Fraunhofer
IPA

FRAUNHOFER INSTITUTE FOR MANUFACTURING ENGINEERING AND AUTOMATION IPA

SERVICE PORTFOLIO
DEPARTMENT FUNCTIONAL MATERIALS

2014

INTRODUCTION

Fraunhofer is Europe's largest application-oriented research organization. Our research efforts are geared entirely to people's needs: health, security, communication, energy and the environment. As a result, the work undertaken by our researchers and developers has a significant impact on people's lives. We are creative. We shape technology. We design products. We improve methods and techniques. We open up new vistas. In short, we forge the future.

At the Functional Materials department of Fraunhofer IPA we focus on process engineering and the development of novel production technologies for new and emerging materials. Designing technical solutions for material innovations is one of our main tasks. This involves investigating all aspects along the supply chain that are relevant to the process and market. Striving to significantly shorten product development cycles is one of our main objectives. We achieve this by creating a closely meshed development partnership with our customers and international experts based on the principles of open innovation.

For ten years now, the researchers at Fraunhofer IPA have been developing new products and materials based on carbon nanotubes and other allotropes such as graphene. Inspired by topics such as energy and resources efficiency, our department works on the synthesis, modeling, dispersion and application of nanostructured carbon. Due to our high technology standards and integration methods, we are able to find customized solutions very quickly and are able to offer our customers a unique range of services: metals with higher durability and significantly improved tribological properties; energy-efficient heating coatings, which allow totally new design options; transparent and electrically conductive films for photovoltaics; as well as consumer electronics, such as touch panels and displays. In order to cope with such complex tasks, we are constantly developing and evolving the integration of new materials such as graphene, as well as the engineering of nanostructured functional particles, like carbon.

Trust in our abilities and expertise and find out for yourself how we can help you to characterize, optimize and further develop your products towards the application and specifications you desire. Begin your future with Fraunhofer IPA.

CONTENT

COATINGS

Our Expertise

The market developments during the last decade have shown the importance of functional coatings. During this time the department of Functional Materials at Fraunhofer IPA has complemented its expertise along the value chain with different coating technologies and has developed this expertise into one of its key competences. This experience is mainly based on national and EU wide founded projects like CarboTCF within the InnoCNT Alliance, where transparent conductive coatings of hybrid materials were developed. Today we can offer the most common coating techniques combined with the appropriate characterization methods.

What we offer

In our laboratory we can apply inks and dispersions of different nano sized particles onto various rigid and flexible surfaces. Processible substrates can vary from polymers over composites to glasses. Since all these surfaces have a big difference in surface potential we also offer surface pretreatment with plasma or different primer layers. With dedicated surface treatment the potential can be adjusted to the coating material in order to achieve the desired property. Depending on the substrate, the coating material and the desired functionality, different coating methods like bar coating, dip coating, spray coating or screen printing can be used. To ensure the quality in terms of layer thickness and homogeneity we employ appropriate characterization methods like optical and laser microscopy or optical spectroscopy. Depending on the functionality, electrical or mechanical properties or the adhesion can be tested. The characterization methods can also be applied on ready coated samples of our customers.

Your Benefits

Within the scope of the research and development activities, the department of Functional Materials at Fraunhofer IPA offers services that vary from single measurements to detailed characterization or even development. Our long year experience in the field as well as our multidisciplinary team guarantee a highly qualified consulting for our customers starting from the definition of the problem over the conception until the application. With us you have an easy and quick access to highend processing and characterization equipment.

MICROSCOPY

3D LASERSCANNING MICROSCOPE
KEYENCE VK 9700 AND VK 9710

Our Color 3D Laser Scanning Microscope combines the convenience of an optical microscope, SEM and roughness gauge analyses. The following features give it an advantage over commonly used SEMs and Roughness Gauges:

- No pre-processing required; thus, the sample can be reused for further testing
- Non-contact measurement; thus, avoiding damages on the surface of soft targets
- High definition and ultra-depth examination in real color

Applications:

Type of measurement	Evaluation data
Profile	Height, width, dimensions, shape, angle
Roughness	Line, curve or plane roughness
3D Measurement	Volume, surface area, ratio of area to surface area
Comparative measurement	Differences in width, height and cross section of two objects

Technical Key Data:

HD-Magnification of observation	18,000x
Magnification of objective lens	10x / 20x / 50x / 150x
Height measuring range	0.28” (7mm)
Laser waveform	Violet laser, 408 nm

LIGHT MICROSCOPE
ZEISS AXIO IMAGER Z1M

Our microscope platform offers bright colors via its excellent optics and supports illumination variants for reflected light and transmitted light. Various filters are available, including polfilter. The 5 mega-pixel color camera (Axio MRc5) with 1:1,300 dynamic range and 36 bit RGB color depth enables high color accuracy. The magnification ranges up to 150x.

DIGITAL MICROSCOPE
KEYENCE VHX–700F

Our digital microscopes are equipped with high performance zoom lenses (20x – 200x) as well as high-resolution zoom lenses (500x – 5,000x).
Advanced functions include depth composition, 3D display and large depth-of-field imaging.

THERMOGRAVIMETRIC ANALYSIS
NETZSCH TG 209 IRIS

- Measurement of mass changes versus temperature or time
- Defined and controlled environment (atmosphere, flow rate, sample crucible, etc.)
- For both solids and liquids

Analysis:

- Mass changes
- Temperature stability
- Oxidation/reduction behavior
- Filler content
- Moisture and volatiles content
- Decomposition (dehydration, stability, residual solvent, pyrolysis)
- Corrosion studies
- Compositional analysis of multicomponent materials/blends (polymers, plasticizers, solvents, additives)
- Thermokinetic analysis

Applications:

- Polymers
  - Mixture's composition
  - Glass fiber content
  - Maximum working temperature
  - Temperature resistance
  - Mass losses during polycondensation
- Purity of materials
- Mass changes during oxidation
- Ceramics (temperature at which ceramic's binder burns out)

Technical Key Data:

Temperature range	(10°C) 20°C – 1,100°C
Cooling and heating rate	0.001 – 100 K/min
Measurement range	Up to 2,000 mg
Tare range	Up to 2 g
Resolution	0.1 µg
Gas atmospheres	Argon/synthetic air
Coupled with c-DTA	Sample temperature measured directly

DIFFERENTIAL SCANNING CALORIMETRY
NETZSCH DSC 204 F1 PHOENIX

- Analysis of energetic effects (e.g. transition temperatures, enthalpy changes, etc.) during thermal treatment
- Different measurement standards according to material-, product- and property-oriented applications and evaluations

Analysis:

- Glass transition temperature (T_g)
- Melting/crystallization temperature (T_m)
- Degree of crystallinity
- Melting/crystallization enthalpies
- Crosslinking temperatures and enthalpies
- Oxidative stability
- Decomposition effects
- Thermokinetic analysis
- Degree of curing
- Purity determination
- Peak separation
- Solid-solid transitions
- Polymorphism
- Phase diagrams

Technical Key Data:

Temperature range	-85°C to 600°C
Cooling and heating range	0.001 to 100 K/min
Resolution	0.1 µg
Sensitivity	τ-Sensor (high resolution): 3.2 µV/mW µ-Sensor (high sensitivity): 70 µV/mW
Enthalpy accuracy	<1%
Gas atmospheres	Inert/oxidizing
Gas flow	Static/dynamic

THERMAL ANALYSIS TECHNIQUES

THERMAL DIFFUSIVITY/CONDUCTIVITY
NETZSCH LFA 426 NANOFLASH

- Characterization of standard and high-performance specimens
- Defined atmospheres
- Consideration of radial and facial heat losses and finite pulse effects

Measured Data:

- Thermal diffusivity (a, [mm²/s])
- Thermal conductivity (λ, [W/m·K]); in case density is known in advance
- Specific heat (c_p, [J/gK])
- Thermal transition

Field of Use:

- Nanoparticle-reinforced matrices
- Fiber-reinforced polymers, metals or ceramics
- Composites
- Water dispersions

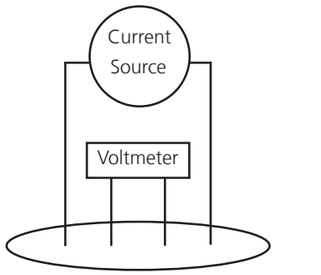
Unified Standards:

ASTM E1461, DIN EN 821, DIN 30905 and ISO 22007-4:2008

Technical Key Data:

Temperature range	Ambient to 300°C
Thermal diffusivity range	0.01 mm²/s to 1,000 mm²/s
Thermal conductivity	0.1 W/(m·K) to 2,000 W/(m·K)
Repeatability	Temperature conductivity: ±2% Specific heat: ±3%
Accuracy	Thermal diffusivity: ±3% Specific heat: ±5%
Sample size	Diameter: up to 25.4 mm or Square: 6 mm / 8 mm / 10 mm / 12.7 mm Thickness: up to 3 mm

ELECTRICAL CONDUCTIVITY MEASUREMENTS



Four–Point Collinear Probe Resistivity Configuration

FOUR-POINT MEASUREMENTS

Electrical conductivity is one of the key properties used to characterize materials. It varies in more than 25 orders of magnitude. Also sample size and shapes vary over a broad range. Therefore it requires a high level of expertise to analyze demanding samples. Within several projects over the past years Fraunhofer IPA has developed this expertise and can offer various methods to evaluate and characterize your samples.

One of the most common measurement methods is the four-point collinear probe method. It involves bringing four equally spaced probes in contact with the test material. The two outer probes are used for sourcing current and the two inner probes are used for measuring the resulting voltage drop across the surface of the sample. Especially for low-level resistance measurements a four-point probe technique is often used. We also offer our customers the following measurement methods which are listed below.

Measured Data:

- Volume resistivity
- Sheet Resistance
- Resistivity/conductivity
- Resistance/conductance
- Van der Pauw method
- Four-Probe method
- Four-Point method

Applications:

- Layer resistivity
- Homogeneity monitoring
- Characterize semi-condutive layers

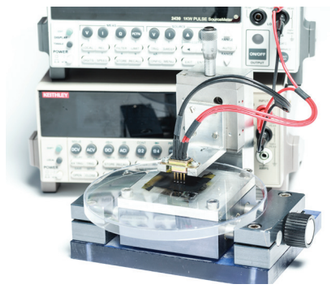
NANOVOLT/MICRO-OHM METER
AGILENT 34420A

- Optimized performance of low-level resistance measurements
- Low-noise voltage measurement
- Temperature measurements

Technical Key Data:

Max. resolution	0.1 nV, 0.1 µΩ
Sensitivity	100 pV, 100 nΩ
Noise performance	1.3 nVrms; 8 nVpp
Resistance measuring range	1 Ω to 1 MΩ
Voltage measuring range DC	1 mV to 100 V
Measurements	Direct SPRT, RTD, thermistor and thermocouple

PULSE SOURCEMETER
KEITHLEY 2430 AND KEITHLEY 2000



- Highly stable DC power source
- Low-noise measurements

Technical Key Data:

Digit resolution	$5^1/_2$
Voltage measuring range DC	200 mV to 100 V
Current measurement range	10 µA to 3 A (in 1 kW pulse mode: up to 10 A)
Resistance measuring range	0.2 Ω to 20 MΩ

RESISTIVITY METER
LORESTA MCP T610

- Accurate and simple measurement of resistivity of conductive plastics, thin films, etc.
- One-touch direct reading
- 18 measuring range settings
- Calculation of correction coefficients

Technical Key Data:

Method	Constant-current method
Resistance measuring range	0.01 Ω to 10 MΩ
Current measurement range	100 mA to 0.1 µA
Accuracy	Between 2.0% and 1.0%

LONG-TERM ENVIRONMENTAL STABILITY
VÖTSCH VCV 40605

- Parameters of influence: humidity and temperature
- Additional possibilities: combined conductivity measurements; testing under UV light source

Field of Use:

- Paints
- Lacquers
- OLEDs
- OPV and other atmospherical sensitive materials

Technical Key Data:

Test space volume	600 l
Performance for temperature tests	
Temperature range	-40°C to +180°C
Temperature rates	Cooling: 5.5 K/min Heating: 5.0 K/min
Performance for climatic tests	
Temperature range	+10°C to +95°C
Humidity range	10% RH to 95% RH (with 1 to 3% RH deviation with time)
Dew point range	+4°C to +94°C

TEMPERATURE TEST CHAMBER
RS-SIMULATOREN TS 130/70

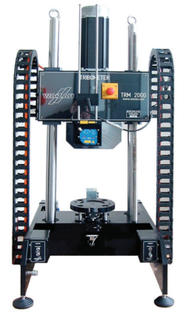
- Program control based on CAN-Bus
- Additional possibilities: combined conductivity measurements

Technical Key Data:

Test space volume	197 l
Performance for temperature tests	
Temperature range	-130°C to +190°C
Temperature rates	5 K/min

TRIBOLOGICAL MEASUREMENTS
TRIBOMETER TRM 2000

- Examination and simulation of materials response to friction and abrasion processes under sliding load
- Actuating elements: normal force, rotational speed, temperature



Measured Data:

- Normal force
- Ambient temperature in the bowl
- Linear distance of both friction materials
- Rotational speed
- Friction torque

Modules:

- Power input module
- Temperature input module
- Inertia mass simulation module
- Oil recirculating lubrication module
- Low temperature module
- High temperature module
- Heating ring module
- Four ball mechanism module
- Linear oscillation module

Technical Key Data:

Type of motion	Sliding
Kind of motion	Continuous – rotating/oscillating/vibrating
Overlapping movement	Oscillation/vibration
Geometry of specimen	Pin – disc Disc – disc Ring – disc Ball – disc Four ball mechanism
Lubricant	Without/fluids
Normal force	5 – 2,000 N
Rotational speed	0,1 – 3,000 min^{-1}
Temperature	Ambient to 150°C
Friction radius	0 – 45 mm
Active torque	5 / 10 / 15 / 20 Nm

UV/VIS SPECTROSCOPY
PG INSTRUMENTS T80+

- Optical analysis (color and general appearance)
- Determination of the frequencies at maximum degradation of additives, binders and pigments in UV and Vis range
- Used for designing coatings, pigments, filters, dispersions, etc.

Measured Data:

- Reflection
- Absorption
- Transmission

Applications and Features:

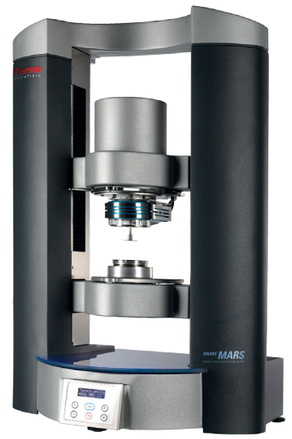
- Photometric measurements
- Spectrum scans
- Kinetic measurements
- Quantitative determination
- 3D spectrum analysis
- GLP laboratory protocol

Technical Key Data:

Optical system	Dual beam
Spectral bandwidth	0.5 / 1 / 2 / 5 nm
Wavelength range	190 – 1,100 nm
Wavelength accuracy	± 0.3 nm
Photometric mode	Transmittance Absorbency Energy concentration
Photometric range	-0.3 – 3.0 Abs
Photometric accuracy	± 0.002 Abs (0 ~ 0.5 A) ± 0.004 Abs (0.5 ~ 1 A) ± 0.3% T (0 ~ 100% T)

RHEOLOGICAL MEASUREMENTS
THERMO SCIENTIFIC HAAKE MARS III

- Materials behavior under a set of processing conditions
- Correlation to fundamental structural properties through thixotropic parameters like surface leveling, structural regeneration and sagging behavior
- Measurement modes: Controlled Rate (CR), Controlled Stress (CS) and Controlled Deformation (CD)



Measured Data:

- Viscoelastic/dynamic moduli
- Viscoelastic properties (as a function of shear stress/shear rate, time, frequency, temperature)

Applications and Features:

- Effects of particle size distribution
- Effects of additives and viscosity modifiers
- Polymers (solutions, melts, semi-solids)
- Dispersions (stability under high shear conditions)

Technical Key Data:

Min. torque rotation in CS and CR	0.01 µNm
Min. torque oscillation in CS and CD	0.003 µNm
Max. torque	200 mNm
Torque resolution	0.1 nNm
Min. rotational speed	In CS: 10^{-7} rpm In CR: 10^{-8} rpm
Max. rotational speed	1,500 (4,500) rpm
Step in velocity	10 m/s
Oscillation frequency range	10^{-6} Hz – 100Hz
Normal force range	0.01 N – 50 N
Temperature range	-150°C – 600°C
Measurement geometries	Plate-plate (20 mm and 35 mm) Plate-cone (35 mm)

PROCESSING EQUIPMENT

DIP–COATING
KSV DX 25–500

- Thin film deposition
- Controlled and repeatable manner of preparation
- Various film thicknesses
- Individual adjustment for upper and lower end point of substrate movement

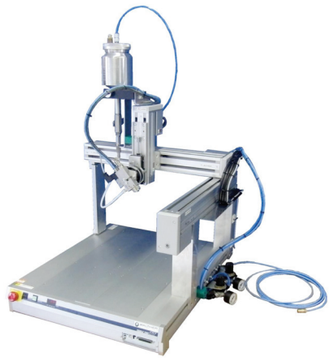
Field of Use:

- Creation of smart surfaces
- Sol-gel coatings
- Layer-by-layer assembly
- Self-assembled mono-layers

Technical Key Data:

Withdrawal speed	0.1 to 1,000 mm/min
Deposition cycles	Unlimited
Dwell times	0 to 9,999 s
Deposition arm	145 mm max. stroke
Substrate dimensions	100 mm x 100 mm x 10 mm
Linear movement of dipper unit	Range: 0 to 600 mm Speed: 0.01 mm to 400 mm/min

SPRAY COATING
SELF-ASSEMBLED SPRAY COATING ROBOTER



- Continuous and intermittent applications
- XSEL controller ensures high positioning repeatability and constant speed
- Handling of fixed components of irregular shape
- Variables: material pressure and speed

Technical Key Data:

Stroke	X-axis: 400 mm Y-axis: 400 mm Z-axis: 100 mm
Maximum speed	300 mm/sec
Positioning repeatability	±0.02 mm
Compressed air	6 bar
Material pressure	0.5 bar – 5 bar
Positioning points	3,000

SCREEN PRINTING
CMS MI TYPE SPECIAL 50X70

Another conventional method of dense film deposition is screen printing. It is mainly used in the development of electro-conductive coatings on a wide variety of substrates, including paper, paperboard, plastics, glass, metal, etc. Depending on the content and the distribution sheet resistances in the range of 50 Ω/sqr to 200 Ω/sqr can be achieved.

HIGH TEMPERATURE TUBE FURNACE
CARBOLITE MZS 12/-/1200

- Cascade control systems: faster heating rates; counteracts side load troubles
- Excellent temperature uniformity
- Process observation up to 600°C

Technical Key Data:

Type	Horizontal split 3 zone
Max. continuous operating temperature	1,100°C
Heated length	1,200 mm

Applications and Features:

- Application of solid thin film coatings to various substrates
- Production of high purity bulk materials and powders
- Fabrication of composite materials via infiltration techniques
- Purification at elevated temperatures
- Chemical functionalization
- Reactions under protective gas atmospheres or vacuum

GRINDING/POLISHING MACHINE
STRUERS TEGRAPOL-31

- Grinding, lapping and polishing preparation of materialographic specimens
- Standard sample preparation for cross-section analysis, e.g. particle distribution within filler material

DISPERSIONS

Our Expertise

The development of future materials such as coatings and composites relies on the ability to properly disperse and deagglomerate particles within the nano-range. However, the whole processing chain in order to create dispersions with the desired properties sets certain technical challenges.

The department of Functional Materials at Fraunhofer IPA covers the development of both dispersion processes as well as of suitable materials, ranging from particle production to dispersion formulation. In the course of many national and international projects we have gained the highly sought-after expertise in preparing homogeneous dispersions with high quality and narrow particle size distribution. We offer a wide range of processing and characterization equipment and a thorough expertise in the control of interparticle forces and the stabilization of dispersions. We can handle and improve dispersions from 100 ml up to 5 l, in specific cases even up to 50 l. To process dispersions from low to high viscosity we offer our customers a variety of techniques. The processing of temperature sensitive materials is also possible. A subsequent verification of key properties plays an important role in our everyday work. We develop dispersions for your individual needs in various applications such as surface heating elements, printed electronics, etc. For applications on flexible substrates, our dispersions can be applied to different temperature-stable films such as Kaptonfoil, Nomexpaper, PET, silicone, etc. Our dispersions are optimized for screen printing, spraying, bar coating and dip coating and can be applied homogeneously on many different substrates.

What we offer

We offer our customers the successful processing of custom made dispersions tailored to your specific needs. This is achieved in several steps. In the particle preparation step several milling and grinding methods are being adopted to achieve the desired particle dimensions. These differ from each other in terms of grinding force and performed conditions (wet/dry). Another processing step is the dispersion itself. We can support you by dispersing and stabilizing the nanoparticles using various processing methods, e.g. ultra-sonication or by using different stabilizing agents. The used methods can easily be scaled up. Reproducibility is also an important factor in the concept of full control over the processing parameters. Especially essential is the analytical capability. For that purpose we offer our customers the investigation of parameters such as transparency, particle size, rheology, adhesion to a specified substrate, as well as optical characterizations and the determination of absorbance indices.

Your Benefits

Within the scope of the research and development activities, the department of Functional Materials at Fraunhofer IPA offers you a wide selection of platforms, infrastructure and expertise in particle processing, which allow us to run a series of experiments optimally adapted to the nature of your problems. The well distributed particles in our custom made dispersions enhance the specific features of your products in terms of mechanical, optical and electrical properties, thereby reducing your production costs and improving the performance and functionality of your products. Also we will support and consult you in every aspect of the dispersion process in order to give you a competitive edge.

MILLING AND GRINDING

PLANETARY BALL MILL
RETSCH PM 400

- High degree of fineness, down to the nano range
- Mechanism: pulverization due to high centrifugal forces
- Controll over speed and energy
- Reproducible results

Applications:

- Pulverizing
- Mixing
- Homogenizing
- Colloidal Grinding
- Mechanical Alloying
- Dry and wet grinding

Field of Use:

- Carbon Fibers
- Composites
- Ceramics
- Polymers
- Metals

Technical Key Data:

Material feed size	< 10 mm
Final fineness	< 1 µm; for colloidal grinding < 0.1 µm
Speed ratio	1 : – 2 / 1 : –2.5 / 1 : –3
Sun wheel speed	30 – 400 min^{-1}
G-force	26.8 g
Type of grinding tools	Hardened and stainless steel, tungsten, carbide, agate, sintered aluminum oxide, zirconium oxide

HIGH ENERGY BALL MILL
ZOZ SIMOLOYER CM08

– Mechanism: grinding through shearing with free moving steel balls
– Controllable process parameters: temperature and milling-power (torque)

Applications:

– High energy milling
– Mechanical alloying
– Reactive milling (ceramics and other materials)

Technical Key Data:

Rotational speed	100 – 1,000 rpm
Atmosphere	Vacuum/inert-gas
Controllable temperature	-20°C to 100°C
Working pressure	10^{-4} mbar up to 2 bar
Grinding units	5 l / 8 l (in powder load 500 – 1,500 g)
Operation	Batch or continuous

THREE ROLL MILL
EXAKT 80E

– Breaking-up of agglomerates and powder nests
– Reduction of particle size with high reproducibility
– Simplified transfer of the production-specific processing conditions to production
– Cooling/heating units

Applications:

– Dispersion
– Homogenization
– Deagglomeration

Technical Key Data:

Throughput	Min: 0.02 l/h Max: 20 l/h
Roller dimension	Diameter: 80 mm Length: 200 mm
Roller material	Zirconium oxide
Scraper knife material	Steel, plastics, aluminum oxide, zirconium oxide
Gap size	5 µm - 150 µm

With our advanced dispersion preparation devices, such as sonication rods, silent crushers, centrifuges and many others we can help you develop a tailor made dispersion technique for your products.

ULTRASONIC HOMOGENIZATION
SONOPULS HD 3200

– Integrated amplitude control: holding it constant independent from changing conditions within
– Reproducible results for process validation
– Fluids of low and middle viscosity
– Accurate cooling system

Applications:

– Sample preparation for particle size analysis
– Homogenization of substances
– Dispersion preparation
– Degassing of fluids
– Acceleration of chemical analysis

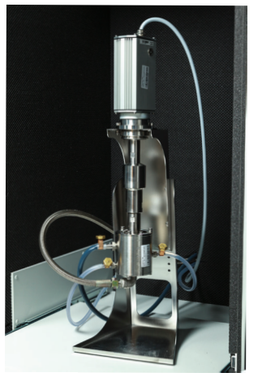
Technical Key Data:

HF–Power/processing frequency	200 Watt/20 kHz
Sample volume	100 ml
Amplitude control	10 – 100 %
Processing frequency	20 kHz

Refrigerated circulator

Working temperature range	-10°C to 100°C
Flow rate	12.5 l/min or 15 l/min

INDUSTRIAL ULTRASONIC HOMOGENIZATION
HIELSCHER UIP500HD



- Mechanism: cavitational effect, caused by high frequencies
- Continuous operation in demanding environments
- Reproducible results for process validation in industrial scale
- Refrigerated circulator: processing at constant temperature

Applications:

- Emulsifying
- Dispersing and Degassing
- Deagglomeration
- Wet-milling & Grinding
- Extraction procedures
- Cell Disintegration

Technical Key Data:

Power/frequency	500 W / 20 kHz
Amplitude control	25 microns (adjustable from 50 to 100%)
Refrigerated circulator	
Working temperature range	-30°C to 200°C
Flow rate	11 l/min – 16 l/min

LABORATORY ROTOR-SATOR-MIXER
HEIDOLPH SILENTCRUSHER M

- Magnetic drive technology: operation in reduced particle environments

Technical Key Data:

Speed range	5,000 rpm – 26,000 rpm
Max. viscosity	5,000 mPas
Quantity range	0.8 ml – 2,000 ml

INLINE DISPERSER
NETZSCH MICRO Ψ-MIX

- Test and production of homogeneous, fine dispersions
- Reproducible quality; scale-up basis
- Mechanism: powder solids (e.g. nanoparticles) wetted with shearing force under vacuum and micro-cavitation
- Processing of both low and high viscosity suspensions
- Optimal performance for:
  - high solids content
  - low solids content in large liquid batches
  - solids that are difficult to wet
  - extremely fine solids

Technical Key Data:

Rotational speed	2,000 rpm
Speed range	1,000 – 3,000 min^{-1}
Dispersion flow	1 – 2 m^3/h
Capacity	Up to 50 l per hour
Pressure	<3.0 bar

LABORATORY STIRRER
IKA RW 28

– Suitable for highly viscous fluids
– Two speed ranges

Technical Key Data:

Speed	72 rpm – 1,680 rpm
Max. viscosity	50,000 mPas
Max. quantity	80 l (H_2O)

LABORATORY PLANETARY MIXER
NETZSCH PML 1

– Suitable for challenging mixing tasks of high- and medium-viscosity products and most difficult-to-wet solids
– Mechanism: optimal wetting through shearing force
– Mixing without dead zones

Applications:

– Dispersion of nanoparticles in fluids of high viscosity
– De-aeration
– Adhesives
– Fillers and plasticizers
– Synthetic Lubricants
– Sealing compounds
– Liquid Silicone Rubbers
– Pastes
– Powdery reaction materials

Technical Key Data:

Speed	0 – 900 min^{-1}
Max. viscosity	3,000,000 mPas
Max. quantity	0.5 – 0.6 l

DIP-COATING
KSV DX 25-500

– Thin film deposition
– Controlled and repeatable manner of preparation
– Various film thicknesses
– Individual adjustment for upper and lower end point of substrate movement

Field of Use:

– Creation of smart surfaces
– Sol-gel coatings
– Layer-by-layer assembly
– Self-assembled mono-layers

Technical Key Data:

Withdrawal speed	0.1 to 1,000 mm/min
Deposition cycles	Unlimited
Dwell times	0 to 9,999 s
Deposition arm	145 mm max. stroke
Substrate dimensions	100 mm x 100 mm x 10 mm
Linear movement of dipper unit	Range: 0 to 600 mm Speed: 0.01 mm to 400 mm/min

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SPRAY COATING
SELF-ASSEMBLED SPRAY COATING ROBOTER

- Continuous and intermittent applications
- XSEL controller ensures high positioning repeatability and constant speed
- Handling of fixed components of irregular shape
- Variables: material pressure and speed

Technical Key Data:

Stroke	X-axis: 400 mm Y-axis: 400 mm Z-axis: 100 mm
Maximum speed	300 mm/sec
Positioning repeatability	±0.02 mm
Compressed air	6 bar
Material pressure	0.5 bar – 5 bar
Positioning points	3,000

THERMOGRAVIMETRIC ANALYSIS
NETZSCH TG 209 IRIS

- Measurement of mass changes versus temperature or time
- Defined and controlled environment (atmosphere, flow rate, sample crucible, etc.)
- For both solids and liquids

Analysis:

- Mass changes
- Temperature stability
- Oxidation/reduction behavior
- Filler content
- Moisture and volatiles content
- Decomposition (dehydration, stability, residual solvent, pyrolysis)
- Corrosion studies
- Compositional analysis of multicomponent materials/blends (polymers, plasticizers, solvents, additives)
- Thermokinetic analysis

Applications:

- Polymers
  - Mixture's composition
  - Glass fiber content
  - Maximum working temperature
  - Temperature resistance
  - Mass losses during polycondensation
- Purity of materials
- Mass changes during oxidation
- Ceramics (temperature at which ceramic's binder burns out)

Technical Key Data:

Temperature range	(10°C) 20°C – 1,100°C
Cooling and heating rate	0.00 1– 100 K/min
Measurement range	Up to 2,000 mg
Tare range	Up to 2 g
Resolution	0.1 µg
Gas atmospheres	Argon/synthetic air
Coupled with c-DTA	Sample temperature measured directly

DIFFERENTIAL SCANNING CALORIMETRY
NETZSCH DSC 204 F1 PHOENIX

– Analysis of energetic effects (e.g. transition temperatures, enthalpy changes, etc.) during thermal treatment
– Different measurement standards according to material-, product- and property-oriented applications and evaluations

Analysis:

– Glass transition temperature (T_g)
– Melting/crystallization temperature (T_m)
– Degree of crystallinity
– Melting/crystallization enthalpies
– Cross-linking temperatures and enthalpies
– Oxidative stability
– Decomposition effects
– Thermokinetic analysis
– Degree of curing
– Purity determination
– Peak separation
– Solid-solid transitions
– Polymorphism
– Phase diagrams

Technical Key Data:

Temperature range	-85°C to 600°C
Cooling and heating range	0.001 to 100 K/min
Resolution	0.1 µg
Sensitivity	τ-Sensor (high resolution): 3.2 µV/mW µ-Sensor (high sensitivity): 70 µV/mW
Enthalpy accuracy	<1%
Gas atmospheres	Inert/oxidizing
Gas flow	Static/dynamic

ANALYTICAL EQUIPMENT

THERMAL DIFFUSIVITY/CONDUCTIVITY
NETZSCH LFA 426 NANOFLASH

– Characterization of standard and high-performance specimens
– Defined atmospheres
– Consideration of radial and facial heat losses and finite pulse effects

Measured Data:

– Thermal diffusivity (a, [mm²/s])
– Thermal conductivity (λ, [W/m·K]); in case density is known in advance
– Specific heat (c_p, [J/gK])
– Thermal transition

Field of Use:

– Nanoparticle-reinforced matrices
– Fiber-reinforced polymers, metals or ceramics
– Composites
– Water dispersions

Unified Standards:

ASTM E1461, DIN EN 821, DIN 30905 and ISO 22007-4:2008

Technical Key Data:

Temperature range	Ambient to 300°C
Thermal diffusivity range	0.01 mm²/s to 1,000 mm²/s
Thermal conductivity	0.1 W/(m·K) to 2,000 W/(m·K)
Repeatability	Temperature conductivity: ±2% Specific heat: ±3%
Accuracy	Thermal diffusivity: ±3% Specific heat: ±5%
Sample size	Diameter: up to 25.4 mm or Square: 6 mm / 8 mm / 10 mm / 12.7 mm Thickness: up to 3 mm

UV/VIS SPECTROSCOPY
PG INSTRUMENTS T80+

- Optical analysis (color and general appearance)
- Determination of the frequencies at maximum degradation of additives, binders and pigments in UV and Vis range
- Used for designing coatings, pigments, filters, dispersions, etc.

Measured Data:

- Reflection
- Absorption
- Transmission

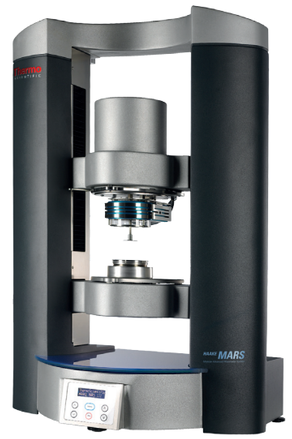
Applications and Features:

- Photometric measurements
- Spectrum scans
- Kinetic measurements
- Quantitative determination
- 3D spectrum analysis
- GLP laboratory protocol

Technical Key Data:

Optical system	Dual beam
Spectral bandwidth	0.5 / 1 / 2 / 5 nm
Wavelength range	190 – 1,100 nm
Wavelength accuracy	± 0.3 nm
Photometric mode	Transmittance Absorbency Energy concentration
Photometric range	-0.3 – 3.0 Abs
Photometric accuracy	± 0.002 Abs (0 ~ 0.5 A) ± 0.004 Abs (0.5 ~ 1 A) ± 0.3% T (0 ~ 100% T)

RHEOLOGICAL MEASUREMENTS
THERMO SCIENTIFIC HAAKE MARS III



- Materials behavior under a set of processing conditions
- Correlation to fundamental structural properties through thixotropic parameters like surface leveling, structural regeneration and sagging behavior
- Measurement modes: Controlled Rate (CR), Controlled Stress (CS) and Controlled Deformation (CD)

Measured Data:

- Viscoelastic/dynamic moduli
- Viscoelastic properties (as a function of shear stress/shear rate, time, frequency, temperature)

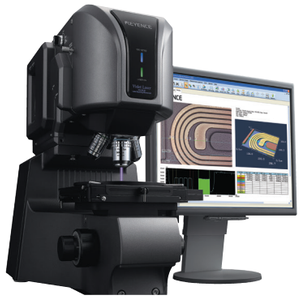
Applications and Features:

- Effects of particle size distribution
- Effects of additives and viscosity modifiers
- Polymers (solutions, melts, semi-solids)
- Dispersions (stability under high shear conditions)

Technical Key Data:

Min. torque rotation in CS and CR	0.01 µNm
Min. torque oscillation in CS and CD	0.003 µNm
Max. torque	200 mNm
Torque resolution	0.1 nNm
Min. rotational speed	In CS: 10^{-7} rpm In CR: 10^{-8} rpm
Max. rotational speed	1,500 (4,500) rpm
Step in velocity	10 m/s
Oscillation frequency range	10^{-6} Hz – 100Hz
Normal force range	0.01 N – 50 N
Temperature range	-150°C – 600°C
Measurement geometries	Plate-plate (20 mm and 35 mm) Plate-cone (35 mm)

MICROSCOPY



3D LASERSCANNING MICROSCOPE
KEYENCE VK 9700 AND VK 9710

Our Color 3D Laser Scanning Microscope combines the convenience of an optical microscope, SEM and roughness gauge analyses. The following features give it an advantage over commonly used SEMs and Roughness Gauges:

- No pre-processing required; thus, the sample can be reused for further testing
- Non-contact measurement; thus, avoiding damages on the surface of soft targets
- High definition and ultra-depth examination in real color

Applications:

Type of measurement	Evaluation data
Profile	Height, width, dimensions, shape, angle
Roughness	Line, curve or plane roughness
3D Measurement	Volume, surface area, ratio of area to surface area
Comparative Measurement	Differences in width, height and cross section of two objects

Technical Key Data:

HD-Magnification of observation	18,000x
Magnification of objective lens	10x / 20x / 50x / 150x
Height Measuring Range	0.28” (7mm)
Laser Waveform	violet laser, 408 nm

LIGHT MICROSCOPE
ZEISS AXIO IMAGER Z1M

Our microscope platform offers bright colors via its excellent optics and supports illumination variants for reflected light and transmitted light. Various filters are available, including polfilter. The 5 mega-pixel color camera (Axio MRc5) with 1:1,300 dynamic range and 36 bit RGB color depth enables high color accuracy. The magnification ranges up to 150x.

DIGITAL MICROSCOPE
KEYENCE VHX-700F

Our digital microscopes are equipped with high performance zoom lenses (20x – 200x) as well as high-resolution zoom lenses (500x – 5,000x). Advanced functions include depth composition, 3D display and large depth-of-field imaging.

MATERIALS AND COMPOSITES

Our Expertise

The development and the entire processing of new materials and composites can be very challenging. Every step has its influence on its own on the appearance and the final properties of the end product. The department of Functional Materials at Fraunhofer IPA is specialized in the synthesis, functionalization, and integration of nanoparticles in several matrices. Project topics we are focusing on range from lightweight metals for automotive and aircraft applications to electrically conductive polymer composites as heating elements in different industry sectors. In such projects we cover the whole processing chain for polymers as well as powder metallurgy including the analysis of the influence of processing and material parameters on composite properties.

What we offer

Our long term experience within the nano carbon domain, such as with CNTs, GNPs, CNHs, carbon black and many other materials enables us to adopt our expertise to your specific R&D needs. Especially if you are interested in optimizing the processing setup and final quality of your products we are the right partner for you. By varying processing parameters, e.g. during the production of polymer composites, we can study the influence of particle uniformity on the final properties, such as electrical and/or thermal conductivity by using the necessary characterization devices. Thus, we help you to improve your know-how by making correlations between experimental results and the corresponding performance of your material. Further, a constantly posed question is the process stability. We address this question by investigating statistic sample properties like the particle concentration (TGA), particle distribution (thermography) or by mechanical performance testing (hardness, tensile, tribology). Summarized we deepen your insights in terms of observation of the effects of process parameters, the effects of particles themselves on the final properties, the stability of your final product, as well as the distribution of filler materials in the matrix itself.

Your Benefits

Within the scope of the research and development activities, the department of Functional Materials at Fraunhofer IPA offers you its ability and expertise in how to analyze several physical properties and how to correlate them to your processing parameters. Our scientists have a longtime work experience in the materials and composite field and will help you to clarify which analysis method is most suitable to fit your specific needs. Of course we can also help you by developing experimental plans for your individual questions. Complementing our services we also offer you to set up the by us optimized process chain for your products at your laboratories.

VICKERS HARDNESS TEST
BRÜCK VHT-500

- Equipped with a diamond pyramid indenter with 136° angle between opposite faces
- Used in research, product quality control and the development of product certification materials

Technical Key Data:

Load settings	0.2 kp up to 10 kp (1kp = 9.80665 N)
Sample dimensions	Height: 210 mm Depth: 160 mm
Testing of	Metals Composites Ceramics Individual micro-structures
Certification	DIN EN ISO 6507

TEMPERATURE TEST CHAMBER
RS-SIMULATOREN TS 130/70

- Program control based on CAN-Bus
- Additional possibilities: combined conductivity measurements

Technical Key Data:

Test space volume	197 l
Performance for temperature tests	
Temperature range	-130°C to +190°C
Temperature rates	5 K/min

LONG-TERM ENVIRONMENTAL STABILITY
VÖTSCH VCV 4060-5

- Parameters of influence: humidity and temperature
- Additional possibilities: combined conductivity measurements; testing under UV light source

Field of Use:

- Paints
- Lacquers
- OLEDs
- OPV and other atmospheric sensitive materials

Technical Key Data:

Test space volume	600 l

Performance for temperature tests

Temperature range	-40°C to +180°C
Temperature rates	Cooling: 5.5 K/min Heating: 5.0 K/min

Performance for climatic tests

Temperature range	+10°C to +95°C
Humidity range	10% RH to 95% RH (with 1 to 3% RH deviation with time)
Dew Point range	+4°C to +94°C

TENSILE TEST
ZWICK/ROELL BZ2.05 TN1S

- Tensile/compression tests
- Videoextensometer-assisted contactless measurement of longitudinal and transversal strains (Limess RTSS HS)
- Used for flat and round specimens with constant distance to the camera
- Determination of Stress-strain curves, E-modulus and Poisson's ratio

Applications and Features:

- Tensile strength and elastic deformation of isotropic materials
- Conductivity dependence on elongation of stretchable conductors

Measured Data:

- Ultimate tensile strength
- Maximum elongation
- Reduction in area
- Young's modulus
- Poisson's ratio
- Yield strength
- Strain hardening

Technical Key Data:

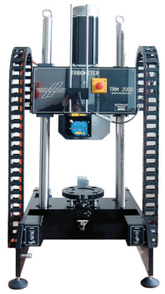
Test load capacity (tensile/compression)	50 – 50 N 100 – 100 N 2,000 – 2,000 N

Drive system

Crosshead speed	V_{min}: 0.001 mm/min V_{max}: 1,000 mm/min
Accuracy of speed	0.05%
Drive system travel resolution	0.0828 µm

Videoextensometer

Measured strain	Up to 500%
Measurement accuracy for strain	0.02%
Measurement rate	4 kHz



TRIBOLOGICAL MEASUREMENTS
TRIBOMETER TRM 2000

– Examination and simulation of materials response to friction and abrasion processes under sliding load
– Actuating elements: normal force, rotational speed, temperature

Measured Data:

– Normal force
– Ambient temperature in the bowl
– Linear distance of both friction materials
– Rotational speed
– Friction torque

Modules:

– Power input module
– Temperature input module
– Inertia mass simulation module
– Oil recirculating lubrication module
– Low temperature module
– High temperature module
– Heating ring module
– Four ball mechanism module
– Linear oscillation module

Technical Key Data:

Type of motion	Sliding
Kind of motion	Continuous – rotating/oscillating/vibrating
Overlapping movement	Oscillation/vibration
Geometry of specimen	Pin-disc Disc-disc Ring-disc Ball-disc Four ball mechanism
Lubricant	Without/fluids
Normal force	5 – 2,000 N
Rotational speed	0.1 – 3,000 min^{-1}
Temperature	Ambient to 150°C
Friction radius	0 – 45 mm
Active torque	5 / 10 / 15 / 20 Nm

PISTON INJECTION MOLDING SYSTEM
THERMO SCIENTIFIC HAAKE MINIJET II

– Specimen geometries for common mechanical testing: from standard to unique, customized forms
– Sample weight as little as 5 g
– Raw material: various (powders, pellets, or melts)
– Processing of even highly viscous materials
– Control over processing parameters (temperature, injection pressure, duration)

Applications:

– Sample preparation for rheometry, optical and mechanical testing
– Process optimization

Technical Key Data:

Injection pressure	Up to 1,200 bar
Dimensions	300 mm x 460 mm x 710 mm
Mold temperature	max. 250°C
Cylinder temperature	max. 400°C

SINTERING HOT PRESS
DR. FRITSCH DSP 510 SA

- Control over the manufacturing process parameters (temperature, magnitude of applied pressure and stroke)
- Correlation to thermal, physical or electrical material properties
- Raw material: ceramic/metal powders; nanoparticles
- Information about the impact of additives or different pretreatments
- Customized specimen geometries: cylinders, tubular, quadratic shape with rounded corners in different dimensions
- Subsequent characterization of the nanostructure

Technical Key Data:

Specimen dimensions	Max. surface area: 225 cm^2 Max. height: 6 cm
Temperature range	250°C – 2,400°C
Inert gas	Nitrogen, forming gas, noble gas (pressure 1 – 5 bar)
Pressure force – differential – nominal	 24 kN – 285 kN 31 kN – 368 kN

MIXER AND EXTRUDER SYSTEM
THERMO SCIENTIFIC HAAKE POLYLAB OS

- Measuring mixer and twin-screw extruder system for testing or small-scale production
- Torque rheometer with precise speed controller and accurate torque sensor

Process–relevant Material Characterization:

- Melting behavior
- Influence of additives
- Temperature stability
- Shear stability
- Melt viscosity

MIXING SYSTEM
THERMO SCIENTIFIC HAAKE RHEOMIX OS

Applications:

- Batch mixing of highly viscous substaces (polymers, elastomers, additives and fillers)
- Examination of process-relevant data and its influence

Typical Investigations:

- Melting and degradation behavior of polymer melts
- Gelation and plasticizing behavior
- Flow- and curing behavior of thermosetting plastics
- Processability of high-performance plastics
- Influences of different additives or fillers on the matrix (stable torque, quantifying viscosity, etc.)
- Electrical conductivity measurements

Technical Key Data:

Volume capacity	69 – 90 cm^3; approx. 500g
Gear ratio	3:2
Max. speed	250 min^{-1}
Max. torque	160 Nm
Max. temperature	400°C
Temperature control	3 zones

TWIN-SCREW EXTRUDER
THERMO SCIENTIFIC HAAKE RHEOMEX PTW 100 OS

Applications:

Process simulations of very small sample volumes:
- Compounding with complex fillers
- Blending
- Reinforcing matrices and extrusion of strands, profiles or films
- Rheological measurements

Typical Investigations:

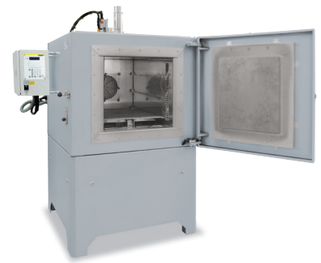
- Measuring rheological behavior (viscosity, elasticity)
- Testing melting behavior
- Testing influences of (functional) additives
- Extrudability and scale-up data
- Blend ratio
- Morphology of polymer and nano-composites
- Recycling capabilities
- Predictions for the injection molding process
- Influence of screw geometry on processability

Technical Key Data:

Screw diameter	16 mm
L/D ratio	25
Max. temperature	350°C
Typical output	0.2 to 2 kg/h
Max. pressure	100 bar
Max. screw speed	1,100 min^{-1}
Max. torque	130 Nm
Heating zones	7
Feeding systems	Volumetric/gravimetric
Direction of rotation	Co-rotating

CHAMBER FURNACES WITH AIR CIRCULATION
NABERTHERM N30 65 HA

- Processing in protective or reaction accelerating gas atmospheres with high air circulation rates
- Temperature uniformity up to ΔT 6 K in usable space



Applications:

- Tempering
- Quenching and tempering
- Precipitation hardening/curing
- Solution annealing
- Artificial aging
- Preheating
- Soft annealing and brazing

Technical Key Data:

T_{max}	650°C
Dimensions	290 mm x 420 mm x 260 mm
Volume	30 l

MILLING AND GRINDING

HIGH TEMPERATURE VACUUM FURNACE
LINN HIGH THERM HT 1800 M VAC

- Heat treatment under air, protective gas atmospheres or vacuum
- Fast heating and cooling rates due to fiber insulation
- Temperature uniformity up to ΔT 8 K

Applications:

- Preheating
- Crystallization (Sol-Gel System)
- Age-hardening

Technical Key Data:

T_{max}	1,800°C
Dimensions	250 mm x 250 mm x 200 mm
Volume	12.5 l
Temperature uniformity	ΔT 8 K

GRINDING/POLISHING MACHINE
STRUERS TEGRAPOL-31

- Grinding, lapping and polishing preparation of materialographic specimens
- Standard sample preparation for cross-section analysis, e.g. particle distribution within filler material

PLANETARY BALL MILL
RETSCH PM 400

- High degree of fineness, down to the nano range
- Mechanism: pulverization due to high centrifugal forces
- Controll over speed and energy
- Reproducible results

Applications:

- Pulverizing
- Mixing
- Homogenizing
- Colloidal Grinding
- Mechanical Alloying
- Dry and wet grinding

Field of Use:

- Carbon Fibers
- Composites
- Ceramics
- Polymers
- Metals

Technical Key Data:

Material feed size	< 10 mm
Final fineness	< 1 µm; for colloidal grinding < 0.1 µm
Speed ratio	1 : -2 / 1 : -2.5 / 1 : -3
Sun wheel speed	30 – 400 min^{-1}
G-force	26.8 g
Type of grinding tools	Hardened and stainless steel, tungsten, carbide, agate, sintered aluminum oxide, zirconium oxide

HIGH ENERGY BALL MILL
ZOZ SIMOLOYER CM08

- Mechanism: grinding through shearing with free moving steel balls
- Controllable process parameters: temperature and milling-power (torque)

Applications:

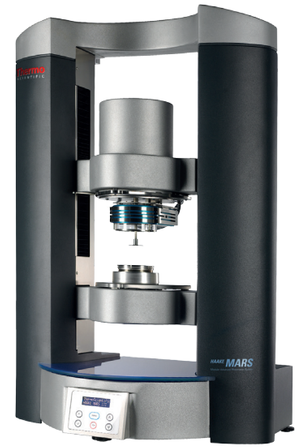
- High energy milling
- Mechanical alloying
- Reactive milling (ceramics and other materials)

Technical Key Data:

Rotational speed	100 – 1,000 rpm
Atmosphere	Vacuum/inert-gas
Controllable temperature	-20°C to 100°C
Working pressure	10^{-4} mbar up to 2 bar
Grinding units	5 l / 8 l (in powder load 500 – 1,500 g)
Operation	Batch or continuous

RHEOLOGICAL MEASUREMENTS
THERMO SCIENTIFIC HAAKE MARS III

- Materials behavior under a set of processing conditions
- Correlation to fundamental structural properties through thixotropic parameters like surface leveling, structural regeneration and sagging behavior
- Measurement modes: Controlled Rate (CR), Controlled Stress (CS) and Controlled Deformation (CD)



Measured Data:

- Viscoelastic/dynamic moduli
- Viscoelastic properties (as a function of shear stress/shear rate, time, frequency, temperature)

Applications and Features:

- Effects of particle size distribution
- Effects of additives and viscosity modifiers
- Polymers (solutions, melts, semi-solids)
- Dispersions (stability under high shear conditions)

Technical Key Data:

Min. torque rotation in CS and CR	0.01 µNm
Min. torque oscillation in CS and CD	0.003 µNm
Max. torque	200 mNm
Torque resolution	0.1 nNm
Min. rotational speed	In CS: 10^{-7} rpm In CR: 10^{-8} rpm
Max. rotational speed	1,500 (4,500) rpm
Step in velocity	10 m/s
Oscillation frequency range	10^{-6} Hz – 100Hz
Normal force range	0.01 N – 50 N
Temperature range	-150°C – 600°C
Measurement geometries	Plate-plate (20 mm and 35 mm) Plate-cone (35 mm)

THERMOGRAVIMETRIC ANALYSIS
NETZSCH TG 209 IRIS:

- Measurement of mass changes versus temperature or time
- Defined and controlled environment (atmosphere, flow rate, sample crucible, etc.)
- For both solids and liquids

Analysis:

- Mass changes
- Temperature stability
- Oxidation/reduction behavior
- Filler content
- Moisture and volatiles content
- Decomposition (dehydration, stability, residual solvent, pyrolysis)
- Corrosion studies
- Compositional analysis of multicomponent materials/blends (polymers, plasticizers, solvents, additives)
- Thermokinetic analysis

Applications:

- Polymers
  - Mixture's composition
  - Glass fiber content
  - Maximum working temperature
  - Temperature resistance
  - Mass losses during polycondensation
- Purity of materials
- Mass changes during oxidation
- Ceramics (temperature at which ceramic's binder burns out)

Technical Key Data:

Temperature range	(10°C) 20°C – 1,100°C
Cooling and heating rate	0.001 – 100 K/min
Measurement range	Up to 2,000 mg
Tare Range	Up to 2 g
Resolution	0.1 µg
Gas atmospheres	Argon/synthetic air
Coupled with c-DTA	Sample temperature measured directly

DIFFERENTIAL SCANNING CALORIMETRY
NETZSCH DSC 204 F1 PHOENIX

- Analysis of energetic effects (e.g. transition temperatures, enthalpy changes, etc.) during thermal treatment
- Different measurement standards according to material-, product- and property-oriented applications and evaluations

Analysis:

- Glass transition temperature (T_g)
- Melting/crystallization temperature (T_m)
- Degree of crystallinity
- Melting/crystallization enthalpies
- Cross-linking temperatures and enthalpies
- Oxidative stability
- Decomposition effects
- Thermokinetic analysis
- Degree of curing
- Purity determination
- Peak separation
- Solid-solid transitions
- Polymorphism
- Phase diagrams

Technical Key Data:

Temperature range	-85°C to 600°C
Cooling and heating range	0.001 to 100 K/min
Resolution	0.1 µg
Sensitivity	τ-Sensor (high resolution): 3.2 µV/mW µ-Sensor (high sensitivity): 70 µV/mW
Enthalpy accuracy	<1%
Gas atmospheres	Inert/oxidizing
Gas flow	Static/dynamic

THERMAL DIFFUSIVITY/CONDUCTIVITY
NETZSCH LFA 426 NANOFLASH

- Characterization of standard and high-performance specimens
- Defined atmospheres
- Consideration of radial and facial heat losses and finite pulse effects

Measured Data:

- Thermal diffusivity (a, [mm²/s])
- Thermal conductivity (λ, [W/m·K]); in case density is known in advance
- Specific heat (c_p, [J/gK])
- Thermal transition

Field of Use:

- Nanoparticle-reinforced matrices
- Fiber-reinforced polymers, metals or ceramics
- Composites
- Water dispersions

Unified Standards:

ASTM E1461, DIN EN 821, DIN 30905 and ISO 22007-4:2008

Technical Key Data:

Temperature range	Ambient to 300°C
Thermal diffusivity range	0.01 mm²/s to 1,000 mm²/s
Thermal conductivity	0.1 W/(m·K) to 2,000 W/(m·K)
Repeatability	Temperature conductivity: ±2% Specific heat: ±3%
Accuracy	Thermal diffusivity: ±3% Specific heat: ±5%
Sample size	Diameter: up to 25.4 mm or Square: 6 mm / 8 mm / 10 mm / 12.7 mm Thickness: up to 3 mm

SIMULATION AND ANALYSIS

Our Expertise

Within the scope of the research and development activities the department of Functional Materials at Fraunhofer IPA pursues a holistic approach in their R&D activities: we are not only committed to generating knowledge and innovations in applied material research, but also to demonstrate our expertise in functional prototypes and optimized products for our customers. Simulation and scientific modeling support us in our goal to transfer cutting-edge technologies and latest material developments into innovative real-life applications and optimized manufacturing processes. Today, the use of computer technologies for the fast and easy treatment of engineering problems is a standard procedure in most sectors of industry. As a research partner for our industrial customers we need to not only understand these procedures, but to maintain a high level of technical skills and expertise in order to complement our customers and partners and to provide them with the latest solutions in research and technology.

What we offer

Whether you want to predict material properties of unprecedented nano- or micro-composites, investigate mechanical, thermal and electrical functionalities of your components and devices, or if you simply want to validate the performance of your functional materials within your newly designed product without expensive test procedures – we support you in every stage of your development. We distinguish between three main activities involving computer based simulation and modeling: computer aided engineering and system modeling, computer enhanced multi-scale material modeling, and electronics design. We offer a broad range of tools and expertise to help you optimize your materials and products and make them ready for the international market.

Your Benefits

As an integral part of the Fraunhofer society and in collaboration with our research partners, our department has established an extensive scientific network and has access to substantial resources in simulation technology. By participating in advanced publicly funded research projects we generate new fields of application. That is what enables us to break new grounds and find new approaches and solutions for our customers' individual problems.

COMPUTER-AIDED ENGINEERING (CAE)

Scope:

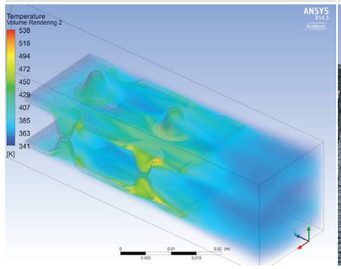
Engineering simulation facilitates the analysis of complex engineering problems such as structural mechanics, fluid dynamics, electromagnetics, and thermal processes. The department of Functional Materials uses CAE (computer aided engineering) to analyze and optimize the robustness and performance of materials, components and assemblies before transferring them into market-ready applications. Thus, testing and characterization efforts are minimized and costs for research and development projects can be cut down.

Ressources:

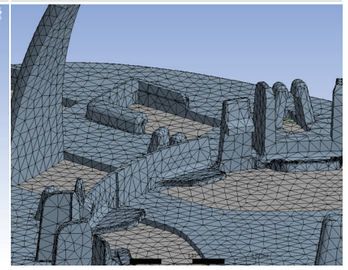
- The main CAE-system used at Fraunhofer IPA is the ANSYS Multiphysics simulation environment.
- For 3D-Modelling, SolidWorks, an industrial standard, is available with all necessary interface products for model transfer and rapid prototyping.

Portfolio:

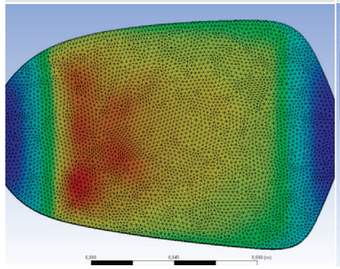
Computational Fluid Dynamics, aerodynamics (CFX, Fluent)



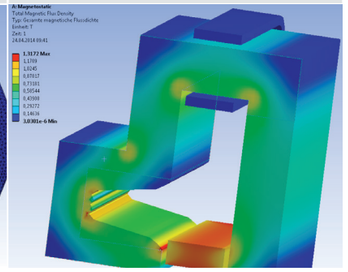
Static & dynamic structural mechanics analysis (classic FE-methods)



Coupled thermal-electric analysis for electrical heating applications



Coupled electro-magnetic analysis (energy harvesting, energy applications)

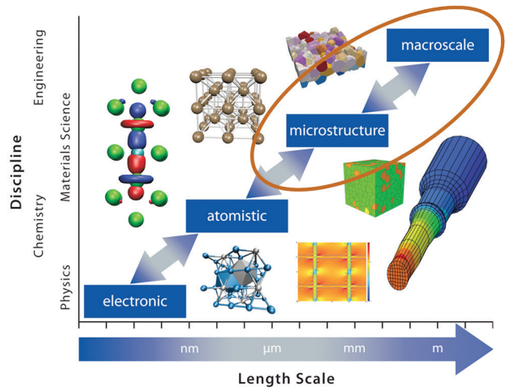


MULTI-SCALE SIMULATION

Scope:

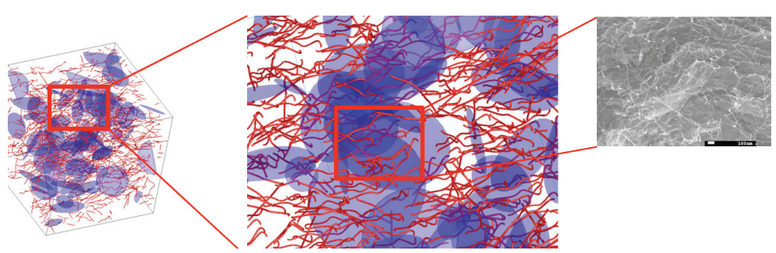
Multi-scale simulation serves for solving physical problems which have important features at multiple scales, particularly multiple spatial and temporal scales. It allows predicting material properties or system behavior based on knowledge of the atomistic structure of the material or composite, involving properties of elementary processes. Small (micro-)scale models calculate material properties, or relationships between properties and parameters, e.g. yield strength vs. temperature, which are subsequently used as input parameters in macro-scale continuum/FE models.

Modern material simulation tools feature methods of describing the microstructure of the composite as well as the material properties of its constituents in order to generate a FE model of the nano-composite microstructure's Representative Volume Element (RVE). The generated model is transferred to CAE software for solving the computational model for any boundary conditions to be analyzed. The variation of process parameters, substrate types and precursors can easily be integrated into the simulation process in order to find optimized configurations of the microstructure with respect to its relevant material properties (damping, thermal conductivity, dynamic stiffness, elasticity, etc.).



Ressources:

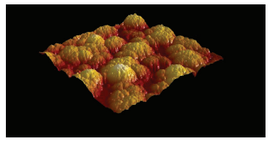
- The software tool family Digimat-FE developed by e-Xstream is mainly used for composite simulations and analysis of multi-material properties such as mechanical, electrical, thermal and tribological performance characteristics.

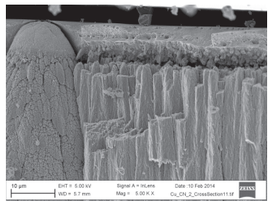


SIMULATION AND ANALYSIS

Portfolio:

- Influence of micro- and nano-structured fillers in matrix composites
- Piezo-, electrostrictive materials and composites modelling
- Integrated Computational Materials Engineering (ICME)
- An approach to design products, the materials that comprise them, and their associated materials processing methods by linking material models at multiple length scales





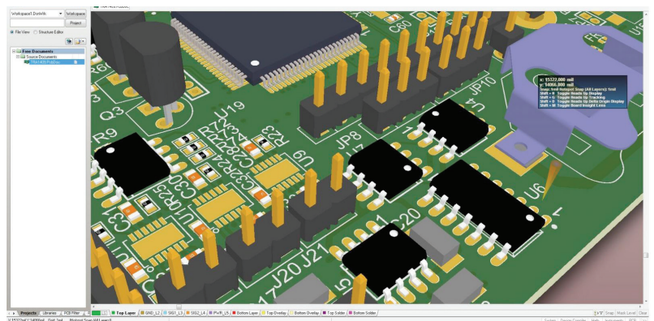
ELECTRONIC DESIGN AUTOMATION (EDA)

Scope:

A significant part of our expertise at Fraunhofer IPA consists of system integration activities. For electronic components, highly specialized software tools are used for designing electronic systems such as printed circuit boards and integrated circuits. Custom-made special designs are developed, optimized and prototyped using a variety of supporting tools and automated design methods. By using these tools, we are able to quickly respond to any change of requirements coming from the customer. For integration and testing of the final application, we closely cooperate with companies specialized in fast manufacturing of prototype PCBs.

Ressources:

- Altium Designer
- FEMM electronic modeller



Portfolio:

- Native 3D PCB design of customized electronic platforms
- Cost assessment of prototype and mass-scale manufacturing processes
- Virtual visualization of final PCB product and easy integration of wiring changes and component substitution

Fraunhofer Institute for Manufacturing Engineering and Automation IPA
Dipl.-Ing. FH MBA Ivica Kolaric
Head of Department Functional Materials
Nobelstrasse 12
70569 Stuttgart | Germany

Phone +49 711 970-3729 | Fax -3995
lab-services@ipa.fraunhofer.de

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