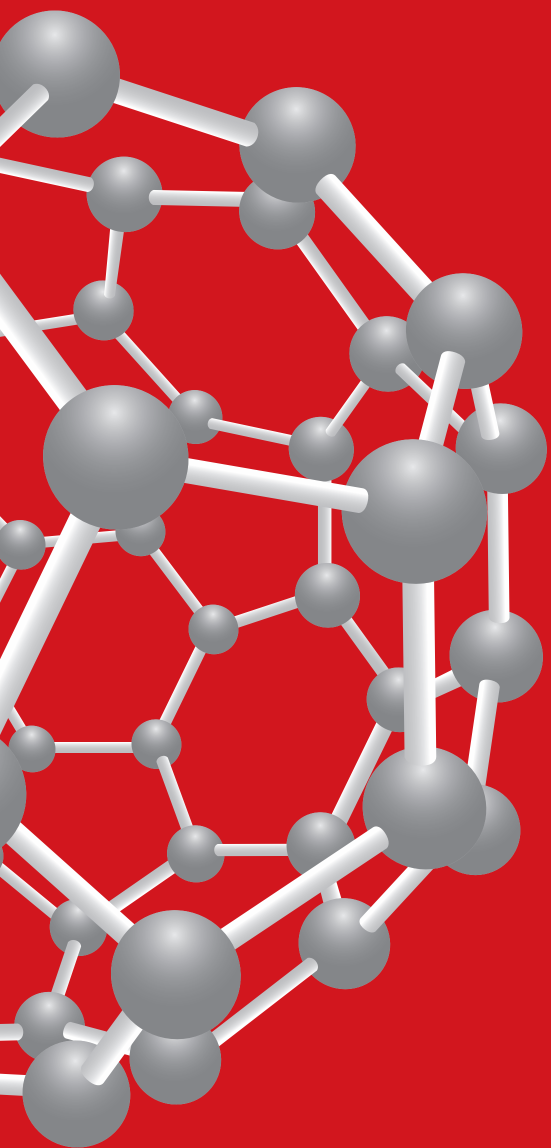
Anton Paar



Solutions for Nanotechnology

Focusing on solutions

Anton Paar has been developing, producing and distributing high-precision measuring and analytical instrumentation for laboratory and process applications since 1922.

The company understands that preparing, synthesizing and investigating nanomaterials requires know-how and technology at the cutting edge, instruments with outstanding precision and reproducibility.

To meet these needs, Anton Paar provides instruments realized with a passion for precision, a love of science, and a shared enthusiasm in the entire chain of production, every step of the way.

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Products

Definition

The size range from 1 nm (nanometer) to 100 nm is called "nanoscale". Materials which are composed of one or more interrelated constituent parts in the nanometer size range are referred to as nanomaterials.

Nanomaterials can have many different morphologies: there are nanoparticles, nanofibers, nanowires, nanoplates, nanobelts, nanotubes and many more. Some of them are nanosized in only one dimension (nanoplates, nano-surface coatings), some in two dimensions (nanofibers, nanowires and nanotubes) and some in all three dimensions (nanoparticles).

What is special about nanomaterials?

When a particle becomes smaller, its surface becomes bigger relative to its volume, thus changing the overall properties of the resulting nanomaterial. It may be more reactive, have different optical, magnetic and electrical behavior, be mechanically stronger or more toxic compared to the same material on a larger scale. One major reason for these changes is that nanomaterials break a size barrier below which **quantum effects** can begin to dominate their behavior.

How big is one nanometer?

The following table illustrates the size of one nanometer:

Width (diameter)	Example	
1 nm	Carbon nanotube	**Ratio tennis ball/1 nm** 6.5 x 10^7
6.5 x 10^7 nm	Tennis ball	
2.2 x 10^8 nm	Football	**Ratio earth/football** 5.9 x 10^7
1.3 x 10^{16} nm	Earth	

For a deeper understanding and tuning of nanomaterial properties, the nanostructure is of utmost importance. Nanostructures can either form in the bulk material or on the surface. Often they form naturally due to intermolecular forces. Knowledge of these processes is, however, invaluable for tailor-making technical materials. X-ray scattering, more specifically **small-angle X-ray scattering (SAXS)**, is the technique of choice for nanostructure analysis.

Nanotechnology

Nanotechnology makes use of the ability to synthesize, manipulate and characterize matter at the atomic and molecular level (i.e. at the sub 100 nm level) in order to benefit from size- and structure-dependent properties and phenomena. The applications of nanotechnology are wide-ranging, involving a multitude of science and engineering disciplines, with applications in electronics, the chemical industry, advanced materials, medicine and information technologies.

Colloidal nanoparticle dispersions

A colloidal system is a dispersion in which one material is finely dispersed in another material, the dispersion medium. The term "collloid" refers to dispersed particles in the size range from 1 nm to 1 µm. Therefore, the nanoscale and colloidal size scale have a large overlapping area.

Colloidal dispersions are stabilized by surfactants which occur naturally or are added on purpose. Surfactants consist of a hydrophilic (water-friendly) group (often the head group) and a hydrophobic (water-repellant) part (tails) and are common in the size range from 0.5 nm to 5 nm. These compounds lower the surface tension of a liquid, the energy that maintains the interface between two liquids, or the surface tension between a liquid and a solid. At low concentrations, surfactants migrate to the surface of the liquid and arrange themselves there. Above the critical micelle concentration, surfactants self-assemble in the bulk solution to form aggregates (vesicles and micelles).

There are several types of colloidal dispersions depending on the aggregate state (phase state) of the combined materials: Emulsions are widely found in manufactured products, including food, agrochemicals, inks, paints, pharmaceuticals and cosmetic products. They also occur naturally, such as milk.

Name	Constitution
Suspension	solid–liquid
Emulsion	liquid-liquid
Foam	gas-liquid/gas-solid
Aerosol	liquid in gas/solid in gas

Microemulsions based on nanoscale structures are clear or translucent in contrast to emulsions containing micrometer-sized structures, which are cloudy. Microemulsions are widely used in the pharmaceutical and cosmetics industries, for example as drug delivery systems and for reduced-fat food products such as low-fat mayonnaise.

Nanosuspensions, which are colloidal suspensions of nanoscale particles stabilized by surfactants, are mainly used to improve the solubility of poorly water-soluble drugs. Nanofoams are investigated for use as cheap and efficient insulator materials. Their properties can differ remarkably from the bulk materials, e.g. carbon nanofoam shows ferromagnetic behavior, which is unusual for carbon material. Properties of dispersions and their interfaces or surfaces can be determined via **rheological measurements**.

Stability of dispersions

The stability and behavior of dispersions, irrespective of the size range of the dispersed particles, are based on surface forces between the dispersed particles. Surface forces depend on particle-size distribution, pH, temperature, type and concentration of stabilizing additives. Stabilization based on repulsion between the dispersed particles is achieved by adsorbed or grafted non-ionic surfactants or polymer layers on the particles (steric stabilization) or surface charges (electrostatic stabilization). Electrostatically stabilized dispersions are sensitive to the addition of electrolytes; sterically stabilized dispersions are sensitive to mechanical forces and temperature.

Studies on the influence of mechanical forces, e.g. shear on the behavior of dispersions, is essential in many application fields. Some dispersions show thixotropic behavior: the **viscosity** changes at a given shear rate but returns to its initial value after removing the shear. These characteristics allow important applications in paints, cosmetics and food science and can be investigated using rheometry.

Nanostructured surfaces

One-dimensional nanomaterials, such as thin films, layers and surface coatings, are widely used, often in the production of electronic devices. Monolayers, which are layers consisting of one layer of atoms or molecules, are already routinely produced and applied in many fields of modern chemistry. Surfaces with tailored properties, such as a large surface area or specific reactivity, are utilized for fuel cells and catalysts.

One example of an outstanding property of a nanostructured surface is “the lotus effect”. The leaves of the lotus flower repel water efficiently. Water adhesion is decreased due to the microscopic and nanoscopic architecture of the surface. The plant surface has a first layer of papillae in the micro-scale range which reduces the contact area, and a second layer of nanoscale hydrophobic waxes. If water droplets roll off the leaf, the adhesion between a dirt particle and a water droplet is higher than between the particle and the surface, resulting in a cleaning effect. The lotus effect is used in nanotechnology for self-cleaning windows, mirrors, clothes and many other surfaces. Surface properties and their pH-dependent changes can be investigated via **zeta potential measurements**.

Nanomanufacturing

Nanomaterials can be prepared using the top-down or bottom-up method. The “top-down method” breaks down larger sized chemical compounds into nanosized materials. However, the major approach, high-energy ball milling, suffers from contamination problems, and results in a highly polydisperse size distribution of the obtained nanoparticles. Nevertheless, this technique is used to generate different kinds of nanoparticles and is sufficient for some common applications.

The “bottom-up method” uses specific synthesis techniques that allow control of the formation of nanoscale materials. The two main techniques are sol-gel processing and gas phase synthesis. The sol-gel process is a wet-chemical technique in which hydrolysis and subsequent polymerization reactions result in dimers, trimers and finally polymers until particles can be observed. The production of nanoparticles via gas phase synthesis is based on an oversaturated vapor which is obtained either by a chemical reaction or by a change of ambient conditions. If the vapor is saturated enough, a seed crystal can form which grows and results in a particle.

One big issue in nanomaterial synthesis is the possibility of tuning the physical and chemical properties by varying the crystal size and shape. Zinc sulfide, which is one of the most important semiconductors, can be produced with different crystallite sizes depending on the reactant concentrations and the applied heating method (conventional or **microwave**-assisted). Besides a shorter reaction time the greatest advantage of using microwave irradiation is that it allows exact control of reaction conditions to tailor the resulting nanoparticles according to requirements. The structural characterization of the obtained nanoparticles (size and size distribution, shape) can be performed using **small-angle X-ray scattering (SAXS)**.

Nanomedicine

Nanomedicine is the field that uses nanotechnology in medical applications.

Living organisms are built up of cells which are usually in the size range of around 10 µm. Cell parts are built up of proteins which are in the nanometer size range. This is the same size range as various nanoparticles applied in medicine.

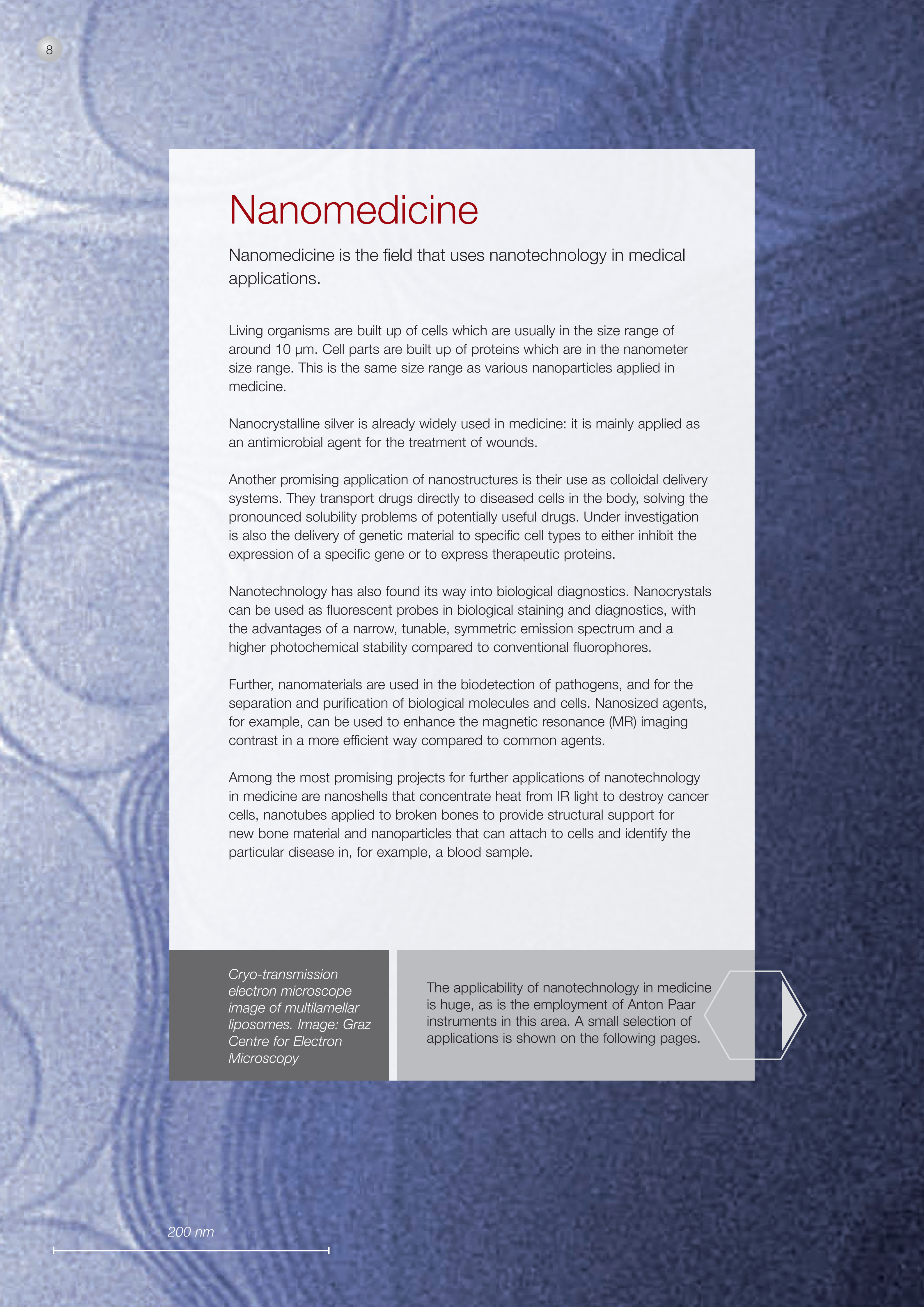
Nanocrystalline silver is already widely used in medicine: it is mainly applied as an antimicrobial agent for the treatment of wounds.

Another promising application of nanostructures is their use as colloidal delivery systems. They transport drugs directly to diseased cells in the body, solving the pronounced solubility problems of potentially useful drugs. Under investigation is also the delivery of genetic material to specific cell types to either inhibit the expression of a specific gene or to express therapeutic proteins.

Nanotechnology has also found its way into biological diagnostics. Nanocrystals can be used as fluorescent probes in biological staining and diagnostics, with the advantages of a narrow, tunable, symmetric emission spectrum and a higher photochemical stability compared to conventional fluorophores.

Further, nanomaterials are used in the biodetection of pathogens, and for the separation and purification of biological molecules and cells. Nanosized agents, for example, can be used to enhance the magnetic resonance (MR) imaging contrast in a more efficient way compared to common agents.

Among the most promising projects for further applications of nanotechnology in medicine are nanoshells that concentrate heat from IR light to destroy cancer cells, nanotubes applied to broken bones to provide structural support for new bone material and nanoparticles that can attach to cells and identify the particular disease in, for example, a blood sample.



Cryo-transmission electron microscope image of multilamellar liposomes. Image: Graz Centre for Electron Microscopy

The applicability of nanotechnology in medicine is huge, as is the employment of Anton Paar instruments in this area. A small selection of applications is shown on the following pages.

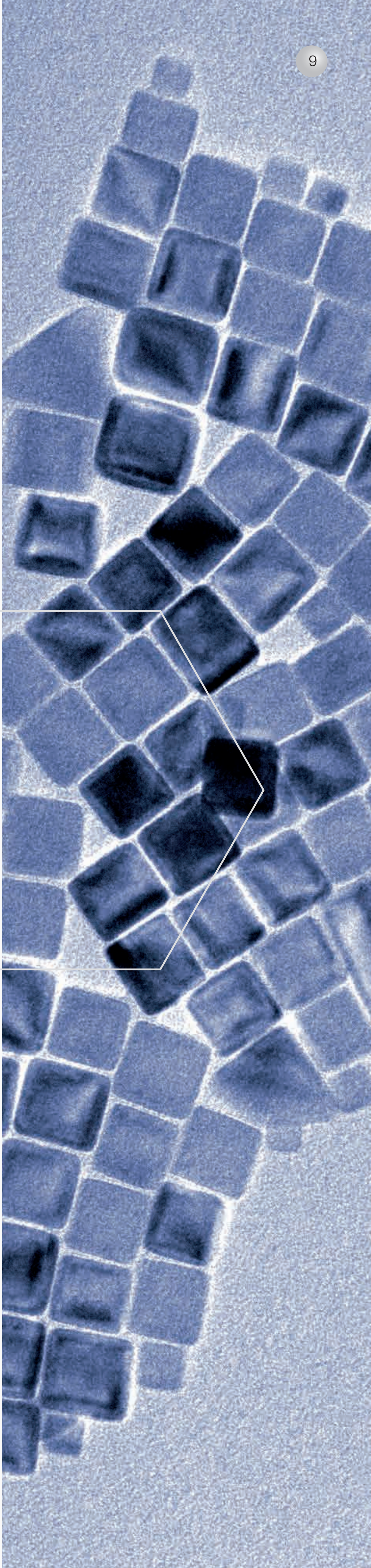
How can you precisely determine the size distribution of nanodrugs?

With the Abbemat refractometer the refractive index of nanocrystals and nanoparticles can be reliably and precisely determined in order to analyze laser diffraction data.

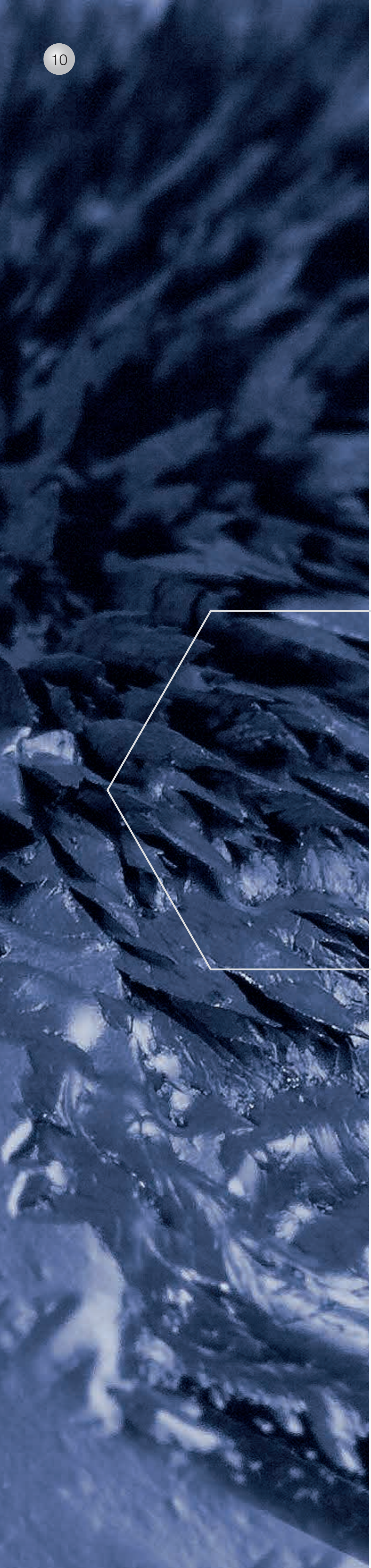
Nanoparticles and nanocrystals are widely used in pharmaceuticals and cosmetics. The size distribution of these nanodrugs strongly influences their chemical and biological behavior and the associated effectiveness. It is therefore a highly requested determinant.

The size of nanoparticles or nanocrystals can be investigated employing laser diffraction. The size distribution is calculated from the diffraction pattern. For this calculation the refractive index of the nanoparticles needs to be exactly known at the laser wavelength used. However, the refractive index is often taken without measurement, leading to inaccurate results.

Due to the solubility of the nanoparticles and crystals the refractive index has to be measured at low concentrations and then is extrapolated to the pure substance. Using Anton Paar's Abbemat refractometer the refractive index can be measured highly accurately, which minimizes extrapolation errors. The Abbemat multiple wavelength model provides the possibility to choose the wavelengths of the laser beams.



Abbemat refractometer



How can you find the required magnetorheological fluid?

Valuable information about the behavior of magnetorheological fluids under the influence of a magnetic field is gained by rheological measurements.

A thorough characterization of magnetorheological fluid (MRF) properties is essential for choosing the right fluid to suit the application, as well as for optimizing MRFs for further implementation.

Magnetorheological fluids are suspensions of particles which can be magnetized. They exhibit fast, strong and reversible changes in their rheological properties when a magnetic field is applied, making them very interesting for many technical applications such as semi-active human prosthetic legs. The introduction of nano-MRFs has now solved the problem of sedimentation.

Data concerning field-induced changes of fluid viscosity for a broad range of shear rates, viscoelastic properties and yield stress can be obtained using an MCR rheometer together with the Magneto-Rheological Device.

MCR rheometer and MRD

How can you secure drinking water quality?

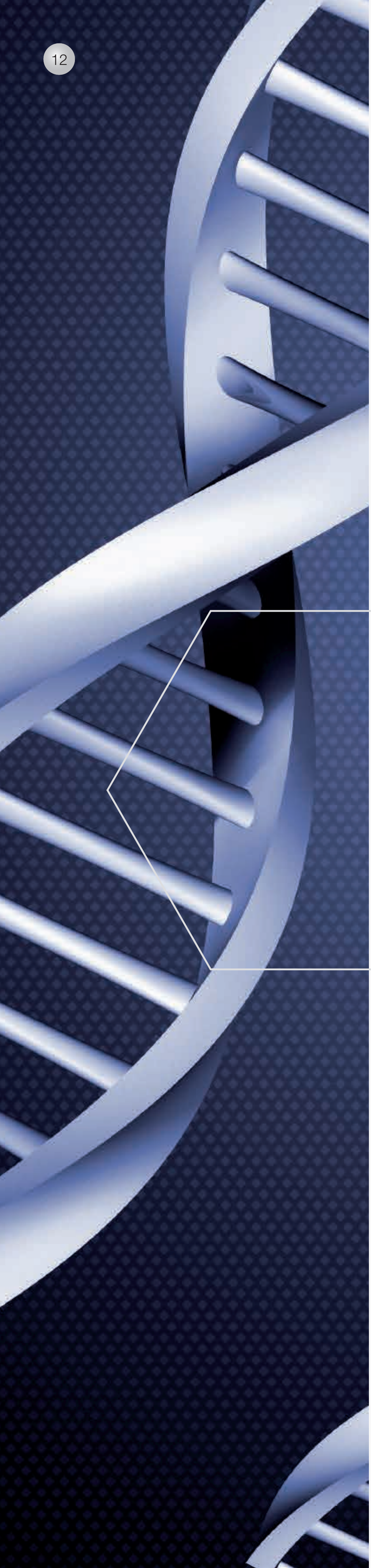
The charging behavior of inner and outer membrane surfaces can be investigated using the SurPASS electrokinetic analyzer.

The zeta potential gives comprehensive information about the charging behavior inside pores of ceramic filters made of diatomaceous earth.

Ceramic filters are commonly used for ground water filtration to effectively remove bacteria. Viruses are 100 times smaller than bacteria and the pore size of ceramic filters is usually too big to ensure complete removal. Besides pore size the surface charge is an important filter parameter.

At the pH of surface and ground water viruses are negatively charged. If ceramic membranes are modified with a heavy metal oxide a positive surface charge can be obtained. The negatively charged virus particles can then be successfully filtered due to their electrostatic attraction to the membrane pore walls. The SurPASS instrument helps to predict the filtration properties of modified membranes.

SurPASS



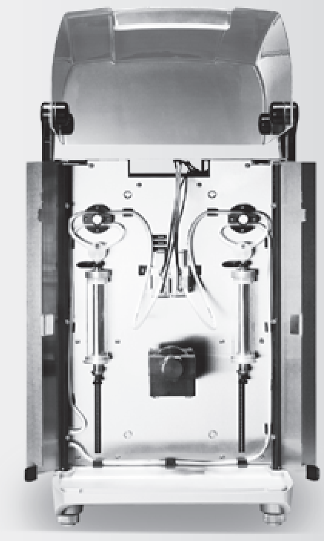
What are smart coatings?

Zeta potential measurement assists in tailoring the properties of technical and biomedical surfaces.

Self-assembled monolayers (SAMs) are formed when amphiphilic molecules, such as surfactants or silanes, adsorb as a monomolecular layer on surfaces. Nanoscale coatings of organic silanes or thiols with functional end-groups are a smart procedure to tune material surface properties without changing the material thickness.

The major application fields of SAMs are the control of wetting and adhesion, the improvement of chemical resistance and bio-compatibility and molecular recognition.

Alkane thiol-anchored self-assembled monolayers on gold are widely used to immobilize and detect molecules, including DNA, which become covalently bonded to the SAM on the gold surface. To improve the selectivity of the SAM coating, the surface charge, measurable by SurPASS, can be tailored by adding different functional end-groups.



SurPASS

How does controlled drug delivery work?

SAXSpace provides the possibility of time-resolved small-angle X-ray scattering experiments.

The potential application of micelles as vehicles for the delivery and sustained release of active ingredients such as drugs can be determined by following their structure changes over a long period of time.

Dispersions with liquid-crystalline nanosized substructures are of great importance in numerous scientific and industrial applications. These systems exhibit nanostructures with a high interfacial area, low viscosity and the capability to solubilize various molecules. They are important as membrane mimetic matrices, as vehicles for active ingredients and as unique microenvironments for the controlled release of additives such as drugs.

Substructured emulsions can be investigated with the SAXSpace in the time-resolved mode in order to study the kinetics of transport processes.

SAXSpace

"Nano" in Everyday Products

Nanosystems are all around you in daily life. Milk, mayonnaise, many detergents, paints, inks, shampoos and toothpaste are all colloidal dispersions.

The stability and properties of these products depend on surfactants which either occur naturally or are used as additives. Supplements like omega-3 fatty acids are often encapsulated in nanostructures to prevent food tasting fishy. Drinks which change their color and taste depending on whether they are shaken or stirred are currently under exploration. They contain nanocapsules full of different flavors and colors. Depending on the applied mechanical forces, different capsules burst and release their contents.

Recently, the inner walls of fridges have begun to be coated with nano-silver to inhibit bacterial growth and eliminate odors.

Another important application field of nanostructures is the food packaging sector: Nanocomposites in packaging materials are used to extend the life of food and drinks by inhibiting bacterial growth or strengthening the barrier for carbon dioxide and oxygen. A possible future application is packaging which changes color when food begins to spoil or becomes contaminated with pathogens.

Nanosized pesticides are better absorbed by plants, resulting in increased effectiveness of treatment. To improve genetic engineering breeding programs, nanostructures are investigated for delivering DNA and chemicals into plant and animal cells and tissues.

Nanosized zinc oxide particles are applied in transparent sunscreens. Cotton, synthetics, wool, silk, rayon and polypropylene are treated with nanoparticles to enhance their properties, such as spill control, fast drying and stain resistance. The utilization of nanotechnology in electrical energy stores, such as batteries, aims at improving their capacity and safety.

Transmission electron microscope image of cobalt iron oxide nanoparticles. Image: Graz Centre for Electron Microscopy

Nanotechnology is already frequently applied in everyday products. The following applications of Anton Paar instruments are only a small selection of their use in this area.

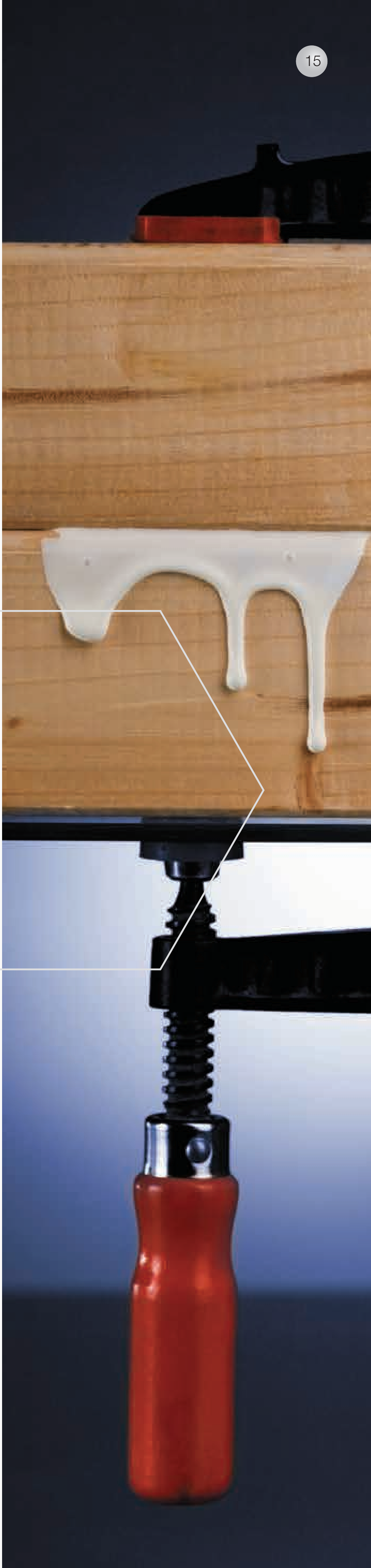
How can nanotechnology help you tune glue?

The Abbemat refractometer enables precise monitoring of the curing process of glue containing nanoparticles.

Epoxy resins are widely applied as glues for everyday products and also for high-end applications, e.g. in the aircraft industry, the boat building industry and the electronics industry.

Nanoparticles are used to tailor-make glues suiting specific application needs. The addition of nanoparticles changes the chemical, electrical, mechanical and surface properties of glues. The influence on the curing behavior can be determined with a refractometer.

The phase transition during the hardening process of glues manifests itself in a change of refractive index. Anton Paar's Abbemat refractometer enables monitoring of the refractive index during curing without being influenced by the volume change. After curing the sample can be easily removed from the scratch-proof prism surface.



Abbemat refractometer

How does rheometry help to develop the perfect “crema“ and foam?

Interfacial shear rheology employing an MCR rheometer is a very sensitive technique for the investigation of foam and emulsion stability.

The stability of food products in the form of emulsions or foams is dependent on interfacial properties, which play a major role in preventing the coalescence of emulsions or film drainage of foams.

Surface-active additives adsorb at the air/liquid or liquid/liquid interface, often building a monolayer with a thickness of only a few nanometers. This interface can be investigated with an MCR rheometer, which provides information on the dynamics of the film formation as well as the rheological properties of the final film.

In the case of coffee, besides the initial film formation and the stability of the final film, the thixotropic behavior is an important parameter. The required information can be easily obtained using Anton Paar’s MCR rheometer plus Interfacial Rheology System.

MCR rheometer and IRS

Do nanoparticles influence the liquid-crystalline structure of soap?

The structure of micellar systems under varying conditions can be investigated via small-angle X-ray scattering (SAXS).

Micelles are a classical example of nanostructures formed through the self-assembly of amphiphilic molecules in aqueous solvents. The micellar size, shape and structure are dependent on parameters such as temperature, pH and the presence of ions.

Triton® X-100 is a common emulsifier agent mainly used in detergents. It is non-ionic (neutral) and one of the most frequently studied and exploited micellar systems. To ensure the required applicability, the behavior of Triton® X-100 under changing conditions has to be investigated.

The effect of temperature and the presence of macro-ions, such as small nanoparticles, on the structure of Triton® X-100 micelles can be elucidated using the SAXSpace small-angle X-ray scattering instrument from Anton Paar.

SAXSpace

Are nanoparticles the solution for affordable electric cars?

Microwave-assisted synthesis simplifies the preparation of tailored nanoparticles.

Chemical syntheses are often performed at elevated temperature, since it is commonly known that an increase in temperature results in shorter reaction times. Microwave reactors allow for rapid heating far beyond the boiling point of the applied solvent.

To reduce the costs of lithium-ion batteries the automobile industry has changed from using lithium cobalt oxide to using less expensive lithium iron phosphate. However, the typical iron phosphate manufacturing process takes hours of baking at high temperatures, resulting in high costs due to the extra work and energy required. Microwave heating can be used to speed up the synthesis process and save money.

When producing lithium iron phosphate by applying a microwave reactor the reaction time can be significantly reduced from hours down to minutes.

Masterwave BTR

How can you optimize microemulsions?

The stability and behavior of microemulsions can be investigated using either small-angle X-ray scattering (with SAXSpace) or rheometry.

Knowledge of parameters such as flow behavior, “yield point”, structural regeneration and temperature dependence of microemulsions is essential for the manufacturing process (homogenizing, pumping, filling) of microemulsions and for the design of end products such as gels and lotions with customized properties.

Microemulsions are made of at least two immiscible fluids plus a surfactant. High surfactant content influences the skin barrier and allows the active ingredients which are dissolved in the microemulsions to move through the skin into the organism.

The MCR rheometers are well suited for quality control tasks in the cosmetics industry, such as monitoring the flow behavior, determination of the yield point and structural regeneration. Deeper knowledge about the contained nanosized structures can be obtained employing SAXSpace.

SAXSpace

Nano-electrotechnology

Nano-electrotechnology defines a large area combining nanostructured sensors, nanoelectronics, optoelectronics, magnetic materials and devices, radiofrequency devices, electrodes with nanostructured surfaces and many more.

Typically, nano-based materials and devices are integrated into existing products or materials in order to make them more efficient or more effective.

Inorganic semiconducting nanomaterials have become a popular field of research owing to their variety of physical and chemical properties and the associated wide range of possible applications. Some of these nanomaterials are investigated for their applicability as future field emission devices used, for example, in displays. Compared to conventional methods, the application of nanostructures should result in a faster device turn-on time, increased compactness and higher sustainability.

Electrodes made from nanowires would enable flat panel displays to be flexible as well as thinner than common flat panel displays. Nanoscale electronic devices can perform as both switches and amplifiers, and should replace commonly used transistors in the next generation of smaller, denser and faster digital computers. For this application, carbon nanotubes are of major interest as they enable the production of minimum size transistors.

Nanotechnology further assists in producing memory chips with remarkably increased disk space. Nanoparticles are investigated for new developments in photovoltaic systems, such as thin-layer solar cells, dye solar cells or polymer solar cells.

Another important field of investigation is thermal energy storage. Employing nano-enabled microencapsulated phase change materials the efficiency can be increased compared to conventional structures.

Transmission electron microscope image of cobalt iron oxide nanocrystals. Image: Graz Centre for Electron Microscopy

The field of nano-electrotechnology often overlaps with other fields of nanotechnology. A selection of applications for Anton Paar instruments is given on the following pages.

Why do you need a density meter for the production of solar cells?

Capable of detecting tiny changes in sample composition, the DMA 5000 M is the most accurate density meter on the market.

A new technique referred to as silicon ink technology remarkably reduces the production costs of solar cells. This technique is based on a special ink that contains dispersed silicon nanoparticles. Conventional solar cell manufacturing lines can be optimized by adding a single silicon ink printing step which results in solar cells with higher conversion efficiency.

The composition of this ink requires careful fine tuning as the final product has to be suitable for a variety of industrial printers such as screen printers or inkjet printers. Composition and viscosity are equally important factors in the consistency of this ink. Anton Paar instruments are used to optimize product quality and cost-efficiency at the same time.

Combining Anton Paar's DMA 5000 M density meter and Lovis 2000 ME viscometer provides a system for measuring the density and viscosity of inks in one run. The easy and highly accurate determination of these parameters ensures the right ink composition for a variety of printing equipment.

DMA 5000 M

How can you maximize your information about polymer-carbon black?

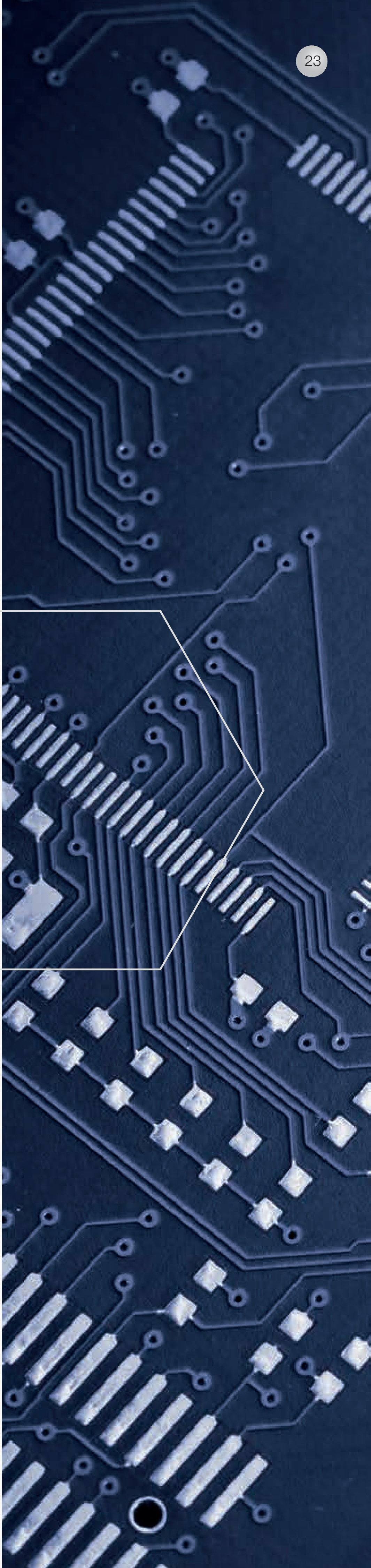
Dielectric spectroscopy can be used as a complementary technique to rheology, providing additional information on structure and behavior.

Dielectric spectroscopy is an investigative technique based on the study of the material response to an applied electric field. It can be used as a complementary technique to rheology in order to identify structural changes in the systems analyzed as well as to distinguish between the contributions of each component of a complex system to the global behavior of the sample.

Polymer-carbon black composites are viscoelastic materials that consist of carbon black clusters inducing dielectric properties which are dispersed in a polymeric matrix. The adhesion between the carbon black particles and the polymer plays a fundamental role in controlling the viscoelastic characteristics of these materials.

The behavior of polymer-carbon black under shear can be easily investigated via the Dielectro-Rheological Device accessory of the MCR rheometer series.

MCR rheometer and DRD



Why does the electronics industry investigate inks using a microviscometer?

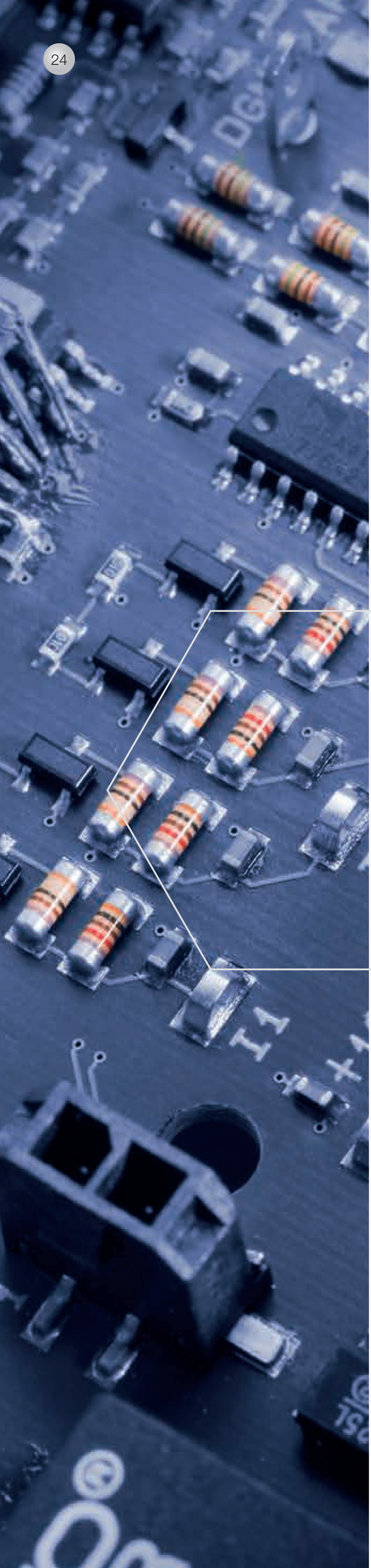
The Lovis 2000 M/ME microviscometer performs highly precise viscosity determinations on low-viscosity inks, requiring a sample volume as small as an inkjetted droplet.

Inkjet printing technology, in which metallic nanoparticle suspensions are printed using ordinary commercial printers, is a promising technique for fabricating conductive lines for electronic applications. The conductive lines can be drawn onto the substrate in one step, followed by curing to remove the solvent and to observe sintering effects between the nanoparticles.

Whether substances are "inkjetable" is mainly related to their viscosity, density and surface tension. These factors have to be optimized to obtain stable inkjetting properties.

With Lovis 2000 M/ME the viscosities of inks or other transparent or opaque liquids can be quickly determined. With the DMA 5000 M density meter the density of liquids can be measured with the utmost accuracy. The knowledge of these parameters enables conclusions to be made on the inkjetability.

Lovis 2000 M



How can you obtain nanocrystalline zinc sulfide?

Microwave heating can be used for the preparation of nanocrystals. Their structure and particle size can be determined with XRD and SAXS, respectively.

The size of nanocrystals is influenced by their preparation conditions. Microwave-assisted synthesis provides accurate temperature control in addition to short reaction times, simplicity of experiments and energy efficiency.

Zinc sulfide (ZnS) is one of the most important semiconductors. It has a great potential in several different technological applications such as in optoelectronic devices or as photonic crystals.

ZnS crystals can be synthesized by microwave-assisted heating, resulting in bigger crystallites compared to those produced by conventional routes. The primary crystallite size can be determined by X-ray diffraction (XRD) to give information on the crystalline phase and by small-angle X-ray scattering (using SAXSpace) to reveal the size of the primary particles and their packing.

Monowave 300

How can you predict whether wafer cleaning will be successful?

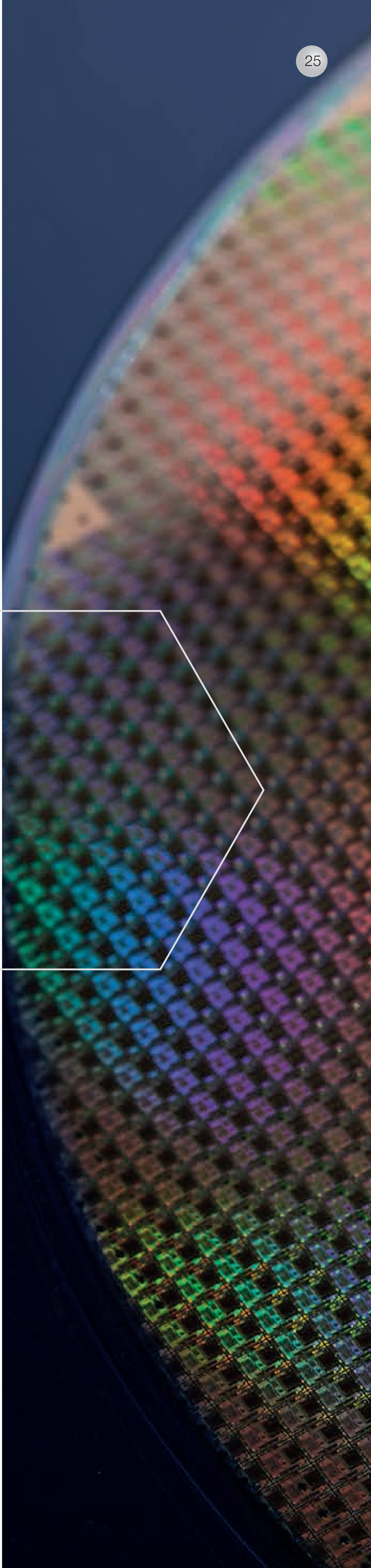
The charge of a surface is related to the zeta potential, which can be determined with the SurPASS electrokinetic analyzer.

Chemical-mechanical polishing (CMP) is a common process in semiconductor wafer cleaning that combines chemical action with mechanical abrasion. The cleaning efficiency is dependent on the properties of the outermost surface.

The interaction between particles of a CMP slurry and surfaces is driven by electrostatic forces. The knowledge of the solid surface charge, which can be determined via the zeta potential, is an important indicator for the optimization of this process.

The surface charge of a semiconductor wafer can be investigated via zeta potential measurements employing SurPASS. Additionally, the impact of the pH on the charging behavior can be easily demonstrated due to the integrated automated titration unit.

SurPASS



Nanochemistry

Nanochemistry includes chemical synthesis, analysis and biochemical diagnostics, taking advantage of the unique properties of nanomaterials.

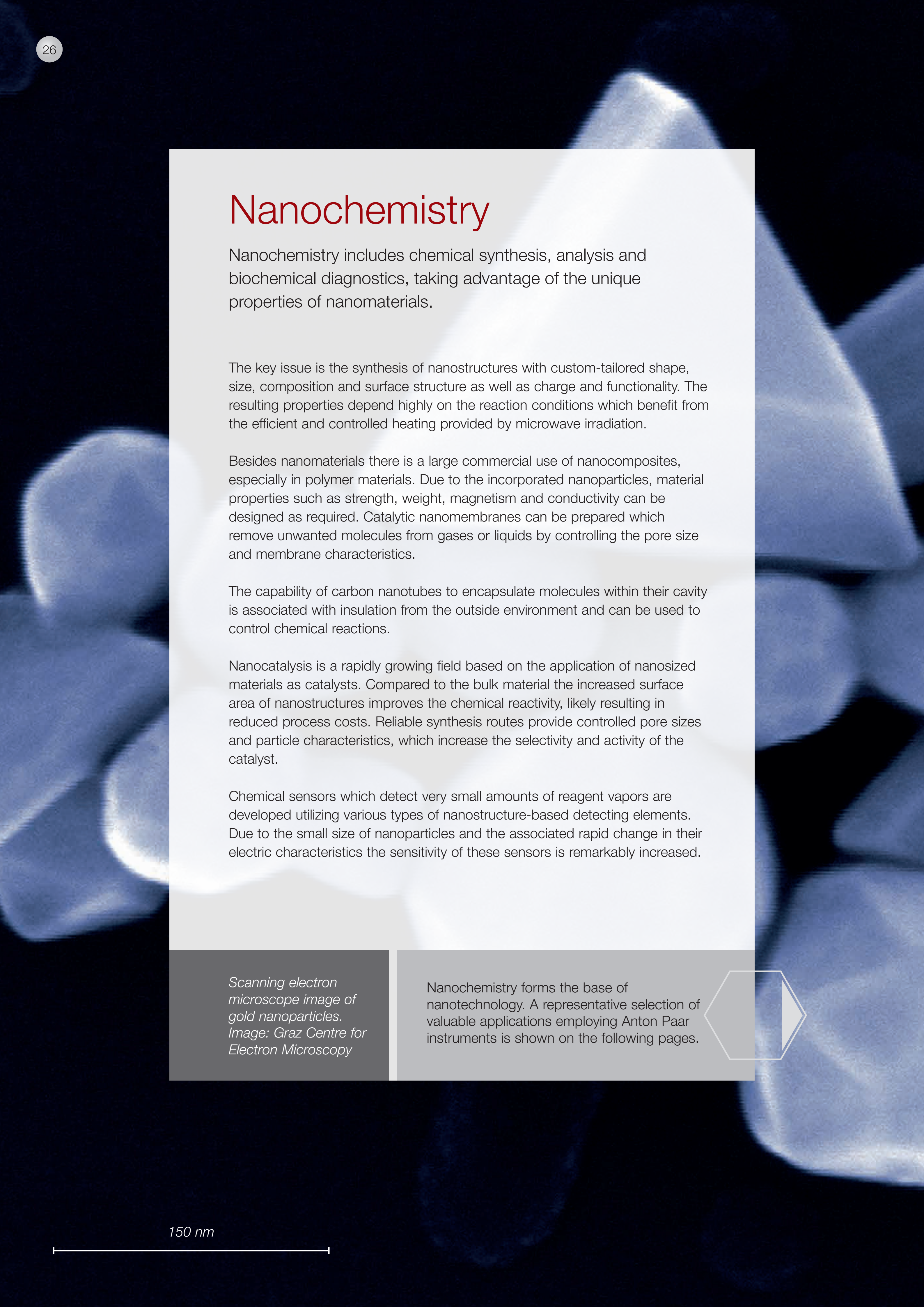
The key issue is the synthesis of nanostructures with custom-tailored shape, size, composition and surface structure as well as charge and functionality. The resulting properties depend highly on the reaction conditions which benefit from the efficient and controlled heating provided by microwave irradiation.

Besides nanomaterials there is a large commercial use of nanocomposites, especially in polymer materials. Due to the incorporated nanoparticles, material properties such as strength, weight, magnetism and conductivity can be designed as required. Catalytic nanomembranes can be prepared which remove unwanted molecules from gases or liquids by controlling the pore size and membrane characteristics.

The capability of carbon nanotubes to encapsulate molecules within their cavity is associated with insulation from the outside environment and can be used to control chemical reactions.

Nanocatalysis is a rapidly growing field based on the application of nanosized materials as catalysts. Compared to the bulk material the increased surface area of nanostructures improves the chemical reactivity, likely resulting in reduced process costs. Reliable synthesis routes provide controlled pore sizes and particle characteristics, which increase the selectivity and activity of the catalyst.

Chemical sensors which detect very small amounts of reagent vapors are developed utilizing various types of nanostructure-based detecting elements. Due to the small size of nanoparticles and the associated rapid change in their electric characteristics the sensitivity of these sensors is remarkably increased.



Scanning electron microscope image of gold nanoparticles. Image: Graz Centre for Electron Microscopy

Nanochemistry forms the base of nanotechnology. A representative selection of valuable applications employing Anton Paar instruments is shown on the following pages.

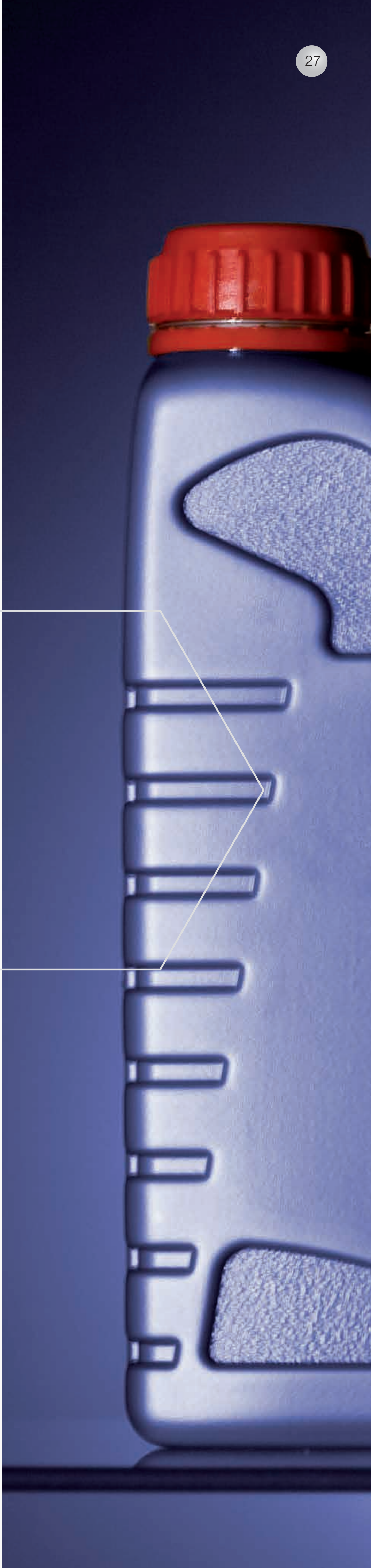
How can you obtain crude oil out of “empty” sources?

The MCR rheometer in combination with the high-pressure cell is a reliable tool for the determination of the rheological behavior of oils under high pressure.

Work under high-pressure conditions, such as exploring crude oil, is routine in the oil industries. Knowledge about rheological behavior under pressure is therefore essential.

After an oil field is conventionally exploited a large amount of crude oil still remains. This is trapped as oil droplets in the tiny pores and gaps of the surrounding rock. Nevertheless, there are some methods to reach parts of the remaining crude oil. One of them is the injection of nanoparticles to manipulate the viscosity and interfacial tension of the oil droplets in order to make them more fluid.

The MCR rheometer in combination with the high-pressure cell is useful for obtaining information about the behavior of mineral oils under varying pressure and temperature.



MCR rheometer and Pressure Cell

How do you design a polymer-nanocomposite with the properties you want?

SAXSpace provides access to the morphological behavior of inorganic fillers in polymers.

The performance of polymeric materials can be tuned using inorganic nanoparticles with different morphologies as fillers. The aim is to improve the thermomechanical properties as well as to achieve electrical conductivity, thermal conductivity and selective permeability.

Surface-modified layered silicates are of great interest for the modification of polymeric materials. The characterization of the morphology of the nanoparticles and their degree of dispersion are important aspects in developing such nanocomposites.

The morphological behavior of layered silicates which are dispersed in a polymeric matrix can be characterized by small-angle X-ray scattering. The degree of intercalation and exfoliation can be estimated and the processing conditions and material used can be optimized according to the results.

SAXSpace

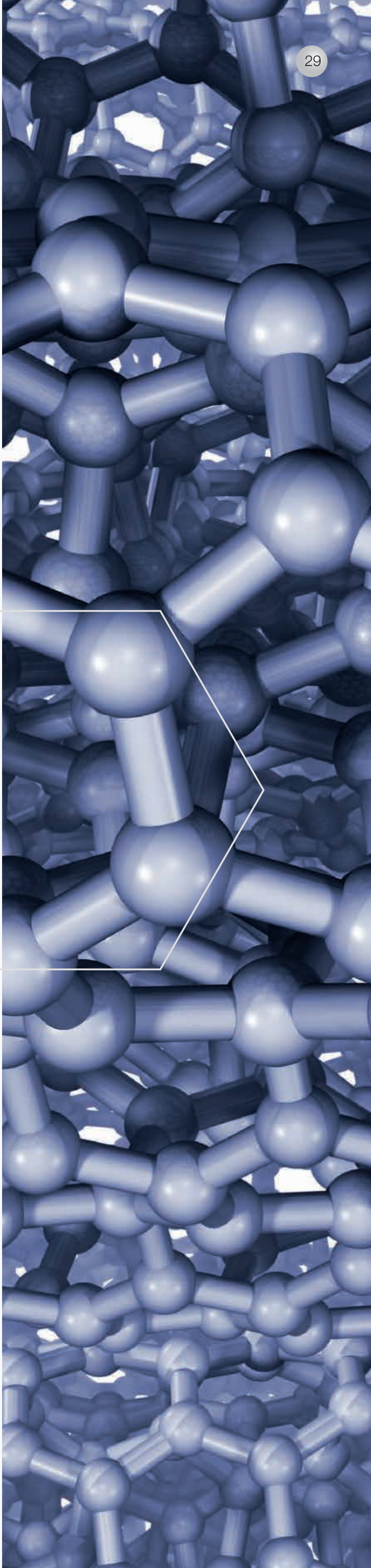
How can you reliable digest carbon nanotubes?

Carbon nanotubes can be completely digested using microwave-induced oxygen combustion (MIC) employing Multiwave PRO.

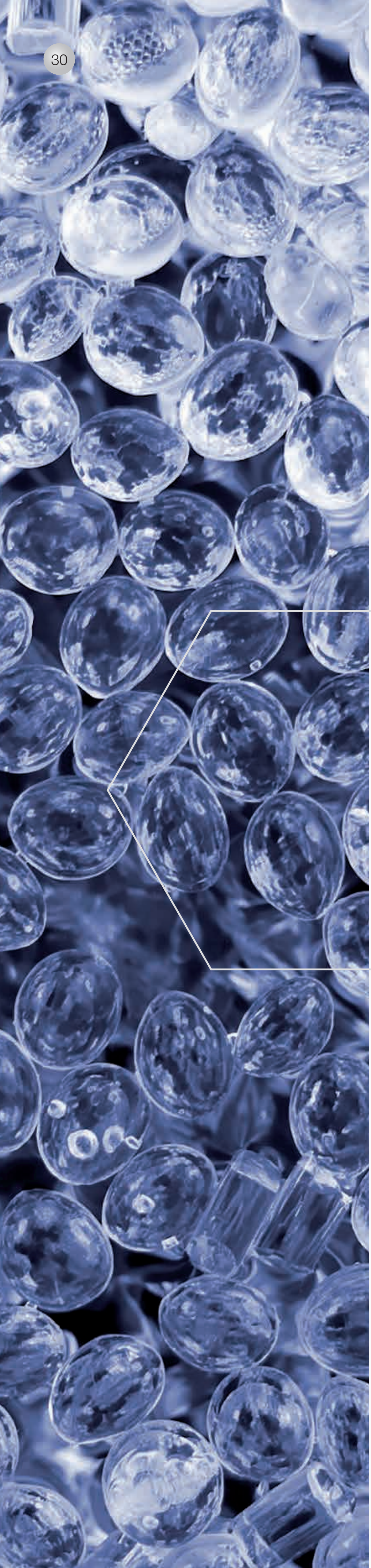
Synthesis of carbon nanotubes (CNTs) is commonly performed by chemical vapour deposition, arc discharge or by the high pressure carbon monoxide method. CNTs prepared with these procedures are frequently contaminated by the residues of metal catalysts used in the production process.

Metal contaminations may influence the properties of CNTs, changing their electronic or toxic behaviour. The accurate analytical determination of those low concentrations of metal contents requires the complete digestion of CNTs, which is a difficult task by conventional acid wet digestion.

Microwave-induced oxygen combustion in Multiwave PRO combines the advantages of combustion and closed-vessel acid digestion in one run demineralizing the sample totally. MIC is the ideal method for digesting carbon based materials such as carbon nanotubes.



Multiwave PRO



How can you easily prepare uniform nanoparticles?

Microwave-assisted synthesis is fast, simple and provides highly uniform nanoparticles, as can be verified with XRD and SAXS.

Size, shape and dimension clearly affect the properties of nanomaterials. Therefore, development of reliable synthesis methods giving defined structures is of considerable interest.

Rare earth compounds are widely used in industry as catalysts, optical devices or in other valuable composites. Therefore, preparing these compounds quickly in nanostructure form allows generation of highly functionalized materials.

Doped rare earth oxide nanoparticles can be prepared via an easy and efficient one-step single-vessel microwave hydrothermal synthesis route. Analysis of the obtained materials can be performed by X-ray diffraction (XRD) and/or small-angle X-ray scattering (SAXS).

Monowave 300 and MAS 24

Are nanomaterials the solution for hydrogen storage?

The XRK 900 and HPC 900 sample chambers for in-situ X-ray diffraction (XRD) allow investigations at elevated temperatures and pressures.

Hydrogen is assumed to be an ideal fuel: it is abundant, renewable and the combustion products are only water vapor and heat. It is not an energy source, but an effective energy carrier. However, the storage of hydrogen gas is still a challenge, especially on board an automobile.

The extraordinary mechanical, thermal and electrical properties of nanostructured carbon materials make them extremely interesting, not only as polymer nanocomposites but also as potential media for hydrogen storage.

In-situ X-ray diffraction studies using Anton Paar sample chambers can be performed to investigate the catalytic chemical vapor deposition synthesis of graphitic nanofibers and to evaluate their potential for hydrogen storage.

HPC 900

Monowave 300 – Monomode Microwave Synthesis Reactor

Monowave 300 provides the highest reliability and the most extended operation limits for microwave synthesis at the R&D stage. It can be upgraded at any time with the 24-position autosampler unit MAS 24.

- Rapid and efficient heating with 850 W installed microwave power
- Reaction conditions up to 300 °C and 30 bar
- Simultaneous internal and external temperature measurement
- Utmost accuracy and reproducibility
- High-performance magnetic stirrer
- Proven scalability of optimized reaction protocols

For applications see Page 18, 24, 29, 30

Detailed information:

MCR – The Modular Compact Rheometer Series

The MCR rheometers can be used to describe the deformation and flow behavior of all types of materials.

- Air-bearing-supported synchronous motor ensures high efficiency, large torque range and fast response time
- Excellent speed control over more than 9 decades
- Precision air bearing for accurate measurements at low torques
- Toolmaster™ – automatic recognition of measuring systems and accessories
- TruGap™ – patented monitoring and control of the measuring gap
- The quick-fitting coupling ensures easy exchange of accessories

For applications see Page 10, 16, 19, 22, 27

Multiwave Pro – Microwave Reaction Platform for Digestion, Synthesis, Extraction

The versatile Multiwave PRO microwave reaction platform provides various rotor types for excellent trace analysis results and parallel synthesis on different scale.

- Two magnetrons providing 1700 W installed microwave power
- Installation-free wireless p/T sensor technology
- Exceptional reaction conditions up to 300 °C and 80 bar
- From reaction screening to gram scale library generation by simply simple rotor switch
- Unique microwave-assisted applications, e.g. oxygen combustion

For applications see Page 18, 24, 29, 30

Masterwave BTR – Large-Scale Microwave Synthesis

The Masterwave BTR for the first time successfully transfers microwave synthesis to the kilolab, providing a 1 L reaction vessel for efficient batch-type processing.

- Revolutionary technique providing 1700 W microwave output power from two magnetrons
- Bayonet-locked PTFE reaction vessel with integrated paddle stirrer
- Common reaction conditions up to 250 °C and 30 bar
- Precise reaction control by rising Pt100 temperature sensor
- Seamless method transfer from Monowave 300
- Proven kilogram productivity for industrial applications

For applications see Page 18, 24, 29, 30

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DMA 5000 M – Density Meter

The DMA 5000 Generation M is the most accurate density meter for liquids on the market.

- Density measurement with an accuracy of 0.000005 g/cm^3
- Highly reproducible results
- FillingCheck™ – automatic detection of filling errors
- U-View™ – the filling process of the sample can be checked on the screen
- Meets the requirements of the 21 CFR Part 11, cGMP/GLP, GAMP 5 and USP <1058>
- Built-in high-precision platinum thermometer

For applications see Page 21, 23

Lovis 2000 M/ME – Microviscometer

Lovis 2000 M/ME can be applied for high-precision viscosity measurements of low-viscosity substances. It is based on the approved rolling ball principle.

- High repeatability and reproducibility
- Extremely small sample volume required
- Closed measuring system means no sample/air contact
- Variable inclination angle of the capillary enables automatic zero-shear-rate viscosity determination
- Quick and precise heating and cooling
- Excellent chemical resistance
- Sample changer for automatic measurements of up to 96 samples

For applications see Page 21, 23

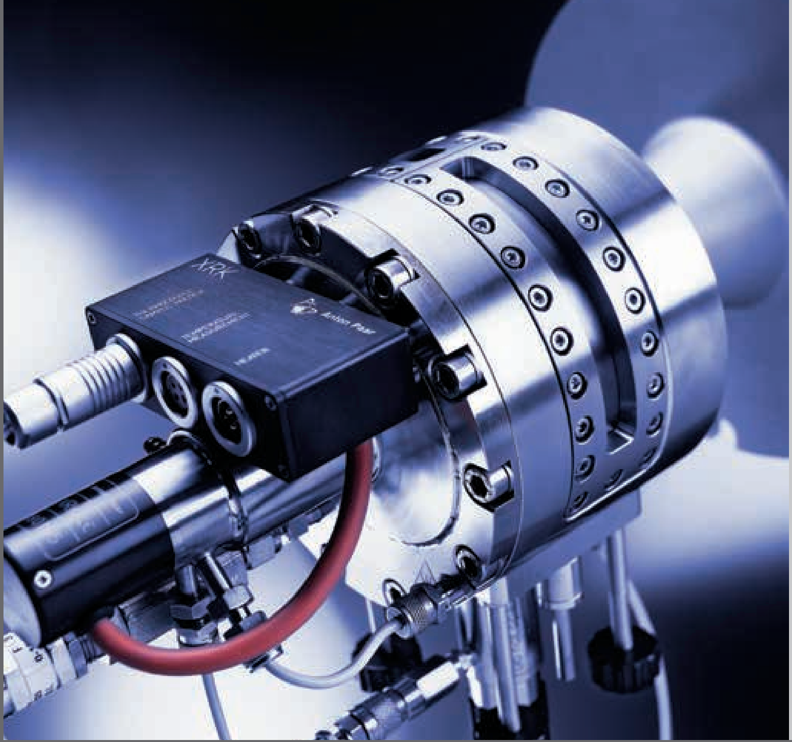
Contact:

SurPASS – Electrokinetic Analyzer for Solid Samples

SurPASS provides the zeta potential of solid surfaces and gives insights into the charge and adsorption characteristics at the solid/liquid interface.

- High sensitivity
- Integrated titration unit for fully automated pH-dependent studies
- Time-resolved measurements
- Calibration-free electronics
- Versatility due to various measuring cells
- Non-destructive investigation of solid surfaces
- Easy operation
- Maintenance-free electrodes

For applications see Page 11, 12, 25



XRK 900 / HPC 900 – Non-ambient XRD Attachments

The XRK 900 and HPC 900 are members of the family of non-ambient heating and cooling attachments for X-ray diffraction supplied by Anton Paar.

- High quality, high reliability and ease of use
- Compact design
- Fits on all common diffractometers
- Furnace heater guarantees excellent temperature uniformity in the sample
- Reliable measurement and control of the sample temperature
- Allows investigations in various atmospheres and at different pressures
- Homogeneous gas atmosphere without dead volumes

For applications see Page 31

SAXSpace – Modular Solution for Nanostructure Analysis

The SAXSpace is a small- and wide-angle X-ray scattering system used for the determination of structure, size and shape of nanoparticle systems.

- Compact system for fast measurements
- Easy operation and handling, automatic alignment
- Excellent resolution for nanostructures with a size of 0.12 to 200 nm
- Full experimental flexibility: precise temperature control, humidity-dependent studies, GI-SAXS studies of nanostructured surfaces and more
- Autosampler for high-throughput screening of liquids and solids
- Powerful data acquisition and evaluation software

For applications see Page 13, 17, 19, 24, 28, 30

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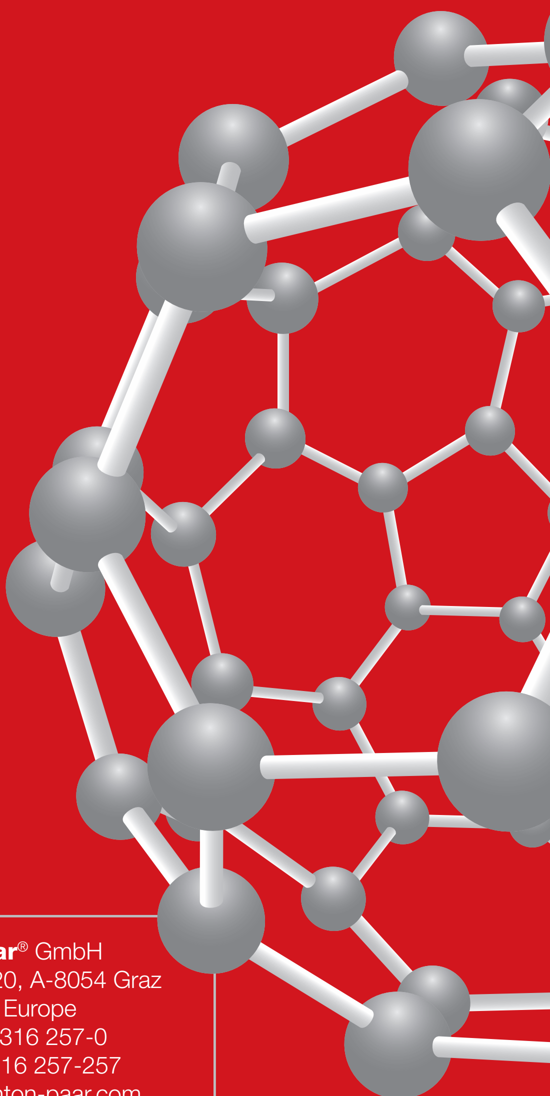
Abbemat – Refractometer Series

The Abbemat refractometer provides quick and reliable refractive index measurements at multiple wavelengths (optional) for all kinds of samples.

- High-precision measurement
- Wide range of refractive indices from 1.30 nD to 1.72 nD are detectable
- Measurements at multiple wavelengths
- High-temperature measurements up to 110 °C (optional)
- Required sample volume of only a few microliters
- Temperature accuracy of 0.03 °C
- Non-destructive method
- No sample preparation necessary

For applications see Page 9, 15



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