SFB 920

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

NEWSLETTER 22 (1/2022)

DFG Deutsche Forschungsgemeinschaft

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

DEAR READERS,

increasing demands for higher metal quality and lower reject rates on the part of users and processors call for customized solutions in the design, manufacture and use of functionalized filter materials and filter systems. In addition to sustainability, resource and energy efficiency, climate and environmental protection are key factors in the networked research activities of the CRC 920 scientists. These are becoming more and more important in the transfer of research results into industrial applications as well as in the exchange of scientific knowledge on a national and international level.

The Collaborative Research Center CRC 920 now presents selected results of its cross-project and interdisciplinary work in the form of a further special publication. 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.

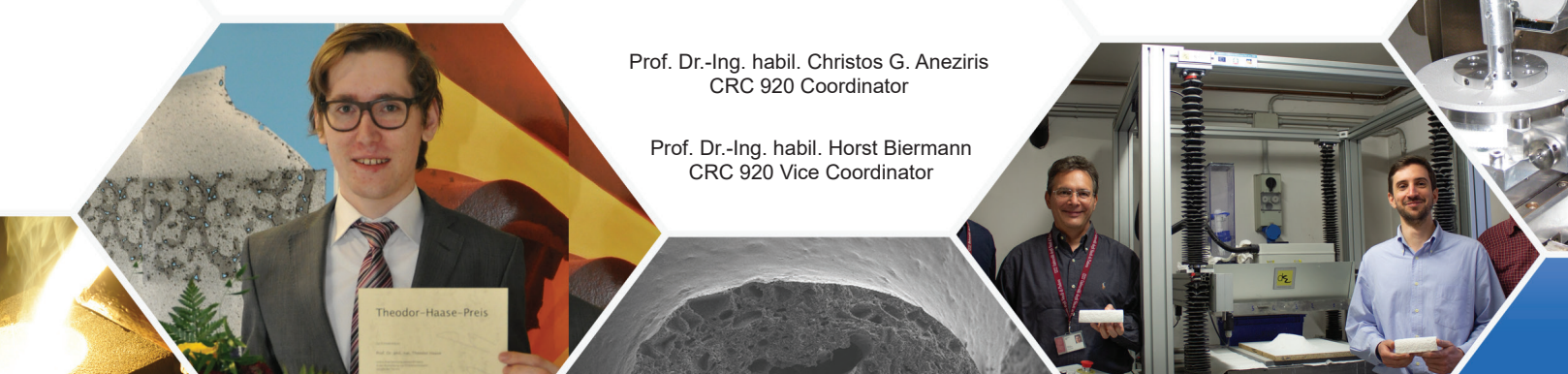
We hope you will enjoy the newsletter!

Yours sincerely,

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

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

CONTENT

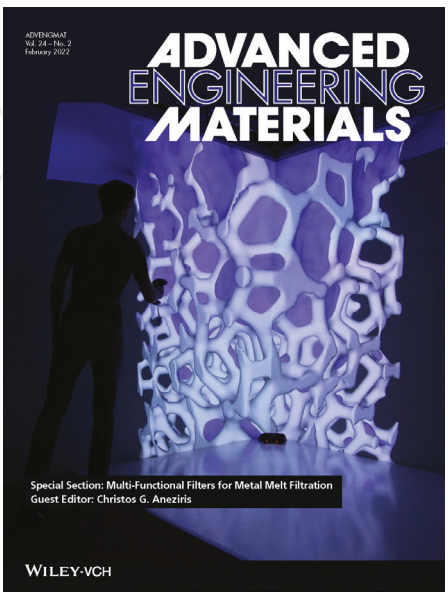


LATEST DEVELOPEMENTS AND INTERNATIONAL EXCHANGE ON METAL MELT FILTRATION

The aim of the Collaborative Research Center 920 "Multi-Functional Filters for Metal Melt Filtration - a Contribution towards Zero Defect Materials" is the enormous reduction of inorganic non-metallic inclusions in the metal matrix by using intelligent filter materials as well as filter systems with functionalized filter surfaces. A special issue of "Advanced Engineering Materials" as well as the 12th Freiberg Refractory Forum are dedicated in a comprehensive way to selected research results along the process chain of metal melt filtration.

Especially in the third funding period of the CRC 920, **a new generation of combined refining filter systems** is in the focus of the research activities. The metal melt comes first in contact with a reactive filter which generates gas bubbles in the melt as well as activates gas bubbles on the surface of the inclusions. As a result a kind of flotation of the inclusions towards the slag on the surface of the melt takes place. Further, the high reactivity as well as the gas bubbles contribute to the agglomeration of the fine inclusions to big clusters which flow due to buoyancy forces to the surface of the melt or are filtrated on the surface of active filters, which do not form gas bubbles but provide on their functionalized surfaces the same chemistry as the inclusions for a sufficient adhesion and as a result for a sufficient filtration of the inclusions. The modelling is focusing mainly on the several contributions of the gas bubbles and on the in situ formed reactive layers on the surface of the reactive filters as well as on the generation of codes with respect to the thermo-mechanical and functional properties of the filters for a 3D-printing of filter structures which are then given their final shape and functionalization for instance with the aid of a robot-assisted flame spraying technique.

These and other current research results of the CRC 920 are presented in a **special section of "Advanced Engineering Materials"**. In 23 contributions, the entire process chain of molten metal filtration "from material to component" is presented from 19 interdisciplinary projects by more than 25 funded scientists. Noteworthy, the special issue contains also cross-project publications from doctoral students in CRC 920. In addition to the filtration of steel melts, research findings for the metal melt filtration of aluminum and magnesium alloys will also be shown. ■



With a focus on current climate protection targets, the use of green hydrogen as a climate-friendly energy carrier of the future and the associated effects on refractory materials in high-temperature processes, the **12th Freiberg Refractory Forum** was held digitally in December 2021 at the invitation of the CRC 920 "Multifunctional Filters for Metal Melt Filtration - a Contribution towards Zero Defect Materials", the DGM/DKG technical committee "Refractories" and the DFG research group FOR 3010 "Refrabund".

About 90 participants from Germany and abroad from science, industry and professionals associations exchanged information on current developments in refractory materials and their applications. The speakers included international experts from industry and science. Participants from CRC 920 and FOR 3010 informed about the latest developments and innovative research approaches in the field of metal melt filtration and refractory composite materials in a digital poster exhibition.

A comprehensive overview of the energy transition in Germany was given by **Dr. Georg Nikolaus Stamatelopoulos**, Member of the Executive Board of **EnBW Energie Baden-Württemberg AG** in Stuttgart. **Prof. Dr. Helge Jansen**, Managing Director at **Refratechnik Steel GmbH and Refratechnik Casting GmbH** in Düsseldorf, presented the latest findings on the influence of hydrogen or hydrous atmospheres on common refractory materials in high-temperature applications. Information on energy aspects in the use of gas bubbles for cleaning steel melts was provided by **Prof. Dr. Victor Carlos Pandolfelli** from the **Universidada Federal de Sao Carlos** in Brazil. Furthermore, **Mr. Vincent Leroux** from the company **Vesuvius Group AG** in Belgium described in his presentation innovative approaches to improve the purity of steel. **Dr. Vania Regina Salvini** from **FATEC Sertaozinho** in Brazil presented recent developments in the manufacturing process of ceramic foam filters.

An important concern of the Freiberg Refractories Forum is the promotion of young scientists. To this end, the association "MORE - Meeting of Refractory Experts Freiberg e.V." annually endows the **Theodor Haase Award** for outstanding master and diploma theses in the field of "refractory high-temperature applications", which is awarded at the Freiberg Refractory Forum. This year, the award was given to M.Eng. Serhii Yaroshevskyi from the TU Bergakademie Freiberg. In his masters thesis, which was conducted at the Institute of Ceramics, Refractories and Composite Materials, Mr. Yaroshevskyi developed filaments made of metalloceramic composites for additive manufacturing. The work was done under the supervision of Prof. Christos G. Aneziris. The award commemorates the Freiberg scientist Theodor Haase and his commitment to the training of silicate technicians. ■

MORE NEWS

From November 2021 to February 2022, **Dr.-Ing. Hanka Becker** took the chance to spend a research stay at the **Technical University of Denmark (DTU)** in Kongens Lyngby. DTU has approximately 13,000 students and is one of the leading technical institutions in Europe.

Dr. Becker follows an invitation from the head of the Department of Materials and Surface Engineering at the Faculty of Mechanical Engineering, Prof. Wolfgang Pantleon. At DTU in Kongens Lyngby, she carried out part of the work for subproject A07, which deals with the removal of iron from secondary aluminum using metal melt filtration.

"In the research group at DTU, I was able to work intensively on the research tasks under the best conditions", Dr. Becker summarizes her stay. Using computed tomography and scanning electron microscopy, she successfully investigated the kinetics of formation of primary particles from iron-containing intermetallic phases in secondary iron-containing Al-Si melts on filter substrates of alumina and carbon-bonded alumina. By using suitable filter substrates to remove iron, the quality of ferrous Al-Si alloys can be specifically improved. ■

In addition, **Dr.-Ing. Enrico Storti** (subproject A01, C01) spent May 2022 as a guest at the **Universita di Padova** in Italy to carry out studies on the manufacture of filter structures using additive manufacturing together with scientists from Prof. Paolo Colombo's research group. This involved the 3D printing of test specimens based on the ceramic material compositions developed in CRC 920, which can be used as filter materials, using binder jetting technology.

Prof. Colombo is a specialist in the field of cellular materials, in particular the development of new process routes for porous glasses and ceramics, such as the additive manufacturing of porous ceramic components. He has been supporting the CRC 920 since the first funding period, among others as a Mercator Fellow. ■

INTERNATIONAL EXCHANGE

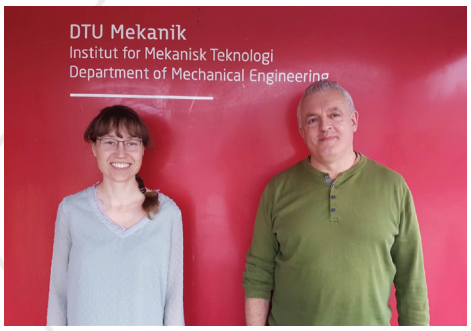


Photo (fom left to right): Dr.-Ing. Hanka Becker, Prof. Wolfgang Pantleon (DTU Denmark).

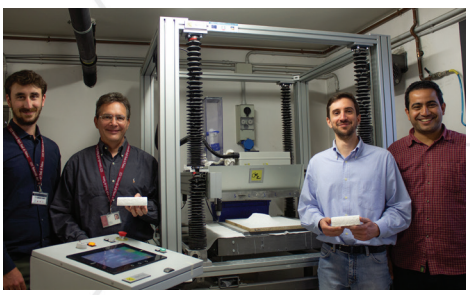


Photo (from left to right): Dr. Filippo Gobbin, Prof. Paolo Colombo (both Universita di Padova), Dr.-Ing. Enrico Storti (TU BAF), Dr. Hamada Elsayed (Universita di Padova).

The production of dross-free large castings in cast iron alloys with nodular graphite (GJS alloys) is the subject of a **new transfer project** coordinated by **Prof. Gotthard Wolf and Prof. Michal Szucki** (both Foundry Institute), which was approved by the German Research Foundation (DFG). Together with an industrial partner from Thuringia, the **targeted use of innovative filter components for metal melt filtration in mold casting for cast iron alloys** is to be investigated.

The main focus of the transfer project is the research of a turbulence-free casting technology for the removal of nonmetallic inclusions (dross) in GJS alloys with the help of the intelligent filter materials or filter components for large castings that weigh several tons, which were developed in CRC 920. Together with the application partner Silbitz Guss GmbH, the new filter systems for dross removal are developed and designed according to the casting geometry and used under industrial conditions for complex casting systems in large casting trials. In addition to improved product quality, the targeted filtration of dross is expected to lead to a lower reject rate and thus to less cost-intensive treatment steps in foundries.

The design and process-reliable use of the new metal melt filters in the casting system for GJS alloys and the testing of the large castings produced with them are carried out by the industrial partner. The development and suitability testing of the new filters for cast iron alloys takes place at the Foundry Institute. ■

FURTHER TRANSFER PROJECT APPROVED

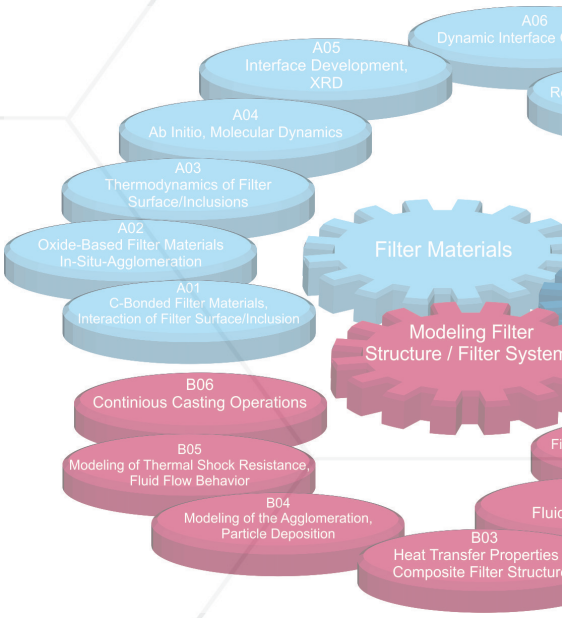
Photo: Impingement test at the Foundry Institute for suitability testing of newly developed metal melt filters.

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.

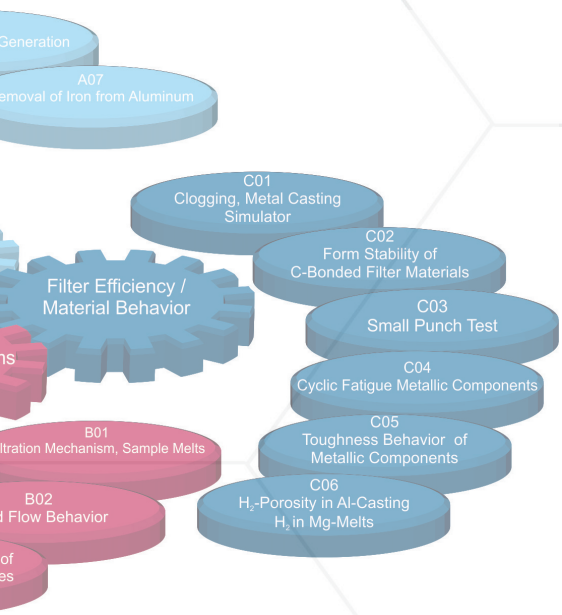
Working Group 1: „Metal melt/inclusions, active/reactive filter material, boundary surface design" (Coordination: Dr.-Ing. Hanka Becker)

- Production of samples (University of Padova and TUBAF) with ceramic formulations suitable for use as filter materials; 3D printing of samples by binder jetting technology (A01),
- Investigation of carbonaceous alumina slips based on lactose and tannin for the alginate-based robo gel casting and their impact on the substrate properties (A01),
- Manufacturing of Al_2O_3-C foam filters with Al_2O_3 flame-sprayed coating for bottom-teeming ingot casting tests at the company Deutsche Edelstahlwerke Specialty Steel (A02, T04),
- Studies in the ternary MgO-TiO_2-SiO_2 system: solid-state reaction and determination of the liquidus area (A03),
- Determination of transition states in the pyrolysis reaction of catechin using the NEB method (A04),
- Investigation of the influence of added SiC on carbon-bonded Al_2O_3 filters by Raman spectroscopy (A04),
- Kinetic description of the interface reaction between molten Al and functionalized SiO_2 coatings under non-isothermal conditions via HTXRD (A05),
- Second production series for $MnAl_2O_4$ from Mn_2O_3 + C + α- and γ-Al_2O_3 (A06),
- New method for the determination of habit planes from data of 2D-EBSD maps for the characterization of interfaces (A07),
- SNMS measurements on spodumene-containing filter materials of different qualities for quantifying spodumene contents (C06),
- Conduction of model and real gravity casting tests with uncoated and Al_2O_3-, MgAlON- or $MgAl_2O_4$-coated Al_2O_3-C filters with AZ91 (C06),
- Investigations on the reduction of the Hydrogen content in an AlSi7Mg melt by using spodumene containing filter materials under practical conditions in sand casting (S03),
- Influence of different filter materials and coatings on removal of iron in a secondary Al-Si alloy using a laboratory filtration apparatus (T03),
- Receiving SiC-fibers from BJS ceramics GmbH for investigations in the RT-model system and castings of a AlSi10Mg-alloy (T05).



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),
- Direct-FE^2 implementation of micromorphic theories to model size effects (B05),
- Strength evaluation of the immersed filter in comparison to the experimental data from transfer project T04 (B05),
- Simulation of carbothermal reduction and subsequent precipitation of corundum using the developed phase-field model for reactive multi-component/multi-phase systems (B05),
- Direct-FE² investigations to identify the dominant micromorphic effect acting in foam structures (B05),
- Fracture mechanical tests on Al_2O_3-C compact bars based on the lactose-tannin binder system (C02),
- Thermomechanical tests (700 to 1400 °C) on Al_2O_3-C foam filters based on the lactose-tannin binder system (C02),
- Investigation of various types of filter materials with the high temperature Brazilian disc test (C03),
- Determination of the room and high temperature fracture toughness of filter materials using cohesive zone models and experimental data (C03),
- .



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

- Extension of the layer model for describing van der Waals forces for surfaces with non-uniform coating, assuming the distribution to be either random or dependent on roughness-depth (B01),
- Iterative determination of capillary force distributions on the basis of size distributions of nanobubbles, obtained from AFM topography data (B01),
- Extension and parallelization of a code for solving the 1D radiative transfer equation for model-based determination of extinction coefficient and scattering albedo of ceramic foam filters from measurements of transmission and reflection (B02, B03),
- Improvement of the cooling water supply of the high-temperature magnetic suspension balance for measuring gas solubility in metal melts in order to realize higher measuring temperatures and to enable a precise regulation of the furnace temperature with defined cooling rates (B03),
- Conduction of first experiments to determine the volumetric heat transfer coefficient using cast iron melt (B03, S03),
- CP-AFM investigation of the contact behavior of model inclusions interacting with hetero-coagulates (B04),
- Evaluation of the 2D study of a rising bubble and the interaction between the rising bubble and dispersed particles in a water model as well as conduction of preliminary CFD simulations of a bubble chain using the VOF method, aiming towards the detailed modeling of the particle-bubble interaction using the VOF-DPM approach (B06),
- Evaluation of comprehensive pore-scale simulations on the influence of various modifications of the foam geometry on the filtration process during continuous casting of aluminum using a tool for automated report generation based on Python and Markdown (S02, B02).

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

- Selection of an optimal refractory for the Fe-TiC alloy production. Three ceramics substrates Al_2O_3, $CaZrO_3$, and MgO stabilized ZrO_2 were contacted with the liquid Fe-TiC alloy at 1650 °C by applying the sessile drop method. FactSage was used to calculated the possible reactions between the liquid Fe-TiC alloy and the selected refractory materials. (C01),
- Selenium was proved as a possible candidate for the decopperization process. Copper selenide was found to form by addition of Se into the liquid Fe-Cu (1 wt%) alloy. Furthermore, with a secondary metallurgical ladle slag addition to the Fe-Cu-Se alloy, a massive percent of copper selenide was transferred to the side of the slag. To improve the decopperization efficiency, more types of slags were selected for the experimental trials. (C01),
- Nanoindentation of α-Al_2O_3 inclusions in 42CrMo4 and analysis of their deformation behavior using focused ion beam technique and transmission scanning electron microscopy (C04),-
- Analysis of activated slip systems in α-Al_2O_3 during nanoindentation using EBSD data and the MATLAB toolbox MTEX (C04),
- Confocal laser scanning microscope studies of the behavior of spessartine-containing multiphase inclusions up to 1300 °C and deduction of the evolution of these inclusions during reactive and active filtration of steel melt (A01, C04),
- Simulation of heating and cooling of the specimen in pulse-pause mode employing temperature initial and Dirichlet and Neumann boundary conditions based on experimental thermography data. Validation of the 3D FEM computation for cooling by comparison with results obtained from a 1D problem formulation and numerical and analytical solutions to the associated heat conduction problem. (C04),
- Fracture mechanics characterization of samples of filtration test utilizing a combination of immersion and casting filters at quasi-static loading rats. Analysis of the fracture surface with respect to features that initiate cleavage fracture. These features result in high scatter in the lower part of the ductile-brittle transition zone of the temperature-dependent fracture toughness (C01, C05).

MANUFACTURE AND PROPERTIES OF Al_2O_3-C COMPACT CYLINDERS BASED ON THE LACTOSE-TANNIN BINDER SYSTEMS

Author: Dr. Xian Wu
(Subproject C02)

The subproject C02 investigates the strength and stability of Al_2O_3-C in compact and filter form at room and high temperature. Recently, a slip casting route for the manufacture of compact cylindrical Al_2O_3-C specimens based on the lactose-tannin (L-T) binder system has been developed.

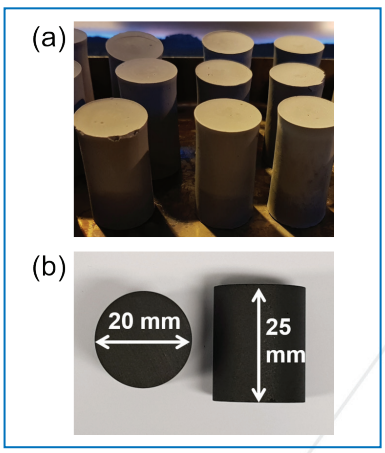


Fig 1: Slip casts after hardening (a) and after machining (b).

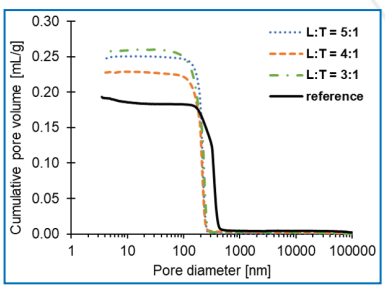


Fig. 2: Mercury intrusion porosimetry measurements.

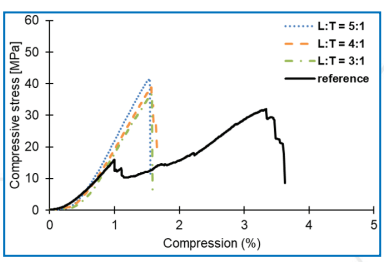


Fig. 3: Typical cold crushing test curves.

Compact bars and cylinders of Al_2O_3-C based on the Carbores P pitch binder have been manufactured and investigated previously [1-3]. They were all shaped by pressing. The correlation of the physical and mechanical properties of these specimens with those of Al_2O_3-C foam filters based on the same or similar raw material composition is rather limited because the shaping of the latter via the replica process is without pressure. An alternative is the application of slip casting instead of pressing. This was found not suitable for compact bars due to the appearance of cracks on the slip casts after drying.

Subsequently, the direct manufacture of compact cylinders (Ø 20 mm × 25 mm height) using the slip casting method was tested and applied to specimens based on the L-T binder system (16 wt% L-T + 4 wt% Carbores P) [4]. Using hollow cylindrical plastic or metal molds with appropriate inner diameter, slurry with defined raw material composition was shaped by slip casting. The slurry viscosity played a crucial role in the casting process. Optimal dynamic viscosity lay between 200 and 500 mPa·s at a shear rate of 100 s^{-1}. After drying, hardening (necessary for the L-T binder system) and coking (up to 1000 °C), the specimens were machined precisely into the desired size (Fig. 2). Thus, high-quality compact cylinders were obtained with L-T mass ratios of 5:1, 4:1 and 3:1. Reference specimens based on the conventional Carbores P binder were manufactured as well in a similar manner.

The L-T-based specimens exhibited lower bulk density (1.72 – 1.76 g·cm^{-3}) and higher open porosity (44 – 45 %) compared to the reference (1.82 g·cm^{-3} and 38 %). This was also reflected in the relatively higher mass reduction and lower volume shrinkage after coking. According to the mercury intrusion porosimetry (MIP) measurements, the pore size of the L-T-based specimens concentrated in the range of 190 – 250 nm, whereas the reference shifted to larger values (310 – 390 nm) (Fig. 2). The residual carbon content of the L-T-based specimens (23 %) was, as expected, much lower than that of the reference (30 %).

The following mechanical parameters were determined at room temperature: cold crushing strength (CCS), splitting tensile strength (T_{sp}) and dynamic elastic modulus (E_{dyn}). The L-T-based specimens showed CCS (34 – 47 MPa) and E_{dyn} values (11 – 14 GPa) comparable to the reference, although the T_{sp} values were significantly lower (3 – 5 MPa vs. 11 MPa). Furthermore, the compressive strain values (1 % - 2 %) at maximum compressive stress of the L-T-based specimens were only about half of the reference (Fig. 3). Such differences between the L-T-based and the pitch-based specimens arise mainly from the structurally different carbon residues of the two kinds of binder system after coking. While at high temperature the pitch decomposed into laminated carbon packages with oriented structural features at the hexagonal base plane which can be seen as a precursor of graphite (but not yet graphite itself), the hardened L-T binder system produced, similar to phenolic resins, rather glassy carbon residue with poorly arranged structure after thermal treatment. Thermomechanical and fracture mechanical properties of the L-T-based specimens are studied currently. The results will be reported in the near future. ■

[1] Y. Klemm; H. Biermann; C.G. Aneziris, Influence of composition and coking temperature on the properties and microstructure of carbon bonded Al2O3-C filter materials, Adv. Eng. Mat., 2013, 15, 1224-1229.
[2] Y. Klemm; H. Biermann; C.G. Aneziris, Microstructure and mechanical properties of fine grained carbon-bonded Al2O3-C materials, Ceram. Int., 2013, 39, 6695-6702.
[3] J. Solarek; C. Himcinschi; Y. Klemm; C.G. Aneziris; H. Biermann, Ductile behavior of fine-grained, carbon-bonded materials at elevated temperatures, Carbon, 2017, 122, 141-149.
[4] X. Wu, A. Weidner, C.G. Aneziris, H. Biermann, Manufacture of carbon-bonded alumina based on a lactose-tannin binder system via slip casting, Ceram. Int. 2022, 48, 148–156.

REMOVAL OF IRON FROM A SECONDARY Al-Si DIE-CASTING ALLOY BY METAL MELT FILTRATION

In cooperation with the subprojects A01, A07, and C04, the transfer project T03 examines the influences of chemical composition, temperature, time, and cooling rate on the formation of iron-rich intermetallic phases. A specially designed laboratory filtration apparatus was used to conduct the reduction of iron from a secondary Al-Si die-casting alloy (AlSi9Cu3(Fe)) using a two-step procedure.

Author: Johannes P. Schoß
(Transfer project T03)

In Al-Si casting alloys, iron (Fe) represents an impurity element, which forms as β-Al4.5FeSi phase, a brittle, plate-like compound in the microstructure during solidification [1]. This β-phase leads to negative influences on the mechanical and casting properties and causes crack initiation and stress concentration [2]. In addition, due to its high solubility in molten Al (≈ 2.5 wt% at 700 °C) [3], Fe can be enriched extensively by insufficient scrap separation in the global materials recycling process.

For this purpose, the reduction of Fe was conducted by a two-step procedure. The procedure includes: First, the conditioning, where additional elements (such as Mn and Cr) are added to the melt to promote the formation of primary solidifying Fe-containing intermetallics (sludge) [4]. Therefore, the melt temperature has to be set above the solidification temperature of the Al dendrites and below the temperature of the sludge formation in order to obtain the Fe-rich intermetallics. These bind the dissolved Fe in the crystal lattice as α-intermetallics [5], and thus reduce the Fe content in the residual melt. In the second step, the filtration process is initiated using a specially developed laboratory filtration apparatus (Fig. 1) to separate the intermetallic particles from the Fe-reduced residual melt.

To evaluate the potential for removal of Fe-containing intermetallic particles from an EN AC-AlSi9Cu3(Fe) alloy, samples were examined before and after filtration using image analysis software (Stream Motion) [1]. The samples were etched with hot 30 % sulfuric acid for enhanced contrast, leading to blackening of the intermetallic phases compared to the less affected eutectic silicon (Fig. 2). Subsequently, the samples were analyzed by light microscopy to determine the pore fraction of a sample section (on polished micrographs) and then to compare to the total fraction (porosity including etched Fe-phases). Since the formation of Fe-rich intermetallic phases can be influenced by temperature, holding time, and chemical composition [4], the parameters were selected according to a predefined field of investigations. For a preselected chemical composition (Leg D: 1.61 % Fe, 1.01 % Mn, and 0.259 % Cr), the variation of temperature (620 °C, 655 °C, and 685 °C) and time (20 min, 70 min, and 120 min) was performed. Whereas the area fractions in the filtered samples decreased from ≈ 5.0 % (685 °C) to ≈ 1.5 % (620 °C) with decreasing temperature in the solidification range of the sludge phase, no further decrease in Fe-rich intermetallic particles was observed between the holding times of 20 min, 70 min, and 120 min at 620 °C [1]. Accordingly, the formation of Fe-rich intermetallics is significantly attributed to the temperature influence, which also underlines the temperature-dependent solubility of Fe in Al.

Furthermore, Fe reduction was evaluated by chemical analyses (OES, SPECTROMAXx) of the analyzed sample material before and after filtration by remelting in the crucible induction furnace at > 800 °C. The results for the elements Fe, Mn and Cr are shown in Fig. 3. The element contents of the samples before filtration continuously exhibit the conditioned reference composition (Leg D). The contents of the elements Fe, Mn, and Cr in the filtered samples are always within the standard deviations of DIN EN 1706:2020-06 of an AlSi9Cu3(Fe) alloy at 0.8 %, 0.34 %, and 0.04 %. Consequently, the maximum Fe reduction is ≈ 50 %, and the elements Mn and Cr are reduced by ≈ 66 % and ≈ 86 %, respectively, after metal melt filtration [1]. ■

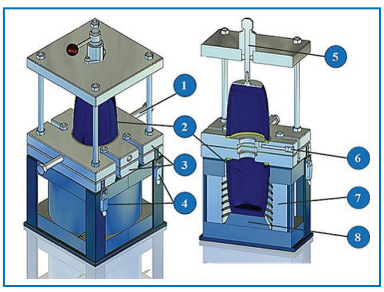


Fig. 1: Laboratory filtration apparatus in isometric illustration and dimetric sectional view including component markings numbered from 1-8 [1].

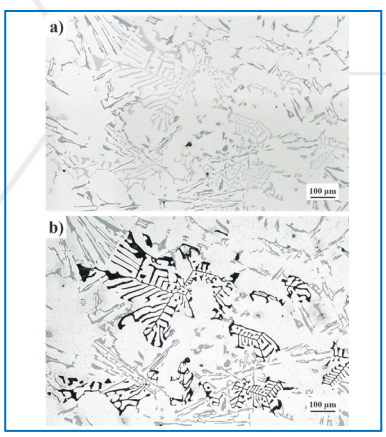


Fig. 2: Schematic for determining the area fraction of Fe-rich intermetallic phases (representative of Chinese script-like morphology) based on micrographs of an exemplary cross section: a) original micrograph, b) after etching (80 °C, 1 min, 30 % H_2SO_4), revealing a black appearance of the Fe-rich intermetallic phases in contrast to the less-affected silicon phase [1].

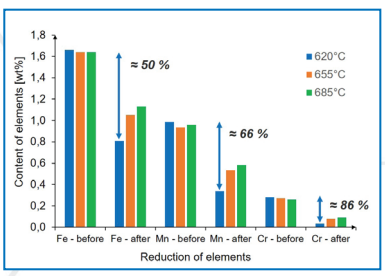


Fig. 3: The chemical composition for the reduction of the elements Fe, Mn and Cr before and after filtration (after the remelting processes of the analyzed materials) [1].

[1] Schoß, J.P., Becker, H., Keßler, A., Leineweber, A., Wolf, G.: Removal of iron from a secondary Al-Si die-casting alloy by metal melt filtration in a laboratory filtration apparatus. Adv. Eng. Mat. 24 (2022), 2100695.
[2] Wagner, R., Seleznev, M., Fischer, H., Ditscherlein, R., Becker, H., Dietrich, B.G., Keßler, A., Leißner, T., Wolf, G., Leineweber, A., Peuker, U.A., Biermann, H., Weidner, A.: Impact of melt conditioning and filtration on iron-rich β phase in AlSi9Cu3 and its fatigue life studied by µCT. Mater. Charact. 174 (2021), 111039.
[3] Taylor, J.A.: Iron-containing intermetallic phases in Al-Si based casting alloys. Procedia Mat. Sci. 1 (2012), 19–33.
[4] Dietrich, B.G., Becker, H., Smolka, M., Keßler, A., Leineweber, A., Wolf, G.: Intermetallic sludge formation in Fe containing secondary Al–Si alloys influenced by Cr and Mn as preparative tool for metal melt filtration. Adv. Eng. Mat. 19 (2017), 1700161.
[5] Becker, H., Leineweber, A.: Approximate icosahedral symmetry of α-Al(Fe,Mn,Cr)Si in electron backscatter diffraction analysis of a secondary Al-Si casting alloy. Mater. Charact. 141 (2018), 406–411.

DFG Deutsche Forschungsgemeinschaft
TU BERGAKADEMIE FREIBERG

CURRENT PUBLICATIONS (NOVEMBER 2021 - June 2022)

Further information about the 142 publications that have been generated since the start of the third program period as well as about the currently 21 patents and patent applications are available at https://tu-freiberg.de/forschung/sfb920

Projectarea A - Filter materials

Subproject A01

Neumann, M., Gehre, P., Nwokoye, R.I., Jelitto, H., Schneider, G.A., Aneziris, C.G. (2021): Life time prediction of self-supporting flame-sprayed alumina-rich coatings, Ceramics International, Vol. 47 Iss. 13, 1 July 2021, pp. 18656-18661, DOI 10.1016/j.ceramint.2021.03.197.

Bock-Seefeld, B., Wetzig, T., Hubálková, J., Schmidt, G., Abendroth, M., Aneziris, C.G.: A novel approach for the production of carbon-bonded alumina filters by water-soluble filter templates, REFRA Prague 2022, 21st Conference on modern refractory materials, May 18-20, 2022, Prague, Czech Republic, oral presentation.

Subproject A02

Neumann, M., Hubálková, J., Voigt, C., Grabenhorst, J., Aneziris, C.G. (2021): On the fracture statistics of open-porous alumina foam structures, Journal of the European Ceramic Society, Vol. 42, Iss. 5, May 2022, pp. 2331-2340, DOI 10.1016/j.jeurceramsoc.2021.12.034.

Voigt, C., Hubálková, J., Bergin, A., Fritzsch, R., Akhtar, S., Aune, R., Aneziris, C.G. (2022): Short- and long-term aluminum filtration trials with carbon-bonded alumina filters, in: Eskin D. (eds) Light Metals 2022. The Minerals, Metals & Materials Series. Springer, Cham, pp. 626-632, DOI 10.1007/978-3-030-92529-1_82.

Bergin, A., Voigt, C., Fritzsch, R., Akhtar, S., Arnberg, L., Aneziris, C.G., Aune, R.E. (2022): Performance of Regular and Modified Ceramic Foam Filters (CFFs) during Aluminium Melt Filtration in a Pilot-Scale Setup, in: Eskin D. (eds), Light Metals 2022, The Minerals, Metals & Materials Series, Springer, Cham, pp. 640-648, DOI 10.1007/978-3-030-92529-1_84.

Voigt, C., Schramm, A., Fankhänel, B., Schmid, E., Malczyk, P., Hubálková, J., Stelter, M., Charitos, A., Aneziris, C.G. (2022): Preparation of ceramic foam filters with a lithium-containing surface, Metallurgical and Materials Transactions B, accepted: 12.04.2022, pp. 1-15, DOI 10.1007/s11663-022-02533-2.

Subproject A03

Illatovskaia, M., Fabrichnaya, O. (2022): Liquid immiscibility and thermodynamic assessment of the Al_2O_3-TiO_2-SiO_2 system, Journal of Phase Equlilibria and Diffusion, 2022, Vol. 43, pp. 15-31, DOI 10.1007/s11669-021-00935-4.

Illatovskaia, M., Fabrichnaya, O.: Thermodynamic assessment of the MgO-TiO_2-SiO_2 system, Calpahd XLIX - International Conference on Computer Coupling of Phase Diagrams and Thermochemistry, Stockholm, Sweden, May 22-27, 2022, poster.

Subproject A04

Kraus, J., Kortus, J. (2022): A theoretical investigation into gallic acid pyrolysis, Journal of Computational Chemistry, Vol. 43, Iss. 15, June 5, 2022, pp. 1023-1032, DOI 10.1002/jcc.26865.

Brehm, S., Kraus, J., Himcinchi, C., Kortus, J. (2022): A Raman spectroscopic study of pyrolysis of lactose and tannins, Journal of Raman Spectroscopy, accepted: 29.04.2022, pp. 1-10, DOI 10.1002/jrs.6376.

Subproject A07

Stelter, M., Aneziris, C.G., Leineweber, A.(2021): ype formation and Al and Si ordering on the crystal structure in β-$Al_{4.5}$FeSi, 30th annual meeting of the German Crystallographic Society - DGK 30, March 14-17, 2022, Munich, web conference, oral presentation.

Becker, H., Bulut, N., Kortus, J., Leineweber, A. (2022): β-Al4.5FeSi: Hierarchical crystal and defect structure: reconciling experimental and theoretical evidence including the influence of Al vs. Si ordering on the crystal structure, Journal of Alloys and Compounds, Vol. 911, August 2022, 165015, DOI 10.1016/j.jallcom.2022.165015.

Projectarea B - Modelling of filter structures/ filter systems

Subproject B01

Ditscherlein, L., Zienert, T., Dudczig, S., Aneziris, C.G., Peuker, U.A. (2021): 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, Advanced Engineering Materials, 2021, 2100634, pp. 1-12, DOI 10.1002/adem.202100634.

Ditscherlein, L., Peuker, U.A.: Van der Waals Kräfte auf rauen Oberflächen – bestehende Konzepte und neue Ansätze, Jahrestreffen der ProcessNet-Fachgruppen Grenzflächenbestimmte Systeme und Prozesse, February 16-17, 2022, web conference, oral presentation.

Ditscherlein, L., Heilmann, C., Daus, S., Nicklas, J., Peuker, U. A.: Hydrophobe Wechselwirkungen am Beispiel Filtration: Ursache und Wirkung, Jahrestreffen der ProcessNet-Fachgruppen Mehrphasenströmungen, Mechanische Flüssigkeitsabtrennung sowie Zerkleinern und Klassieren, February 21-22, 2022, web conference, oral presentation.

Daus, S.; Peuker, U. A.: Inline-Partikeldetektion zur Optimierung der Tiefenfintration von Schaumkeramikfiltern, Jahrestreffen der ProcessNet-Fachgruppen Mehrphasenströmungen, Mechanische Flüssigkeitsabtrennung sowie Zerkleinern und Klassieren, February 21-22, 2022, web conference, poster.

Ditscherlein, L., Peuker, U.A.: Modelling of surface forces between two highly rough surfaces using AFM topography scans, The 8th European Congress on Computational Methods in Applied Sciences and Engineering - ECCOMAS Congress 2022, Oslo, Norway, June 5-9, 2022, oral presentation.

Subproject B04

Nicklas, J., Ditscherlein, L., Peuker, U.A.: Wechselwirkung schlecht benetzbarer Partikel mit gekrümmten Gas-Flüssig Grenzflächen, Jahrestreffen der ProcessNet-Fachgruppen Grenzflächenbestimmte Systeme und Prozesse, February 16-17, 2022, web conference, oral presentation.

Nicklas, J., Ditscherlein, L., Peuker, U.A.: Contact behavior of particle laden bubbles, The 8th European Congress on Computational Methods in Applied Sciences and Engineering - ECCOMAS Congress 2022, Oslo, Norway, June 5-9, 2022, oral presentation.

Projectarea C - Filter performance, materials properties

Subproject C01

Wei, X., Dudczig, S., Chebykin, D., Aneziris, C.G., Volkova, O. (2021): Verification of possibility of molten steels decopperization with $ZnAl_2O_4$, Metals, Metals, 2021, 11 no. 12, 2030, pp. 1-11, DOI 10.3390/met11122030.

Wei, X., Dudczig, S., Storti, E., Ilatovskaia, M., Endo, R., Aneziris, C.G., Volkova, O. (2022): Interaction of molten Armco iron with various ceramic substrates at 1600 °C, Journal of the Europen Ceramic Society, Vol. 42, Iss. 5, May 2022, pp. 2535-2544, DOI 10.1016/j.jeurceramsoc.2022.01.011.

Wei, X., Storti, E., Dudczig, S., Yehorov, A., Fabrichnaya, O., Aneziris, C.G., Volkova, O. (2022): The interaction of carbon-bonded ceramics with Armco iron, Journal of the European Ceramics Society, Vol. 42, Iss. 11, pp. 4676-4685, DOI 10.1016/j.jeurceramsoc.2022.04.058.

Wei, X., Kovtun, O., Yehorov, A., Aneziris, C.G., Volkova, O. (2022): Selenium as a new decopperization for steel scrap, Journal of Materials Letters, Vol. 323, September 2022, 132543, pp. 1-3, DOI 10.1016/j.matlet.2022.132543.

Subproject C03

Takht Firouzeh, S., Abendroth, M., Fischer, U., Aneziris, C.G., Kiefer, B. (2021): Utilization of a Small Miniaturized Brazilian Disc Test for Strength Measurements of C-bonded Alumina Filter Materials, Advanced Engineering Materials, 2021, 2101081, pp. 1-10, DOI 10.1002/adem.202101081.

Subproject C04

Wagner, R., Biermann, H., Weidner, A., Noack, E., Ditscherlein, R., Leißner, T., Peuker, U.A.: Digitale Volumenkorrelation zur Untersuchung des Ermüdungsverhaltens von intermetallischen Phasen in AlSi9Cu3 (Digital volume correlation investigating the influence of intermetallic phases on fatigue behavior of AlSi9Cu3), Tagung Werkstoffprüfung 2021, Werkstoffe und Bauteile auf dem Prüfstand. Prüftechnik - Kennwertermittlung - Schadensvermeidung, December 2-3, 2021, Aachen, Germany, proceedings, pp. 271-276.

Subproject C06

Schramm, A., Recksiek, V., Dudczig, S., Scharf, C., Aneziris, C.G.: Immersion Tests of Variously Coated Ceramic Foam Filters in an AZ91 Magnesium Alloy Melt, MultiScience - microCAD, 34th International Multidisciplinary Scientific Conference, Miskolc, Hungary, September 23-24, 2021, web conference, oral presentation.

Schramm, A., Nowak, R., Bruzda, G., Polkowski, W., Fabrichnaya, O., Aneziris, C.G. (2022): High Temperature Wettability and Corrosion of ZrO_2, Al_2O_3, Al_2O_3-C, MgO and MgAlON Ceramic Substrates by an AZ91 Magnesium Alloy Melt, Journal of the European Ceramic Society, Vol. 42, Iss. 6, June 2022, pp. 3023-3035, DOI 10.1016/j.jeurceramsoc.2022.01.040.

Schramm, A., Thümmler, M., Fabrichanya, O., Brehm, S., Kraus, J., Kortus, J., Rafaja, D., Scharf, C., Aeziris, C.G. (2022): Reaction Sintering of MgAlON at 1500 °C from Al_2O_3, MgO and AlN and its wettability by AlSi7Mg, Crystals, Vol. 12, Iss. 5, 654, pp. 1-26, DOI 10.3390/cryst12050654.

Transfer projects

Transfer project T04

Wetzig, T., Schöttler, L., Schwarz, M., Aneziris, C.G.: New steel melt filtration approaches in industrial ingot casting and continuous casting of steel, 97th Annual Meeting of the German Ceramic Society (DKG) - CERAMICS 2022, March 7-9, 2022, web conference, oral presentation.

Transfer project T05

Hoppach, D., Peuker, U.A.: Using ceramic fibres for enhancing filtration efficiency in al-melts based on a room-temperature model system, FILTECH 2022 Conference, March 8-10, 2022, Cologne, Germany, oral presentation.

Hoppach, D., Peuker, U.A.: Einsatz von keramischen Fasern zur Erhöhung des Reinheitsgrades von Al-Schmelzen basierend auf einem Raumtemperatur-Modellsystem, Jahrestreffen der ProcessNet-Fachgruppen Mehrphasenströmungen, Mechanische Flüssigkeitsabtrennung sowie Zerkleinern und Klassieren, February 21-22, 2022, Leipzig, Germany, web conference, oral presentation.

INTERNATIONAL GUESTS

On several occasions, doctoral students of the SFB 920 had the opportunity to exchange ideas with international scientists on specialist topics as well as research strategy issues.

Prof. Victor Carlos Pandolfelli from the **Universida de Federal de Sao Carlos (UFSCar)** in Brazil, dedicated his workshop to the topic "Trends in high temperature applications and refractory materials". Prof. Pandolfelli is a leading expert in the field of refractory materials and their microstructure design and, as a Mercator Fellow, accompanies the research work on ceramic materials and refractories and components as well as the training of young scientists in the third funding period of the CRC 920.

Photo: Prof. Victor C. Pandolfelli during the workshop.

Futhermore, in an online workshop with guest scientists from the **University of Chemistry and Technology in Prague (VŠCHT Praha)**, PhD students from the research group of **Ass. Prof. Ondřej Jankovský** presented the results of their joint research work with Freiberg scientists from subproject A01 on new approaches to the production of ceramic filter materials in CRC 920.

In addition to an overview by Ass. Prof. Jankovský on the special properties of multilayered inorganic materials, **Dipl.-Ing. Anna-Marie Lauermannová** and **Dipl.-Ing. Michal Lojka** presented the latest findings on the use of carbon-containing nanomaterials in advanced composite materials and on optimization of preparation of ceramic superconductors based on REBCO. ■

EXCELLENT!

For his outstanding dissertation "Agglomeration of hydrophobic particles in aqueous phases", **Dr.-Ing. Paul Knüpfer** received the **Heinrich Schubert Award of the Faculty of Mechanical, Process and Energy Engineering**. The faculty honors his work on the application of fundamental models of the distance dependence of the HAMAKER constant both for mechanical process engineering in the field of agglomeration technology and for processing technology in the field of bubble-particle interactions. The thesis project was carried out within the framework of the CRC 920 in the subproject B04 - Tailored Agglomerates for Increasing Separation Efficiency (Head: Prof. Urs A. Peuker).

Since 2019, the award has been given annually to students and doctoral candidates for excellent young research in the field of mechanical process engineering, mineral processing or recycling. During the conference "Mineral Processing and Recycling", Dean Prof. Tobias Fieback presented the award to the winners in memory of the work and achievements of the former chair holder Prof. Heinrich Schubert.

Photo: Dr.-Ing. Paul Knüpfer received the Heinrich Schubert Award.

In addition, **Eng. Mariia Ilatovskaia** was awarded the **FactSage Best Student Poster Award** for her presentation "Thermodynamic assessment of the MgO-TiO_2-SiO_2 system" at the CALPHAD Conference 2022 in Stockholm, Sweden. The research results were generated in subproject A03 of the CRC 920 "Thermodynamics of the filter surface and the inclusions" under the head of PhD Dr.-Ing. habil. Olga Fabrichnaya. ■

GRADUATION IN CRC 920

With the aim of testing models of the Collaborative Research Center (CRC) 920 for the filtration of steel melts on an industrial scale for the first time, **Dr.-Ing. Tony Wetzig,** a doctoral student in the Transfer Projects T01 and T04 of CRC 920, successfully completed his dissertation entitled **"New approaches for steel melt filtration in continuous casting of steel"** in January. The large-format filter components developed were successfully immersed in the continuous casting tundish of the industrial partner thyssenkrupp Steel Europe AG for around 45 minutes at > 1550 °C in the molten steel. Post-mortem investigations of the filter surface showed clear indications of reactive and active filter effects as known from laboratory tests.

Dr.-Ing. Anne Schmidt, former doctoral student in subproject A01 of CRC 920, successfully defended her dissertation entitled **"Functional coatings for steel melt filtration"** in February. The dissertation investigated the interactions between coated carbon-bonded alumina filters and a steel melt to improve the quality of steel products by filtration of non-metallic inclusions.

Photo: Dr.-Ing. Anne Schmidt.

The influence of various parameters on particle separation in ceramic depth filters using a room temperature model is described by **Dr.-Ing. Daniel Hoppach**, a doctoral student in subproject B01 and transfer project T05, in his dissertation on **"Separation efficiency of ceramic depth filters in a room temperature model system for characterizing aluminum melt filtration"**, which he successfully completed in May. The results obtained make an important contribution to the understanding of the separation processes of impurities in ceramic metal melt filters during aluminum melt filtration.

Photo (from left to right): Prof. M. Szucki, Prof. U.A. Peuker, Dr.-Ing. D. Hoppach, Prof. H. Zeidler, Prof. T. Bier, Prof. C.G. Aneziris.

Dr.-Ing. Andreas Herdering, a doctoral student in the SFB 920 research training group, also successfully defended his dissertation entitled **"Development and evaluation of additive manufacturing processes for the production of macroporous ceramic structures using the example of filters for molten metal filtration"** in May. His work focused on the development of ceramic filters for metal melt filtration with reproducible customized structures using additive manufacturing techniques, such as 3D printing and laser sintering. ■

CONFERENCES AND CALLS FOR PAPERS

ECerS 2022: 17th Conference of the European Creamic Society, July 10-14, 2022, Krakow, Poland, https://icc2022.syskonf.pl/.

MSE 2022: Materials Science Engineering MSE Congress, September 27-29, 2022, Darmstadt, Germany, https://dgm.de/mse/2022.

ICR 2022: 65th International Colloquium on Refractories, September 28-29, 2022, Aachen, Germany, www.ic-refractories.eu.

CellMAT 2022: 7th International Conference on Cellular Materials, October 12-14, 2022, Dresden, Germany, https://dgm.de/cellmat/2022/.

WFC 2022: The 74th World Foundry Congress 2022, October 16-20, 2022, Busan, Republic of Korea, https://www.74wfc.com/.

13. Freiberg Refractory Forum: December 14, 2022, TU Bergakademie Freiberg.

UNITECR 2023: The Unified Technical Conference on Refractories, 18th Biennial Worldwide Congress on Refractories, September 26-29, 2023, Frankfurt am Main, Germany, https://unitecr2023.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. 22, Issue 01/2022
(Two issues per year)

SFB 920
Multifunktionale Filter für die Metallschmelzefiltration – ein Beitrag zu Zero Defect Materials