SFB 920

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

NEWSLETTER 20 (1/2021)

DFG Deutsche Forschungsgemeinschaft

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

DEAR READERS,

the research results on the application of refractory materials for the metal melt filtration in the Collaborative Research Center CRC 920 are attracting great attention worldwide. This is shown in particular by the awards to scientists for their achievements in researching material properties for high-temperature applications and the further development of testing methods in materials engineering and materials science. In addition, current results have been successfully presented at national and international digital conferences and numerous publications have been published in international journals.

The development of resource- and energy-efficient technologies requires close interdisciplinary cooperation across the borders of the individual scientific areas. For this purpose, the CRC 920 has a newly created and modern research infrastructure at its disposal. 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

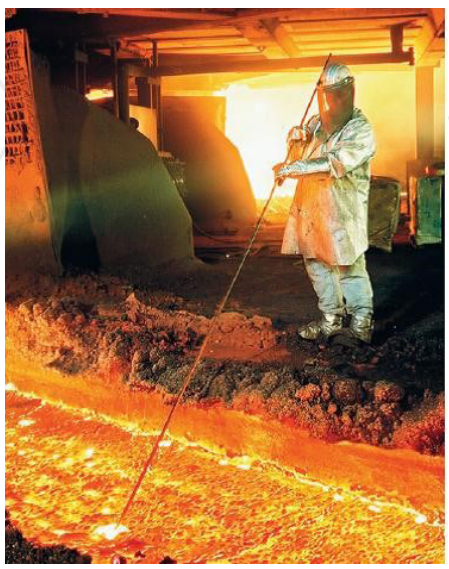
APPLICATION-ORIENTED INTERNATIONAL EXCHANGE AND DIALOGUE ON REFRACTORY MATERIALS

International exchange and dialogue between science and industry serve the continuous further development of refractory materials under the aspect of an energy-efficient, resource and environmentally friendly production and application. Current results of its interdisciplinary research activities were presented by the Collaborative Research Center SFB 920 at the 11th Freiberg Refractories Forum, which was held as a virtual conference for the first time.

For the eleventh time, the CRC 920 "Multi-Functional 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" invited to the **Freiberg Refractory Forum**, which took place digitally for the first time, in December 2020. More than 100 participants from Germany and abroad from science, industry and professional associations exchanged infomation about the latest developments in refractory materials and their fields of application.

In addition to the research and application of refractory materials for metal melt filtration and precious metal metallurgy, the event focused on the properties of metallurgical slags and refractory composite materials. The speakers included international experts from industry and science. Participants of the CRC 920 informed about latest developments and innovative research approaches in the field of metal melt filtration in a digital poster exhibition.

The increased requirements for molten steel filtration when casting large steel cast parts were the focus of the presentation by **Mr. Nick Child**, Manager for International Marketing at **Foseco International Ltd - Vesuvius Group** in Tamworth, Great Britain. **Dr. Christoph Wöhrmeyer**, Head of Product Development at **Imerys Aluminates GmbH** in Oberhausen, provided information on the latest findings on the corrosion resistance of refractory materials based on aluminum oxide spinel in high-temperature applications. Current developments in the field of metallurgical slag were presented by **Prof. Olena Volkova** from the **Institute of Iron and Steel Technology** at TU Bergakademie Freiberg.



Furthermore, **Dr. Ulrich Klotz**, Head of Metallurgy at **fem - Research Institute for Precious Metals and Metal Chemistry** in Schwäbisch-Gmünd, demonstrated innovative approaches to melting titanium and other high-melting and high-reactive alloys. A comprehensive overview of process and technological aspects in copper pyrometallurgy was given by **Prof. Alexandros Charitos** from the **Institute of Nonferrous Metallurgy and Purest Materials** at the TU Bergakademie Freiberg. **Dr. Tilo Zienert** from the **Institute of Ceramics, Refractories and Composites** at TU Bergakademie Freiberg informed the audience about current and future research work on refractory composites within the framework of the DFG research group FOR 3010.

A major concern of the Freiberg Refractory Forum is the constant dialogue between representatives of science and industry for a continuous further development of refractory materials in order to meet current challenges, such as increasing requirements from end users or conditions for a sustainability-oriented economy.

The Refractory Forum also sees itself as an important platform for 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 "refrctory and high temperature applications", which is awarded in the framework of the Freiberg Refractory Forum. This year, the award was given to M.Eng. Denise Ramler from the University of Koblenz-Landau. In her master's thesis, which was carried out at the Deutsches Institut für Feuerfest und Keramik GmbH (DIFK) in Höhr-Grenzhausen, Ms. Ramler investigated the corrosion mechanisms when using graphite-containing SiC materials in copper metallurgy. The work took place under the supervision of Prof. Peter Quirmbach from the University of Koblenz-Landau. The award commemorates the Freiberg scientist Theodor Haase and his commitment to the training of silicate engineers. ■

In addition, the CRC 920 presented current research results at national and international meetings and conferences, which were held virtually for the first time, e. g. **TMS 2021** (150th Annual Meeting & Exhibition TMS - The Mineral, Metals & Materials Society), **CERAMICS 2021** (96th Annual Meeting of the German Ceramics Association - DKG), **GAMM 2021** (91st Annual Meeting of the International Association of Applied Mathematics and Mechanics), **THERMEC 2021** (11th International Conference on processing & manufacturing of advanced materials) and **Werkstoffprüfung 2020** (38th lecture and discussion conference of materials testing). In addition to presenting scientific papers, the researchers also chaired conference sessions on refractory materials, materials modeling and simulation. ■

MORE NEWS

AWARD

For special achievements and merits in the field of materials testing, **PD Dr.-Ing. habil. Anja Weidner** from the Institute for Materials Technology was honored with the **Galileo Prize** by the **German Society for Material Science (DGM)**.

The Freiberg materials scientist received the award for the successful further development of complementary *in situ* methods in materials engineering. With these methods, such as the analysis of acoustic emission, digital image correlation and thermography, essential contributions to the clarification of deformation and damage mechanisms in quasi-static as well as cyclic deformation are possible.

The Galileo Prize is awarded annually by the Deutsche Gesellschaft für Materialkunde e.V., the German Association for Materials Research and Testing and the Steel Institute VDEh as part of the materials testing conference. ■

Photo: PD Dr.-Ing. habil. Anja Weidner received the Galileo Prize of the German Society for Material Science (DGM).

INTERNATIONAL HONOR

For their outstanding scientific contribution of the publication **"On the Nonlinear Behavior of Young's Modulus of Carbon-Bonded Alumina at High Temperatures"**, an international Freiberg research team of the CRC 920 was honored with the **Alfred W. Allen Award** of the **American Ceramic Society (ACerS)**.

Authors and winners of the award are **Dr. Bruno Luchini (TaTa Steel Europe, Holland), Dr. Jörn Grabenhorst and Dr. Jens Fruhstorfer, as well as Prof. Victor Pandolfelli (Universidade Federal de Sao Carlos, Brasilien),** Mercator-Fellow in the CRC 920 and **Prof. Christos G. Aneziris**.

"The article makes an important contribution to understanding the thermomechanical properties of ceramic filters when used for steel melt filtration at about 1600 °C. Using the so-called Young's modulus, we were able to make a statement about the microstructure of the carbon-bonded filter material at very high temperatures, providing a prediction for the thermal shock resistance of the ceramic filters," explains Prof. Christos G. Aneziris.

Every two years, the award committee of the Refractory Ceramics Division of the American Ceramic Society (ACerS) reviews scientific articles in the field of refractory ceramics and evaluates them based on their content and impact on current research. ■

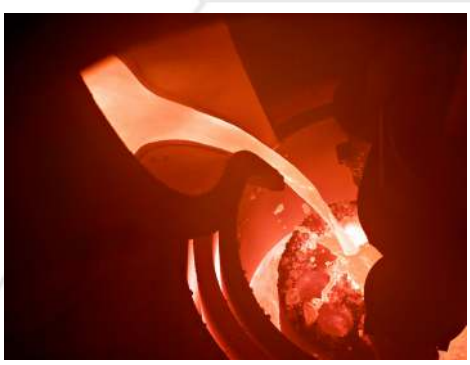


Photo: Casting of molten steel in a steel casting simulator through a ceramic foam filter based on aluminum oxide into a refractory crucible at 1650 °C.

YOUNG TALENTS

Tired of homeschooling? In order to regain the desire for school and learning to some extent, in March 2021, as part of the **topical days at Geschwister-Scholl-Gymnasium in Freiberg**, pupils from grades 5 to 10 were able to participate in a digital workshop at the Institute for Ceramics, Refractories and Composites. Here, they could experience an insight into the fascinating variety of ceramic materials and their areas of application.

To do this, the institute opened its digital windows and doors. In an online lecture with small video clips, the students learned how to manufacture ceramic components for different applications and which special features have to be taken into account. In addition, the participants were able to follow the compressive strength test on a fired component made of ceramic material in a live broadcast from the strength test laboratory. ■

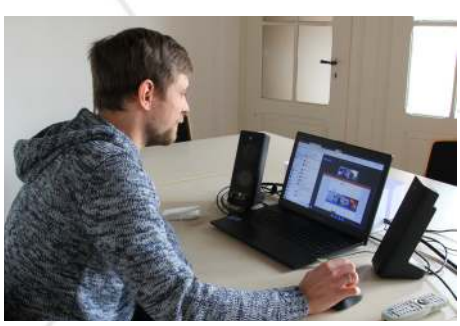


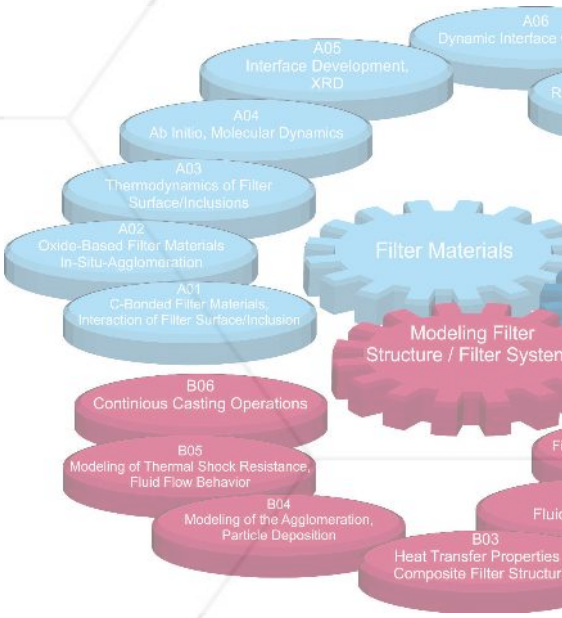
Photo: Dipl.-Ing. Benjamin Bock-Seefeld at the online presentation.

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.

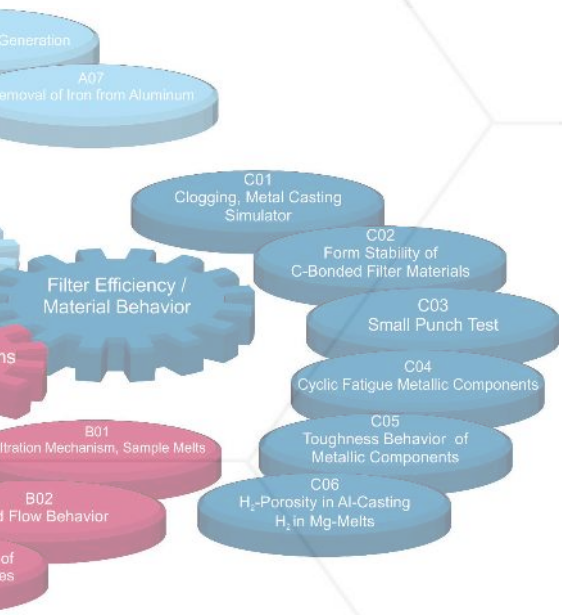
Working Group 1: „Metal melt/inclusions, active/reactive filter material, boundary surface design" (Coordination: Dr.-Ing. Claudia Voigt)

- Evaluation of the mechanical properties and the residual carbon content of carbon-bonded alumina filters with different environment-friendly binder compositions (A01),
- Development of an evaluation routine for the quantification of closed pore windows in ceramic foam filters (A02),
- Simulation of Raman spectra for lactose, gallic acid, ellagic acid, and pyrogallol in order to analyze the pyrolysis process in environmentally friendly carbon-bonded filters (A04),
- Investigations with the help of a Raman spectrometry of carbon-bonded filter materials with varying compositions based on lactose, tannin and Carbores P (coked and uncoked, with Si and without Si) (A04),
- Thermodynamic modelling of the Al_2O_3-TiO_2-SiO_2 system based on own experimental data (A03),
- Estimation of the homogeneity range of the Al_2O_3 depleted oxynitride spinel (MgAlON) at temperatures above 1600 °C (A05),
- Experiments exploring the contact of Cu-contaminated Fe (1 m.% Cu in ARMCO Fe) with $FeAl_2O_4$ and $ZnAl_2O_4$ were conducted, the interfacial reactions in regard to the expected removal of Cu are still being under investigation (A06),
- Validation of the contribution of Al_2O_3-C-filter material to the Fe-removal efficiency in model crucible experiments (A07),
- Evaluation of accomplished combi-tests conducted at the steel casting simulator (finger: CNT's or CA2 and casts through AC5-filter with flame sprayed alumina coatings) as well as reference trials without finger and/or filter. Characterization of the finger, filter and steel samples after casting regarding the chemistry, particle situation and mechanical characteristics (C01),
- Evaluation of sessile drop experiments (in kooperation whit the Łukasiewicz - Krakowski Instytut Technologiczny, Poland) with the magnesium alloy AZ91 on various ceramic substrates (MgAlON, Al_2O3-C, Al_2O_3, MgO, ZrO_2). MgAlON was shown to have the highest and most constant contact angle. (C06),
- Evaluation of a casting series with an AlCu4Ti alloy and active and reactive filter materials to investigate the influence of these filters on hydrogen porosity in the casting. New information was obtained on the mechanism of hydrogen precipitation during filtration. (C06),
- Extrusion materials of the system Al_2O_3-ZrO_2-C were investigated regarding their mechanical strength, porosity and thermal shock resistance, and the extrusion of spaghetti filter starter tubes for the continuous casting of steel was tested based on suitable compositions (T04),
- Flow-through tests at ceramic filters and fibers were conducted in the semi-automated pilot plant (room temperature model system) for the evaluation of the pressure gradient. Furthermore, castings trials were performed at Alexpert to test different fiber addition strategies (T05).



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

- Development and validation of a Matlab post-processing routine for all Hg contact angle measurements based on circle/ellipse/polynomial/Laplace curve approximation (B01),
- Adhesion force measurements between particle and *in situ* layer and correlation with contact angle measurements and micro/macro roughness (B01, C01),
- Investigations on the water model concerning the effect of ppi-number of the filter on the local particle size distribution in the suspension using an in-line probe (B01),
- Comparison of the permeability data obtained from the pressure drop tests with various correlations from the literature to improve the prediction of pressure drop for graded filters (B01),
- Extension of the pore-scale filtration model for a particle slip condition in oder to effectively capture the different particle-wall dynamics between water experiments and real filtration trials (B02),
- Experimental determination of the extinction coefficient of various industrial ceramic filters using the external integrating sphere of the FTIR (Fourier transform infrared spectrometer) and comparison with different predictive methods (B03, B02),
- Improvement of measurement data acquisition and extension of the temperature range for experimental investigations of gas solubility in metal melts using the high-temperature magnetic suspension balance (B03),
- Comparision of nanoindentation of Al_2O_3 thin-films by molecular dynamics simulations with the AFM based experiments (B04),
- Design of a stirred tank for continuous agglomeration and heterocoagulation (B04),
- CFD simulation of the immersion of the filter in steel melt (B06, S02) and construction of an experimental setup with the aim to investigate the attachment of inclusions on an rising gas bubble (B06),
- Generation of foam geometries with deliberately closed windows and development of an algorithm for counting closed windows in CT images of ceramic foams (S02, B02),
- Parameter study on the influence of different morphological and topological parameters on hydraulic tortuosity, viscous and inertial permeability, and filtration coefficient for continuous aluminum melt filtration using pore-scale simulations (S02, B02),
- Construction of a new experimental setup for the water-based model system for evaluation of separation efficiency of ceramic fibers during precoat filtration and in encapsulated ceramic filters (T05) as well as conduction of differential pressure measurements for various ceramic foam filters with 30 ppi pore count (T05, A02).



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

- Characterization of 3D printed filter structures with flame-sprayed modified surface of carbon-containing as well as carbon-free material combinations in contact with impurities containing steel melt in the steel casting simulator. By the use of finger tests suitable optimized 3D filter structures as well as material combinations will be identified and transferred into a combined cleaning system. (C01),
- Wetting experiments with C-bonded alumina and pure alumina with pure iron at 1625 °C. After use of C-bonded alumina, alumina whiskers were observed. In contrast, no reaction between pure alumina and iron was observed. The experimental results were interpreted with the help of thermodynamic simulations. (C01),
- Investigation of non-metallic inclusions in 42CrMo4 after different combinations of reactive and active filter systems within the steel casting simulator by particle analysis in ASPEX, light microscope, SEM and electrolytic extraction (C01, S01, C04),
- Analysis of metastable nonmetallic inclusions in 42CrMo4 by reconstructing and indexing the Kikuchi sphere from EBSD data, and stepwise heat treatment of samples for studies on the evolution of metastable inclusions (A05, C04),
- Mechanical and microstructural investigations of AlSi10Mg samples contaminated with SiC particles and subsequently filtered, as a preliminary investigation for a comprehensive characterization of a larger experimental series (C04, T05),
- Comparison of simulation results and thermography data from ultrasonic testing in the elastic range for calibration of the thermo-elastic model. Using HPC strategies to mimic the high-cycle range in simulations. Defining heat sources and thermal boundary conditions to model heat generation in the bulk of specimens due to microphysical effects (C04),
- Study for simulating non-metallic inclusions by adding specific amounts of alumina particles to a 42CrMo4 steel processed by powder metallurgy, (investigations of the effect of inclusion content on the mechanical and fracture mechanical properties, material damage was analyzed by means of acoustic emissions) (C05),
- Investigations of filter efficiency achieved by combined filter treatment with immersion and cast-through filters (C01), regarding the mechanical properties under quasi-static loading (C05),
- Development and application of a technology for the removal of iron-containing intermetallic phas-es by melt metal filtration in industrial scale (T03),
- Design and construction of an innovative casting model for the comparison of different filter mate-rials with regard to their filtration efficiency (S03).

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

- Preparation, characterization and thermomechanical test of Al_2O_3-C compact specimens based on the lactose/tannin binder system (C02),
- Development and application of Brazilian Disc test variations for the determination of elastic material properties of the filter material at room and elevated temperatures (C03),
- Conducting Ball on Three Ball tests at high temperatures to investigate the temperature dependent shift in ductile properties of fillter materials (C03),
- Detection of the dominating factors of the temperature dependent shift in material behavior (C03),
- Extension of the developed eective 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),
- Development and implementation of a hybrid material model utilizing neural networks for the simulation of small deformations of 3D foam structures and extension for finite deformations (B05),
- Strength evaluation of the immersed filter in comparison to the experimental data from subproject T04 (B05),
- Definition of benchmark problems for separation phenomena during chemical reactions to verify the developed FE code aiming at modelling the in situ layer formation (B05),
- Mechanical, numerical and physical characterization of Al_2O_3-C foam filters produced by distinct routes (A01, T01, B05, S01)

µCT STUDIES ON THE FATIGUE BEHAVIOR OF INTERMETALLIC PHASES IN AlSi9Cu3

Author: Ruben Wagner
(Subproject C04)

Subproject C04, in cooperation with subprojects T03, A07 and S01, investigates the influence of intermetallic phases remaining in the aluminum alloy AlSi9Cu3 after melt conditioning and filtration on the fatigue behavior. µCT scans are used to investigate the material's damage introduced under ultrasonic fatigue testing (USFT). Machine learning algorithms of Trainable Weka Segmentation allow the segmentation of the individual phases from the µCT data.

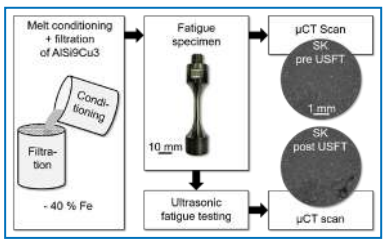


Fig. 1: Experimental procedure: Melt conditioning and filtration, manufacturing of fatigue specimen, µCT scan before (pre) and after (post) ultrasonic fatigue testing [4].

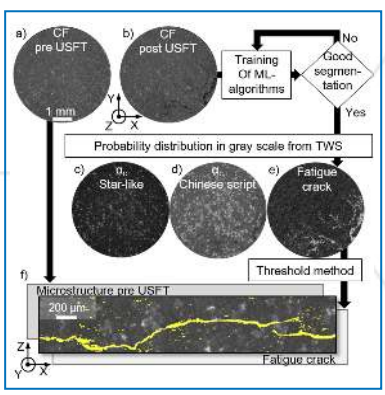


Fig. 2: Schematic representation of superposition of segmented fatigue crack with initial microstructure pre USFT. a) µCT slice in pre USFT condition. b) µCT slice post USFT. Phases and fatigue crack segmented by ML algorithms from TWS as probability distribution in gray scale: c) polyhedral α_c phase, d) α_c phase in Chinese script morphology, e) fatigue crack. f) superposition of fatigue crack (yellow) with microstructure pre USFT [2].

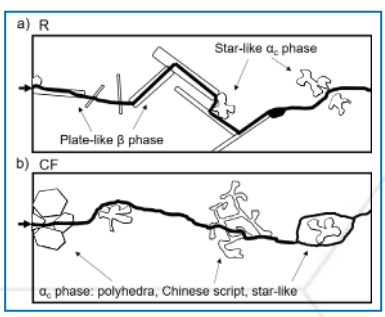


Fig. 3: Schematic representation of fatigue crack paths in a) R and b) CF. a) Plates of β phase cause crack initiation, can be split vertically or lengthwise. b) Polyhedral αc phase is split and causes crack initiation, α_c phase in Chinese script morphology is split; star-like α_c phase deflects crack in R and CF [4].

In secondary aluminum alloys, iron-rich intermetallic phases occur due to insufficient separation. These impair the feeding during casting and reduce the mechanical properties. Based on this motivation, melt conditioning and filtration (CF) of AlSi9Cu3 was performed (Fig. 1a). Samples for ultrasonic fatigue testing were manufactured from this batch as well as from a reference batch (R) without such a treatment. µCT scans (Xradia 510 Versa, Zeiss at Institute of Mechanical Process Engineering and Mineral Processing) were performed at the gauge length of both batches before (pre USFT) and after ultrasonic fatigue testing (post USFT). Since the intermetallic phases in AlSi9Cu3 have similar X-ray attenuation coefficients, segmentation based on gray level is not possible and requires the consideration of the morphology. The application of machine learning (ML) algorithms within the so-called Trainable Weka Segmentation (TWS) allows phase segmentation to investigate the behavior of the intermetallic phases under fatigue loading [1].

Fig. 2 shows an example of the procedure for segmenting the material's phases and the fatigue crack using the µCT data set of batch CF and the subsequent superposition with the initial microstructure (pre USFT, Fig. 2a) [2]. In several iteration steps, the user trains the ML algorithms until a satisfactory segmentation of the phases is achieved (Fig. 2b). As a result of the segmentation, the individual phases as well as the fatigue crack are given as a probability distribution in gray levels (Fig. 2c-e). The fatigue crack is binarized using a thresholding method. Based on the superposition of the fatigue crack with the pre-fatigue microstructure (pre USFT, Fig. 2f), it can be seen that the crack path predominantly proceeds through the Al matrix and occasionally through the α_c phase in Chinese script morphology. The fatigue crack of a sample of batch R segmented with the current method and superimposed with the micro-structure pre USFT is available as video #4 in the research data repository OpARA. [3].

Fig. 3 shows schematic representations of the crack paths under fatigue loading in batches R and CF [4]. In both batches, crack initiation occurs at discontinuities close to the surface. In batch R, these are mostly plates of the β phase. Depending on the orientation of the β phase, plates are split vertically or lengthwise. The star-like α_c phase deflects the fatigue crack and is mostly bypassed in both batches R and CF. Unfiltered α_c polyhedra can initiate the fatigue crack in batch CF. The fatigue crack runs through the αc phase in Chinese script morphology.

The studies show that the method presented here can be used to investigate the different intermetallic phases in AlSi9Cu3 alloy in detail. This allows further development of the material, taking into account the damaging effect of the individual phases.

In future, based on the µCT data and the application of Digital Volume Correlation (DVC), the local damage behavior in areas of intermetallic phases will be investigated for different stages during fatigue. ■

[1] I. Arganda-Carreras, V. Kaynig, C. Rueden, K.W. Eliceiri, J. Schindelin, A. Cardona, H. Sebastian Seung: Trainable Weka Segmentation: a machine learning tool for microscopy pixel classification, Bioinformatics 33 (2017), 2424–2426. https://doi.org/10.1093/bioinformatics/btx180.
[2] R. Wagner, A. Weidner, M. Seleznev, H. Fischer, R. Ditscherlein, A. Keßler, T. Leißner, G. Wolf, U.A. Peuker, H. Biermann: µCT-Untersuchungen zum Einfluss einer Schmelzekonditionierung und -filtration auf die eisenreiche β Phase in AlSi9Cu3 und deren Ermüdungsverhalten, in: proceedings of Tagung Werkstoffprüfung, December 03-04, 2020, in press.
[3] R. Wagner: Microstructural features of AlSi9Cu3 as well as superposition of segmented fatigue crack with initial microstructure studied by µCT (2020). https://doi.org/10.25532/OPARA-87.
[4] R. Wagner, M. Seleznev, H. Fischer, R. Ditscherlein, H. Becker, B.G. Dietrich, A. Keßler, T. Leißner, G. Wolf, A. Leineweber, U.A. Peuker, H. Biermann, A. Weidner: Impact of melt conditioning and filtration on iron-rich β phase in AlSi9Cu3 and its fatigue life studied by µCT, Materials Characterization 174 (2021), 111039. https://doi.org/10.1016/j.matchar.2021.111039.

CAPILLARY INTERACTIONS ON ROUGH FILTER MATERIAL SURFACES

Subproject B01 examines the filter materials with regard to their roughness, wettability and adhesive force using colloidal probe atomic force microscopy in a water-based model system. To create the same wetting conditions as in the real process, the filter material samples and alumina particles (colloidal probes) are silanised as described in [1].

Author: Lisa Ditscherlein
(Subproject B01)

In the model system, silanisation leads to very high contact angles > 100° as under real conditions, so that, due to various causes such as incomplete immersion with liquid, gas supersaturation, chemical reactions with gas generation or perturbation, small bubbles can form on the filter material or particle surface and capillary bridges between inclusion particles and filter surface occur. The nanobubbles are of scientific interest, although most investigations have been carried out on almost ideally smooth surfaces. However, on the rough filters pinning effects occur that lead, for example, to deviations from the ideal cap-like shape, larger stability on the solid surface or a change in amount and position of the bubbles.

Shape, frequency and size of such bubbles can be detected with the atomic force microscope and calculated in Matlab. This requires adequate image processing, which takes into account the curvature of the particle surface or a non-planar filter surface. It can be seen in Fig. 1, that the diameter distributions of the nanobubbles differ slightly regardless of roughness or the degree of supersaturation. Instead, the differences in the height distribution are significant: At a higher degree of supersaturation (ethanol-water exchange instead of temperature gradient), the bubbles have significantly greater heights [2]. This is also evident for samples with greater roughness; here the bubble height increases at a constant degree of gas supersaturation. If the bubbles are located in asperities, high contact forces are required to detach them [3].

If a particulate inclusion contacts the rough filter surface, very different adhesive forces can form depending on chemism, roughness and occurrence of nanobubbles. If there are no bubbles on both interacting surfaces, the only attractive forces are van der Waals interactions. These forces are often 10 times lower compared to capillary interactions and can lead to redetachment of the particle under real conditions due to flow [4]. In the case of interactions with bubbles, the force-distance curves can be distinguished with regard to the occurrence of a small repulsion shortly the liquid film ruptures, also called snap in; this phenomenon occurs in the case of a rather large bubble or of two bubbles as a result of deformation.

In order to generate statistically valid data, a large number of measurement curves are recorded which results in adhesion force distributions. The adhesion force distributions without snap in, i.e. no formation of capillary bridges, can be described well via Weibull distributions, whereby the scale parameter changes depending on the filter material roughness. Rougher samples show smaller adhesive forces if only van der Waals forces are taken into account, but there are transition areas. The results for poorly wetted surfaces are contrary: Median values increase with higher roughness (Fig. 2). This is linked to an increased number of stably seated, larger bubbles that form larger or multiple capillaries. Therefore, it is desirable to ensure a high bubble coverage on the filters, which can also be controlled by roughness. ■

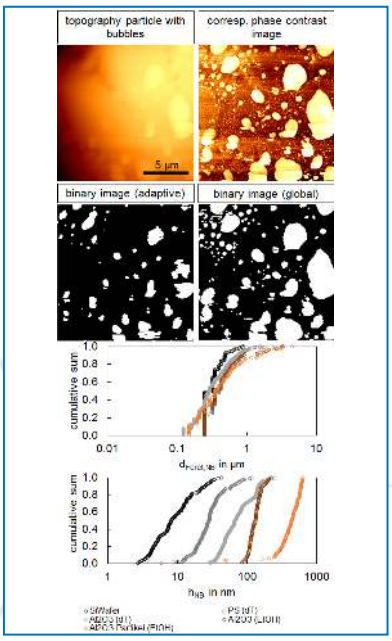


Fig. 1: AFM scans and binary images of a particle with nanobubbles and results of nanobubble sizes on different surfaces under variation of roughness (SiWafer < PS < Al_2O_3) and gas supersaturation level (dT < EtOH).

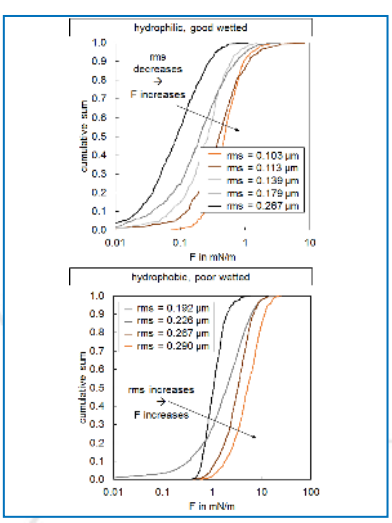


Fig. 2: Comparison of adhesive force distributions and trends depending on roughness concerning van der Waals interactions („hydrophilic“) and capillary interactions („hydrophobic“).

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[3] Ditscherlein, L., et al., Impact of the Roughness of Alumina and Al_2O_3-C Substrates on the Adhe-sion Mechanisms in a Model System. Advanced Engineering Materials 2017, 19(9), 1700088.
[4] Hoppach, D., et al., Experimental Investigations of the Depth Filtration inside Open-Cell Foam Filters Supported by High-Resolution Computed Tomography Scanning and Pore-Scale Numerical Simulations. Advanced Engineering Materials 2020, 22(2), 1900761.

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CURRENT PUBLICATIONS (NOVEMBER 2020 - JUNE 2021)

Further information about the 95 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., Wetzig, T., Fruhstorfer, J., Lamert, V., Jelitto, H., Schneider, G.A., Aneziris, C.G. (2020): Crack propagation behavior of carbon free and carbon bonded alumina based filter materials, Ceramics International Vol. 46, Iss. 8, Part A, 1 June 2020, pp. 11198-11207, DOI 10.1016/j.ceramint.2020.01.141.

Luchini, B., Storti, E., Wetzig, T., Hubálková, J., Pandolfelli, V.C., Aneziris, C.G.: Mechanical and physical characterization of Al_2O_3-C foam filters produced by distinct processing routes, CERAMICS 2021, 96th DKG Annual Meeting, Jülich, April 19-21, 2021, web conference, oral presentation.

Subproject A02

Voigt, C., Hubálková, J., Bergin, A., Fritzsch, R., Aune, R., Aneziris, C.G.: Overview on the possibilities and limitations of the characterization of ceramic foam filters for metal melt filtration, 2021 TMS Annual Meeting & Exhibition, Symposium Cast Shop Technology, March 14-18, 2021, Orlando, Florida, USA, web conference, oral presentation.

Bergin, A., Voigt, C., Fritzsch, R., Akhtar, S., Arnberg, L.E., Aneziris, C.G., Aune, R.E. (2021): Experimental Study on the Chemical Stability of Phosphate-Bonded Al_2O_3-based Ceramic Foam Filters (CFFs), Metallurgical and Materials Transactions B, (2021), accepted: 04.03.2021, DOI 10.1007/s11663-021-02144-3.

Subproject A03

Dubiel, S. M., Gondek, L., Zienert, T., Żukrowski, J. (2021): Mössbauer spectroscopic and XRD studies of two η-Fe2Al5 intermetallics, Intermetallics, Volume 135, August 2021, 107217, DOI 10.1016/j.intermet.2021.107217.

Subproject A05

Thümmler, M., Rafaja, D., Kugler, K.: Interaktives Training von komplexen anwendungsbezogenen Problemstellungen in der Fernlehre, Komplexpraktikum Röntgenfeinstrukturanalyse, E-Education-Awareness-Day, Workshop Matlab GRADER, TU Bergakademie Freiberg, March 25, 2021, web conference, oral presentation.

Subproject A07

Becker, H. (2020): Intermetallische Phasen und Phasenbildung während der Erstarrung von Fehaltigen Al-Si-Legierungen mit Mg, Mn und Cr - Ein Beitrag zum Recycling von Al-Si-Legierungen, Acamonta 27, 2020, TU Bergakademie Freiberg, p. 143-145.

Becker, H., Irmer, D., Li, Y., Bergh, T., Vulum, P.E., Leineweber, A.: Effect of cooling rate and Mn/Fe- and Cr/Fe-ratio on formation of intermetallic phases in a secondary Al7Si-alloy during solidification, Thermec 2021, Mai 09-14, 2021, Wien, Austria, web conference, oral presentation.

Projectarea B - Modelling of filter structures/ filter systems

Subproject B01

Daus, S., Peuker, U.A.: Verbesserung der Filtrationseffizienz von keramischen Tiefenfiltern durch den Einsatz gradierter Filterstrukturen, Process-Net-Jahrestreffen AGG, MFA und ZER 2021, March 15-16, 2021, web conference, poster.

Subproject B04

Weber, C., Knüpfer, P., Buchmann, M., Rudolph, M., Peuker, U.A. (2021): A comparison between approaches for the calculation of van der Waals interactions in flotation systems, Minerals Engineering, Vol. 167, 15 June 2021, 106804, DOI 10.1016/j.mineng.2021.106804.

Subproject B05

Abendroth, M., Malik, A., Hütter, G., Kiefer, B.: Applications of a hybrid approach to describe the elastic-plastic deformation behavior of foam like media involving neural networks, 91st Annual Meeting of the International Association of Applied Mathematics ans Mechanics - GAMM 2021, Kassel, March 15-19, 2021, web conference, oral presentation.

Lange, N., Hütter, G., Kiefer, B. (2021): An efficient monolithic solution scheme for FE2 problems, Computer Methods in Applied Mechanics and Engineering, Vol. 382, 15. August 2021, 113886, pp. 1-15, DOI 10.1016/j.cma.2021.113886.

Subproject B06

Asad, A., Schwarze, R.: Numerical Modeling of Reactive Cleaning of Steel Melt in an Induction Crucible Furnace. 91st Annual Meeting of the International Association of Applied Mathematics ans Mechanics - GAMM 2021, Kassel, March 15-19, 2021, web conference, oral presentation.

Asad, A., Schwarze, R. (2021): Numerical Investigation of the Combined Effect of Reactive Cleaning and Active Filtration on Inclusion Removal in an Induction Crucible Furnace, Steel Research International, accepted: 25.05.2021, DOI 10.1002/srin.202100122.

Projectarea C - Filter performance, materials properties

Subproject C04

Wagner, R., Weidner, A., Seleznev, M., Fischer, H., Ditscherlein, R., Dietrich, B.G., Keßler, A., Leißner, T., Wolf, G., Peuker, U.A., Biermann, H.: µCT-Untersuchungen zum Einfluss einer Schmelzekonditionierung und -filtration auf die eisenreiche ß Phase in AlSi9Cu3 und deren Ermüdungsverhalten, Tagung Werkstoffprüfung 2020, December 03-04, 2020, Berlin, conference proceedings, p. 1-6, DOI 10.48447/WP-2020-054.

Böhme, S.A., Vinogradov, A., Biermann, H., Weidner, A., Schmiedel, A., Henkel, S. (2021): Fatigue of carburised CrNiMo steel: Testing and modelling concept, Fatigue & Fracture of Engineering Materials & Structures, Vol. 44, Iss. 3, March 2021, pp. 788-804, DOI 10.1111/ffe.13394.

Wagner, R., Seleznev, M., Fischer, H., Ditscherlein, R., Becker, H., Dietrich, B.G., Keßler, A., Leißner, T., Wolf, G., Leinweber, A., Peuker, U.A., Biermann, H., Weidner, A. (2021): Impact of melt conditioning and filtration on iron-rich β phase in AlSi9Cu3 and its fatigue life studied by µCT, Materials Characterization, Vol. 174, April 2021, 111039, DOI 10.1016/j.matchar.2021.111039.

Wagner, R., Schmiedel, A., Dudczig, S., Aneziris, C.G., Volkova, O., Biermann, H., Weidner, A. (2021): Tailored nonmetallic inclusions in 42CrMo4 as a preparative tool for active and reactive steel melt filtration, Advanced Engineering Materials, accepted: 18.06.2021, DOI 10.1002/adem.202100640.

Subproject C05

Henschel, S., Posselt, F., Dudczig, S., Wetzig, T., Aneziris, C. G., Krüger, L. (2020): Experimental determination of toughness under mode I/II loading, Procedia Structural Integrity, Vol. 28, 2020, pp. 1369-1377, DOI 10.1016/j.prostr.2020.10.108.

Koch, K., Posselt, F., Kietov, V., Henschel, S., Krüger, L.: Einfluss von keramischen Partikeln auf das statische Festigkeits-, Verformungs- und Zähigkeitsverhalten von 42CrMo4, DVM-Tagung Arbeitskreis Bruchmechanik und Bauteilversagen 2021, February 18-19, 2021, web conference, oral presentation.

Subproject C06

Fankhänel, B., Stelter, M., Charitos, A. (2020): Multi-functional Filters for Metal Melt filtration - Aluminium, World of Metallurgy - ERZMETALL, Vol. 73, 2020, No. 5, S. 242-246, ISSN 1613-2394.

Schramm, A., Recksiek, V., Dudczig, S., Scharf, C., Aneziris, C.G. (2021): Immersion testing of variously coated ceramic foam filters in an AZ91 magnesium melt, Advanced Engineering Materials, 2021, 2100519, pp. 1-12, DOI 10.1002/adem.202100519.

Transfer projects

Transfer project T02

Schmiedel, A., Henkel, S., Weidner, A., Biermann, H.: Ultraschallermüdung der Stahlgusslegierung G42CrMo4 bei erhöhten Temperaturen (Ultrasonic fatigue testing of cast steel G42CrMo4 at elevated temperatures), Tagung Werkstoffprüfung 2020, December 03-04, 2020, Berlin, confernce proceedings, p. 1-6, DOI 10.48447/WP-2020-053.

Transfer project T04

Wetzig, T., Bock, B., Dudczig, S., Aneziris, C.G.: Alginate-based gelcasting of spaghetti filters for metal melt filtration, CERAMICS 2021, 96th DKG Annual Meeting, Jülich, April 19-21, 2021, web conference, oral presentation.

Transfer project T05

Hoppach, D., Peuker, U.A.: Charakterisierung der Partikelabscheidung in schaumkeramischen Tiefenfiltern, ProcessNet-Jahrestreffen AGG, MFA und ZER 2021, March 15-16, 2021, web conference, poster.

Service projects

Service project S03

Schoß, J., 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, 6th Conference on Cellular Materials - CellMAT 2020, October 07-09, 2020, web conference, oral presentation.

Complementary projects

Aneziris, C.G.: Porous ceramics and chemical interactions for clean steel approaches; expectations, limitations, 5th Webinar of Federation for International Refractory Research and Education - FIRE, January 26-28, 2021, web conferenc, invited lecture.

Aneziris, C.G., Voigt, A.: Collaborative Research Center SFB 620 - Results of aluminum filter development and their implementation potentials, Advanced Metals and Processes - AMAP FORUM 2021, April 28-29, 2021, web conference, invited lecture.

Patents and patent applications

Subproject A02

Filters made of carbon-bonded materials for aluminum melt filtration. Patent application no. DE 10 2020 000 969.7, application date: 14.02.2020.

OTHER AWARDS AND HONORS

M.Sc. Jakob Kraus has been honored twice by the Faculty of Chemistry and Physics of TU Bergakademie Freiberg for outstanding professional achievements in his studies and in his master thesis, as well as for a high level of social commitment: with the **Ferdinand Reich Award** and the **Werner Freiesleben Award**. Mr. Kraus has been a research associate at the Institute of Theoretical Physics since 2019. He is doing his PhD in the CRC 920 and is researching in subproject A04 on environmentally friendly binders for carbon-bonded filters for metal melt filtration.

Photo: Award winner M.Sc. Jakob Kraus.

On the other hand, **Dr.-Ing. Tilo Zienert and PD Dr.-Ing. habil. Olga Fabrichnaya** (TP A03) received the **Best Paper Award** from the journal CALPHAD (Computer Coupling of Phase Diagrams and Thermochemistry) for their publication “Prediction of heat capacity for crystalline substances“.

The paper deals with a new method for predicting melting points of a substance from thermophysical data obtained at lower temperatures. For this purpose, an algorithm was developed with which a physically reliable temperature trend of heat capacity, coefficient of thermal expansion, volume and bulk modulus can be predicted and which can be included in new thermodynamic databases. ■

NEW RESEARCH INFRASTRUCTURE

The new **“Center for Efficient High Temperature Processes and Materials Conversion (ZeHS)“** at TU Bergakademie Freiberg starts its work. Since May 2021, future researchers and students can use the new research infrastructure for resource- and energy-efficient technologies for industry. A special feature is that, due to the spatial proximity, close interdisciplinary cooperation between different scientific disciplines is created, which enables topics to be worked on along a closed, model-supported innovation chain, starting from theory via laboratory experiments, smal-scale and pilot plants up to large-scale test engineering.

In addition to extensive testing and analysis technology, large-scale research equipment for process and material developments is available in the two new competence centers “High-temperature processes - From mechanisms to applications“ (Head: Prof. Olena Volkova) and “High-temperature materials - From materials to components“ (Head: Prof. Christos G. Aneziris, Prof. Horst Biermann), which are also used for research in SFB 920. ■

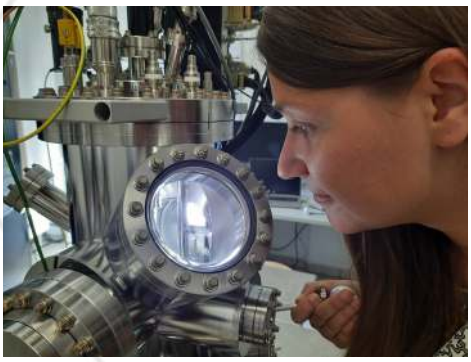

Photo: M.Sc. Lisa Ditscherlein at the high-temperature atomic force microscop.

HABILITATION AND DOCTORATE DEGREE

In June 2021, **PD Dr.-Ing. habil. Patrick Gehre**, subproject leader in SFB 920 (TP A01, A02, T04), successfully completed his **habilitation with the topic "Contribution to high-temperature functional coatings and refractory composites for application at elevated temperature"** at the Faculty of Mechanical, Process and Energy Engineering at TU Bergakademie Freiberg. The habilitation committee, chaired by Prof. Dr. Tobias Fieback, awarded PD Dr.-Ing. habil. Patrick Gehre the habilitation as well as the teaching approval (venia legendi) in the subject of high-temperature coatings and refractory composites.

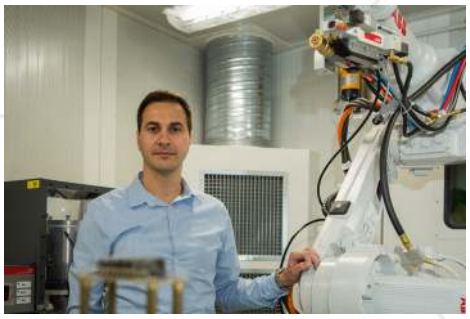

Photo: PD Dr.-Ing. habil. Patrick Gehre.

In addition to his work on high-temperature materials, PD Dr.-Ing. habil. Patrick Gehre is investigating the influence of ceramic filters coated by flame-spray technology on the purity of metallic melts. The scientific presentation on "Contribution of molten metal filters with flame-sprayed alumina coating to the cleanliness of steel" and the demonstration lesson on "Special processes and applications of flame-spray technology" also belong to this field.

Dr.-Ing. Paul Knüpfer, a doctoral student in subproject B04 of SFB 920, successfully defended his dissertation entitled "Agglomeration of hydrophobic particles in aqueous phases" in December.

Photo (from left to right): Prof. F. Plamper, Prof. R. Schwarze, Dr.-Ing. P. Knüpfer, Prof. U.A. Peuker, Prof. C.G. Aneziris.

The dissertation investigates a model system to simulate the agglomeration properties of non-metallic inclusions in metal melts at room temperature. It was found that the interparticle interactions between hydrophobic particles agglomerated in clusters can be attributed to the existence of nanobubbles. The nanobubbles were detected by atomic force microscope measurements. ■

CONFERENCES AND CALLS FOR PAPERS

MaterialsWeek 2021: virtual congress and exhibition, September 07-09, 2021, https://dgm.de/materialsweek/.

12th Freiberg Refractory Forum: December 08, 2021, TU Bergakademie, Freiberg.

UNITECR 2022: 17th Biennial Worldwide Congress on Refractories, March 15-18, 2022, Chicago, USA, https://ceramics.org/event/the-unified-international-technical-conference-on-refractories.

CIMTEC 2022: 15th International Ceramics Congress, June 20-29, 2022, Montecatini Terme, Italy, http://2021.cimtec-congress.org/.

CERAMITEC 2022: Trade fair of the international ceramics industry, June 21-24, 2022, Munich, https://www.ceramitec.com/en.

IMPRESSUM

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

ISSUE: No. 20, Issue 01/2021
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SFB 920
Multifunktionale Filter für die Metallschmelzefiltration – ein Beitrag zu Zero Defect Materials