Institute for Materials Applications in Mechanical Engineering (IWM) RWTH Aachen University

Research profile
The *Institute for Materials Applications in Mechanical Engineering (IWM)* was formed in 2006 through the merger of the *Institute of Materials Science and Ceramic Components* in *Mechanical Engineering.* Closely linked to the IWM is the affiliated institute *IPAK* (*Institute for Processing and Application of Ceramic* at the *RWTH Aachen University*).
Corresponding to their research topics the institute is structured into four Departments: Mechanics of Materials, Rolling Contact Fatigue, Powder Technology and Wear, Material Development and Heat Treatment. The research focuses on powder metallurgical materials such as PM-steels, cemented carbides, engineering ceramics, conventional steels, non-ferrous metals, and cast iron.
Research topics encompass damage and continuum mechanics and lifetime analysis, respectively. In the center of interest are fatigue and failure mechanisms under uniaxial and multi-axial static, cyclic and creep loading and in particular the interaction between microstructural, mechanical, and physical properties. For more precise lifetime prediction, modelling of multiphase materials, fatigue and damage evolution are simulated in both the low cycle and high cycle fatigue regime of multiphase materials by applying a continuum mechanics based multiscale approach.

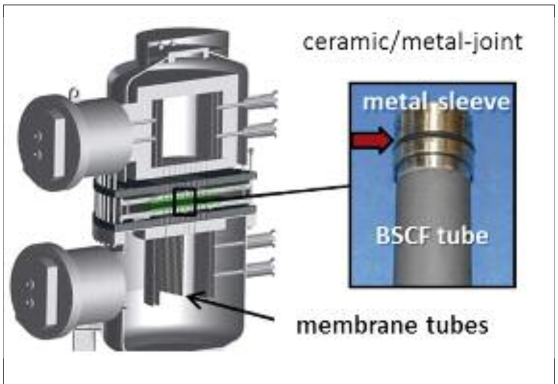

Fig. 1
Pilot module with BSCF-membranes
for separating oxygen from air
(BMWi joint research project Oxycoal-AC, No. 0326890U)

In order to control mechanical or physical properties, thermodynamic modelling, heat treatment, and residual stress measurements are employed to validate the models. In the area of ceramics, the entire process chain from component manufacturing, including design and component analysis, raw material processing, moulding, sintering and any post-machining, to complex component testing conditions is covered. The focus is not on the development of new materials, but rather on the improved use of reliable and cost-oriented available materials, which may be modified for a specific purpose if appropriate. Special attention is paid to complex joining problems, in particular the adhesive joints between ceramic and metallic materials and ceramic structures with metal brazes or glass solders. Safety validation and stress analysis require a number of mechanical and thermophysical material parameters and application-oriented test procedures. For their identification, the IWM has the necessary expertise and comprehensive modern facilities.

Infrastructure
For the above mentioned tasks a well-equipped technical center and labs are available. This includes powder conditioning by milling facilities such as wet milling, attritor or agitator bead mill, dry grinding fluid bed jet mill with an integrated air classifier, and mixing and granulating aggregates. Shaping operation is performed using uniaxial, isostatic or hot isostatic pressing, and field assisted sintering tchnology (FAST), respectively. For sintering up to 2200 °C various electrical sintering kilns are available, operating under air, vacuum or inert gas atmospheric conditions. This allows the production of specimens and components in small lots.
For microstructural characterization, a number of light microscopes and three SEMs are available. Open porosity can be measured by Hg-porosimetry. The thermophysical lab provides a broad and modern equipment in order to characterize thermal expansion, specific heat, and thermal diffusivity.
For the mechanical characterization of ceramics, various uniaxial bending and biaxial testing rigs, such as the brittle ring, the ball-on-3-balls or the ball-on-ring test up to

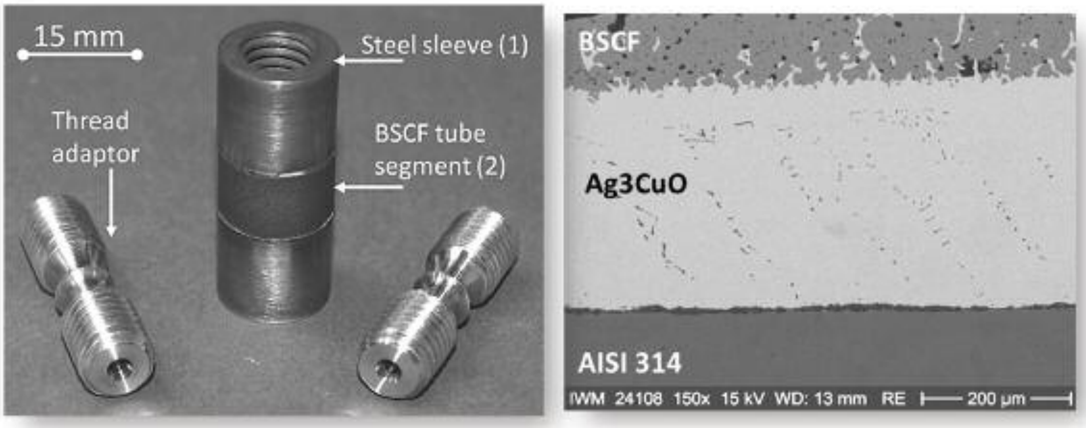

Fig. 2
BSCF/AISI 314 braze joint: specimen for mechanical testing (left), and microstructure of joint interface (right)

1200 °C, and 22 rigs for uniaxial creep testing, are available. The spectrum of fatigue testing covers the low cycle fatigue regime for elevated temperatures and the high cycle fatigue regime up to 10^9 cycles with more than 35 testing machines.

Research activities

For more than 10 years the design of ceramic oxygen transport membranes (OTM) for industrial applications has been a paramount subject at IWM. Perovskite-type $Ba_{0,5}Sr_{0,5}Co_{0,8}Fe_{0,2}O_{3-\delta}$ (BSCF) is used as mixed ionic/electronic conducting (MIEC) membrane material because of its high oxygen permeability at temperatures between 800 – 900 °C. Tubular membranes of 500 mm length, 15,5 mm diameter, and 0,9 mm wall thickness are produced through isostatic pressing. To ensure structural integrity and sufficiently high oxygen flux, microstructural properties have been optimized by adjusting powder processing (milling, mixing, granulation, mold filling and pressing operation) and sintering schemes.

Today the long-term stability of these membranes is investigated under service conditions in a pilot module with 600 tubular membranes operating in three-end mode with a maximum gauge pressure of 20 bar on the feed end and 0,3 bar at the permeate end; the pilot module can provide 0,6 t oxygen per day (Fig. 1).

The development of application-oriented joining techniques is of major importance for practical use of ceramic components that are usually integrated in a metal environment. This applies even more to adhesive material joints. Reactive air brazing (RAB) with AgCuO brazes is a promising joining technology for OTMs used for gas separation. In these systems, mixed ion/electric conducting membrane materials, like BSCF, are used in combination with an austenitic steel for air separation in power plant processes with CO_2 sequestration. At operating temperatures of 850 °C, these membrannes exhibit a reduced strength compared to room temperature. In addition, such compounds are subjected to mechanical stresses resulting from external loads and internal constraints due to temperature gradients and thermal mismatch of the joint partners. This load profile results in significant challenges to the joining technique between the functional ceramic material and the metallic components.

The mechanisms of actions causing degradation of strength and tightness during long-term use at operating temperature as well as thermomechanical fatigue during start-up and shut-down or load changes are investigated in a DFG-funded project. By targeted development of braze

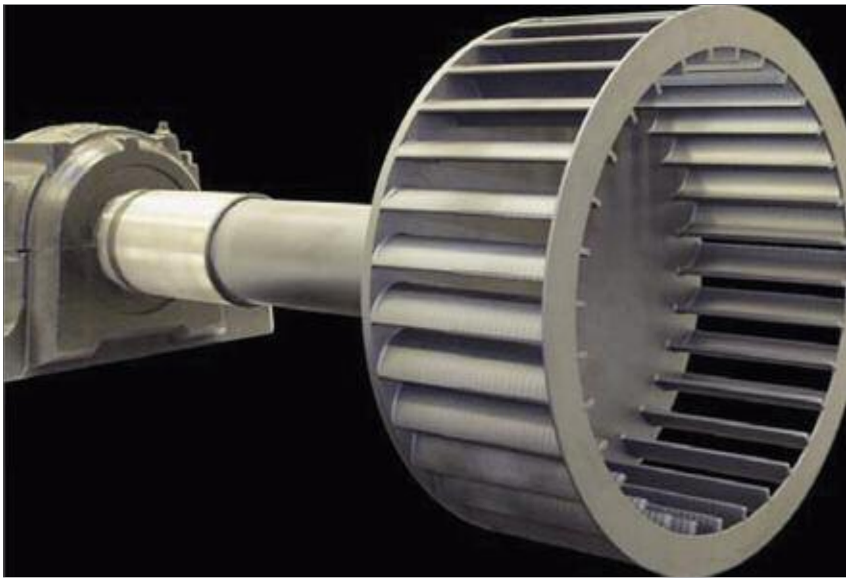

Fig. 3
Monolithic ceramic centrifugal fan
(BMWi joint research project KEEP HIGHT, No. 0327371)

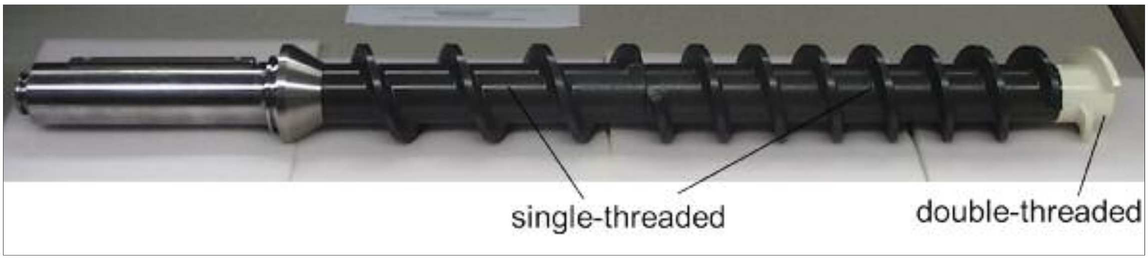

Fig. 4
Segmented water-cooled ceramic auger (BMBF joint research project Keramikschnecke, No. 02PD2210-2216)

materials and processes the microstructural and mechanical integrity of the joint interface (Fig. 2) was improved significantly.
Following the previously introduced IDC concept, several new applications of ceramic components have been realized. Monolithic ceramic (SiSiC) centrifugal fans (Fig. 3) were developed to increase efficiency during heat treatment of non-ferrous metals in floater furnaces. By substituting the nickel alloy, the rotational speed of the fan could be doubled and the maximum service temperature was increased from 1000 – 1200 °C. A special challenge was the design of a shaft connection to the electrical drive.
For wear reduction in injection moulding and extrusion systems, ceramic augers (Fig. 4) and linings have been developed based on stress and reliability analyses.
The interrelationship between microstructural and mechanical properties during powder consolidation by hot isostatic pressing (HIP), and field assisted sintering technology (FAST) is another research item.
The latter is a relatively young method to achieve highly dense materials in a short period of time. In particular, sintering of ultrafine tungsten carbide-cobald hardmetals is investigated aiming to identify the sinter mechanisms and aid in the development of a continuum mechanically-based model for simulation of the consolidation process.
Recently, experimental investigations into the damage evolution of novel multilayer refractory compounds during thermal cycling were initiated. The aim is to predict and optimize the thermal shock resistance through tailored microstructural design.

Contact
Prof. Dr-Ing. Christoph Broeckmann
c.broeckmann@iwm.rwth-aachen.de
Dipl.-Ing. Alexander Bezold
a.bezold@iwm.rwth-aachen.de

Institute for Materials Applications in
Mechanical Engineering (IWM)
RWTH Aachen University
Augustinerbach 4
52062 Aachen
Germany
www.iwm.rwth-aachen.de