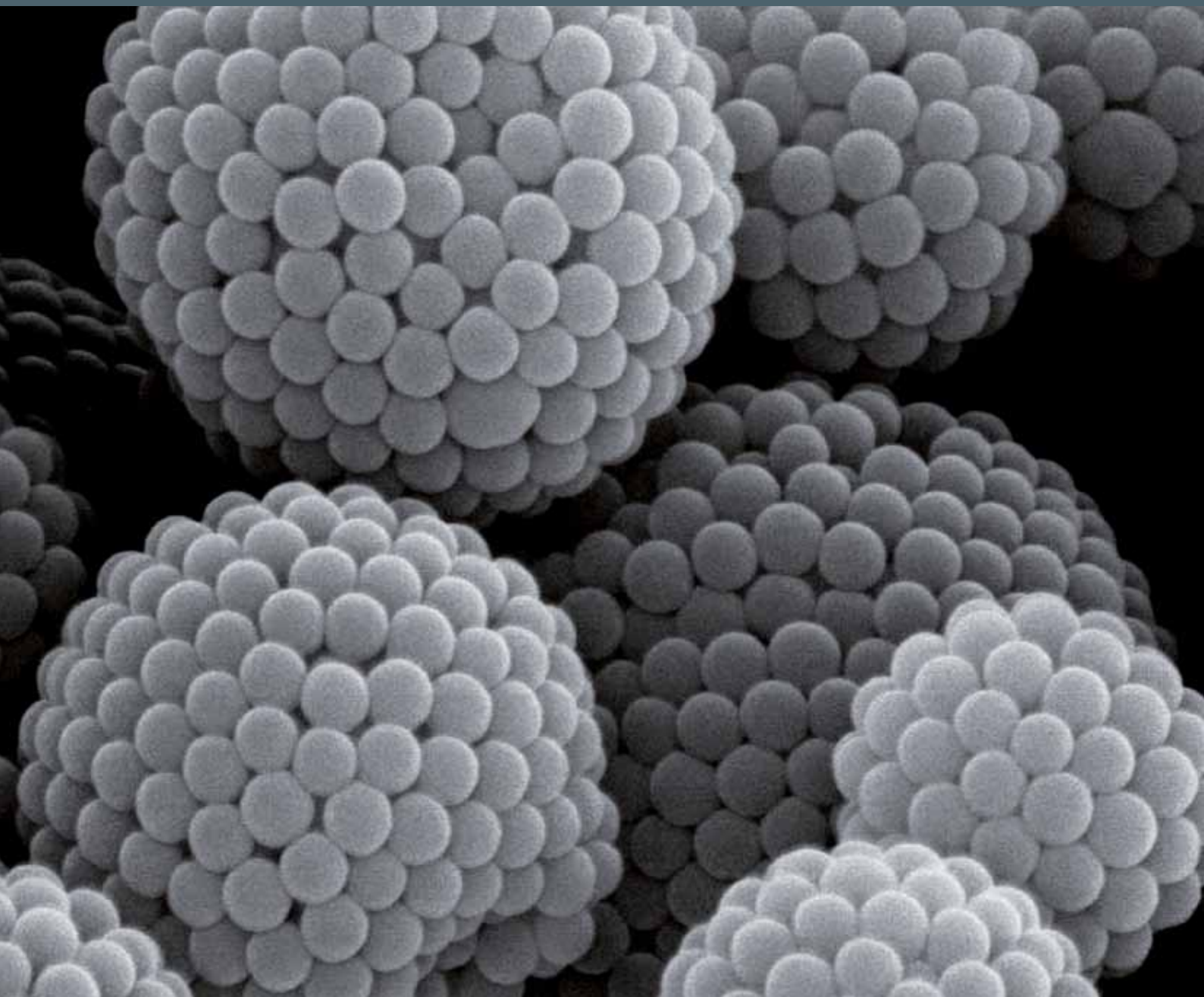




**Fraunhofer**

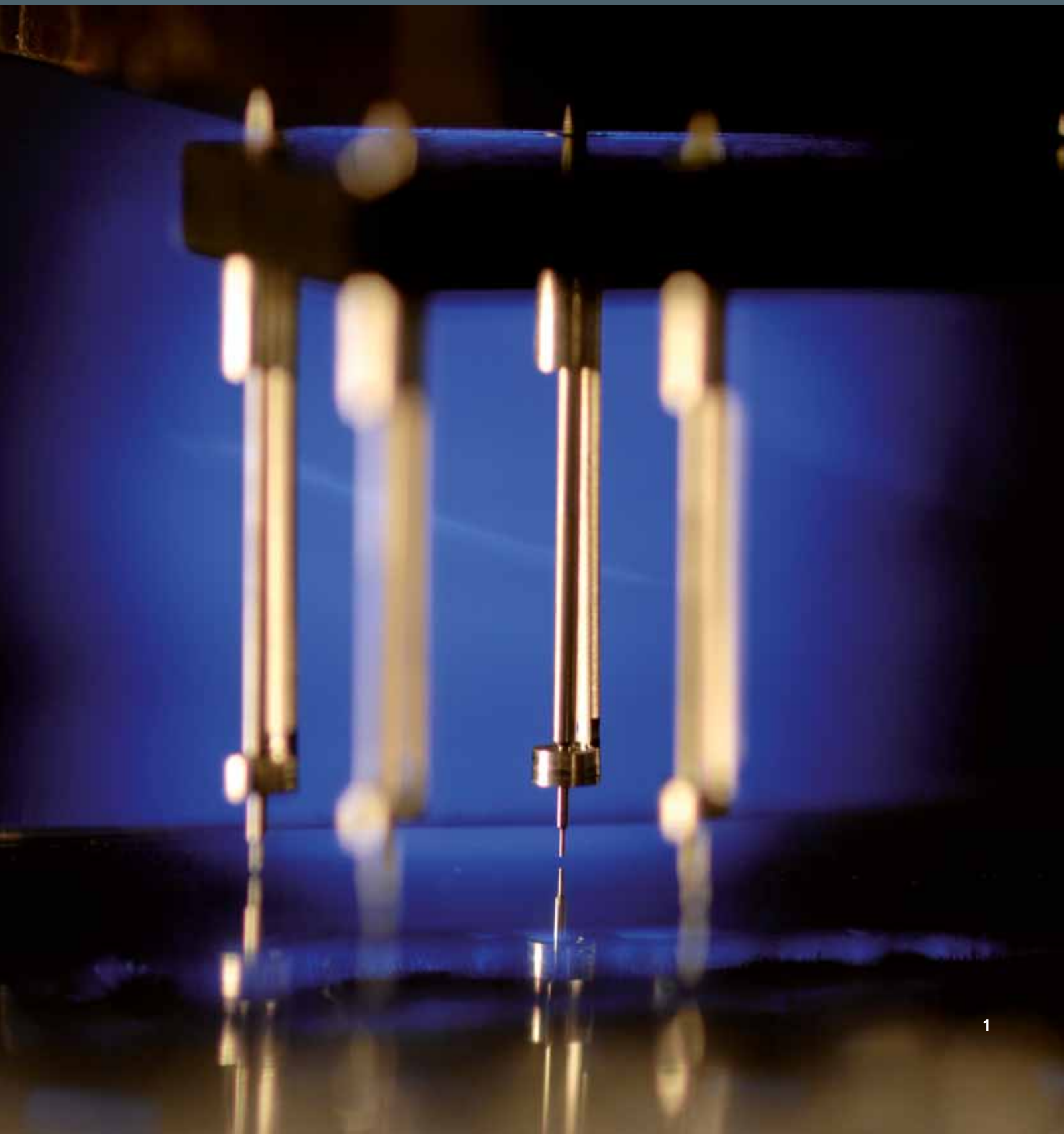
**NANOTECH**

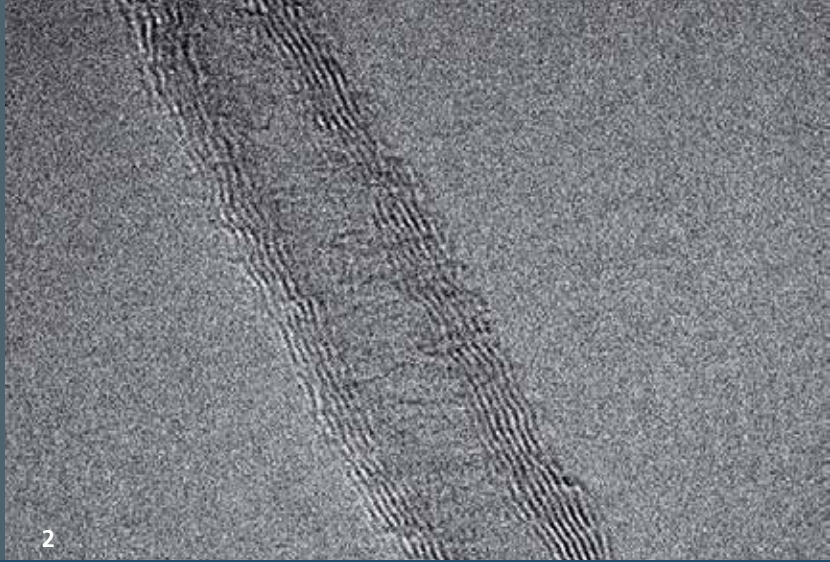
**FRAUNHOFER NANOTECHNOLOGY ALLIANCE**  
**MAKING SMALL THINGS WITH GREAT EFFICIENCY**



# FRAUNHOFER R&D

EXPERTISE AND EXPERIENCE FOR YOUR  
NANOTECH PROJECTS





# NANOTECHNOLOGY – THE GATEWAY TO THE FUTURE

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## NANOTECHNOLOGY

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Nanotechnology is a key technology for the 21st century and is having a rapidly increasing impact on all sectors of industry. This technology deals with materials and systems with size features below 100 nm in at least one dimension: nano-coatings are nanostructured in one dimension, nanotubes in two and nanoparticles in three dimensions. Open your portfolio to the future by manufacturing, processing or employing nanomaterials. Use the skills of our experts to take advantage of surface effects, specific optical properties or quantum-size effects.

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## FRAUNHOFER NANOTECH

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Fraunhofer is Europe's largest application-oriented non-profit 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 give form to the future.

More than 20 Fraunhofer Institutes work in the field of nanotechnology and together they form the Fraunhofer NANO-TECH alliance. This alliance opens the gateway to nanotechnology for you. Together with us you can improve your nanotech performance, and discover and access your nanotech potential. Get in touch with us and experience what we can do for you – and your business of tomorrow.

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## NANOTECH COOPERATION

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The experts of Fraunhofer NANO-TECH carry out most of their projects on behalf of clients in industry. We develop your future business within the scope of projects and contract research. In publicly funded collaborative projects we arrange and coordinate project consortia on a national and international scale. We develop an individual roadmap to innovative R&D together with our partners from industry and the scientific community. Publicly funded basic research is the foundation of the contract research we conduct on behalf of our clients. By carrying out market-oriented strategic research we are continuously sharpening our profile as a business-oriented research partner for our clients. Fraunhofer NANO-TECH is the research alliance you can rely on.

**FRONT PAGE** *Spray-dried silica particles. Fraunhofer ISC*

**1** *Printing nanomaterials. Fraunhofer IGB*

**2** *Multiwall carbon nanotubes. Fraunhofer IKTS*





# IN THE BEGINNING IS THE MATERIAL

## NANOMATERIALS

Nanomaterials provide tailor-made properties based on their nanostructure and result in improved or new performance. New markets can be opened with these materials and products will be upgraded. Usually nanomaterials are divided according to their dimensionality and the degree to which they are confined in one, two or three dimensions. Nanocoatings or nanolayered materials are nanostructured in one dimension (1-D). Nanotubes, nanowires, nanorods, or laterally nanostructured surfaces are materials nanostructured in two dimensions (2-D). Materials such as particles, nano-powders, fullerenes or quantum dots are confined in all three dimensions. The combination of size features and individual properties may turn nanomaterials into the hidden champion of your product.

## SYNTHESIS

Today's and tomorrow's nanomaterials must be synthesized using efficient production routes. Top-down approaches to nanomaterials cover nanostructuring of materials by physical shaping or chemical treatment such as milling or lithography. Bottom-up synthesis permits the design and production of a new material starting with the sketch. Nanomaterials are synthesized by chemical processes or self-assembling of nanoscale building blocks. Fraunhofer NANOTECH is your expert partner

for synthesis throughout the value creation chain. This includes developing new synthesis routes for the nanomaterials required or enhancing the efficiency of your synthesis route.

## PROCESSING

Nanofabrication is more than the synthesis of nanoscaled matter. Creating ready-to-market products in efficient ways is necessary in nanomanufacturing. Manifold processing routes lead to the assembly of nanostructured building blocks to create systems. Fraunhofer's know-how of all the relevant techniques is employed in order to generate nanosystems. Our experienced experts guide you through a jungle of opportunities. Depending on your needs, they develop new nanofabrication routes or increase the performance of your process and improve reliability. The results are integrated nanomanufacturing routes combining synthesis and processing that result in nanostructured products.

- 1 *Nanocoated bearing. Fraunhofer IKTS*
- 2 *Sol-gel-based nanochemistry. Fraunhofer ISC*
- 3 *Bead mill for particle dispersion. Fraunhofer IFAM*
- 4 *Polymer film with nanostructured diffusion barrier. Fraunhofer IVV*





# EXPLORING OPPORTUNITIES

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## ANALYSIS

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With modern methods of analysis we can reveal the structure of materials down to the very last detail. We assess interfaces and surfaces using up-to-date analytical techniques, we identify possible modes of failure and highlight the accessible potential for improvement. In order to characterize materials and components, we investigate reactions to mechanical, thermomechanical and electromechanical loads and identify deformation and failure mechanisms. We determine the stress limits of materials and components, and estimate their lifetime and reliability. Our experts carry out damage analysis and develop strategies to avoid future impairment. Relevant data is recorded and assessed on a large scale and correlated in order to generate microstructures and structural processes. Local variations in material properties are accounted for during component testing.

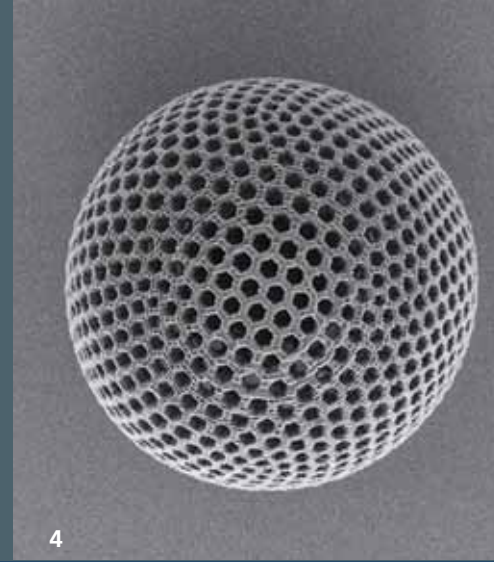
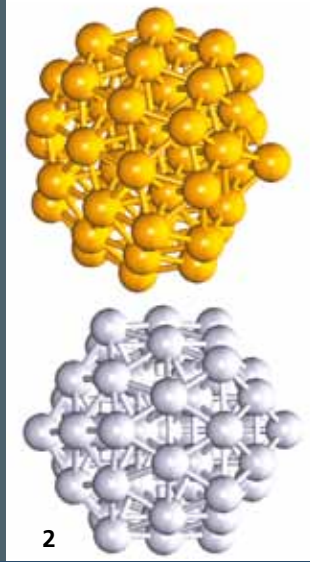
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## MODELING

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We model load scenarios and processes for existing nanomaterials, nanocomponents and nanosystems that are already on the market or currently being developed. This approach permits the economical development of materials or components and enhanced processes. Our expertise is the description of deformation, damage and failure behavior of materials – under various loading or operational conditions. Our simulations provide information about component safety and lifetime. Our process simulations help our clients and partners to improve their tool design in line with subsequent operating conditions and to upgrade the process controls. We model nanomaterials on different scales – multiscale modeling – and measure specific properties by linking and combining various simulation methods. We perform complex numerical simulations in our “virtual lab” and use our “virtual microscope” to predict the properties of materials.





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## CHARACTERIZATION

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Characterization of materials and also the control and monitoring of production processes and industrial plants or components is another important task for Fraunhofer NANOTECH. Our methods are used in industrial applications whenever quality assurance and proof of technical safety are required. The methodological expertise comprises the physical fundamentals, sensor technology, test instrument design and manufacturing. It includes techniques for data evaluation and documentation. In addition, it covers the qualification and validation of new inspection and testing procedures including instrument and system maintenance, staff training, and inspection and testing services.

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## TECHNOLOGY EVALUATION

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FRAUNHOFER NANOTECH supports your future developments with projects ranging from feasibility studies through market analyses to trend forecasts. We support you in your strategy development by dealing with process design and/or organizational requirements. By using an integrated approach – and by ensuring an interdisciplinary mix within our project teams – we are able to develop concepts and strategies that combine perspectives from a range of disciplines in order to create extraordinary potential and opportunities. Our proximity to

applied research and our ability to transfer scientifically-based methods and procedures to operational practice provides us with an innovative edge that allows us to solve highly complex issues. The benefits for our partners are measured primarily in terms of innovation, efficiency and quality improvements. Our activities are supplemented by an extensive range of qualification and training measures, seminars, forums and workshops, as well as customer-specific training courses.

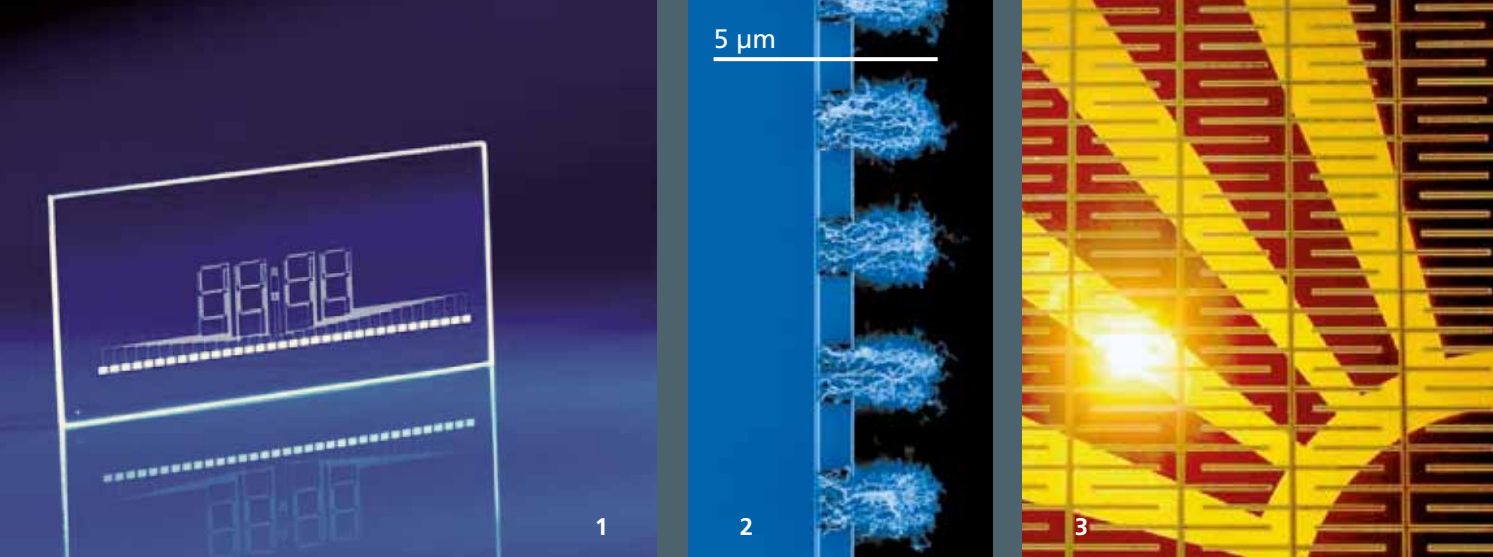
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## NANOMANUFACTURING TECHNOLOGIES

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Micro- and nanoscaled devices require new manufacturing technologies. Our approach to nanofabrication includes new concepts, machines, tools as well as materials for both tools and work pieces. Fraunhofer NANOTECH develops the corresponding new manufacturing strategies and the necessary equipment.

- 1 *Nanocoding. Fraunhofer IFAM*
- 2 *Modeled metal nanoclusters. Fraunhofer IWM*
- 3 *Nanostructured low-drag coating. Fraunhofer IFAM*
- 4 *Photostructured hybrid polymer sphere (CAD-file: [www.georgehart.com/lrplrp.html](http://www.georgehart.com/lrplrp.html)). Fraunhofer ISC*



# MEETING THE REQUIREMENTS

## ELECTRONICS

The evolution of microelectronics is characterized by continuous miniaturization towards nanoscale dimensions and functionality. Ever more demanding requirements concerning costs, performance, reliability, and the lifetime of the electronics components are key issues that have to be faced today. At the same time, the functionalities and application fields of microelectronic devices are broadening enormously. Fraunhofer NANOTECH provides the necessary innovations to meet these challenges. We tailor new materials, such as high-quality semiconductor crystals and layers or carbon nanotubes (CNTs). We focus on the development and optimization of equipment and processes, and the integration of novel materials into established manufacturing lines. This is backed up by advanced metrology and simulation tools. Materials for power electronics and printed electronics are further fields of activity that we specialize in.

## OPTICS

Nanotechnology opens up the path to advanced optical products such as transparent functional coatings. Fraunhofer NANOTECH meets the requirements of our partners for optical components by developing new production technologies and transferring these to production processes. Other fields of activity are industrial optical metrology, ultraprecise surface finishing and optical crystals for lenses or detectors.

## ENERGY

Fraunhofer NANOTECH's research and development activities cover the entire value chain for processes that consume less energy, from materials necessary for this low-energy consumption to innovative energy management. Our innovations in nanotechnology increase the efficiency of energy-consuming processes. Transportation requires less energy by using high performance lightweight nanocomposite materials. Energy-efficient buildings are made possible due to improved materials such as nanostructured thermal insulators. Efficient ther-





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moelectrical systems permit optimized heat management. Nano-LEDs produce more light with less energy. The effectiveness of combustion processes is increased by high-performance ceramic materials. Our experts deal with silicon photovoltaics from materials development and crystallization through solar cell development to module technology. Our dye solar cell technology opens up new possibilities for design and our expertise in hydrogen storage and fuel cell technology helps to achieve efficient energy management.

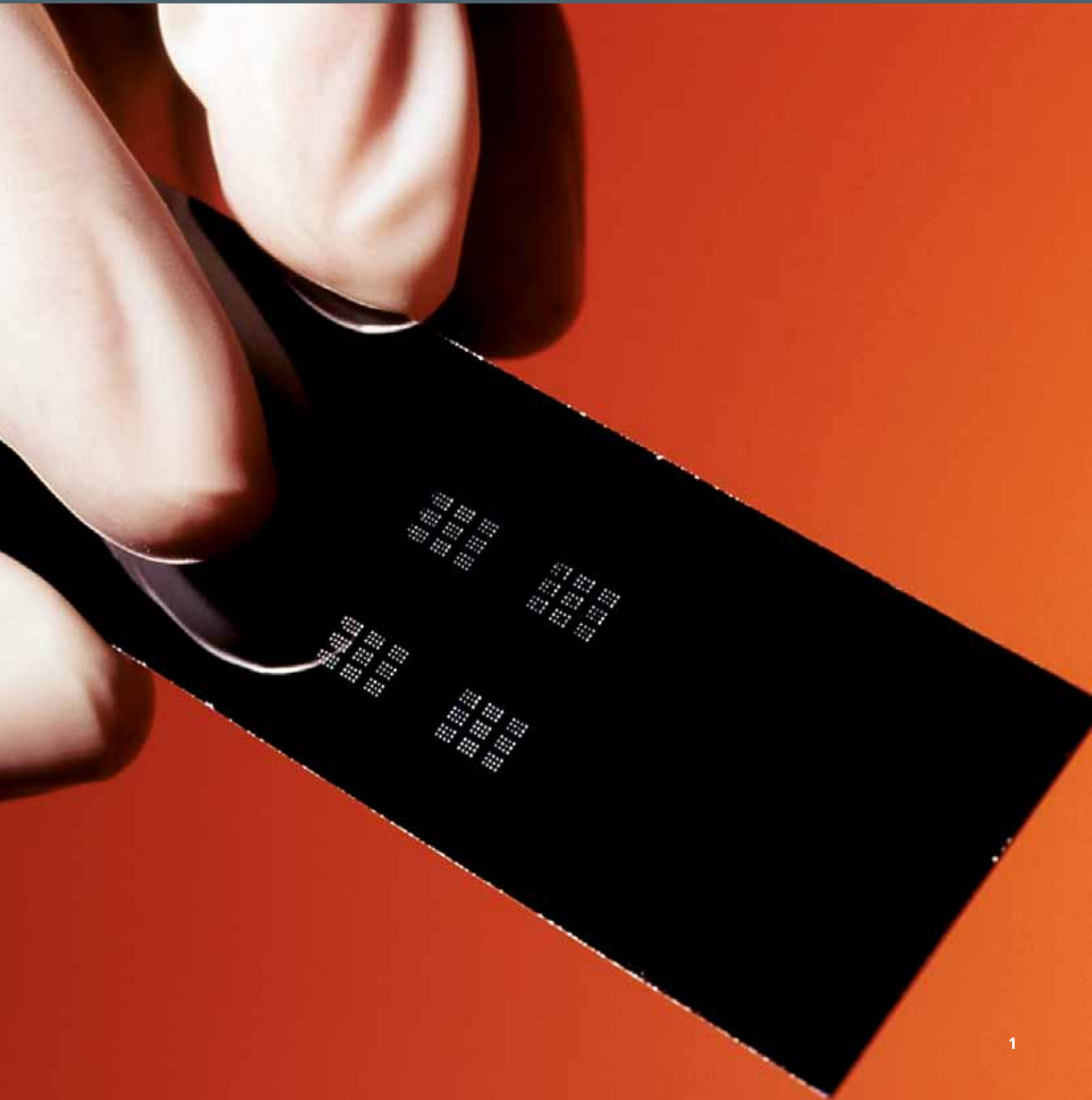
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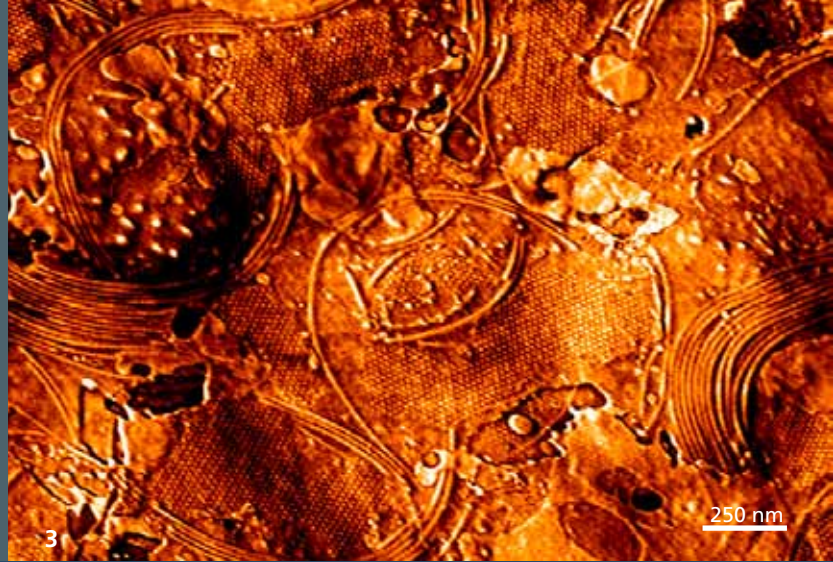
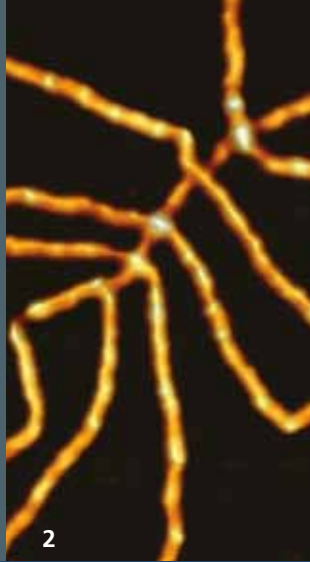
## ENVIRONMENTAL TECHNOLOGY

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From our point of view nanotechnology has become a key factor in modern environmental technology. Our innovative membrane technology insures effective water management. Easy-to-clean surfaces as well as antireflective coatings mean that energy is not wasted. Nanostructured coatings provide protection from degradation by UV light or by corrosion. Scratch-resistant surfaces both reduce mechanical damage and also make possible new processes.

- 1 *Printing with nanoinks. Fraunhofer IFAM*
- 2 *CNTs for interconnects in integrated circuits. Fraunhofer ENAS*
- 3 *Dye solar cell. Fraunhofer ISE*
- 4 *Transparent spinel ceramics. Fraunhofer IKTS*





# SOLVING TOMORROW'S QUESTIONS

## BIOTECHNOLOGY

Biotechnology is a rapidly growing industrial sector. It provides us with novel pharmaceuticals as well as with sustainable raw materials from plants. Biochips and biosensors are indispensable in modern biotechnology. Genomics, proteomics and cellomics – all based on nanotechnology – minimize the time and resources needed for breakthrough discoveries for efficient enzymes, specific diagnostic markers or protein therapeutics. Our experts cover the full range of nanobiotechnology: surface technology renders biochip surfaces bioactive, physical transducer systems transmit the signal and bioinformatics deal with the complexity of information.

## MEDICAL TECHNOLOGY

Medical technology will be revolutionized by nanotechnology. Medical implants will become bioactive by means of cell-communicating surfaces. Regenerative medicine will provide us with organ replicas which will be constructed from cells originating from patients themselves. The cells for the replicas are grown and cultivated in tailor-made nanostructured materials. What sounds like science fiction is already being realized at Fraunhofer. Be part of the revolution and join us as a partner.

## HEALTH

Nanotechnology has all the potential to provide the means to fight diseases – both by a rapid and affordable diagnosis and by providing efficient drug delivery right at the point of need in the body. Drug delivery systems are increasingly based on nanostructured materials. Fraunhofer NANOTECH today opens up the way to tomorrow's diagnostics and therapeutics.

## SAFETY

Consumers and their health are important to us. Our know-how enables our industrial partners to produce substances with minimized hazard potential by taking into account the entire lifetime chain – from materials in production, in use, and afterwards. We cover nanotoxicology following inhalational, oral or dermal exposure using in vitro and in vivo assays, the investigation of toxicokinetics or with our test systems based on 3-D tissue engineering employing state-of-the-art artificial organs and testing by ISO standard procedures. Nanosensors to discover harmful substances are also increasing your safety. In addition, we are ready to carry out process reliability studies along almost any value-generating production chain.

- 1 3-D biochip by nanoparticle technology. Fraunhofer IGB
- 2 Dendritic protein nanostructure. Fraunhofer IWMH
- 3 Nanolayer made from silk fibrils. Fraunhofer IWMH



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