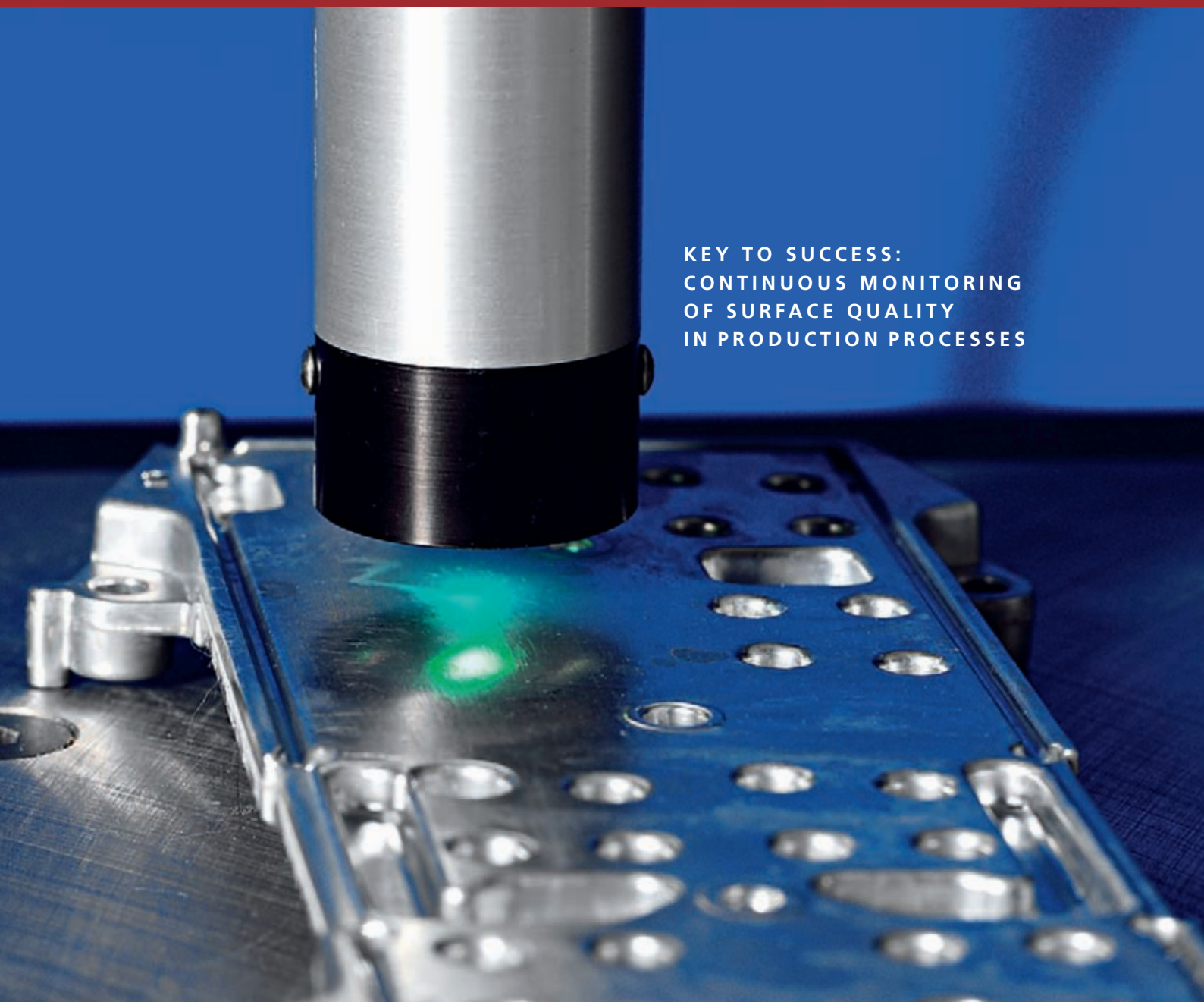
Fraunhofer
IFAM

FRAUNHOFER-INSTITUT FÜR FERTIGUNGSTECHNIK UND ANGEWANDTE MATERIALFORSCHUNG IFAM

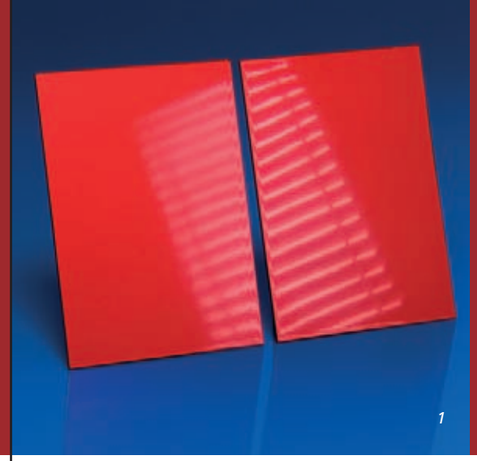
QUALITY ASSURANCE OF SURFACES



KEY TO SUCCESS:
CONTINUOUS MONITORING
OF SURFACE QUALITY
IN PRODUCTION PROCESSES

CONTENTS

Figure, cover page: Identification of residual contamination on an aluminum pressure-cast component using Optically Stimulated Electron Emission (OSEE).



1 Left: defective coating – orange peel effect on a painted surface; right: defect-free coating.

2 Samples after performance of peel test: Cohesive fracture in the adhesive film (left) and adhesive fracture due to a release film at the surface.

Fraunhofer-Gesellschaft

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains more than 80 research units in Germany, including 59 Fraunhofer Institutes. The majority of the 17,000 staff are qualified scientists and engineers, who work with an annual research budget of €1.6 billion. Of this sum, more than €1.3 billion is generated through contract research. Two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Only one third is contributed by the German federal and *Länder* governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe.

Fraunhofer IFAM – Adhesive Bonding Technology and Surfaces – Expertise and know-how

The Department of Adhesive Bonding Technology and Surfaces at the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research is the largest independent research group in Europe working in the area of industrial adhesive bonding technology. More than 210 employees carry out industry-oriented R&D activities in the fields of bonding and surface technology. The R&D activities focus on adhesive bonding technology, as well as plasma technology and paint/lacquer technology. The objective is to supply industry with application-oriented system solutions.

Multifunctional products, lightweight design, and miniaturization – achieved via the intelligent combination of materials and joining techniques – are opening up new opportunities which are being exploited by Fraunhofer IFAM. The activities range from fundamental research through to production and the market introduction of new products. Industrial applications are mainly found in car, rail vehicle, ship and aircraft manufacture, plant construction, energy technology, packaging sector, textile industry, electronics industry, microsystem engineering, and medical technology. The work in the Adhesive Bonding Technology business field involves the development and characterization of adhesives, the design and simulation of bonded, riveted, and hybrid joints, as well as the characterization, testing, and qualification of such joints. The planning and automation of industrial adhesive bonding applications are also undertaken. Further services include process reviews and certified training courses in adhesive bonding technology and fiber composite materials.

The work of the Surfaces business field is subdivided into plasma technology and paint/lacquer technology. Customized surface modification – for example surface pretreatment prior to bonding/coating and functional coatings – considerably expand the industrial uses of many materials.

The Adhesion and Interface Research business field is engaged, amongst other things, with the early detection of degradation phenomena, the validation of aging tests, and inline surface monitoring.

The Fraunhofer Project Group Joining and Assembly FFM of the Fraunhofer IFAM is carrying out ground-breaking work on large carbon fiber reinforced plastic structures and is able to join, assemble, process, repair, and carry out non-destructive tests on large 1:1 scale CFRP structures, thus closing the gap between the laboratory/small pilot-plant scale and industrial scale in the area of CFRP technology.

The Department of Adhesive Bonding Technology and Surfaces is certified according to DIN EN ISO 9001, while the Materials Testing Laboratory and the Corrosion Testing Laboratory are certified according to DIN EN ISO/IEC 17025. The Center for Adhesive Bonding Technology is accredited via DVS-PersZert® in accordance with DIN EN ISO/IEC 17024 as a training establishment for courses in adhesive bonding technology and has an international reputation. Like the Plastics Competence Center, it is also accredited in accordance with the German quality standard for further training, AZWV.

www.ifam.fraunhofer.de

QUALITY ASSURANCE OF SURFACES

Adhesive bonding, painting/lacquering and coating are processing steps used by all sectors of industry, for example in the production of cars, rail vehicles, ships and aircraft, in machine and plant construction, and in the electrical industry. These processes do not always run perfectly. The pretreatment of material surfaces, which is often necessary prior to processing, can result in imperfections which initially remain undiscovered. In order to avoid subsequent failure, the continuous monitoring of the surface quality in production processes is recommended.

Pretreatment: Important, but prone to faults

When adhesive bonds fail due to poor adhesion, experience shows that in about 70 percent of the cases contaminated surfaces are the reason. For paints/lacquers and coatings, defects are often only discovered afterwards. The source of the fault is mostly the pretreatment of the materials. Pretreatment plays a key role in the whole process, because in many cases effective cleaning and activation of surfaces is vital in order to guarantee successful bonds and coatings.

These critical pretreatment processes, some of which involve several steps, take place at the nanometer level. Up until now, the constant monitoring of these processes has been virtually impossible. Quality assurance testing was in general only carried out on random samples using destructive tests after creation of the adhesive bond or after application of the layer of paint/lacquer or coating.

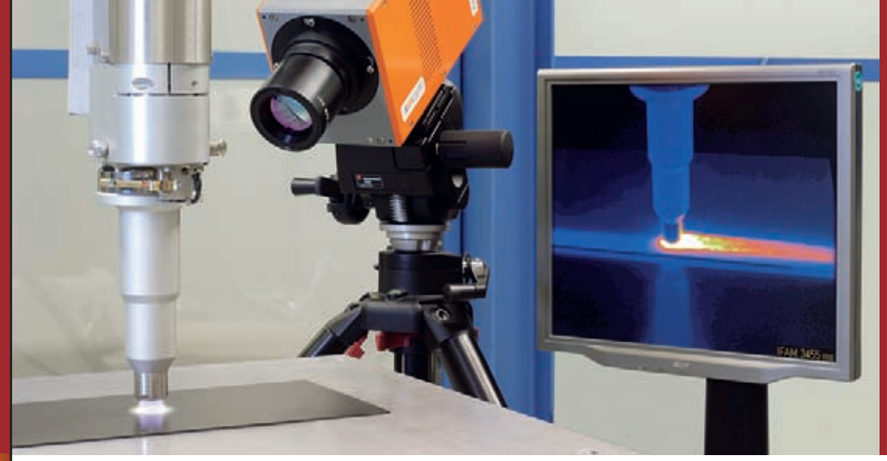
Contaminants or insufficient pretreatment – for example fingerprints or incomplete activation – have to date often remained undiscovered because they were not visible.

The consequences are costly failure which in extreme cases results in production disruption and loss of company image. Optimum quality assurance can hence only be achieved by continuous monitoring of the state of surfaces in the production process, and employing methods which guarantee reliable fault recognition.

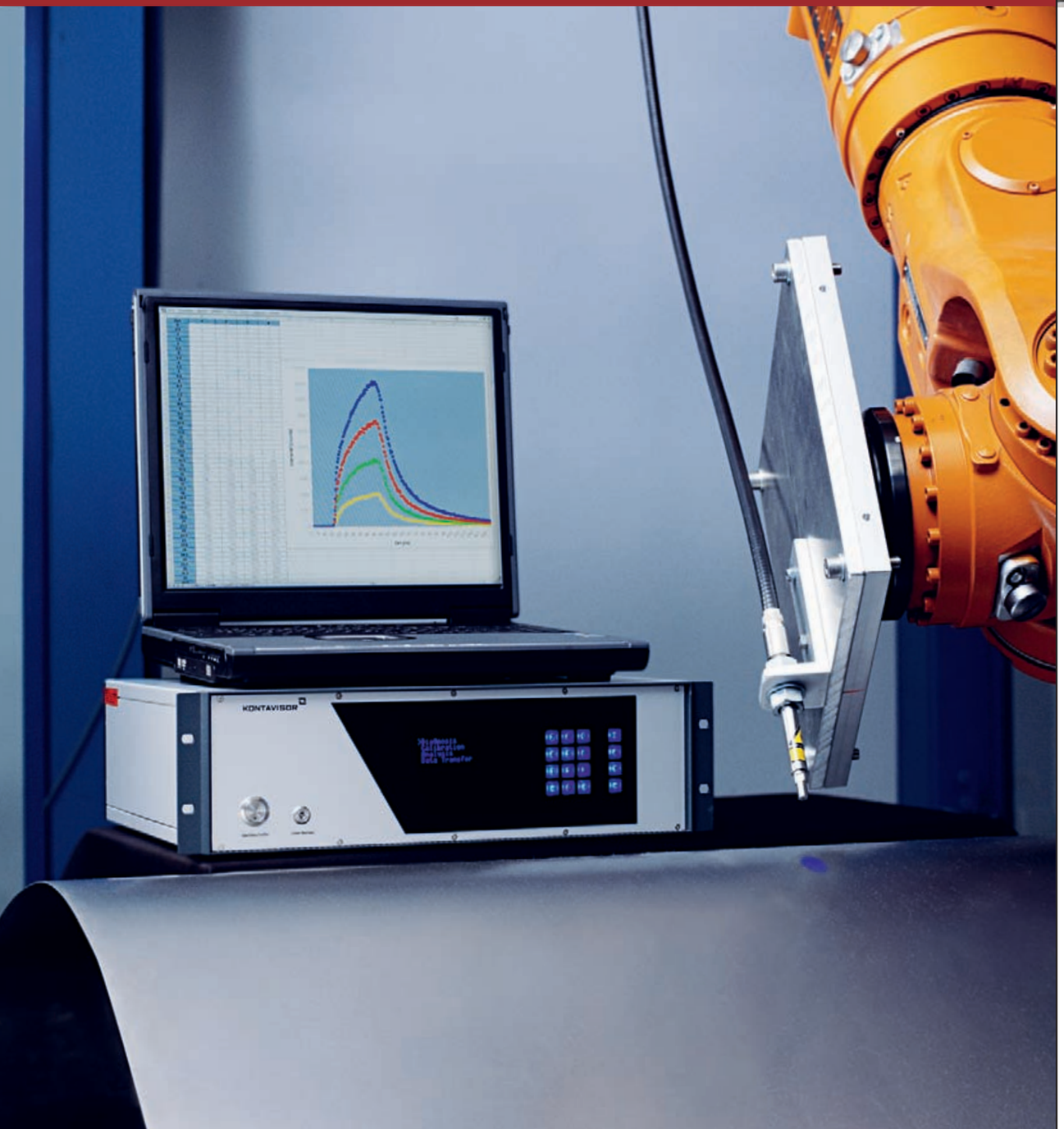
**Permanent monitoring:
Customization to individual processes**

The Quality Assurance of Surfaces work group of the Fraunhofer IFAM develops innovative, advanced methods for continuous surface monitoring in production processes. Procedures are developed for different materials and applications, which allow simple but efficient testing of pretreated surfaces prior to the next processing step. A key aspect here is the versatility of the technical solutions. This versatility allows the tailoring of a continuous monitoring system to the specific production process of a customer.

Automated monitoring of the state of cleanliness of sheet steel prior to adhesive application using Laser Induced Fluorescence Spectroscopy (LIF).



Thermography for monitoring automated pretreatment using atmospheric pressure plasma.



RELIABLE INLINE MONITORING

The Quality Assurance of Surfaces work group of the Fraunhofer IFAM is part of the Adhesion and Interface Research business field. This work group has many years of experience developing pretreatment processes, characterizing surfaces, and analyzing the causes of bonding and coating failure. The high-quality technical infrastructure, which is available, allows application-ready customer specific solutions to be developed.

Simple test methods:
Adaptable and suitable for integration

The monitoring of the surface state during production requires simple methods because complex systems can usually not be integrated into existing manufacturing processes. The extensive knowledge of the Fraunhofer IFAM in the area of surface characterization is the key platform for developing and adapting suitable monitoring methods, which provide a wealth of information and which can be customized to the specific conditions of the respective production process.

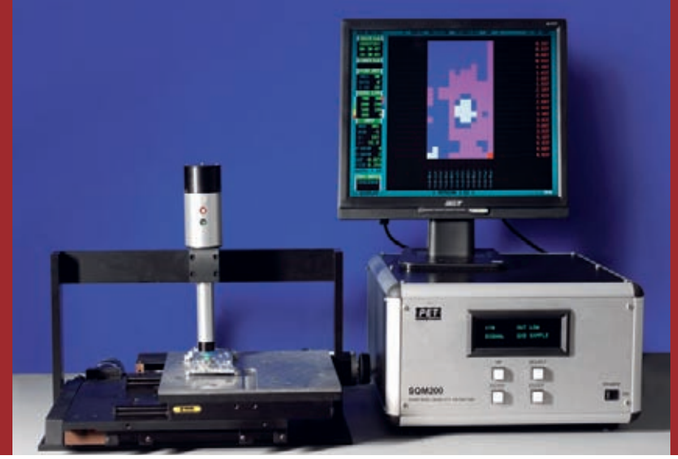
The fact that the Fraunhofer IFAM is the leading European research organization in the area of adhesive bonding technology and surfaces guarantees the effective setting of tasks and targeted development of solutions. New knowledge from research and development work is immediately utilized in the services which are provided to customers. The interdisciplinary approach of the Fraunhofer IFAM also allows a comprehensive perspective to be taken when developing application-oriented test methods.

Step-by-step right through to implementation

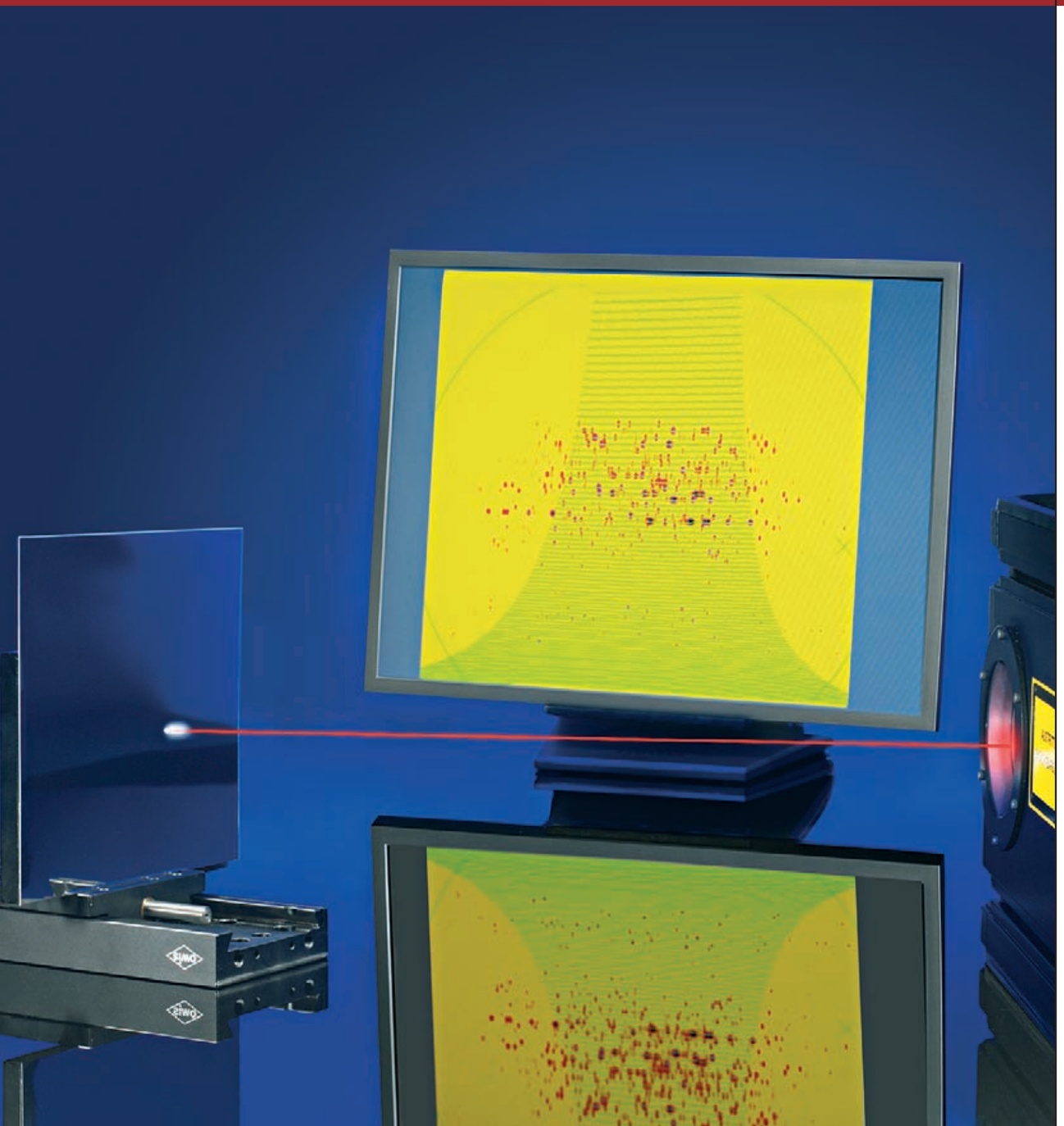
When developing the most suitable method for a specific surface monitoring task, the Quality Assurance of Surfaces work group proceeds in a stepwise way. First of all the existing process is appraised together with the customer. The key aspects are identified and directly examined. Then a fundamental analysis of the surfaces is carried out. Finally, the key quality criteria for evaluating the surfaces after pretreatment are identified together with the customer. These criteria determine the further procedure.

Various monitoring methods are tested to evaluate whether they are suitable for the specified quality criteria and whether they can be integrated into the production process. Conclusions must be drawn about the sensitivity of the methods and calibrations must be carried out. For this, all reference methods for surface analysis are available.

Laser Induced Breakdown Spectroscopy (LIBS) for determining the elemental composition of a sample surface.



Identification of residual contamination on an aluminum pressure-cast component using Optically Stimulated Electron Emission (OSEE).



Finally, the newly developed monitoring system is integrated into the existing production environment. For this step, time frames within the production process are used, for example system-related production downtimes and also venting times or changeover times. Factors for deciding include the space requirements, the ability of the system to be automated, and the route of the component in the production process.

The application in the production can be simulated and demonstrated in the modern and well-equipped pilot plant at the Fraunhofer IFAM.

The Quality Assurance of Surfaces work group is hence able to adapt and modify standard test methods and software systems for specific customer applications. Close collaboration with equipment manufacturers and the development of own methods guarantee practical technical solutions which can be effectively and successfully integrated into production lines.

In addition to offer inline quality monitoring of surfaces in existing processes, the work group also develops solutions for external testing, maintenance, and repairs using hand-held test units.

Inline test methods

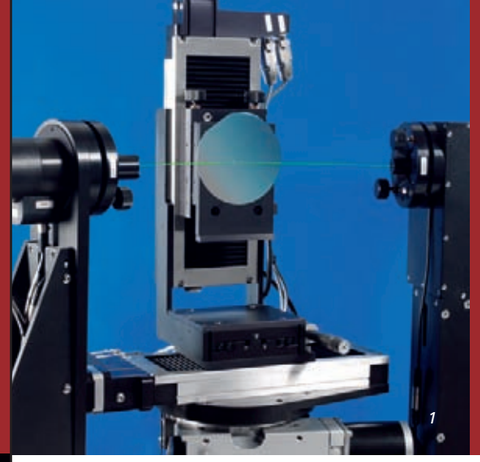
An example of successful application of an inline test method is the detection of residues of silicone-based release agents on component surfaces using LIBS (see page 7). Release agents are often used to facilitate the removal of plastic components from molds. If, after the pretreatment, there remains too much of the residual release agent, the result can be poor adhesive bonding or poor adhesion of coatings.

Another example is the aerosol wetting test (see page 7) for testing the quality of surface treatment on large surfaces. Specially developed imaging systems and analysis routines allow reliable statements to be made about the surfaces and can be optimally integrated into existing production processes.

OSEE (Optically Stimulated Electron Emission) utilizes the photoelectric effect at surfaces for the detection of contamination or coatings. The method can be used on metallic surfaces and also on CFRP surfaces, for example for detecting residual grease contamination on aluminum pressure-cast components.

Attractive for many sectors of industry

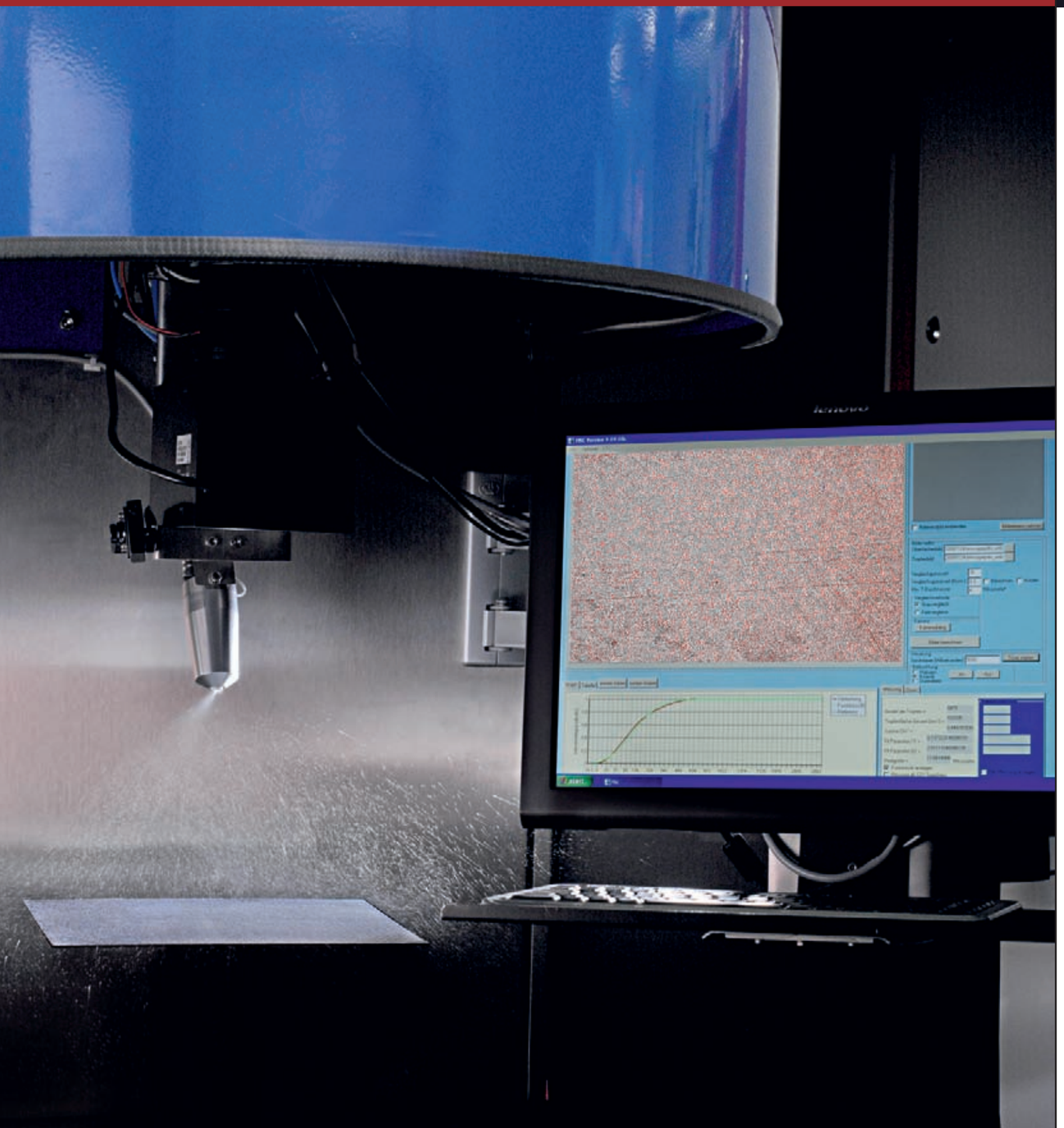
The inline monitoring of surfaces properties is of interest for production in many sectors of industry. Activation and pretreatment steps are as important in the transport sector (car, aircraft, rail vehicle, and ship manufacture) as they are for the production of electronic assemblies and in medical technology. Large wind turbines, both onshore and offshore, often require high-quality, defect-free coatings and paint/lacquer layers, for example for corrosion protection. Efficient monitoring can be achieved using the inline methods developed at the Fraunhofer IFAM, just as they can in the other cited application areas.



1 Characterization of thin surface films using ellipsometry.

2 Laser Induced Fluorescence spectroscopy (LIF) for monitoring surface cleanliness.

Investigation of the wetting properties of surfaces using the aerosol wetting test: Laboratory test set-up.



EFFECTIVE MEASUREMENT AND MONITORING

The Quality Assurance of Surfaces work group offers advice on the selection of suitable measurement systems and the application of suitable test methods. These can either be existing systems and methods optimized for specific customers or can be completely new concepts. Following calibration for the respective application, they are integrated into the production process. Various methods are suitable for automatic quality monitoring.

Measurement methods: Robust, rapid and versatile

When selecting a suitable method for automated quality assurance, a number of factors are important. Adequate detection sensitivity is vital as is a short measurement time. Also important are robustness and the ability to be integrated into existing processes. Potential methods include optical and spectroscopic methods, and wetting tests.

Surfaces after pretreatment often have special optical properties and these can be characterized using optical methods such as ellipsometry, reflectometry, and simple reflection measurements.

Using spectroscopic methods such as Laser Induced Fluorescence (LIF), Laser Induced Breakdown Spectroscopy (LIBS), and infrared techniques, conclusions can be drawn about the chemical make-up of the surface (e. g. elemental composition) after pretreatment. In LIBS, for example, a laser is used to excite a microplasma at the surface. The spectrum of the plasma is characteristic for the elemental composition of the surface. For example, if a component is contaminated with release agents, the spectrum changes and the monitoring unit immediately responds.

For larger surfaces: Aerosol wetting test

The aerosol wetting test has been developed and patented by the Fraunhofer IFAM. For industrial production a test system is already available following collaborative work with a manufacturer of test instruments: An ultrasound atomizer generates a defined water aerosol which forms a characteristic pattern of droplets on the surface to be tested. A camera system records these droplets and determines the drop size distribution. The size of the droplets allows statements to be made about the wetting properties of the surface. By defining target values, the cleaning and activation effect of a surface pretreatment process can be automatically monitored. The advantage of the aerosol test is that large surfaces, for example fiber composite components for aircraft and wind turbine manufacture, can also be tested. The water aerosol dries within a very short time and leaves no residues allowing for an almost immediate further processing of the tested surfaces.

COMPETENCE NETWORK ADHESIVE BONDING TECHNOLOGY AND SURFACES

www.ifam.fraunhofer.de

Fraunhofer Institute for Manufacturing Technology and Applied Materials Research IFAM

Adhesive Bonding Technology
Dipl.-Ing. Manfred Peschka
Phone +49 421 2246-524
manfred.peschka@ifam.fraunhofer.de
Production planning; dosing and application technology; automation; hybrid joining; production of prototypes; selection, characterization and qualification of adhesives, sealants and coatings; failure analysis; electrically/optically conductive contacts; adaptive microsystems; dosing ultra small quantities; properties of polymers in thin films; production concepts.

- Microsystem technology and medical technology
- Adhesives and analysis
- Process development and simulation
- Application methods

Plasma Technology and Surfaces – PLATO –
Dr. Ralph Wilken
Phone +49 421 2246-448
ralph.wilken@ifam.fraunhofer.de
Surface modification (cleaning and activation for bonding, printing, painting/lacquering) and functional layers (e. g. adhesion promotion, corrosion protection, scratch protection, antimicrobial effect, easy-to-clean layers, release layers, permeation barriers) for 3-D components, bulk products, web materials; plant concepts and pilot plant construction.

- Low pressure plasma technology
- Atmospheric pressure plasma technology
- Plant technology/Plant construction

Adhesives and Polymer Chemistry
Priv.-Doz. Dr. Andreas Hartwig
Phone +49 421 2246-470
andreas.hartwig@ifam.fraunhofer.de
Development and characterization of polymers; nanocomposites; network polymers; formulation of adhesives and functional polymers; chemical and physical analysis; peptide and protein chemistry; peptide-polymer hybrids; bonding in medicine; surfaces functionalized with peptides; marine protein adhesives.

- Synthetic materials
- Protein materials

Paint/Lacquer Technology
Dr. Volkmar Stenzel
Phone +49 421 2246-407
volkmar.stenzel@ifam.fraunhofer.de
Development of functional coatings, e. g. anti-icing paints, anti-fouling systems, dirt-repellant systems, self-repairing protective coatings, coatings with favorable flow properties; formulation optimization; raw material testing; development of guide formulations; characterization and qualification of paint/lacquer systems and raw materials; release of products; color management; optimization of coating plants; qualification of coating plants (pretreatment, application, drying); failure analysis; application-related method development.

- Development of coating materials
- Application technology and process engineering

Adhesion and Interface Research
Dr. Stefan Dieckhoff
Phone +49 421 2246-469
stefan.dieckhoff@ifam.fraunhofer.de
Surface, interface and film analysis; analysis of adhesion, release and degradation mechanisms; analysis of reactive interactions at material surfaces; damage analysis; quality assurance via in-line analyses of component surfaces; development of concepts for adhesive, paint/lacquer and surface applications; corrosion on metals, under coatings and in bonded joints; analysis of anodization layers; electrolytic metal deposition; accredited corrosion testing laboratory; modeling of molecular mechanisms of adhesion and degradation; structure formation at interfaces; concentration and transport processes in adhesives and coatings.

- Surface and nanostructure analysis
- Applied computational chemistry
- Electrochemistry/Corrosion protection
- Quality assurance of surfaces

Material Science and Mechanical Engineering
Dr. Markus Brede
Phone +49 421 2246-476
markus.brede@ifam.fraunhofer.de
Testing materials and components; crash and fatigue behavior of riveted and bonded; fiber composite components; lightweight and hybrid constructions; design and dimensioning of bonded joints; qualification of mechanical fasteners; optimization of mechanical joining processes; design and dimensioning of riveted joints.

- Structural calculations and numerical simulation
- Mechanical joining technology

Technology Transfer and Workforce Training
Prof. Dr. Andreas Groß
Phone +49 421 2246-437
andreas.gross@ifam.fraunhofer.de
www.bremen-bonding.com
www.kunststoff-in-bremen.de
Training courses for Adhesive Bonder, Adhesive Specialist and European Adhesive Engineer with Europe-wide certification via DVS®-EWF; in-house courses; consultancy; qualification of production processes; studies; health, safety and the environment; training course for Fiber Composite Technician.

- Center for Adhesive Bonding Technology
- Plastics Competence Center

Fraunhofer Project Group Joining and Assembly FFM
Dr. Dirk Niermann
Phone +49 421 2246-439
dirk.niermann@ifam.fraunhofer.de
Industrial assembly involving bonding, riveting and combinations thereof; adaptive precision machining; automated measuring and positioning processes; non-destructive tests on large fiber composite structures.

Business Field Development
Dr. Michael Wolf
Phone +49 421 2246-640
michael.wolf@ifam.fraunhofer.de

- Technology broker
- New research fields

Certification Body of the Federal Railway Authority in Accordance with DIN 6701-2
Dipl.-Ing. (FH) Andrea Paul
Phone +49 421 2246-520
andrea.paul@ifam.fraunhofer.de
Consultancy; testing and approval of rail vehicle manufacturing companies and their suppliers with regard to their ability to produce adhesive bonds in accordance with the requirements of DIN 6701.

Process Reviews
Dipl.-Ing. Manfred Peschka
Phone +49 421 2246-524
manfred.peschka@ifam.fraunhofer.de
Analysis of development and/or production processes taking into account adhesive bonding aspects and DVS® 3310; processing steps and interfaces; design; products; proof of usage safety, documentation; production environments.

Fraunhofer
IFAM

www.ifam.fraunhofer.de

Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM
– Adhesive Bonding Technology and Surfaces –
Wiener Strasse 12
28359 Bremen
Germany

Phone +49 421 2246-400
Fax +49 421 2246-430
ktinfo@ifam.fraunhofer.de

Institute Director
Prof. Dr. Bernd Mayer

Adhesion and Interface Research
– Quality Assurance of Surfaces –
Dipl.-Phys. Kai Brune
Phone +49 421 2246-459
kai.brune@ifam.fraunhofer.de

www.ifam.fraunhofer.de
More information about the areas
- Adhesive Bonding Technology
- Surfaces