SFB 920

Multifunktionale Filter für die Metallschmelzefiltration – ein Beitrag zu Zero Defect Materials

NEWSLETTER 19 (2/2020)

DFG Deutsche Forschungsgemeinschaft

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

DEAR READERS,

additive manufacturing technologies open the horizon for new, alternative solutions in the fabrication of functionalized filter structures, especially from the point of view of resource efficiency. In the Collaborative Research Center CRC 920 „Multi-Functional Filters for the Metal Melt Filtration - A Contribution towards Zero Defect Materials“, the scientists are researching ceramic filter materials and filter systems, from the model-based design of the filter structure to hybrid processes for their fabrication and functionalization up to the use of ceramic filter components in molten metal filtration in cooperation with industrial partners.

The active and intensive scientific exchange, the national and international presentation of research results as well as the promotion of young scientists by international experts take place online. Details on these and other activities are available in our latest issue of this newsletter. Further information is provided at https://tu-freiberg.de/forschung/sfb920.

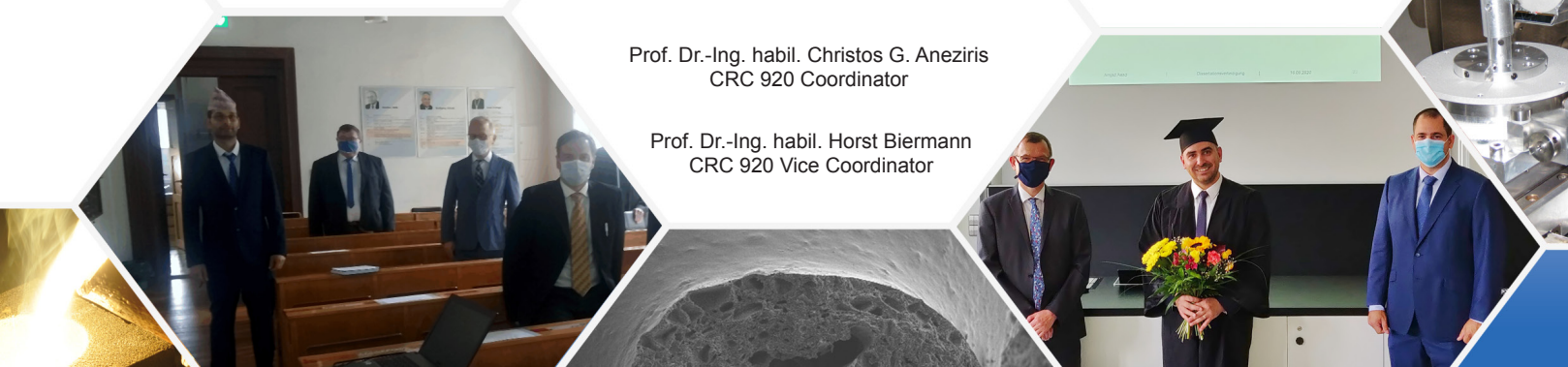
We hope you will enjoy the newsletter!

Yours sincerely,

Prof. Dr.-Ing. habil. Christos G. Aneziris
CRC 920 Coordinator

Prof. Dr.-Ing. habil. Horst Biermann
CRC 920 Vice Coordinator

CONTENT



ALTERNATIVE WAYS FOR RESOURCE-EFFICIENT MANUFACTURE OF CERAMIC FILTER COMPONENTS

In the Collaborative Research Center CRC 920 „Multi-Functional Filters for Metal Melt Filtration - A Contribution towards Zero Defect Materials", the scientists are working on new, alternative, resource-efficient hybrid fabrication methods to manufacture novel ceramic filter materials and filter structures for metal melt filtration. The current results have now been successfully presented at numerous national and international online conferences.

Additive manufacturing technologies, such as 3D printing or alginate-based gel casting, in combination with **robot-assisted flame-spray coating**, make it possible to produce model-based geometries for functionalized ceramic filter structures for steel melt filtration. In the conventional manufacture of ceramic filters for metal melt filtration, polymer foams are used whose cavity structure is random and anisotropic. This makes it impossible to manufacture identical filters with optimal geometry for the filtration process.

In order to manufacture reproducible filter structures, a **new 3D hybrid technology** was developed. In the process, foam templates based on, for example, saccharide are produced by additive manufacturing and the subsequent coating of the templates with, for example, aluminum oxide, is done using a robot-assisted flame spraying system. The temporary foam structures are fabricated according to a model-based filter structure and are thus precisely adapted to the desired flow conditions of the molten metal. Investigations in a steel casting simulator show, that the filter structures manufactured by means of a hybrid process withstand the thermal, chemical and mechanical loads of the molten steel. These reproducible filter structures therefore have great potential for use in steel melt filtration. **(International patent application WO 2018/138210A1, PCT/EP 2018/051864)**

With a further alternative process, alginate-based robo-gelcasting, porous full-strut structures made of materials that are difficult to extrude, for example carbon-bonded aluminum oxide, can be generated at high printing speed and by a gelling process in alginate-containing suspension. Using a portal robot, structures are periodically produced as large-scale „spaghetti filters" for use in molten metal filtration in a continuous process. **(International patent application WO 2017/077024A1, PCT/EP 2016/076647)**

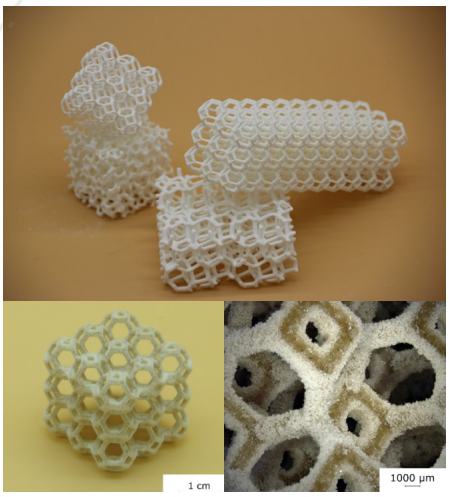


Photo: Additively manufactured 3D filter structures (templates, above) for subsequent flame spray coating below) using the new hybrid technology.

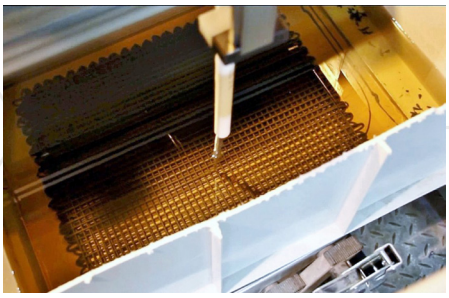


Photo: Manufacture of large-format filter structures using alginate-based robo-gelcasting.

Photo: Test of filter structures in the cast steel simulator.

At three national and international specialist conferences held a web conferences, Dipl.-Ing. Benjamin Bock-Seefeld and Dipl.-Ing. Tony Wetzig presented the results of their research on resource-efficient hybrid technologies for the manufacture of ceramic filters for molten steel: **„Werkstoffe und Additive Fertigung" (Materials and Additive Manufacturing)** of the Deutsche Gesellschaft für Materialkunde (German Society for Material Science, DGM), **„International Colloquium on Refractories"** of the European Center for Refractories (ECREF) and **„The 3rd International Postgraduates Seminar on Refratories"** of the Wuhan University of Science and Technology (China), the Montanuniversität Leoben (Austria) and the Technische Universität Bergakademie Freiberg.

Furthermore, at this year's **„e-CellMAT 2020 - International Conference on Cellular Materials"**, the CRC 920 was able to organize its own session with 17 contributions on the topic of „Multi-Functional Filters for Metal Melt Filtration". Prof. Christos G. Aneziris, the coordinator of the CRC 920, presented research results under the title „Cellular ceramic materials for advanced metal melt filtration; a contribution to zero defect materials" in his keynote speech. Participation in e-CellMAT 2020 as a web conference enables the scientists of the CRC 920 to demonstrate and to show the results of their research in the subprojects to a broad specialist audience despite the COVID-19 pandemic. The CellMAT conference is one of the major platforms for the CRC 920 to present and exchange research projects and results on multi-functional filters for metal melt filtration. ■

MORE NEWS

AWARD

Prof. Christos G. Aneziris was honored by the **German Society for Material Science (DGM)** with the renowned **Tammann commemorative medal**. The DGM thus honors his extraordinary scientific and globally recognized work in the field of modern ceramic materials and refractories as a university lecturer, researcher and also as a partner to industry. At the same time it appreciates Prof. Aneziris' commitment to scientific committees and research associations.

„I feel very honored for having received the price from the board of trustees and thank the executive committee of the DGM for awarding me with the Tammann commemorative medal. In the future, my team and I will continue to contribute to the further development of ceramic, refractory and metal-ceramic composite materials at the TU Bergakademie Freiberg" said Prof. Christos Aneziris on the occasion of the online award ceremony.

The Tammann commemorative medal honors DGM members who have made outstanding contributions to materials science and materials engineering in their scientific work. It is awarded to an individual once a year. ■

Photo: Prof. Christos G. Aneziris received the Tammann commemorative medal of the German Society for Material Science (DGM).

INTERNATIONAL EXCHANGE

From January to March, **Dr.-Ing. Claudia Voigt** took the chance to spend a research stay at the **Norwegian University of Science and Technology (NTNU)**. With 22,000 students the NTNU is the second largest university of Norway. It has the main responsibility for technological research and education in Norway.

At the invitation of Prof. Ragnhild Elizabeth Aune, head of the Institute for Materials Science and Technology at NTNU, Dr. Voigt carried out a part of the scientific work for subproject A02, which deals with oxide-containing filter materials and filter structures for aluminum melt filtration.

In November, at the invitation of the CRC, **Prof. Victor C. Pandolfelli** from the **Universidade Federal de São Carlos in Brazil** was a guest in an online event. He gave a lecture on „Refractories 4.1 - Visions for porous structures and novel needs for the refractory research and industry" for doctoral students, subproject managers and members of the CRC 920. As a Mercator Fellow in the third program period of the CRC 920, Prof. Pandolfelli accompanies the research work on ceramic materials and refractories and components as well as the training of young scientists in the CRC. ■

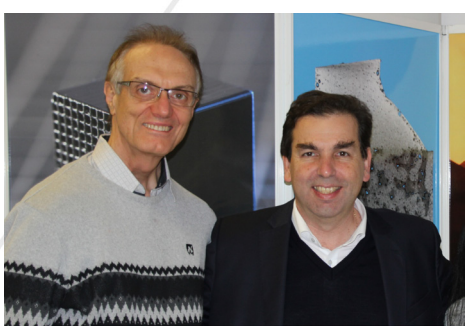


Photo (from left to right): Prof. Victor C. Pandolfelli from the Universidade Federal de São Carlos, Brazil, Prof. Christos G. Aneziris.

NEW INSTITUTE

On October 1st, the **Institute for Ceramics, Refractories and Composite Materials (ICRCM)** was founded at the TU Bergakademie Freiberg. The new institute will combine the professorship for Ceramics, Refractories and metal-ceramic Composites (Prof. Christos G. Aneziris) and the professorship for Building Chemistry and Composite Construction Materials (Prof. Thomas Bier), which have also been newly named, in order to point out the thematic orientation of two fields in research and teaching.

Prof. Aneziris, head of the new institute, would also like to use the restructuring to strengthen the visibility of ceramic materials and refractories as well as composite materials and building materials chemistry as interdisciplinary disciplines. Further information is provided at https://tu-freiberg.de/en/ikfvw. ■

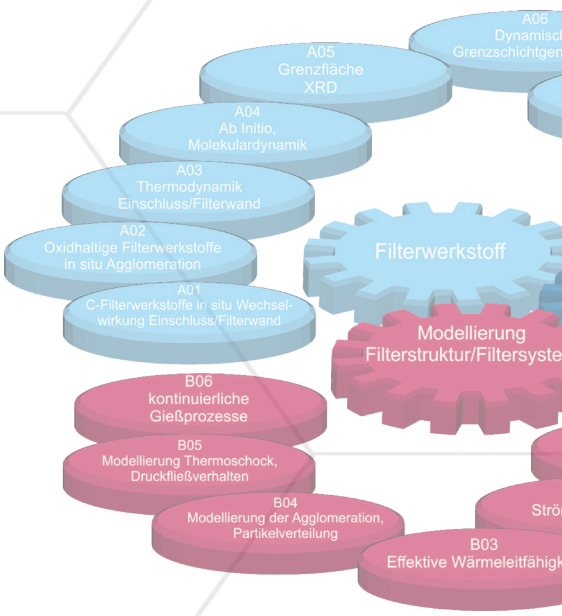
Institute of Ceramics, Refractories and Composite Materials

WORKING GROUPS' REPORT

Research teams in the CRC 920 are connected in four working groups, thus ensuring targeted activities, close collaborations between subprojects, and intensive exchanges between all researchers involved. Young scientists are taking responsibility for coordinating these working groups - a measure the CRC has taken to support young scientists already in early career stages to promote their capabilities to work independently as well as in teams and to strengthen their management skills.

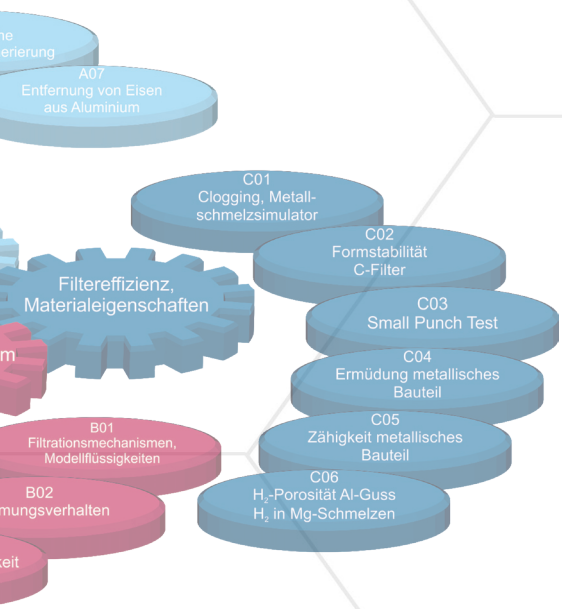
Working Group 1: „Metal melt/inclusions, active/reactive filter material, boundary surface design" (Coordination: Dr.-Ing. Claudia Voigt)

- PU foams with form-fit geometry for the application in bottom-teeming ingot casting at Deutsche Edelstahlwerke Specialty Steel GmbH & Co. KG were designed, printed via selective laser sintering and converted into operational filter prototypes using Al_2O_3-C slurries and flame-sprayed Al_2O_3; first industrial trials will be conducted soon (T04),
- Effect of the transition metal elements of the 4th period of the PTE on the formation of the Fe-containing α_c-phase and its growth morphology (A07),
- Investigation of the mechanical and thermomechanical properties of Al_2O_3 filters for continuous casting (A02),
- Fabrication of carbon-bonded alumina filters based on water-soluble, additive-manufactured filter templates and alginate-containing slips (A01),
- Simulation of raman spectra for precursors materials of the MgAlON synthesis (Al_2O_3, AlN, and MgO) using density functional theory based on experimental as well as relaxed geometries (A04),
- Temperature dependent *in-situ* Raman measurements under argon atmosphere on gallic acid, as well as Raman measurements on MgAlON and its precursors materials (Al_2O_3, AlN und MgO) (A04),
- Thermodynamic assessment of the Al_2O_3-MnO system with emphasis on modeling Al_2MnO_4 cubic spinel using c_p data measured at 250-873 K and own experimental data on melting relations (A03),
- Description of the formation kinetic and structural characterization of the oxynitride spinel $Mg_2Al_{2+x}O_{3+z}N_x$ within the ternary system Al_2O_3-AlN-MgO (A05),
- Castings using the CFCs and subsequent determination of the hydrogen porosity to investigate the influence of these filters on the hydrogen porosity, taking into account the surface roughness of these filters (C06),
- Evaluation of immersion tests performed using differently coated Al_2O_3-C-filter structures in an AZ91 magnesium melt at holding times ranging from 5-60 minutes and a melt temperature of 680 °C regarding durability and state of the filter surface after melt contact. AZ91 samples taken from the melt were evaluated regarding their inclusion content (C06),
- The wettability of several oxide substrates by liquid iron was investigated in a heating microscope under low oxygen partial pressure, (contact angles and surface tensions as functions of time were measured); in some cases, the liquid iron reacted with the substrate material to form new layers (C01).
- Synthesis of gahnite (spinel $ZnAl_2O_4$) and magnesium aluminate spinel ($MgAl_2O_4$) from the starting phases ZnO or MgO as well as α- und γ-Al_2O_3, respectively, using Spark-Plasma-Sintering at 1600 °C with a dwell time of 15 min as the basis for the already initiated analysis of the interplay of all generated spinel phases with molten steel and with aluminum alloy melts (A06).



Working Group 4: „Mechanical properties, metallic materials, critical inclusions" (Coordination: Dr.-Ing. Sebastian Henschel)

- Application of a 3D finite element model for thermo-elasticity to compare simulation results with experimental temperature and strain data using mechanical and thermal material parameters ob-tained from experimental investigations on 42CrMo4 flat specimens; generation of artificial temperature data (thermal fingerprints) to be used to predict the position of heat sources in the bulk of specimens using machine learning approaches (C04),
- Investigations by X-ray microtomography to analyze the influence of iron-rich intermetallic phases in AlSi9Cu3 on the path of the fatigue crack introduced by ultrasonic fatigue testing (C04),
- Study on the effect of intentionally added ceramic particles on the strength, deformation and fracture toughness behavior of 42CrMo4 quenched and tempered steel that was processed by means of powder metallurgy (C05),
- Investigation of non-metallic inclusions in 42CrMo4 after a combined cleaning system of coated Al_2O_3 fingers (reactive) and Al_2O_3 flame-sprayed Al_2O_3-C filters (active) using ASPEX and SEM (C01, S01, C04),
- Analysis of acoustic emissions during deformation and crack extension under static and dynamic loadings in the PM-42CrMo4 quenched and tempered steel (C05),
- Analysis of the filtration of non-metallic impurities (dross) specific to cast iron with nodular graphite (S03),
- Investigations of the morphology of iron-rich intermetallic compounds based on quenching tests with regard to the chemical composition, temperature and holding time (T03).



Working Group 2: „Modelling and designing of the filter geometry" (Coordination: Dipl.-Ing. Eric Werzner)

- Validation of the Stokes-Reynolds-Young-Laplace model for the evaluation of dynamic particle-bubble interactions investigated by AFM (B04) and experimental investigations of particle attachment to a rising bubble (B06),
- Influence of interatomic potentials on predictions of sintering during molecular dynamic simulations as well as MD-investigations on nanoindentation of nanoparticles (B04),
- CP/CP-AFM and contact angle measurements of in situ layers, formed on filter samples during immersion in liquid steel for varied dwell time and spinel lattice parameter as well as measurement of micro and macro roughness (C01, B01),
- FE-implementation of a two-phase/three-components formulation to simulate *in-situ* layer formation considering chemical reactions (B05),
- Modelling of polydisperse foams with the possibility of graded pore configurations (S02, B05) and experimental investigations on the optimization of the separation efficiency with respect to the pressure drop of graded filters with decreasing pore density in flow direction (B01),
- Determination of a strategy for the addition of ceramic fibers to enhance pre-coat filtration: realization and analysis of Al-castings (T05),
- Numerical investigation of reactive cleaning and active filtration through novel filter geometries with modified topology of the strut network (B02, B06, S02, A01),
- Parametric study on the influence of the strut shape on hydraulic tortuosity, viscous and inertial permeability as well as filtration coefficient during the continuous aluminium filtration by pore-scale simulation (S02, B02, B05),
- Evaluation and repetition of experiments for the determination of the volumetric heat transfer coefficient with molten aluminium and planning of the experimental setup for molten steel experiments (B03, S03),
- Optimization and enhancement of the measuring apparatus for direct determination of the hydrogen sorption properties of molten aluminium as well as investigation of the kinetics of oxidation of molten aluminium using thermogravimetric analysis (B03),
- Further development of the hybrid material model to describe the inelastic deformation of 3D foams using neural networks for anisotropic material behavior and geometry as well as preparation of the comparison with FE²-simulations (B05).

Working Group 3: „Thermomechanical properties of the filter material and structures" (Coordination: Dipl.-Ing. Alexander Malik)

- Mechanical, numerical and physical characterization of Al_2O_3-C foam filters produced by distinct routes (A01, T01, B05, S01),
- Investigation and optimization of C-bonded Al_2O_3 compact materials based on the lactose/tannin binder system (C02),
- Mechanical and thermomechanical tests of produced specimens (C02),
- Temperature dependence study of filter material ductility using Brazilian Disc Test, Ball on Three Ball Test and simulations in the range of 1000 °C to 1400 °C (C03),
- Investigation on the size influence in Brazilian Disc Test and effect of preformed stress concentrating cavities introduction such as holes and cracks (C03),
- Design of high temperature testing setup for Brazilian Disc Test (C03),
- Focus on finding critical temperatures in terms of viscoplastic deformation and identification of the dominating factor in shift of material behavior on different filter materials (C03),
- Development of an effective material law for foam structures to design ceramic filters. Required data for the filter material are provided by the subprojects A01, A02 and C01. (B05),
- Investigation on neural network dependencies regarding data sampling (B05),
- Strength evaluation of the immersed filter in comparison to the experimental data from subproject T04 (B05).

INVESTIGATION OF CERAMIC FOAM FILTERS WITH MERCURY INTRUSION POROSIMETRY

Author: Claudia Voigt
(Subproject A02)

Subproject A02 investigates ceramic metal melt filters for aluminum melt filtration. Using the replica method, it is possible to manufacture ceramic foam filters with a very high open porosity resulting in a high permeability, low pressure drop at high tortuosity and high specific surface area [1].

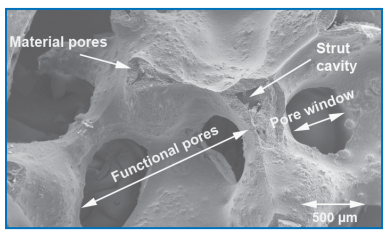


Fig. 1: SEM image of ceramic foam.

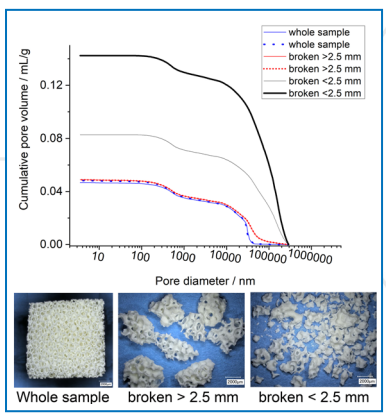


Fig. 2: Cumulative pore volume in dependence on the pore diameter and the sample size.

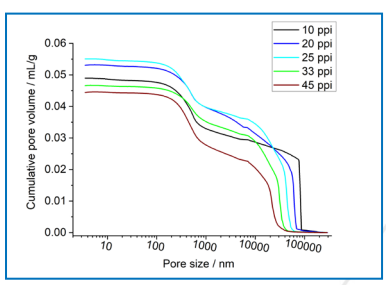


Fig. 3: Cumulative pore volume in dependence on the pore diameter and the ppi-number.

Due to the complex structure of ceramic foams, three different kinds of pores have to be distinguished (Fig. 1): functional pores surrounded by struts, strut cavities which are formed due to the decomposition of the polymeric foam and material pores within the struts. Ceramic foams were examined by mercury intrusion porosimeter using non-wetting mercury which has to be forced into the pores with elevated pressures. The intruded mercury volume is measured as a function of pressure which is converted into the corresponding pore radius r with the help of the Washburn equation [2]. One should keep in mind that the mercury intrusion porosimeter measures only open pores and solely the entryway between the pore cavities (largest entrance of a pore) and not the radius of the pore cavities itself [3].

There are many measuring parameters influencing the porosity results, e.g. the stem and bulb volume of the penetrometer, equilibrium conditions, sample amount and particularly sample size [4]. Fig. 2 displays the influence of the sample size on the results of the mercury intrusion porosimetry measurements. The results of the whole ceramic foam sample and the crushed particles > 2.5 mm are comparable except for a broadening of the cumulative pore volume curve at larger pore sizes (between 30 µm and 150 µm), which can be explained by a better accessibility of the pores of the crushed pieces. Samples consisting of fragments < 2.5 mm show an immense increase of the cumulative mercury volume for larger pores related to the intrusion of mercury in the interstices between the sample fragments. The differences in the two measurements of fragments < 2.5 mm show clearly the low repeatability combined with a to high measured porosity value [3]. This result demonstrates the importance of the sample size for mercury intrusion measurements which should not be too small (fragments > 2.5 mm).

Fig. 3 shows the intruded mercury volume in dependence on the pore size and the ppi-number of the foam ceramic possessing two clear increases of the intruded mercury volume. One pronounced increase between 20 and 82 µm depends on the ppi-number of the ceramic foam samples whereby the mean pore size decreases with increasing ppi-number. This increase is caused by the intrusion of the strut cavities. Thereby the mercury intrusion porosimetry allows the characterization of the strut cavities of ceramic foams produced by the replica process.

The second pronounced increase of the intruded mercury volume (at a pore size of around 1 µm) is related to the intrusion of the material pores and the progression of the curve is comparable for the different ppi-numbers caused by the application of the same slurry for the preparation of the different ceramic foam types. However, the height of the cumulative volume is slightly different for the different ppi-numbers. This scatter is explainable by the standard scaling on the sample mass (results are given in milliliter intruded mercury per gram sample - ml/g) during the evaluation. This scaling introduces a failure because the pore cavity is not related to the sample mass but rather to the sample volume. In contrast, the material pores depend on the sample mass.

In conclusion, material pores and strut cavities can be characterized by mercury intrusion porosimetry whereas functional pores with a pore size of over 500 µm are not detectable. ■

[1] J. Adler, G. Standke: Offenzellige Schaumkeramik, Teil 1, Keramische Zeitschrift 55, 9 (2003) 694-703.
[2] H. Giesche: Mercury porosity. Handbook of porous solids Vol. 1, Wiley-VCH (2002) 309-351.
[3] Voigt, C., Hubalkova, J., Ditscherlein, L., Ditscherlein, R., Peuker, U., Giesche H., Aneziris, C.G.: Characterization of reticulated ceramic foams with mercury intrusion porosimetry and mercury probe atomic force microscopy, Ceramics International 44 [18] (2018) 22963-22975.
[4] Voigt, C., Hubálková, J., Giesche, H., Aneziris, C.G.: Intrusion and extrusion mercury porosimetry measurements at Al_2O_3-C - Influence of measuring parameter, Microporous and Mesoporous Materials 299 (2020) 110125.

THERMODYNAMIC ASSESSMENT FOR MODELING INTERFACIAL INTERACTIONS BETWEEN CERAMIC FILTER AND METAL MELT

Author: Mariia Ilatovskaia
(Subproject A03)

Subproject A03 deals with the thermodynamic databases development for a metal melt filtration process. Possible interfacial interactions between steel or aluminum-alloy and Al_2O_3-based filter material coated with various ceramic materials can be predicted using thermodynamic calculations. The CALPHAD approach is used for the thermodynamic description.

Thermodynamic databases are developed by means of the CALPHAD approach, i.e. by using the available phase diagram data and experimental thermodynamic values to optimize the parameters describing the Gibbs energy of phases possible in the system. Thermodynamic data are the basis for more advance simulation of technological processes.

Rutile (TiO_2) coatings deposited on corundum (Al_2O_3) are supposed to actively filter the $MgAl_2O_4$-spinel phase from Al-based molten alloy. The molten Al-based alloy will then react with TiO_2, reducing it to sub-oxides and metallic titanium. An excess of Ti not dissolved in Al can lead to the formation of intermetallic compounds $TiAl_3$, $TiAl_2$ or TiAl. Due to the dissolution of Mg in the Al alloy, the phases $MgAl_2O_4$ or $MgTiO_3$ can form. The presence of Si in the Al alloy can cause the formation of $Ti_5(Si,Al)_3$, $Ti(Al,Si)_3$ and ternary phases. Therefore, the thermodynamic database for the Al-Mg-Si-Ti-O system is essential to model interface reactions between TiO_2 and Al-based melt. As a part, the thermodynamic description for the Al_2O_3-TiO_2-SiO_2 system is needed to model interaction between oxide inclusions, filter and coating materials.

To ensure a reliable thermodynamic description of the ternary system, phase relations in the Al_2O_3-TiO_2-SiO_2 system were studied experimentally [1]. The samples prepared by a co-hydrolysis method followed by annealing experiments were investigated by means of X-ray diffraction (URD63 X-ray diffractometer, Seifert, FPM, Germany) and scanning electron microscopy (LEO1530 Gemini, Zeiss, Germany) equipped with an EDX detector (Bruker AXS Mikroanalysis GmbH, Germany). In addition, investigations using TG-DTA (Setsys Evo-1750, SETARAM, France) were performed to determine the temperatures of the solid-state transformations and melting behavior. Based on the results obtained, the isothermal sections at 1213 °C, 1449 °C, 1474 °C, and 1517 °C were constructed (Fig. 1). The solid-state invariant reaction of a transitional type

$$TiO_2 + Al_6Si_2O_{13} \leftrightarrow SiO_2 + Al_2TiO_5$$

was indicated at about 1470 °C for the first time. In support to the literature data, three invariant reactions on the liquidus projection were observed:

(1) eutectic invariant reaction between TiO_2 rutil, SiO_2 crystoballite, and Al_2TiO_5 tialite at 1477 °C;

(2) transitional-type reaction

$L + Al_6Si_2O_{13} \leftrightarrow SiO_2 + Al_2TiO_5$ at 1506 °C, and

(3) transitional-type reaction

$L + Al_2O_3 \leftrightarrow Al_6Si_2O_{13} + Al_2TiO_5$ at 1733 °C.

Change of the phase relations with temperature is also shown on the vertical section SiO_2-Al_2TiO_5 (Fig. 2).

Further research will include the study of the miscibility gap in the liquid phase that extends into the ternary system from the binary TiO_2-SiO_2 system. Furthermore, the experimental data obtained along with the previously assessed parameters for the binary Al_2O_3-TiO_2, TiO_2-SiO_2, and Al_2O_3-SiO_2 systems will be used to derive the thermodynamic description of the Al_2O_3-TiO_2-SiO_2 system by means of the CALPHAD approach. The derived thermodynamic database will be useful for calculations related to the interactions of the solid, liquid and gas phases that can form during the filtration of the Al melt. ■

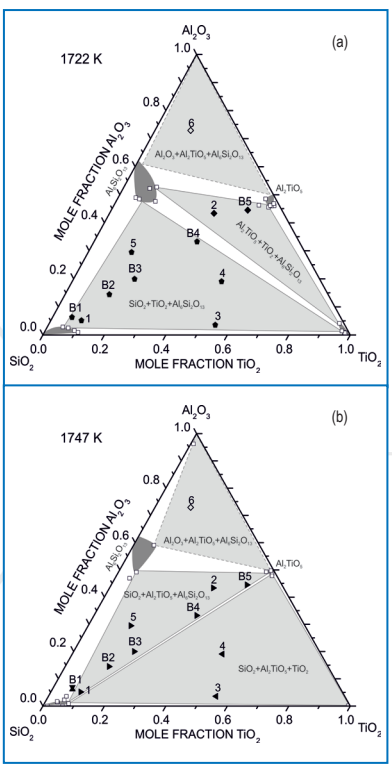


Fig. 1: Isothermal sections of the Al_2O_3–TiO_2–SiO_2 system constructed using experimental data at (a) 1722 K/1449 °C and (b) 1747 K/1474 °C at $p(O_2)$ = 0.21 bar .

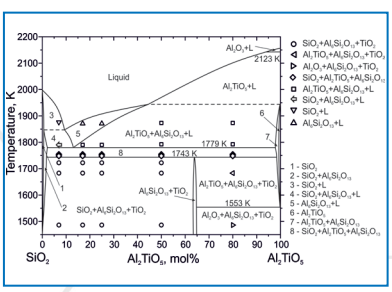


Fig. 2: Phase diagram of the SiO_2–Al_2TiO_5 section at $p(O_2)$ = 0.21 bar.

[1] Ilatovskaia M., Bärthel F., Fabrichnaya O.: Phase relations in the Al_2O_3-TiO_2-SiO_2 system, Ceramic International, 46 [18] (2020), 29402-29142.

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CURRENT PUBLICATIONS (JUNE - NOVEMBER 2020)

Further information about the 78 publications that have been generated since the start of the third program period as well as about the currently 20 patents and patent applications are available at https://tu-freiberg.de/forschung/sfb920

Projectarea A - Filter materials

Subproject A01

Neumann, M., Gehre, P., Hubálková, J., Zielke, H., Abendroth, M., Aneziris, C.G. (2020): Statistical Analysis of the flexural strength of free-standing flame-sprayed alumina coatings prior and after thermal shock, Journal of Thermal Spray Technology, accepted: 13.10.2020, DOI 10.1007/s11666-020-01114-6.

Bock, B., Aneziris, C.G. (2020): Impact of slip- and flame-spray coated carbon-bonded alumina filters on the steel melt filtration and filter fabrication by means of additive manufacturing, 3rd International Postgraduates Seminar of Refractories, Wuhan, China, 13.-14.10.2020, web conference, oral presentation.

Bock, B., Wetzig, T., Herdering, A., Gehre, P., Hubálková, J., Dudczig, S., Aneziris, C.G. (2020): Development of ceramic foam filters based on additive manufacturing and their impact on steel melt filtration, 63rd International Colloquium on Refractories 2020, 16.-17.09.2020, Aachen, web conference, oral presentation, Proceedings of the 62th International Colloquium on Refractories 2020 - REFRACTORIES enabling High Temperature Technologies, pp. 143-146, ISBN 978-3-9815813-6-2.

Subproject A02

Voigt, C., Fankhänel, B., Dietrich, B., Storti, E., Badowski, M., Gorshunova, M., Wolf, G., Stelter, M., Aneziris, C.G. (2020): Al_2O_3 Nanocoating on Ceramic Foam Filters, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Voigt, C., Hubálková, J., Zienert, T., Fankhänel, B., Stelter, M., Charitos, A., Aneziris, C. G. (2020): Aluminum melt filtration with carbon bonded alumina filters, Materials, 2020, 13 (8), 3962, pp.1-13, DOI 10.3390/ma13183962.

Voigt, C., Fankhänel, B., Dietrich, B., Storti, E., Badowski, M., Gorshunova, M., Wolf, G., Stelter, M., Aneziris, C.G. (2020): Influence of Ceramic Foam Filters with Al_2O_3 Nanocoating on the Aluminum Filtration Behavior tested with and without Grain Refiner, Metallurgical and Materials Transactions B, 2020, 51B, pp. 2371-2380, DOI 10.1007/s11663-020-01900-1.

Subproject A03

Ilatovskaia, M., Fabrichnaya, O. (2020): Thermodynamic assessment of the Al_2O_3-TiO_2-SiO_2 system for modeling interactions at the ceramic filter - melt interface, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Fabrichnaya, O., Ilatovskaia, M. (2020): Experimental study and thermodynamic modelling of the Al_2O_3–MnO system, 17th Discussion Meeting on Thermodynamics of Alloys - TOFA 2020, Bad Staffelstein, 28.09-02.10.2020, oral presentation.

Ilatovskaia, M., Fabrichnaya, O. (2020): Thermodynamic assessment of the Al_2O_3-TiO_2-SiO_2 system, 17th Discussion Meeting on Thermodynamics of Alloys - TOFA 2020, Bad Staffelstein, 28.09-02.10.2020, oral presentation.

Ilatovskaia, M., Fabrichnaya, O. (2020): Thermodynamic assessment of the Al_2O_3-MnO system, MSE 2020 - Materials Science and Engineering Congress, Darmstadt, 22.-25.09.2020, web conference, oral presentation.

Ilatovskaia, M., Bärthel, F., Fabrichnaya, O. (2020): The Al_2O_3-TiO_2-SiO_2-System: experiments and thermodynamik calculations, XVI International Conference on Thermal Analysis and Calorimetry in Russia (RTAC-2020), 06. Juli 2020, Moscow, Russia, web conference, Book of Abstracts - Moscow, “Pero” Publisher, 2020, p. 86, ISBN 978-5-00171-240-4.

Fabrichnaya, O., Ilatovskaia, M. (2020): Experimental study and thermodynamic modelling of the Al_2O_3-based systems for ceramic filter application, XVI International Conference on Thermal Analysis and Calorimetry in Russia (RTAC-2020), 06.Juli 2020, Moscow, Russia, web conference, Book of Abstracts - Moscow, “Pero” Publisher, 2020, p. 62, ISBN 978-5-00171-240-4.

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Subproject A04

Kraus, J., Schwalbe, S., Trepte, K., Kortus, J. (2020): Self-interaction correction applied to molecules in solution, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Brehm, S., Himcinschi, C., Rudolph, M., Hammer, T., Bock, B., Rafaja, D., Aneziris, C.G., Kortus, J. (2020): Raman spectroscopic characterization of binder systems for carbon-bonded filters, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Kraus, J., Schwalbe, S., Brehm, S., Himcinschi, C., Kortus, J. (2020): DFT modeling of Raman spectra for binder components, MSE 2020 - Materials Science and Engineering Congress, Darmstadt, 22.-25.09.2020, web conference, oral presentation.

Schwalbe, S., Fiedler, L., Kraus, J., Kortus, J., Trepte, K., Lehtola, S. (2020): PyFLOSIC - Python based Fermi-Löwdin orbital self-interaction correction, The Journal of Chemical Physics, 2020, 153 (8), 084104, DOI 10.1063/5.0012519.

Subproject A05

Thümmler, M., Fischer, P., Becker, H., Wagner, R., Leineweber, A., Rafaja, D. (2020): Partial reconstruction of the Kikuchi sphere for unknown crystal structures, DGM-Arbeitskreis Mikrostrukturcharakterisierung im REM (EBSD), online, 22.10.2020, oral presentation

Thümmler, M., Salomon, A., Schimpf, C., Kriegel, M., Fabrichnaya, O., Rafaja, D. (2020): In situ observation of the thermally induced reduction of fused silica coatings in contact with molten aluminum, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Subproject A06

Salomon, A., Rafaja, D. (2020): Synthesis of hercynite and related spinel structures using SPS, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Projectarea B - Modeling of filter structures/ filter systems

Subproject B01

Ditscherlein, L., Zienert, T., Dudczig, S., Aneziris, C.G., Peuker, U.A. (2020): AFM investigation of the in situ-formed oxide layer at the interface of Al_2O_3-C/steel melt in terms of adhesion force and roughness in a model system, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Subproject B05

Malik, A., Abendroth, M., Kiefer, B. (2020): Applications of a hybrid approach to describe the elastic-plastic deformation behavior of highly porous media by neural networks, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Subproject B06

Asad, A., Schwarze, R. (2020): Numerical Modeling of the combination between reactive cleaning and active filtration in an induction crucible furnace, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, Webkonferenz, Vortrag.

Projectarea C - Filter performance, materials properties

Subproject C02

Wu, X., Ranglack-Klemm, Y., Storti, E., Dudczig, S., Aneziris, C.G., Biermann, H. (2020): Residual properties of carbon-bonded alumina filters after contact with liquid steel melt, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Wu, X., Ranglack-Klemm, Y., Hubálková, J., Solarek, J., Aneziris, C.G., Weidner, A., Biermann, H. (2020): Impact of high temperature on the compression behavior of carbon-bonded alumina filters with functionalized coatings, Ceramics International, (2020), accepted: 27.09.2020, DOI 10.1016/j.ceramint.2020.09.255.

Subproject C04

Wagner, R., Seleznev, M., Fischer, H., Ditscherlein, R., Dietrich, B.G., Baumann, B., Schoß, J., Keßler, A., Leißner, T., Weidner, A., Wolf, G., Peuker, U., Biermann, H. (2020): Impact of Melt Conditioning and filtration on iron-rich β phase in AlSi9Cu3 and its fatigue life, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Seleznev, M., Weidner, A., Biermann, H., Vinogradov, A. (2021): Novel method for in situ damage monitoring during ultrasonic fatigue testing by the advanced acoustic emission technique, International Journal of Fatigue, 2021, 142, 105918, DOI 10.1016/j.ijfatigue.2020.105918.

Subproject C05

Henschel, S., Wagner, R., Seleznev, M., Dudczig, S., Storti, E., Gehre, P., Weidner, A., Biermann, H., Aneziris, C.G., Krüger, L. (2020): Effect of filter coating on strength and deformation behavior 42CrMo4 steel, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation

Henschel, S., Posselt, F., Dudczig, S., Aneziris, C.G., Krüger, L. (2020): Experimental determination of toughness under mode I/II loading, 1st Virtual European Conference on Fracture - VECF1, 29.06.2020, web conference, oral presentation.

Subproject C06

Schramm, A., Voigt, C., Hubálková, J., Scharf, C., Aneziris, C.G. (2020): Manufacturing techniques and their impact on the properties, macro- and microstructure of carbon-bonded alumina foams, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Fankhänel, B., Stelter, M. (2020): Influencing the hydrogen porosity in aluminium casting by (re) active filter materials, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation

Transfer projects

Transfer project T02

Schmiedel, A., Henkel, S., Kirste, T., Morgenstern, R., Weidner, A., Biermann, H. (2020): Ultrasonic fatigue testing of cast steel G42CrMo4 at elevated temperatures, Fatigue and Fracture of Engineering Materials and Structures, 2020, 43 (10), pp. 2455-2475, DOI 10.1111/ffe.13316.

Kirste, T., Morgenstern, R., Schmiedel, A., Weidner, A., Biermann, H. (2020): Influence of the local degree of deformation on the temperature dependent fatigue behavior of a ferritic-pearlitic steel, Fatigue and Fracture of Engineering Materials and Structures, 2020, 43 (12), pp. 2786-2799, DOI 10.1111/ffe.13288.

Transfer project T04

Wetzig, T., Aneziris, C.G. (2020): A new approach for filtration in continuous casting of steel, 3rd International Postgraduates Seminar of Refractories, Wuhan, China, 13.-14.10.2020, web conference, oral presentation.

Wetzig, T., Bock, B., Dudczig, S., Aneziris, C.G. (2020): Alginate-based robo gelcasting of cellular ceramics for steel melt filtration, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Service projects

Service project S02

Lehmann, H., Werzner, E., Malik, A., Abendroth, M., Ray, S., Jung, B. (2020): Influence of the Strut Shape of Open-Cell Foams on Hydraulic Tortuosity, Permeability and Removal Efficiency for non-metallic Inclusions during Filtration of Liquid Aluminum, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation.

Complementary projects

Aneziris, C.G. (2020): Active and reactive filtercosmos for metall melt filtration due to cellular ceramics - a contribution to zero defect materials, 6th Conference on Cellular Materials - CellMAT 2020, 07.-09.10.2020, web conference, oral presentation (keynote).

Fischer, U., Bock, B., Wetzig, T., Hubálková, J., Gehre, P., Aneziris, C.G. (2020): Ressourceneffiziente Hybridverfahren für keramische Stahlschmelzefilter, Kompass I - Ressourceneffizienz, Additive Fertigung und Digitalisierung, Hrsg.: Bundesvereinigung-GRAT „Gesellschaft für Ressourceneffizienz und Additive Technologien“ e. V., Verlag: ALPHA Informationsgesellschaft mbH, Projekt-Nr: 117-001, S. 39-41.

Patents and patent applications

Subproject B01

Ceramic filters for molten metal and processes for filtration of molten metal. Patent no. DE 10 2019 117 513 B3, patent granted: 2020-08-06.

Subproject C06

Coatings and ceramic filters for filtration of molten metal. Patent application no. DE 10 2020 006 167.2, application date: 2020-10-07.

Transfer project T05

Ceramic filters for molten metal and processes for filtration of molten metal. Patent application no. DE 10 2018 126 326 A1, application date: 2018-12-23, publication date: 2020-04-23.

CRC 920 PUBLICATION AWARD

The CRC 920 assigned the publication award three times to young researchers by Prof. Christos G. Aneziris, coordinator of the CRC 920. The award was presented for the first time online as part of a virtual cours of a doctoral colloquium of the CRC.

The award recieved on the one hand **Dr.-Ing. Henry Zielke (TP C03) and Dipl.-Ing. Tony Wetzig (TP T04)** for their publication „Influence of carbon content and coking temperature on the biaxial flexural strength of carbon-bonded alumina at elevated temperatures”. The authors describe the influence of the carbon content and the coking temperature on the thermal and mechanical properties of the open cell ceramic foam filters. The ceramic filters are used for metal melt filtration and are made of carbon bonded alumina. Thereby, the method of miniaturized material testing, the „Ball on Three Balls test“ (B3B), at temperature up to 1500 °C was used.

Photo (from left to right): Awardees of the puplication award of the CRC 920, Dipl.-Ing. Tony Wetzig and Dr.-Ing. Claudia Voigt.

On the other hand, **Dr.-Ing. Christoph Settgast (TP B05)** was honored for his publication „A hybrid approach to simulate the homogenized irreversible elastic–plastic deformations and damage of foams by neural networks”. The contribution deals with the application of neural networks for the description and modeling of the irreversible material behavior of ceramic foam structures.

A new hybrid approach to simulating the elastic-plastic behavior with coupled demage evolution in the material was developed.

In her publication „Intrusion and extrusion mercury porosimetry measurements at Al_2O_3-C - influence of measuring parameter", **Dr.-Ing. Claudia Voigt** researches the application of the mercurry porosimetry measurements to characterize the pore structure of porous materials. Therby, the influence of the measuring parameters during perfoming combined intrusion studies and extrusion studies was examined for reproducible measurement results of the mercury porosimetry. For this work, Mrs. Dr. Voigt was awarded the publication award of the CRC 920. ■

GRADUATIONS IN CRC 920

In June, **Dr.-Ing. Ashish Pokhrel**, PhD student at the research training group of the CRC 920, successfully defended his dissertation entiteled „Open Porous Ceramics by Non-Conventional Direct Foaming". The dissertation investigates the manufacturing technology of porous ceramic materials by direct forming. The microstructures obtained on this way were compared with the processing parameters.

Photo (from left to right): Dr.-Ing. A. Pokhrel, Prof. T. Bier, Prof. T. Graule, Prof. A. Bräuer, Prof. H. Biermann, Prof. C.G. Aneziris.

In September, **Dr.-Ing. Amjad Asad** finished his dissertation with excellent success on „Numerical and Experimental Investigation of Particle Separation and Flow Behavior Inside an Induction Crucible Furnace". The dissertation investigates a numerical model for the simulation of the steel melt flow in an industrial induction crucible furnace. It was shown, that reactive filtration and bubble formation have a positive effect of the cleanness of the molten steel. ■

Photo (from left to right): Prof. C.G. Aneziris, Prof. R. Schwarze, Dr.-Ing. A. Asad, Prof. T. Fieback, Prof. O. Volkova.

CONFERENCES AND CALLS FOR PAPERS

11th Freiberg Refractory Forum: December 09, 2020,TU Bergakademie, Freiberg.

TMS 2021: Annual Meeting & Exhibition, March 14-18, 2021, Orlando, USA, https://www.tms.org/TMS2021.

REFRA Prague 2021: 21st Conference on modern refractory materials and key achievements in high temperature technologies, April 07-09, 2021, Praque, Czech Republic, http://www.silikaty.cz/www-30-refra-prague-2021.

CERAMICS 2021: 96th DKG Annual Meeting 2021, April 19-21, 2021, Forschungszentrum Jülich, http://www.2021.dkg.de/.

CIMTEC 2021: 15th International Ceramics Congress, June 21-25, 2021, Montecatini Terme, Italien, http://2021.cimtec-congress.org/.

IMPRESSUM

EDITOR
Prof. Dr.-Ing. habil. Christos G. Aneziris
CRC 920 Coordinator
TU Bergakademie Freiberg
Institute of Ceramic, Refractories and Composite Materials
Agricolastraße 17, 09599 Freiberg
Phone: +49 3731 39 2505
Fax: +49 3731 39 2419
E-mail: aneziris@ikfvw.tu-freiberg.de

Dr.-Ing. Undine Fischer
CRC 920 Manager
TU Bergakademie Freiberg
Institut of Ceramic, Refractories and Composite Materials
Agricolastraße 17, 09599 Freiberg
Phone: +49 3731 39 3324
Fax: +49 3731 39 2419
E-mail: undine.fischer@ikfvw.tu-freiberg.de

EDITORIAL OFFICE
Prof. Dr. habil. Anja Geigenmüller
TU Ilmenau
Faculty of Economic Science and Media
Department of Marketing
Langewiesener Straße 22, 98693 Ilmenau
Phone: +49 3677 69 4085
Fax: +49 3677 69 4223
E-mail: anja.geigenmueller@tu-ilmenau.de

PHOTOS
TU Bergakademie Freiberg, CRC 920 „Multi-Funktional Filters for Metal Melt Filtration - A Contribution towards Zero Defect Materials", Detlev Müller.

ISSUE: No. 19, Issue 02/2020
(Two issues per year)