CENTER MATERIALS CHARACTERIZATION AND TESTING

Behind the aircraft nose made of composite material - the radome - is the radar unit. A millimeter-wave terahertz system developed by our institute checks every single radome in the MEGGITT company for defects.

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HEAD OF DEPARTMENT

OPTICAL MEASUREMENT TECHNOLOGY – NON-DESTRUCTIVE MEASUREMENT WITH TERAHERTZ AND MILLIMETER WAVES

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We develop industrial measuring and testing systems for the quality control of composite materials and coatings. The scientists, engineers and technicians fall back on competences from optical system and measurement technology, spectroscopy and the development of crystal and semiconductor components.

The technologies range from optical coherence tomography (OCT) in the visible spectral range to time domain spectroscopy in the terahertz frequency range and electronic system concepts in the millimeter wave range. Our systems are tailor-made for the customer. This includes both the application and the evaluation software, which clearly presents the main target variables. Throughout the entire development process, our customers benefit from our employees' understanding of the process.

In quality control, our systems detect defects in ceramics, plastics or fibre-reinforced composites non-destructively. Particular interest is shown in non-contact coating thickness measurement, for example in painting processes. In addition to OCT, terahertz and millimeter wave measurement technology is an alternative to ultrasonic measurements and X-ray technology: No mechanical contact with the sample is necessary and the radiation energy is non-ionizing. In addition to determining the thickness, our measuring systems also determine the material parameters of the individual layers. Chemometric evaluation methods clearly and reliably identify the composition of the materials.

MAIN TOPICS

- Non-destructive Testing
- Layer Thickness Measurement
- Analysis of Chemicals

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EXAMINATION OF VERY THIN LAYERS WITH INTERFEROMETRIC IMAGING

1 *Enamelled wire is used for the construction of electric coils and transformers. We measure the layer thickness of the insulating varnish on the wire without contact.*

Coatings often not only enhance aesthetics, but also have functional properties; these include protection against mechanical influences and harmful weather influences or the improvement of the haptics. Coating thickness is therefore of particular importance in industry.

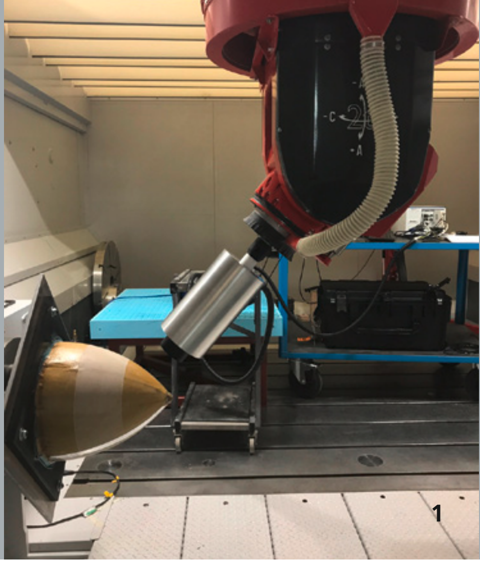
Functional properties require a minimum thickness, unnecessary thick layers waste resources and thus increase production costs. There is now a solution for measuring very thin, semitransparent layers: optical coherence tomography (OCT). This method has been originally developed for the depth-resolved visualization of biological and medical materials. Thanks to intensive research, it has now also established itself outside medicine. High-resolution sample cross-sections, which are generated completely non-destructively in real time with visible or infrared light, make the OCT the ideal non-contact inspection technology for many applications.

Reflection provides information

The physical principle behind this method is the interferometric superposition of a light beam, which is reflected from different sample depths, with a reference boundary beam. From the intensity and temporal shift of the reflected beam, the depth information of the sample can be determined mathematically and displayed as a cross-sectional image. The resolution is between 1 and 20 µm, depending on the spectral width. Optical coherence tomography is suitable for all materials that are at least partially transparent to visible or near-infrared light. These are many plastics, composite materials, glasses, ceramics or semiconductor materials.

Inspection of enamelled wire

Enamelled wire, also known as winding wire, is a metal wire coated with an electrically insulating enamel layer during production. The thickness and weight of this lacquer insulation is very low compared to other insulating materials with the same effect. This wire is therefore preferred for the construction of electrical coils, transformers and machines. We successfully use OCT to measure the enamel thickness on copper wires. The thinnest wire had a diameter of 50 µm and a coating thickness of 3 µm.



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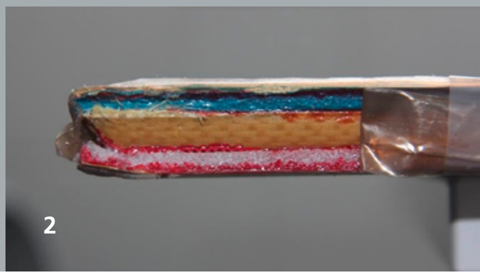

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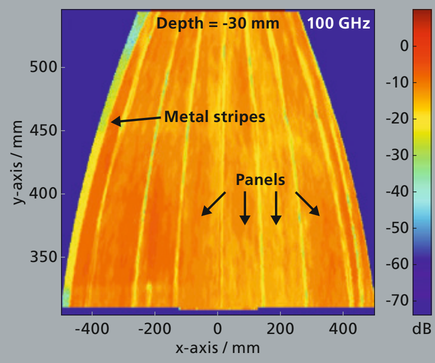

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QUALITY CONTROL IN THE AEROSPACE INDUSTRY: RADOME INSPECTION WITH TERAHERTZ

Imaging with terahertz waves is ideal for the nondestructive inspection of glass-fiber-reinforced composites. Such structures are used, for example, for the radar domes (radomes) of aircraft, among other things to protect sensitive radar technology. Terahertz technology enables contactless testing of structural integrity in the field or during production.

Radar domes must withstand harsh weather conditions and impacts. They are routinely tested in use, but it is important to optimize their structural integrity and transmission properties for radio-signals during manufacture. Previously used testing techniques such as ultrasound procedures and knocking tests can often only be used to a limited extent and if necessary only under special conditions.

Terahertz imaging allows a non-contact and non-destructive examination of the external and internal structure of composite materials at every manufacturing step or even in the field. Furthermore, image-processing methods can be used for the automatic detection of defects or other characteristics.

Spiral scanning of the radome

For the British company Meggitt Polymers & Composites we developed an industrial 3D Terahertz imaging system for the inspection of radar domes. The simple integration of the measuring unit into the company's production plant enables the entire radome, which can be up to two metres long, to be scanned in a spiral.

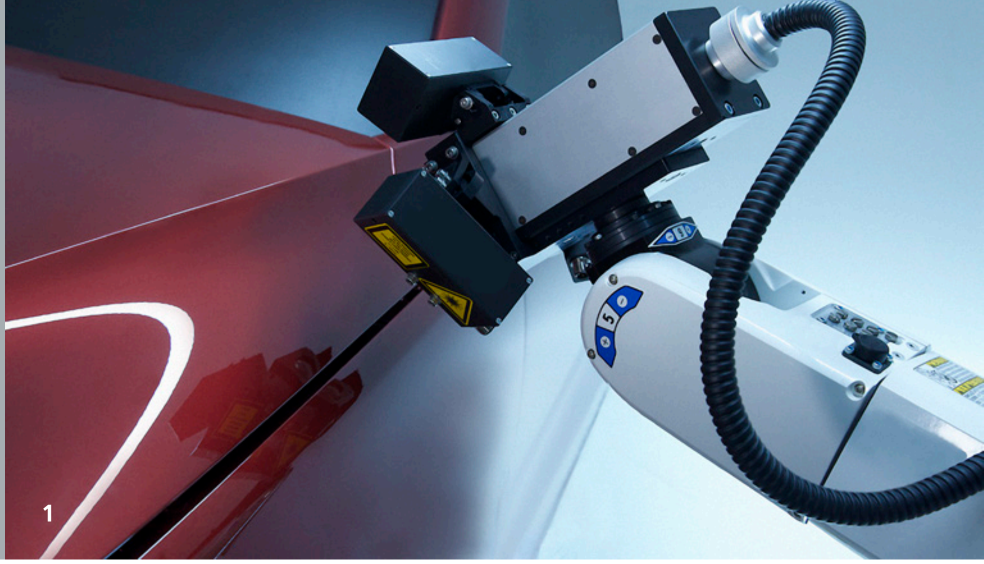
Depending on the type of radome, the thickness and composition of the structure can vary greatly. This has a significant influence on the penetration depth of the terahertz measurement signal. The choice of sensors often requires a compromise between image resolution and penetration depth. We have integrated two different terahertz sensors with adjacent frequency ranges into one measuring system so that both, structures with a few centimeters thickness as well as thinner ones, can be examined with the best possible resolution. For improved depth resolution, the measurement data of both sensors are combined with each other.

1 *Sensor unit in the tool holder of the production machine*

2 *The structure of the radome consists of different layers of different materials (e. g. aramid and foam structures).*

3 *Terahertz measuring unit with connected data connection and power supply*

4 *Reconstructed image of the radome at 100 GHz showing the back of the radome. The elements of the radome can be clearly recognized.*



TERAHERTZ FILM THICKNESS MEASUREMENT FOR THE SELF-PROGRAMMING PAINTING CELL

1 *Robot-guided terahertz measuring head with three positioning sensors for measuring the layer thickness on a car body*

The painting process presents many entrepreneurs with great challenges, as automation and individualization of the products do not yet match when it comes to painting technology. In many industries, well over half of all components are therefore painted by hand - the variety of variants is simply too large.

Programming a painting robot is only worthwhile if numerous identical parts have to be spray-painted. The automatic coating system SelfPaint offers companies a compromise between automation and individualization for the first time - and also offers numerous potential savings: 20 percent less coating, 15 percent less energy, five percent less production time - its advantages over the previously dominant manual coating process are enormous. And for the first time it is also suitable for individual pieces.

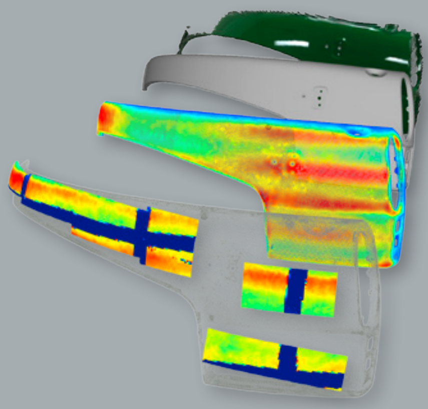
We developed the self-programming painting cell together with the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and the Swedish Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC.

Algorithms calculate optimal robot path

The automatic painting process consists of five steps. First of all, the component is scanned in three dimensions, whereupon the scan data form the basis for a fluid dynamic simulation. Algorithms simulate the trajectory of the coating particles and determine which coating and air quantities are optimal for the desired coating thickness. In a third step, the system uses this simulation data to determine the best possible robot path for the painting process. Now follows the actual painting process, which is controlled in the last step using terahertz technology. In the project we realize the three-dimensional recording of the component and the terahertz layer thickness measurement.

Three-dimensional object and position detection

In order for the painting cell to know the position of the object for simulation and painting, it must be recorded in three dimensions. However, systems designed for industrial use for 3D object acquisition are usually designed for very precise topographic measurements of unknown objects, which makes them expensive.



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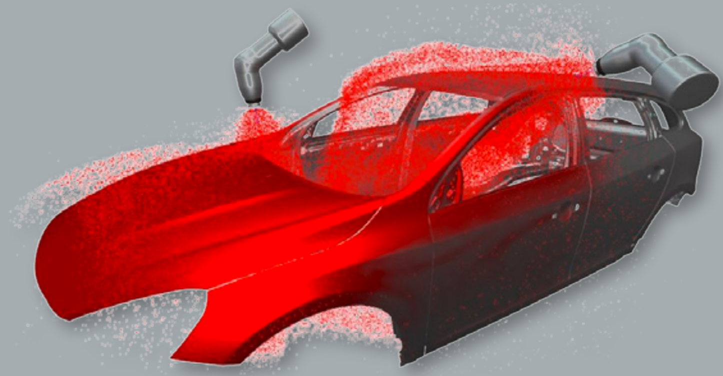

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If object geometry information is a priori available in the form of CAD data, very cost-effective products from the field of consumer electronics can be used. All that is needed here is to determine the position of the components in the room.

The self-programming painting cell uses 3D sensors that were originally developed to control video games - a global mass market. The accuracy of the position detection is more exact than the deviations of common components from the CAD data and is therefore within the manufacturing and positioning tolerances. This high resolution is made possible by tailor-made algorithms for data processing. The pure three-dimensional image, which is captured by the sensor and is available as a point cloud or network, cannot normally be used directly for position detection. However, if filters are used that make use of the imaging properties of the sensor system and automatically remove faulty information from the measurement, the point clouds can be reworked so that they are of high quality. High enough to perform fully automated 3D position detection for paint simulation and painting.

Terahertz technology for quality control

In the final process step of automated painting, the quality is finally checked: Is the thickness of the coating as desired? For this quality-control we use terahertz waves. With this technology developed by us wet and coloured lacquers can be measured without contact. The quality of the paint layers can already be checked during or after the painting process.

The method used enables non-contact measurement of even single layer thicknesses of a multi-layer system, which is also used in many painting processes. Substrates – the basis of the coating layers – do not have to be metallic, but can also consist of other materials. The measuring systems for this quality control have reached and proven industrial maturity in recent years.

In everyday painting, everything will soon be automatic: The component is scanned, painted and checked for quality by robots - without the intervention of an employee.

2 *Sequence of the automated painting process (from back to front: 3D recording of the component, adjustment with CAD model, simulation of the painting result, result of the terahertz measurement - blue areas masked for comparison measurements)*

3 *Multiphysical simulation of a high rotation atomizer with contact charging for calculating the droplet trajectory using a Volvo V60 body as an example*

NEWS

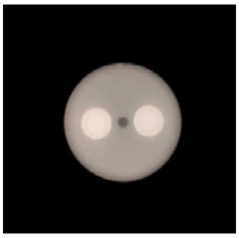
INTELLECTUAL PROPERTY RIGHTS FOR INTERFEROMETRIC DISTANCE CONTROL

The interferometric distance control allows the correction of vibrations that inevitably occur during terahertz layer thickness measurement under industrial conditions. Both the paths within the spectrometer and the distance to the sample to be measured (e. g. a car body) are measured quasi in real-time in order to determine correction values for the layer thickness measurement. Especially for the measurement of industrially relevant thin films (< 20 µm), this method is indispensable for the determination of error-free measured values. We hold the industrial property rights for both correction procedures.

THE SLAPCOPS LASER – A NEW LIGHT SOURCE FOR TERAHERTZ TIME DOMAIN SPECTROSCOPY

For terahertz time-domain spectroscopy, two variable delayed laser pulses are required in order to be able to scan the measurement signal in a time-resolved manner. The time delay is usually provided by a mechanical displacement unit. Newer approaches use two laser sources that either operate with slightly detuned repetition frequencies or also actively control the repetition rate of one laser. Disadvantage of the mechanical control is the inertia and vibration susceptibility of the systems, disadvantage of the approaches based on two lasers are the high costs.

We have now developed a laser system that works without a mechanical displacement unit and still uses only one laser. The system emits laser pulses with orthogonal polarization. Each polarization propagates at a different speed, resulting in different repetition rates. A scanning delay can also be realized by a specific detuning of the resonator length for one of the two polarizations. A mechanically robust and at the same time cost-effective process. The intellectual property rights are owned by us and our client Hübner GmbH & Co. KG.



Front, left to right: Jens Klier, Nina Schreiner, Robert Kranz, Dr. Joachim Jonuscheit, Prof. Dr. Georg von Freymann, Claudia Busch-Crolly, Andreas Keil, Ph.D., Christoph Kaiser, Alexander Theis, Dr. Daniel Molter, Ute Rein-Rech, Raphael Hussong, Caroline Cappel, Wladimir Zwetow, Shiva Mohammadzadeh, Oliver Boidol, Dmytro Kharik, Maris Bauer, Sebastian Bachtler