Fraunhofer
IKTS

FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

BUSINESS DIVISION

BIO- AND MEDICAL TECHNOLOGY

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BIO- AND MEDICAL TECHNOLOGY

Fraunhofer IKTS has for many years been a reliable partner in the development of medical implants, surgical instruments and the latest methods in testing, characterization and analytics in life sciences.

Ceramics, biology and diagnostics – based on these fields of competence, Fraunhofer IKTS supports the development of innovation in medicine and medical technology. The researchers use their outstanding technical infrastructure with certified labs. Quality, cost and regulatory requirements are the criteria on which the research efforts are focused.

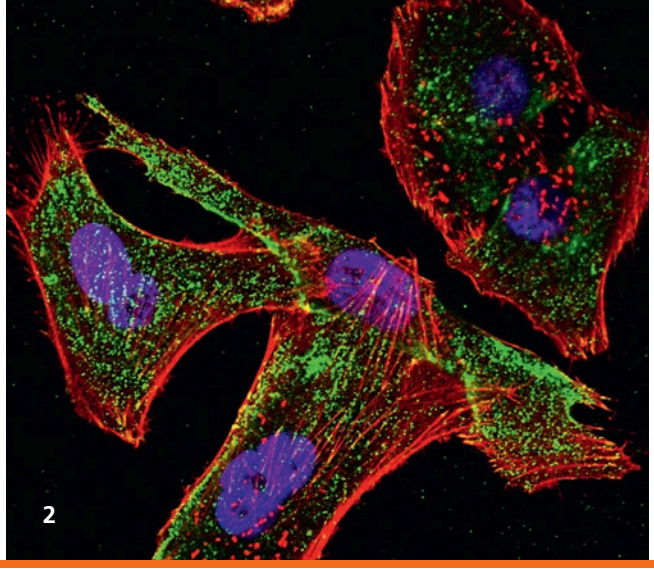
At IKTS, interdisciplinary teams from the fields of materials science, immunobiology and diagnostics work together on existing and new generations of implants. Based on commercially available materials, the scientists develop new ceramic materials and components with improved mechanical, aesthetic and biological properties.

The researchers support projects as required by the client – from material development and selection to shaping, functionalization and biological in vitro assessment. Sophisticated characterization and analytics round off the overall range of services for our partners in industry and scientific institutions. This makes it possible to shorten development times and identify potential risks at an early stage. Our comprehensive skills with regard to evaluating ceramic materials and components (e.g. for particle design, microstructure and tribology) enable targeted improvements of structural and property relationships.

The teams make use of biological material analytics, enabling them to arrive at additional statements on the degradation behavior and immunological reactions under in vitro conditions. In this context, the researchers use specifically developed measuring and test methods not just for internal quality assurance alone: they also make these available as specific service and system developments for ceramics and other types of materials.

To respond to the challenges of an aging society, Fraunhofer IKTS conducts preparatory research aimed at continuously optimizing the properties and functionality of the next generation of implants.

At the center of these research efforts are novel manufacturing routes for patient-specific medical products using additive manufacturing, as well as the functionalization of implants and implant surfaces through constructive and actuator- or sensor-based elements. The researchers oversee the complete process, from technical feasibility through to the valid, reproducible final product. They design and develop the required inline-capable test technologies, as well as analytical systems for medical applications.



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RANGE OF APPLICATIONS

Implant ceramics

The researchers at Fraunhofer IKTS develop preparation and shaping technologies for oxide ceramic and silicon nitride materials, for dental and orthopedic applications. All developments can be used for prototypes or targeted scaling up to the industrial scale.

One focus of dental and orthopaedic implants made of oxide ceramics is on new concepts and technologies for structuring the ceramic surface in the shaping process. The advantage is that it is no longer necessary to finish the sintered ceramics. For anatomical dental restorations a special TZ3Y ceramic material is available which boasts more translucency and higher wear resistance and is not subject to hydrothermal aging. In order to meet the aesthetic requirements for crowns or bridge frameworks, the dental restorations are coated with a lithium silicate spray, which forms a very intensive adhesive bond with the TZ3Y framework.

The manufacture of fine-grained dispersion ceramics (alumina toughened zirconia ATZ, zirconia toughened alumina ZTA) is also part of the service portfolio offered. The IKTS site in Hermsdorf is certified in accordance with ISO:2016 13485 for research and development in the field of oxide ceramic materials and components, material compounds and the manufacture of semi-finished products for medical engineering.

Material development

- Raw material selection
- Synthesis
- Powder and slip preparation

Technology

- Foaming, replica, slip casting technologies
- Thick-film and multilayer technology
- Surface structuring
- CAD/CAM
- Additive manufacturing
- High-temperature isostatic pressing

Functionalization

- Biofunctionalization
- Nanoparticle-based functionalization
- Topical (local) functionalization
- Plasma coating
- Sol-gel process
- Sensor/actuator components
- Printed electronics

Supporting analytics and characterization

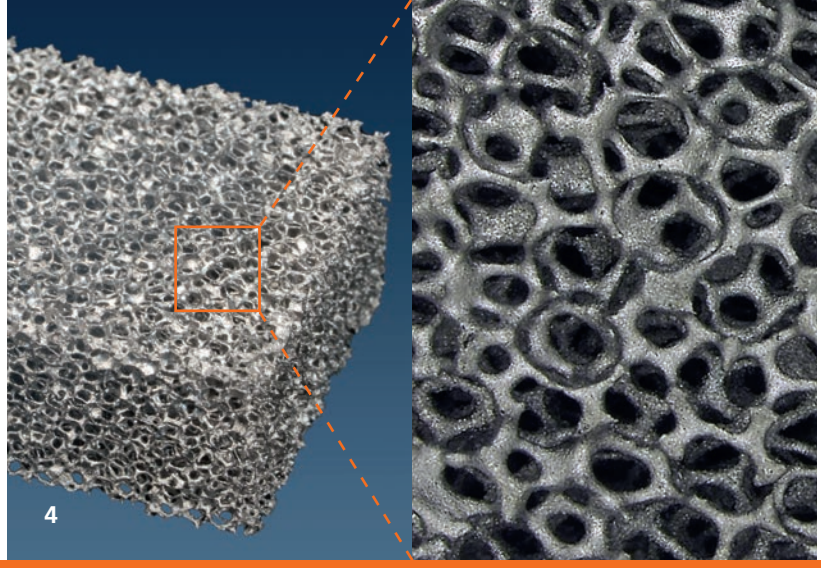
Physical, chemical test and diagnostic methods

- Bioelectrical, topography-based, acoustic and optical measuring systems
- Biophysical characterization
- In-line monitoring
- Structural analysis
- Tribological analysis
- Particle characterization
- Eddy-current spectroscopy

Biological material analytics

- Biodegradation
- Immunobiological diagnostic testing
- In vitro analytics
- In vivo analytics
- Diagnostics

Service portfolio and unique measuring technology



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Bone substitutes

Human bones consist of a large number of macro-, meso- and micropores with 100 to 700 µm in diameter. This porosity is especially important for the stability and integration of cells into the bone structure. The researchers of Fraunhofer IKTS produce precise porosities using various replica and placeholder methods or direct foaming techniques. Freeze foaming is one such unique type of direct foaming. It is used to produce potential bone substitute material from materials that are similar to the human body, such as hydroxylapatite or tricalcium powder [$Ca_5(PO_4)_3(OH)$, $Ca_2(PO_4)_3$], allowing the decomposition of the artificial material as the endogenous tissue rebuilds. Bioinert materials such as Al_2O_3 or ZrO_2 may also be used for long-term stable implants. Fraunhofer IKTS evaluates and uses new approaches, such as additive manufacturing, in order to produce patient-specific biomimetic bone structures.

Surgical instruments and components

Ceramic materials are not only wear-resistant, biocompatible and chemically inert, their electric conductivity can also be precisely configured. This enables creative approaches for functionalized surgical instruments and various components in medical engineering: high-precision ceramic cutting materials and instruments that clamp and sclerose in one step, or ceramic springs for x-ray machines. Ceramic materials come into their own where other materials fail.

Diagnostic/therapeutic systems and characterization

When it comes to developing novel, patient-specific implants, for instance with biofunctionalized material surfaces, reliable standard operating procedures (SOPs) are paramount. They alone allow to assess beforehand the biological and immunobiological safety and functionality of the materials for their intended purpose.

Fraunhofer IKTS develops innovative in vitro test methods as well as standardized testing systems. In addition to the biological testing of ceramics and other implant materials in accordance with DIN EN ISO 10993, Fraunhofer IKTS also develops immunological compatibility tests. The conversion of experimental test approaches into client-specific, standardized test procedures is part of the service portfolio.

Furthermore, the researchers develop, in close cooperation with industry partners, innovative analysis technologies, sensors and devices to reliably and accurately detect biomedically relevant measured variables.

1 *Patented in vitro test system for biomaterials.*
2 *Osteoblasts on silicon nitride (actin/vinculin/DAPI).*
3 *Coated forceps tips.*
4 *Titanium foam for implants.*
5 *3D visualization of a tooth using optical coherence tomography.*

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COMPETENCES

Ceramic materials and surfaces

- High-purity dense or porous bioceramics [Al_2O_3, ZrO_2 (ATZ, ZTA, Y-TZP), $Ca_3(PO_4)_2$), HAP, Si_3N_4]
- Open-cell foam ceramics and metal foams
- Glass and glass ceramics
- Oxide and non-oxide ceramics with precise electric, thermal, mechanical and optical functionalities
- Composites and material compounds (porous/dense, metal/ceramic)

Technologies

- Powder and slip preparation, granulate development
- Casting, pressing and (thermo)plastic shaping processes
- Foaming and replica technologies for cellular structures
- CAD/CAM line, additive manufacturing processes (powder- and suspension-based)
- Manufacturing of blanks and preforms by dry pressing
- Sample series of oxide ceramic semi-finished products (certified according to EN ISO 13485:2016)
- Plasma coating and sol-gel processes
- Thick-film and multilayer technology (complete line for HTCC, LTCC)
- Thin-film technology (thermal CVD, PECVD, thermal ALD, PVD, LPD)
- Joining technologies for ceramic/metal and ceramic/ceramic combinations
- High-temperature isostatic pressing/post-HIP processes
- Micro- and surface preparation; surface functionalization (inkjet and aerosol printing, diode laser array finishing)
- Biocompatible joining and packaging techniques, medical device construction

Diagnostic/therapeutic systems and characterization

- Bioelectrical, topography-based, acoustic and optical measuring systems
- Biophysical characterization on nano, micro and macro level (TEM, SEM, AFM, AFAM, Raman)
- In vivo as well as in vitro analysis and diagnostic systems
- Plasmonic sensor systems
- Biological evaluation of materials (medical products) in accordance with DIN EN ISO 10993
- Differentiation assays
- Development and industrial implementation of innovative in vitro test methods

6 *Dental ceramics – blanks from yttrium-stabilized zirconium oxide (slip casting).*

FRAUNHOFER IKTS IN PROFILE

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden (Saxony) and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes. Test procedures in the fields of acoustics, electromagnetics, optics, microscopy and laser technology contribute substantially to the quality assurance of products and plants.

The institute operates in nine market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application. Industries addressed include ceramic materials and processes, mechanical and automotive engineering, electronics and microsystems, energy, environmental and process engineering, bio- and medical technology, non-destructive testing and monitoring, water as well as materials and process analysis.

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COVER IMAGE *Hybrid manufacturing of complex bone structures.*