Polymer foam structures accompany us in our daily life in many fields, e.g. as sponge, microphone cover, aquarium filter or mattress. Due to their cellular structure, they have a large surface with good storage and sound-absorbing properties and are suitable as deep bed filters. However, they can only be used at room temperature.

For that reason, Schwartzwalder and Somers had the idea in 1961 to develop a method to produce ceramic foams (US 3 090 094), which have an identical structure as polymer foams, but which have the typical ceramic properties such as high-temperature resistance >1000°C, corrosion resistance and chemical inertness. Today, foundry filters with production capacities of several million pieces worldwide are produced by means of this technology and used for the production of high-quality filigree castings. There are three different material classes: alumina, silicate bonded silicon carbide and zirconia which are optionally used for aluminum, steel and cast iron filtration.

The success story of mass-market approved metal melt filters was the starting point for development works at the Fraunhofer Institute for Ceramic Technologies IKTS in Dresden. Research focus is on the material-scientific further development of a variety...
of ceramic foam materials, the manufacturing technology as well as the implementation of ceramic foams into new applications. Due to this wide field of research, new applications such as porous burners, reformers, catalyst supports functionalized with adsorbents and catalysts, heating elements, bone replacement materials, solar receivers, light-weight materials, fireplace filters etc. have been developed for more than 20 years now. This survey is to give an overview over some interesting aspects of development.

In the beginning of the production process of ceramic foams, open-cellular polyurethane foams are cut to near-net shape components which may have different cell sizes. The foams are classified in accordance with their cell width by pores per inch (ppi). Coarse foams with 10 ppi have cell widths of 4 to 5 mm, fine foams with 80 ppi have cell widths smaller than 400 µm.

These ceramic foam components are soaked with a ceramic suspension. For homogenization, excess material is squeezed so that only the polymer is covered and almost exactly replicated. Soaking and squeezing is conducted on squeeze rollers or centrifuges. This requires suspensions which have a shear thinning flow behavior, a sufficient yield point as well as a maximum solid content – adjusted to the particular foam cell width. Thus, the development of the coating suspensions is the true challenge of this technology.

Afterwards, the coated foams are dried, the polyurethane is burned off and the foam is sintered. The sintering regime depends on the material: air is used for all oxide materials and specific atmospheres such as vacuum, nitrogen or argon are used for non-oxide ceramics. After thermal treatment, a ceramic foam has developed with hollow struts and a total porosity of 75 to 92%.

The possible fields of application are determined by the ceramic materials as summarized in the table above. Particularly worth mentioning are silicon carbide foams, where the development was especially pushed by the pore burner technology which is characterized by a particularly high modulation capability and low emissions due to intensive combustion. The ceramic material must have a particularly high temperature resistance, combined with a good thermal shock resistance, and should be characterized by an excellent stability under operational conditions.

In order to fulfill these requirements, researchers at Fraunhofer IKTS work on the development of a silicon carbide foam with a low total porosity which is significantly more stable against oxidation than the materials developed so far. The picture on the left shows two qualities of a pressureless sintered silicon carbide foam. The material on the left is a standard material with a porosity of 30%. The material on the right has been further developed and thus is significantly denser and more resistant against oxidation. Tests in model reactors showed a reduction of the oxidation rate for the new materials by two orders of magnitude and an expected life time of 7500 hours.

Furthermore, the purification of industrial process gases is a popular topic, where catalytically coated ceramic foams are applied as well. The cellular foam structure enables an intensive mixing of the process gases, generates low flow resistances and has additional effects such as high or low thermal conductivity by choosing the suitable ceramic material. By means of centrifugation techniques ceramic foam supports can be coated with washcoats from γ-alumina, cer-zirconia or calcium aluminate and other materials systems in order to increase the available ceramic surface and to functionalize their surface with precious metal bearing or precious metal free catalysts. Additionally, Fraunhofer IKTS has also experience in coating foams with adsorbents like active carbons and zeolithes.

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties or selection criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressureless sintered silicon carbide (WO 02/20426 (2002))</td>
<td>Temperature resistance up to 1500°C, high thermal shock resistance</td>
</tr>
<tr>
<td>Silicon infiltrated silicon carbide (US 6.635.339 (1997))</td>
<td>Strength that is five times higher than this of standard foam ceramics</td>
</tr>
<tr>
<td>Silicate bonded silicon carbide</td>
<td>Cheapest ceramic foam material, material used for molten metal filtration</td>
</tr>
<tr>
<td>Alumina (purity 99.5 %)</td>
<td>Low thermal conductivity, electrically insulating properties</td>
</tr>
<tr>
<td>Cordierite</td>
<td>Low thermal expansion, cheap materials</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Very high temperature resistance &gt;1500°C</td>
</tr>
</tbody>
</table>

CONTINUED FROM PAGE 1
SUCCESS STORIES

COMPACT, ROBUST AND WATERPROOF

From medical engineering to mechanical engineering to automotive industry applications – for years piezo-ceramic actuators have been an integral part of a broad range of applications and have proven their effectiveness millions of times over. The only problem: the actuator’s vulnerability to high humidity and the associated reduction in its durability.

CeramTec has now succeeded in developing piezo-ceramic actuators with hermetically sealed protection that also offer outstanding long-term stability. The piezo-ceramic actuators are made from hundreds of layers of lead zirconate titanate (PZT) films and exhibit a charge separation when subjected to the deformation process by an external force. With a speed of up to 0.1 milliseconds, they can react very quickly while simultaneously exerting a force of one to two kilonewtons.

Conventional piezo-ceramic actuators are protected by a polymer or ceramic coating. However, micro fissures may form during operation, allowing water molecules to come into contact with the piezoceramic. The stray current that arises as a result of this process reduces the performance capability of the actuator and can even destroy it. This is why CeramTec has developed a special manufacturing process that chemically converts the adsorbed water once the piezo-ceramic actuator has been sealed. The result is a completely water-free environment in the stainless steel housing, which simultaneously serves as a diffusion barrier against external exposure to humidity. Moreover, the bellows ensure the housing maintains a low stiffness, which is essential in order for the actuator to expand freely as voltage is applied. The electrical connection feedthroughs in the stainless steel housing also play a key role in protecting the actuator from humidity and moisture: They are firmly integrated into the component with a specially developed glass solder and ensure that no humidity enters the interior of the stainless steel housing along the wiring. This opens up a world of exciting new possibilities in industry and technology.

CERAMIC WELDING SHOES FOR PLASTICS PROCESSING

Since its foundation in 1986, BCE Special Ceramics considers itself to be both, a ceramic manufacturer for customized components in small batches and a provider of ideas when realizing customer projects. Within the framework of a research project of FGK and TIME, BCE Special Ceramics together with Herz and Dohle Extrusions-technik developed a ceramic welding shoe for the processing of plastics – in this case of perfluoralkoxy copolymers (PFA). Research focus was on the selection of the suitable material and the ceramic-compatible design. On account of the corrosive atmospheres released during the welding of PFA the used material has to meet high requirements in terms of its thermal properties. On the one hand, the melt must not freeze inside the extrusion channel, and on the other hand, the nozzle’s surface should not become so hot that the components to be welded plasticize in the contact area resulting in predetermined breaking points. Additionally, the mechanical properties of the welding shoes must withstand the rough environment in the different applications.

Preliminary studies have shown that the BCE zirconia quality Z-700 (Y-TZP) is the best possible material for the ceramic welding shoe. Based on CAD/CAM data of the various welding shoes the different contours were cut by means of CNC machining centers. Subsequent surface finishing plays an important role, especially for those surfaces coming into contact with the product. Using this ceramic welding shoe and the newly developed extruder, it became possible for the first time to produce welded joints of PFA where there is no difference in the material quality between welded and base material.
IMPORTANT DATES

AdvanCer training courses
“Advanced ceramic materials”
• Part 1: Materials, technologies, applications
  March 5 and 6, 2014 in Dresden
• Teil 2: Machining
  May 7 and 8, 2014 in Berlin
• Part 3: Construction, testing
  November 13 and 14, 2014 in Freiburg

Seminars and workshops at Fraunhofer IKTS
• Ceramics Vision 2014
  January 16 and 17, 2014
• DKG seminar “Thermoplastic shaping of advanced ceramics”
  May 15 and 16, 2014
• DKG seminar “Debinding of ceramic components”
  May 22 and 23, 2014

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

NEWS

CERAMTEC WINS MATERIALICA AWARD
At this year’s Materialica trade fair in Munich in the middle of October, CeramTec won the best-of-prize of the Materialica Design + Technology award in the material category for its extraordinary PERLUCOR® transparent ceramics. At the official award ceremony Robert Metzger, CEO MunichExpo Veranstaltungen GmbH, handed over the Materialica Award to Dr. Lars Schnetter, Product Manager PERLUCOR®, and Dieter Efflenberger, Managing Director at CeramTec-ETEC (see picture above). The jury was impressed by the transparent ceramic material’s multifaceted and extraordinary properties. Alongside its high degree of transparency, PERLUCOR® exhibits tremendous mechanical strength and hardness, making it the material of choice for use under extreme wear conditions. PERLUCOR® also features extraordinary thermal and chemical stability: It can be used at temperatures of up to 1,600 degrees Celsius – and even applications in sulfuric acid, hydrochloric acid, hydrofluoric acid, phosphoric acid, potassium hydroxide or sodium hydrosxide are possible.

CERAMICS VISION 2014
On January 16 and 17, 2014, the symposium series “Ceramics Vision”, already taking place for the eight time, will be held at Fraunhofer IKTS in Dresden. In the program filled with top-class talks from industry and science the potentials of innovative technologies for new solutions will be presented covering all aspects from material development to system integration in the field of structural and functional ceramics. Aside from current developments ranging from whiteware ceramics to advanced ceramics, future prospects are particularly focused. The main emphasis is placed on energy and environmental technology as well as “smart materials” which are dynamically developing. Together with Fraunhofer IZFP, which will be integrated into Fraunhofer IKTS on January 1, 2014 (please see next article), the Center of Material Diagnostics CMD will be founded. This will also be a topic at Ceramics Vision. Additionally, Prof. Prabhakar Singh will give background information on the newly established Fraunhofer Center for Energy Innovation CEI in Connecticut/USA. The symposium is accompanied by an exhibition.

FRAUNHOFER IKTS GROWS
Fraunhofer IZFP currently has two locations in Saarbrücken and Dresden. The Fraunhofer Executive Board is committed to uphold and further develop both sites separately from January 1, 2014. The IZFP Saarbrücken will continue under the managing direction of Prof. Randolf Hanke, during the Dresden part is going to be integrated into the Fraunhofer IKTS led by Prof. Alexander Michaelis. The business areas and core competencies are to be adjusted to each other.

EDITORIAL NOTES
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