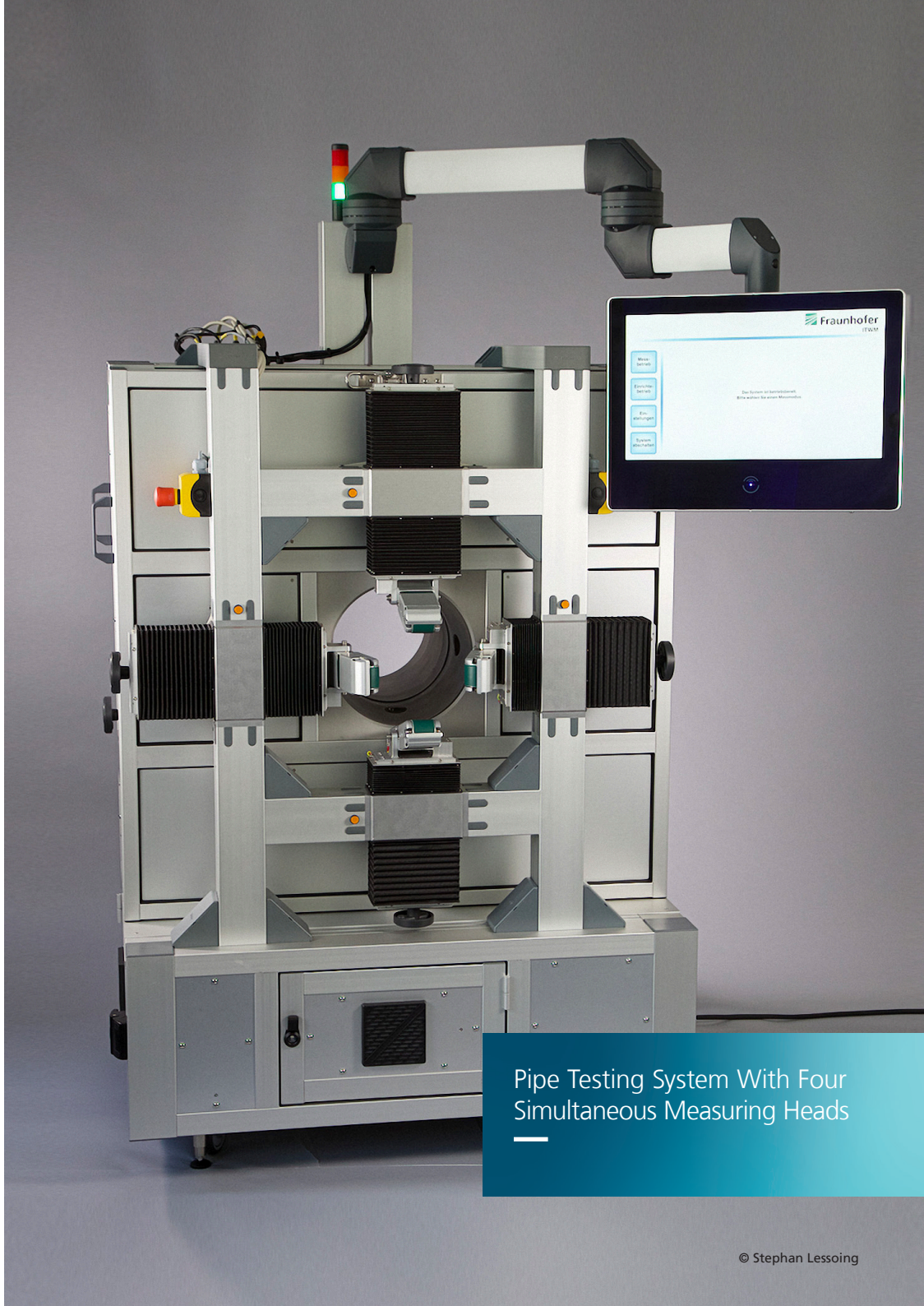


Microscope image of a plastic pipe



Terahertz measurement data of a plastic pipe with clearly recognizable layer structure

www.itwm.fraunhofer.de/pipe-inspection



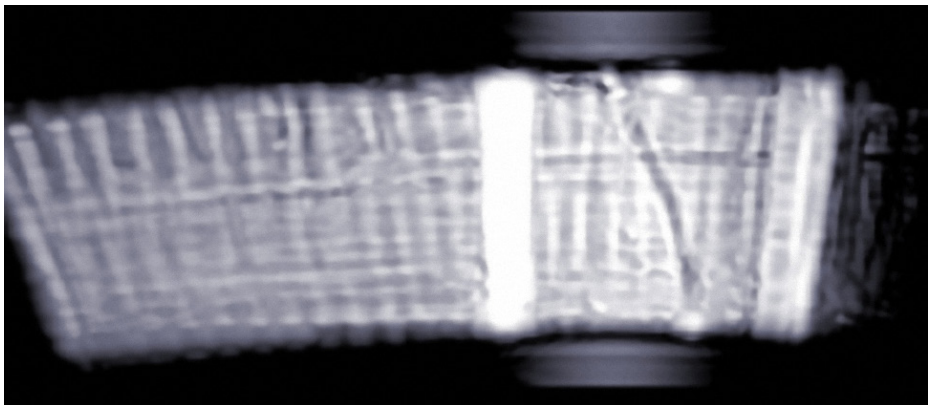
Pipe Testing System With Four Simultaneous Measuring Heads

© Stephan Lessoing

Structural Analysis of the Mica Insulation of Generator Bars

Structure and Defect Detection

Looking inside non-transparent materials, such as plastics and composites or foams, is only possible to a limited extent using conventional measurement methods. However, millimeter and terahertz waves can penetrate non-conductive or weakly conductive materials and thus provide information on the internal structure of the components.



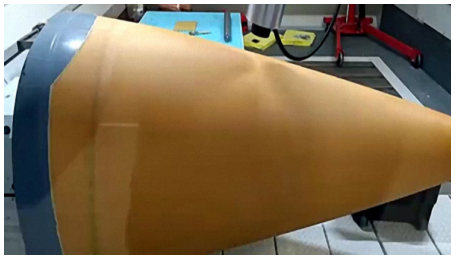
Terahertz image of a generator rod with a crack in the insulation

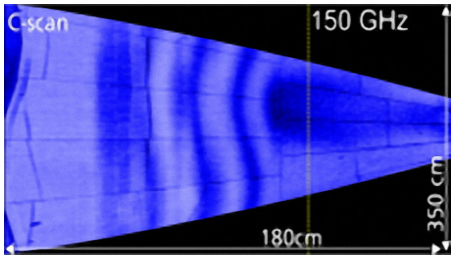
With our portfolio, we offer measuring systems for examining external and internal component structures. We also measure large and difficult-to-access objects with our approaches.

The mica insulation of generator rods can be examined for defects, such as fine cracks, at all critical positions using a dielectric measuring tip as a quasi near field probe.

Lateral resolutions of less than 1 mm and depth resolutions of a few millimeters with penetration depths of up to several centimeters can be achieved. The processing of the results is individually adapted to your requirements.

Composite Materials





Structure detection on aircraft radomes using a 150 GHz FMCW system. The robot-guided measurement captures the entire freeform.

Composite materials – such as CFRP, GFRP and NFRP – are future-proof materials for achieving specific product performance requirements. Using radar technology, defects in the structure of composite layers can be detected over a large area with a resolution of up to 1 mm, as shown here using the example of a radome.

The substrate-independent measuring systems from our portfolio can be used to test GFRP and NFRP-based composites both on the surface and in volume.

Measurement of

- Differences in the thickness of the coating and the substrate
- Imperfections
- Inclusions and cavities
- Porosity

Advantages

- Complex samples measurable
- Coating and substrate analyze simultaneously
- Detect defects at an early stage

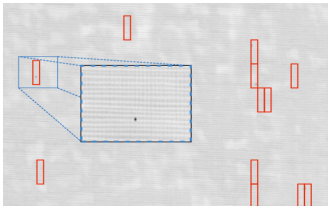
Specifications

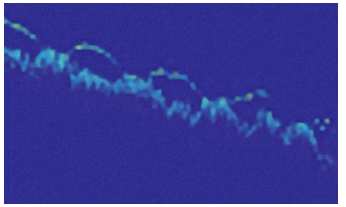
- Substrate-independent
- Area scans with a few minutes per m²
- Lateral resolution of better than 1 mm
- Reproducibility better than 1 µm

Plastics

Air inclusions, delamination and rough surfaces are common causes of defective plastic components.

Optical coherence tomography as an imaging measurement method for semi-transparent products and terahertz technology for non-transparent products are very well suited to detect the finest defects during production. This means that further production steps for rejects can be avoided, saving costs and energy. Topographical measurements of the surface quality are also addressed with our technologies. We monitor roughness as well as cracks and scratches with micrometer precision.





Above: Full-surface inspection of press sleeves for internal defects. The automatic AI-based evaluation takes place in the background.

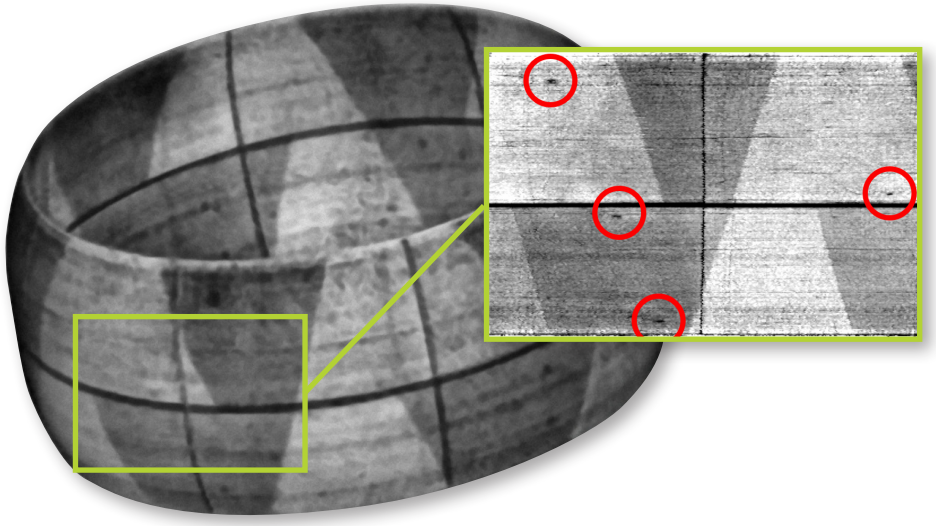
Bottom left: Terahertz image of a press sleeve with automated defect detection (red)

Bottom right: Roughness measurements with micrometer resolution

Foams and Bonding

A “100 percent control” of modern high-performance components is challenging. We offer a wide range of solutions for component analysis.

Foams and their bonds are often several millimeters thick and consist of different layer sequences. With our terahertz systems, we offer techniques with very high measurement rates and penetration depths of up to several centimeters with depth resolutions in the micrometer range. This means that complex components, such as several bonded foams on CFRP, can be examined over their entire surface for defects and inclusions and a distinction can be made between anomalies in the individual layers. Thanks to the robotic capability of our measuring heads, we can also successfully inspect large samples with complex shapes and process the data in 1D, 2D or 3D according to your requirements.



Terahertz images of the foam insulation on a cylindrical CFRP carrier

Defect Testing in the Space Travel

Material Identification and Characterization

When materials are irradiated with visible or non-visible light, many materials show specific absorption properties that can be used for characterization.

We use visible and infrared light as well as terahertz and millimeter waves for the spectral analysis of substances. Drugs and explosives show specific "fingerprints" in the terahertz range. Wood, paper and fruit show distinguishable properties in the visible and near-infrared spectral range, as do coated rubber compounds in UV fluorescence behavior. The detection of all these properties makes it possible to identify and characterize the materials, which can be used for detection, sorting and concentration determination. Used as laboratory equipment or directly in the production lines, our systems generate, analyze and process important information. System design, implementation, integration and software all come from a single source.

www.itwm.fraunhofer.de/materialanalyse_en

Vector Network Analyzers – VNA

The use of established high-frequency measurement technology, such as network analyzers for material characterization and testing, enables the complex reflection and transmission coefficients of materials to be measured precisely over a wide frequency range.

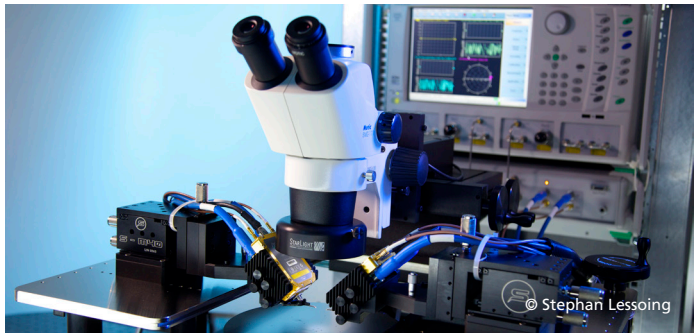
This information can be used to determine the electrical properties of materials. The possible applications of such systems are very diverse.

Dielectric Materials
The dielectric properties of materials can be measured, e. g. their dielectric constant and their loss tangent.

Conductive Materials
Conductive materials can be used to measure the conductivity of materials such as metals and semiconductors.

Thin Films and Coatings
Network analyzers are used to measure the thickness of thin films and coatings.

Antennas, Radomes and other Components
They can be used to measure the impedance of antennas and other components.



Network analyzer with high-frequency measuring probes

Mail Scanner

The detection of drugs and explosives in letters – based on terahertz time-domain spectroscopy – increases security in prisons.

Terahertz radiation penetrates many non-conductive materials, including paper and plastics. Some of the radiation is absorbed, which changes the spectral response of the sample. If these exhibit characteristic dips in the terahertz spectral range – as is the case with drugs and explosives – they are detected on the basis of these "fingerprints". The mail scanner developed by us in cooperation with Hübner phtononics automatically examines letters and analyzes the contents for unwanted substances in real time. If it is used in prisons and other relevant facilities, the scanner can contribute to security.

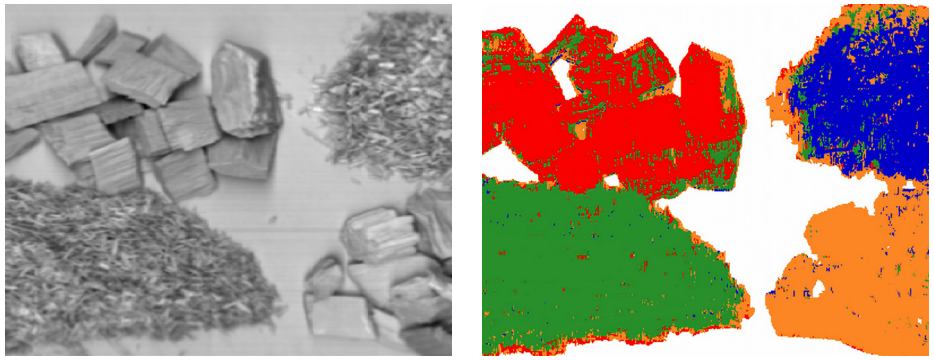
www.itwm.fraunhofer.de/mail_scanner

Recognizing Types of Wood

Different types of wood show distinguishable characteristics in the optical spectrum that help with identification. This makes it possible to determine the composition of wood chip and wood shavings.

The mixing ratio between hardwood and softwood determines the stability and cost of a chipboard or MDF board. However, this ratio is rarely defined when the raw materials are delivered. Measuring methods are, therefore, required to reliably analyze the wood products in order to ensure the best possible ratios.

Hyperspectral imaging enables fast, pixel-by-pixel categorization based on chemical characteristics between wood species. We have already successfully demonstrated the differentiation between hardwood and softwood, but also between different types of wood, such as beech, pine, spruce, birch, etc.



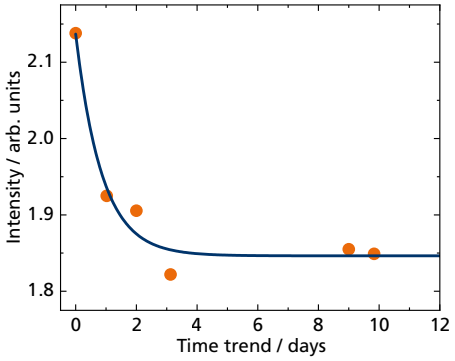
The captured spectral image data is assigned to the pre-trained classes in real time with pixel accuracy.

Determining the Degree of Maturity

Whether bananas, avocados or tomatoes, climacteric fruit in the ripening process change their sugar content, which can be used to determine the ideal harvest time using hyperspectral imaging.

The Brix or sugar content can be measured using hyperspectral imaging in the near-infrared spectrum. The spectral response of the fruit from more than 200 channels is recorded simultaneously with a camera, analyzed and the result processed in real time.

Due to very high measurement rates of up to 300 line measurements per second and low readout noise, this measurement technology is ideal for use on the assembly line. The systems consist of a compact hyperspectral camera and a light source for uniform illumination of the products.



The example shows the changed spectral response of an avocado during the ripening process.

www.itwm.fraunhofer.de/ripe_tomatoes

Waste Recycling and Paper Identification

Recycling waste is an important part of saving raw materials. Hyperspectral imaging and terahertz imaging measurement technology can help to analyze and separate waste more efficiently and comprehensively.

Although the people already have a high awareness of waste separation, mechanical analysis and separation of waste is essential in order to achieve a high recycling rate.

The separation of different materials and types within the waste category is also crucial here. Hyperspectral imaging in the visible and near-infrared spectral range can differentiate waste on the basis of its characteristic chemical composition. A basic distinction can be made between metal, plastic, paper, glass, and wood, for example, but also between normal paper and wet-strength paper. Terahertz imaging also offers the potential to identify hidden plastics and types of wood.

The "ASKIVIT" research project, which is funded by the German Federal Ministry of Food and Agriculture (BMEL), focuses on recovering waste wood from bulky waste using artificial intelligence and image processing.

www.itwm.fraunhofer.de/askivit_en

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