On September 27 and 28, 2006 the Fraunhofer LBF hosts part III »Construction, Joining Technology, System Integration« of the »AdvanCer« training courses »Advanced Ceramic Materials«. For further information please see www.advancer.fraunhofer.com/trainings.
Survey
Non-Destructive Testing of Advanced Ceramic Materials

In the characterization and analysis of defects during the development and manufacturing process of ceramic components various destructive and non-destructive testing methods are required. Common non-destructive testing methods based on optical, acoustic, magnetic, electrical, and electromagnetic methods are optimized for the testing of metals. Hence, these methods have to be adapted to the specific properties of ceramic materials.

Non-Destructive Testing for Online-Control
A cost-benefit analysis, in which testing time and the ability for defect detection are important factors, decides on the necessity of non-destructive testing within the production process.

The check for critical surface defects is realized by optical techniques. In some cases colorants are additionally used in accordance with the prestandard PrEN 623-1. Components are often tested integrally by means of vibrational analysis. The eigenmode oscillations are excited in the component, e.g. by an impact, and the sequence of the spectral distribution of the oscillations is analyzed. Defects result in a change of the component’s characteristic acoustic signature.

Thermography is an efficient testing method which provides visual information on surface near defects very quickly. At first, transient heating of the component is applied, e.g. by a flash or an inductor, and then the temperature distribution on the surface is recorded by an infrared camera. Surface near changes of the thermal conductivity due to defects affect the thermal diffusion and result in different cooling rates at the surface.

Non-Destructive Testing for Analysis
By choosing the appropriate optical devices a very high resolution can be achieved by thermography testing. In combination with periodically modulated thermal waves, e.g. caused by laser energy, very small cracks can be detected, even under the surface. The non-destructive testing for defects in the component’s volume by ultrasonics is realized by scanning the component with high-frequency ultrasonic waves (typically 20 MHz to 200 MHz) and by analyzing signals reflected from defects. Specific wave modes allow for the detection of surface near defects and cracks.

Advances in computer technology and X-ray detectors resulted in a rapid development in 3D X-ray computer tomography (3D-CT). This method allows checking for defects like pores, inclusions, density and inhomogeneities in complex components having hidden structures. Furthermore, very inhomogeneous materials like fiber reinforced ceramics can be tested. For the analysis, the component is cut into sections by software and automatically checked for defects.

If the requirements are lower with regard to resolution, e.g. in optimizing the parameters of an injection molding machine, the test results are already available in 2-3 minutes. CT can be applied in various fields: the application spans from the analysis of the structure of joined components, via the generation of surface data for reverse engineering, to the analysis of the component’s state during lifetime tests, e.g. for analyzing the ash distribution in ceramic particulate filters.

Non-destructive testing methods supplement the competencies of »AdvanCer« in the development of components and systems with advanced ceramics. They are already widely used as development tool. In the future, they will play an even more important role for quality assurance in series production.
News

»AdvancCer« at Trade Shows in Springtime

With its participation at GrindTec (Augsburg), HMI (Hannover), ACHEMA (Frankfurt/Main) and CERAMITEC (Munich) »AdvancCer« has started this year’s trade show marathon. Particularly the tradeshows in Hannover and Munich were very successful. The rapid prototyping process chain for thermoplastic shape-forming as well as the demonstrators CT-Mini and TOMMI found favor with the guests.

On June 30, more than 4,000 people visited the Fraunhofer Institute Center Dresden (IZD) to celebrate the »Day of Technology« and the »Long Night of the Sciences«. Pupils from class one to twelve could explore, experience, and feel technology. By means of many different exciting experiments the pupils learned to understand the laws of science. They also demonstrated their inventive spirit in creating objects out of high-tech materials like ceramic foams and metallic hollow balls. Furthermore, the pupils found out that modern materials and technologies play an important role in sports. They had the opportunity to play boules with ceramic balls, to play golf with ceramic clubs as well as to test a shock-absorbing tennis racket. The »Day of Technology« became a fascinating event for young and old due to exhibits like the AutoTram®, a high-tech vehicle that was presented for the first time ever, and the first ice cream made from lupine.

The festivities had already begun the day before when the Executive Board of the Fraunhofer-Gesellschaft visited the IZD. With eleven institutes and more than 1,150 employees Dresden has become an important business site for the Fraunhofer-Gesellschaft.

Current Training Courses

• September 27/28, 2006 in Darmstadt: Design, Joining Technologies, System Integration
• November 16/17, 2006 in Freiburg: Materials Testing and Calculation of Durability
• October 4/5, 2006 in Dresden: Thermoplastic Shape-Forming of Advanced Ceramics (Technology and Training)

For further information please see www.advancer.fraunhofer.com/trainings.
Success Stories
Ceramics and Computers for a Healthy Smile

Caries is the most widespread dental disease. It is removed from the tooth by the dentist. The resulting cavities are filled with materials made of alloys or composite resins, depending on the size of the cavity. However, these restorative materials are foreign to the body, chemically unstable and esthetically unsatisfactory. Sintered full ceramics like silicates or oxide ceramics have proven to be perfect materials for restorative and prosthetic dentistry over the past few years. Their structure is similar to that of dental enamel. Furthermore, they can be permanently bonded to the remaining tooth, and they are very biocompatible as they are chemically inert.

For more than 20 years, dentists worldwide have been using the CEREC system from Sirona Dental Systems as the standard dental CAD/CAM device in their practices. For designing a dental restoration, the prepared cavity is recorded using a triangulation camera with a CCD video chip and infrared light. This starting situation is shown on a monitor as a virtual model, and the dental restoration is designed by means of a tooth databank. To adjust the occlusal contact points, a further image of the antagonists is recorded. The inlay or the crown is milled from a ceramic block in just a few minutes and is ready for adhesive bonding. The advantage of this method is that crowns or inlays can be made in a single treatment session directly in the practice without the need for impressions and provisional fillings.

Multiple-unit bridges, if required, are fabricated in a dental laboratory with the inLab system, which is similar to the CEREC technology. At first, a conventional impression of the teeth is made. Afterwards, a plaster model is produced and laser-scanned. The dental technician designs the bridge as a 3D-CAD model. The technician fits the elements virtually and checks the wall thicknesses of the abutment framework as well as the fitting accuracy.

The developers of CEREC, Dr. Marco Brandestini and Prof. Werner Mörmann, were supported by the company VITA right from the beginning. After MARK I, the finely structured feldspar blocks VITABLOCS Mark II were introduced in 1991, which scientists consider to be one of the best dental ceramics in terms of antagonist wear on the market. After 18 years, the survival rate is an outstanding 84.4 %. Restorations made of VITABLOCS show a survival rate that is similar to restorations made of gold. VITABLOCS Mark II consist of natural feldspar, such as potassium feldspar (orthoklas) and albite. Compared to other ceramic materials, natural feldspar is characterized by high purity and a wide temperature range during melting. The mean particle size of the used raw materials is on the average approx. 4 µm.

Therefore, the microstructure of the sintered Mark II ceramics consists of very fine crystalline fractions which are surrounded by a glass matrix. Due to this fine microstructure as well as the industrial sintering process, Mark II ceramics can be polished quite easily and show outstanding abrasion properties which are similar to that of dental enamel. Due to the fine microstructure, harmful »sanding effects« on the antagonists can be avoided.

In autumn 2003, VITABLOCS TriLuxe were introduced onto the market as a new type of VITABLOCS. They are made of the proven MARK II ceramics. A special manufacturing method allows for the combination of three different degrees of color saturation, and thus different degrees of translucence in one block. They follow the systematic structuring of the 3D-Master system, the modern system for colorimetry and reproduction of VITA. They allow the reproduction of the characteristic color gradient of a natural tooth with regard to translucence and intensity. Thus, a better integration of the restoration into the remaining tooth structure can be realized. VITABLOCS are a milestone for the success of the CEREC system. CEREC system and VITABLOCS – now in its third generation since its inception in 1985 – have been clinically proven to perform excellently. More than 12 million ceramic restorations have been fabricated and successfully integrated.