The name »AdvancEr« conveys a sense of foresight, progress and benefit. Ceramics manufacturers and users find in it their »Advanced Ceramics« materials holding great promise for the future. »AdvancEr« presents innovative applications for high-performance ceramics: systems solutions with »Ceramics inside« for today and tomorrow.

Computed tomography (CT) is an important tool in the development of ceramic components in order to optimize the production process. It is preferably used to analyze green bodies, to detect defects, to display the geometry as well as to determine the density distribution in the green body. The density can only be partly determined as nonlinearities in the detector sensitivity curve as well as in the reconstruction algorithm cause artefacts resulting in inaccuracies. For this reason, methods are developed within the framework of the Fraunhofer Demonstration Center »AdvancEr« giving reliable density values in computed tomography. Here two different approaches are pursued. One method can be used in existing computer tomographs. By means of a correction curve nonlinearities are corrected during data acquisition and artefacts are suppressed. The correction curve is determined by means of a specific algorithm from measurements at a good part. Thus, special test specimen is not necessary. An increase of noise can be compensated by longer measurement periods.

The second method uses a specific energy-selective x-ray detector and adjusted reconstruction methods. By selecting the energy it is even possible to reconstruct element-specifically. At present, the method is optimized in order to reduce the measurement period.

»GreenCT« is one of another five demonstration systems which are developed within the framework of the Fraunhofer Demonstration Center »AdvancEr« (system solutions with advanced ceramics).
Survey

**FAST/SPS for the manufacturing of ceramic components**

Pressure-assisted sintering methods for the manufacturing of ceramic components became widely accepted in those cases in which the materials are subject to high stress, and in which a high reliability is an absolute requirement for their successful application. So, for example, Si₃N₄ based cutting ceramics and many other Si₃N₄ machine components subject to high stress are densified by gas pressure sintering. Si₃N₄ balls for bearings, Al₂O₃ hip joint implants and transparent ceramics are densified by hot isostatic pressing.

These more costly methods as compared to normal pressure sintering have established there where new applications were developed on account of new material properties or where the material can only be realized by pressure-assisted sintering (e.g. commercial hot pressed hBN materials or hBN/TiB₂ composites for evaporation boats).

The development and evaluation of different nanomaterials, in particular, requires a sintering method which prevents grain growth during the complete densification as far as possible. In this case pressure-assisted sintering methods have also proved successful.

Due to the steadily increasing demands on the materials and based on hot pressing «field assisted sintering technology» or «spark plasma sintering» (FAST/SPS) has been established in the past ten years. In FAST/SPS, the tool or the sample volume is heated by a direct (pulsed or non-pulsed) current flow. The idea to densify porous powder bulks by Joule heat in the electrically conductive or very close to the electrically non-constructive sample volume is very old. The first patents date from the 1920’s.

Only now the use of high-strength isotropites with a bending strength in the range of 50 to 100 MPa as well as further developed power electronics and control engineering allow one to manufacture also components of large geometry (according to manufacturers’ data up to 300 mm) under high mechanical stress and high temperatures.

Using FAST/SPS heating times of several 100 K/min can be achieved so that sintering cycles of several hours in conventional hot pressing can be reduced to some minutes. The method has high potential not only for this purpose, particularly for the manufacturing of metastable composite materials or nanomaterials, but also because the grain growth of the single components can largely be prevented. So, for example, cBN and diamond/WC/Co composites with increased wear resistance were produced (Fig. 2).

Fig. 2: Microstructure of a cBN hard metal composite made by FAST/SPS and prepared by ion beam technique. It shows no reaction zones or transition.

Similar examples of metastable composites are known from bioceramics (hydroxyapatite/ZrO₂) and functional ceramic materials. Due to the decreased grain growth materials with increased wear resistance were realized.

FAST/SPS is advantageous when the manufacturing of metastable composite materials, nanomaterials with minimum grain growth, graded or multilayer materials is required, or when metastable materials are to be densified directly during their synthesis. In addition, this method also offers a number of advantages for materials difficult to densify which are hot pressed or the manufacturing of which is not a possibility due to economic reasons. By using the direct current passage through the material volume to be densified conducting materials are best suited for FAST/SPS. Furthermore, FAST/SPS offers significant advantages for the sintering of various ceramic materials, which are non-conductive or slightly conductive at high temperatures.

On account of the fast heating processes the temperature distribution within the material plays an important role, particularly with large geometries. Temperature inhomogeneities can be avoided by an adjusted design of the tool geometry. This design is based on appropriate FEM calculations for current density and temperature distribution (Fig. 3). Furthermore, concepts of hybrid heating systems are under development.

Fig. 3: Current density distribution (left) and temperature distribution (right), calculated by FE simulation, in the tool during the sintering of an electrically non-conductive material.

Generally, the enormous amount of publications in the last years signalizes a great interest in this fast, efficient and innovative sintering method. Even if the exact processes are still subject of scientific disputes, and can be different from material system to material system, reproducible densifications may be achieved for the most materials, and thus meet the requirements for an industrial production. By means of FAST/SPS new, innovative material solutions are developed and made efficient.

As FAST/SPS is industrially used in the Asian region to produce hard metals/composites, cutting materials and others, this technology also starts to leave the laboratory applications and to prove its suitability for series production in Europe.

Fig. 1: FAST furnace at Fraunhofer IKTS.
Saxon ministries opened the colloquium. knecht, as well as representatives of the Free State of Thuringia, Christine Lieberknecht, minister Lieberknecht, Prof. Bullinger).Whenever a new ceramic component is introduced to the market, interest in the potential properties and applications for the material is high. Recent interest in ceramic components comes from the development of fuel cell systems. The prime minister of the mechanical engineering, photovoltaics, and systems in markets such as electronics, and a wide spectrum of materials, components and systems in markets such as electronics, mechanical engineering, photovoltaics, and fuel cell systems. The prime minister of the Free State of Thuringia, Christine Lieberknecht, as well as representatives of the Saxon ministries opened the colloquium.

Another highlight is the demonstration of ceramic-ceramic and metal-ceramic joints with the help of components or model joints such as, e.g., Pb-free and hermetic joints for Al2O3 ceramic reactors.

Current Training Courses »AdvanCer« continues its training courses »Advanced Ceramic Materials for Technicians and Engineers«. Dates and locations are as follows:

- Part 1: Construction, assessment, November 11 and 12, 2010 in Freiburg
- Part 2: Machining, May 5 and 6, 2010 in Berlin
- Part 3: Construction, assessment, November 11 and 12, 2010 in Freiburg

For further information please see www.advancer.fraunhofer.de

Furthermore, the following advanced training courses will take place at Fraunhofer IKTS in Dresden:

- April 22 and 23, 2010: »Technological fundamentals of granulation and granule processing«
- September 8 to 10, 2010: »Spray drying of ceramic suspensions – Technology and design of experiments«
- October 6 and 7, 2010: »Thermoplastic shaping of advanced ceramics – Technology and training«

For further information please see www.dkg.fraunhofer.de

Fraunhofer IKTS Hermsdorf wins Innovation Award
The Fraunhofer Institute for Ceramic Technologies and Systems, branch Hermsdorf, won the Innovation Award of the Fördergesellschaft für Erneuerbare Energien e.V. (FEE), which was announced nationwide, for the development of a nanoporous membrane to dry bioethanol. With this award the FEE honors inventions for the reduction of energy consumption, efficient energy conversion and storage as well as for the use of renewable resources.

Among the 31 candidates the IKTS came out on top with a ceramic filter, which is able to separate ethanol from water by a kind of »sieving«. The pore size of the filter is only 0.4 nanometer, and thus is larger than the water molecule’s diameter, but smaller than the ethanol molecule. In contrast to conventional methods the newly developed filter saves up to 90 % of energy. The method is already used in a production plant for biofuel.

Pb-free and hermetically joined Al2O3 reactors.

Review: Ceramics Vision 2010+
On January 22 the colloquium series »Ceramics Vision«, already taking place for the 7th time, was not held in Dresden as usual, but in Hermsdorf celebrating the integration of the Hermsdorfer Institut für Technische Keramik into the Fraunhofer IKTS. Under the motto »Integrated ceramic research from the idea to the product« the potentials of innovative ceramic technologies for new solutions were presented in interesting papers from industry and science.

Aside from current developments the prospects of ceramic applications and technologies were shown. The presentations covered a wide spectrum of materials, components and systems in markets such as electronics, mechanical engineering, photovoltaics, and fuel cell systems. The prime minister of the Free State of Thuringia, Christine Lieberknecht, as well as representatives of the Saxon ministries opened the colloquium.

Afterwards Prof. Hans-Jörg Bullinger, president of the Fraunhofer-Gesellschaft, presented the successful model of the Fraunhofer-Gesellschaft as innovation driver for industry.

Ceramic expert awarded with Bridge Building Award
Professor Dr. Walter Krenkel, holding the Chair of Ceramic Materials Engineering (CME) at the University of Bayreuth and director of Fraunhofer Project Group Ceramic Composites, was awarded the Bridge Building Award. Professor Krenkel received the award of the American Ceramic Society at the 34th ICACC conference in Daytona Beach. He is just the third German scientist who was given this award.

With this award, the American Ceramic Society recognizes international scientist who have made outstanding contributions to engineering ceramics. The winner of the Bridge Building Award expanded knowledge base, transferred ceramic materials to commercial use, and contributed to the visibility of the field and international advocacy.

The winners of the FEE Innovation Award: Dr. Marcus Weyd, Jan-Thomas Kühnert, Dr. Ingolf Vaigt and Dr. Hannes Richter (left to right).

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The winners of the FEE Innovation Award: Dr. Marcus Weyd, Jan-Thomas Kühnert, Dr. Ingolf Vaigt and Dr. Hannes Richter (left to right).

Dr. Jonathan A. Salem of the American Ceramic Society (left) awarded the Bridge Building Award to Professor Dr. Walter Krenkel (right).
Success Stories

Ceramic cores stay stable as casting temperatures soar

Morgan Technical Ceramics Certech (MTC Certech), a leader in the investment casting industry, has introduced a new ceramic core material, P52.

«We’re pleased to announce this new material which enables our customers to optimise their metal casting processes,» says Evan Reed, Sales Manager, Morgan Technical Ceramics – Certech. Developed to maintain rigidity and provide tight dimensional and geometric control, P52 ensures ceramic cores remain extremely stable during the casting of turbine blades with high temperature super alloys that are now being used in quieter and more fuel-efficient jet engines.

Ideal for airfoil casting of blades and vanes used in rotating and static engine parts the P52 material’s ability to hold thinner metal walls more accurately provides part manufacturers with higher casting yields, reduced scrap rates and lower casting costs. The stability of P52 also enables manufacturers to reduce or eliminate the use of costly platinum pins that hold the ceramic in place and support the core during the casting process.

In addition to dimensional strength P52 exhibits improved crushability during solidification. This means that it remains rigid and stable through the cooling process but is crushable when it needs to be during the metal solidification process. This is particularly useful for alloys that are prone to hot-tearing or re-crystallization. »We continue to develop materials that push boundaries in the manufacture of turbine blades and allow more complex geometries with higher tolerances to be cast,« explains Evan Reed.

Precision down to grain boundaries

Emil BRÖLL GmbH & Co. KG, Dornbirn (Austria) has now been mass-producing components made of tailored superpure metal oxides with enhanced properties for ten years. BRÖLL is keen to capture the best of ceramic performance by adjusting production methods to minimize potential defects.

After selecting the aluminum oxides, zirconium oxides or dispersion ceramics the appropriate binder systems and shaping methods are adjusted and optimized. The subsequent debinding and sintering steps are also tailored for the individual components. Wear occurs first at weak points, which in the world of ceramics, means micro cracks and pores. Therefore, BRÖLL always follows the maxim: small grains and high density.

The density of the ceramic components produced by BRÖLL is exceptionally high and they are extremely free of pores. So not only are the mechanical properties improved, but also the thermodynamical, chemical and optical properties, as well as the haptics (“look and feel”) of the product.

Almost defect-free microstructures, at very high material densities, can be mass-produced with high precision. (Source: BRÖLL)

The BRÖLL team including the partners Felix Backmeister, Helmut Sommer and Dr. Eckhard Sonntag consists of approx. 35 employees. (Source: BRÖLL)