SFB 920

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

NEWSLETTER 13 (2/2017)

DFG Deutsche Forschungsgemeinschaft

TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

DEAR READERS,

Intensive collaborations between different disciplines in an international environment significantly contribute to the success of of the CRC 920's research activities. An interdisciplinary network of scholars from Canada, USA, Brasil, China, Czech Republic, Poland, Switzerland, Italy, Greece and Belgium provides strong support specifically for the CRC's doctoral students and their academic career. They benefit from rich opportunites to study abroad, from international courses and workshops, or from opportunities for joint research activities with international visiting scholars. These opportunities enable doctoral students to succeed in an international competitive environment and to become world-wide visible by publishing their work in internationally leading journals. To honor and foster this success, the CRC has launched a publication award for its young scientists.

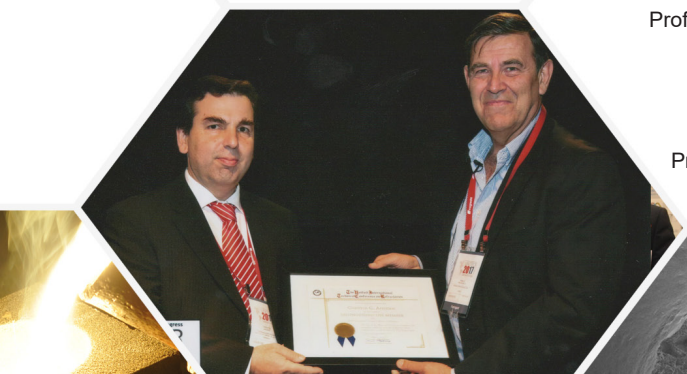
Details on related activities and results are available in our latest issue of this newsletter. Further information is provided at http://sfb920.tu-freiberg.de. We hope you'll enjoy the newsletter.

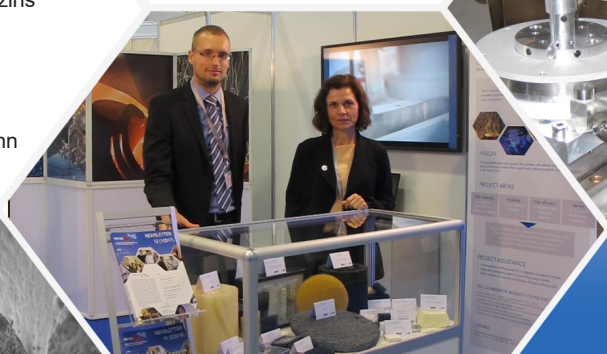
Yours sincerely,

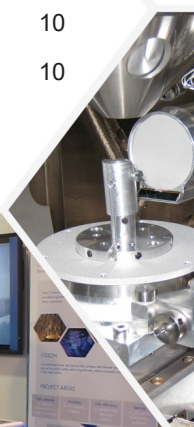
Prof. Dr.-Ing. habil. Christos G. Aneziris
CRC 920 Coordinator

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

INHALT







VIVID EXCHANGE, CROSS-DISCIPLINARY COLLABORATIONS, INTERNATIONAL VISIBILITY

Mutual exchange of research ideas, experiences, and results - conveyed as presentations at national or international conferences, publications, or teaching activities and materials for students - are vivid for an active scienific dialogue. A significant number of conference papers and journal publications demonstrate both relevance and excellence of the team of the Collaborative Research Center CRC 920 „Multi-Functional Filters for Metal Melt Filtration - A Contribution towards Zero Defect Materials“ as part of the scientific dialogue.

Researchers of the Collaborative Research Center CRC 920 have presented their research results at national and international conferences, for instance at the annual conference of the European Ceramic Society **ECerS** in Budapest/Hungary, at the globally leading conference on refractory materiales and components **UNITECR** in Santiago de Chile and at the **60th International Colloquium on Refractories** in Aachen/Germany. On the occasion of the **DGM Werkstoffwoche** in Dresden, the CRC 920 gave an introduction to its research program and, jointly with the second CRC established at TU Freiberg, the CRC 799 “TRIP-MATRIX Composite - Design of tough and transformation toughened composite materials and structures based on Fe-ZrO_2“, run a booth to exhibited its research.

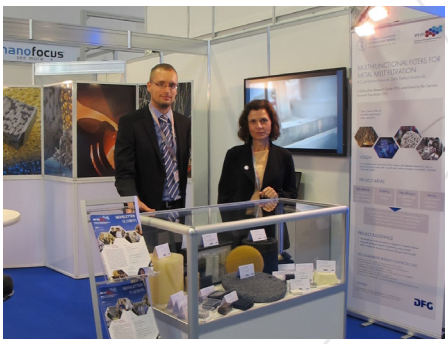
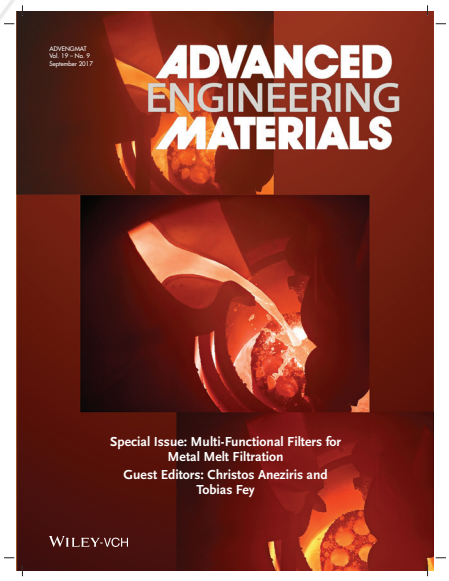


Photo (from left to right): Dipl.-Ing. Tilo Zienert and Dr.-Ing. Undine Fischer at the booth jointly operated by the Collaborative Research Centers 920 and 799 at DGM WerkstoffWoche in September 2017 in Dresden.

CRC‘s submissions to the Cellmat conference 2016 were invited to a **special issue of the journal “Advanced Engineering Materials AEM.“** Prof. Dr. Christos G. Aneziris, CRC coordinator, and Dr. Tobias Fey, who chairs the technical committee “Characterization of porous cermamics“ of the German Ceramic Society DKG served as guest editors.



The special issue contains 16 papers from all three project areas, which demonstrate both the innovativeness of the CRC 920 and decisive contributions researchers of the CRC have accomplished so far during the first two program periods. This special issue is the second one that has been dedicated to the CRC 920. The journal “Advanced Engineering Materials AEM“ is among the leading outlets for research publications on novel materials.

For the first time, the CRC assigned **a publication award to young researchers** to honor their excellent publications. This year, the award was given to Dipl.-Ing. Anton Salomon, Dipl.-Ing. Tilo Zienert and Dr.-Ing. Claudia Voigt for their paper “Formation of different alumina phases and magnesium aluminate spinel during contact of molten AlSi7Mg alloy with mullite and amorphous silica,” published 2017 in the Journal of Corrosion Science (Vol. 114, pp. 79-87, DOI 10.1016/j.corsci.2016.10.023). The paper was co-authored by Dr. Milan Dopita (Charles University Prague) as well as Dr. Olga Fabrichnaya, Prof. Dr. Christos G. Aneziris and Prof. Dr. David Rafaja (all with TU Freiberg).

“This award is to recognize the extraordinary dedication of all young authors who are involved in the CRC and successfully published their excellent interdisciplinary research results in leading, high-quality journals. These publications ensure that their findings are presented to a truly international audience,“ said the CRC coordinator Prof. Dr. Christos G. Anezisis. ■

Photo (from left to right): Dr.-Ing. Claudia Voigt, Dipl.-Ing. Tilo Zienert, Dipl.-Ing. Anton Salomon.

MORE NEWS

INTERNATIONAL AWARDS

Two international professional organizations in the field of ceramics awarded prizes to Prof. Dr. Christos G. Aneziris. At its biennal conference in Santiago de Chile, the **Unified International Technical Conference on Refractories UNITECR** honored Prof. Aneziris as a **Distinguished Life Member**. With this award, UNITECR recognized Prof. Aneziris' life achievements, his merits as "bridge-builder" between academic education, cutting-edge research and the refractory industry as well as his engagement for professional organizations, work groups, and technical committees in the field. For this engagement, Prof. Aneziris is given credits as a leading scholar in the field of refractories not only in Germany or across Europe, but worldwide.

Also, the **European Ceramics Society ECerS** awarded Prof. Dr. Christos G. Aneziris at its conference in Budapest and assigned to him the title of a **Fellow**. The ECerS honored Prof. Aneziris' long-standing basic and applied research in the field of innovative refractory materials for applications in ferrous metallurgy, non-ferrous metallurgy, or power engineering and his expertise in traditional ceramic manufacturing technologies. With this award, the ECerS aimed to thank Prof. Aneziris for his work and contributions to various scientific bodies and research collaborations. ■

Photo: (from left to right): Prof. Dr. Christos G. Aneziris and Pablo Valenzuela (President of UNITECR 2017).

INTERNATIONAL ATTENDANCE

M. Sc. Christoph Settgast, doctoral student involved in subproject B05, presented his research at the **CISM workshop "Mechanics of Fluid and Solids Foams"** in July 2017 in Udine (Italy). Together with other researchers and industry representatives he discussed is findings on the effects of production-related cavities in filter struts produced by the replica process during mechanical and thermal stresses. The course offered by the "International Center for Mechanical Sciences" dealt with relationships between the cellular microstructure and the non-linear mechanical behavior of liquid and solid foams. Course participants from various disciplines and research institutions discussed results of their theoretical, numerical and experimental investigations on foam structures. The course had been organized by Andrew Kraynik (Sandia National Laboratories, Albuquerque, USA) and Stelios Kyriakides (University of Texas, USA). ■

Photo: M. Sc. Christoph Settgast (right) discussing his research results with attendees of the CISM.

INTERNATIONAL EXCHANGE

Young researchers involved in the CRC 920 had several opportunities to communicate with leading national and international experts and to exchange ideas and experiences considering research topics, but also strategic issues of their careers as researchers. **Prof. Dr. Victor Carlos Pandolfelli from UFSCar in São Carlos**, Brasil offered a workshop on "Refractory castables and principles of designing microstructures." **Dr. Ana Paula da Luz, Senior Researcher at UFSCar**, gave a presentation on "Applications of thermodynamic simulation of refractory ceramic systems." Moreover, the CRC 920 welcomed **PhD Ondrej Jankovsky from Prague University of Chemistry and Technology (VŠCHT Praha)** as a visiting scholar. Ondrej Jankovsky's expertise is in the field of graphene and nano materials applications in ceramics. During his visit, he contributed to the research in subproject A01 by investigating the generation and thermodynamic evaluation of graphene-containing, nacre-like surfaces. on carbon-containing filter materials. ■

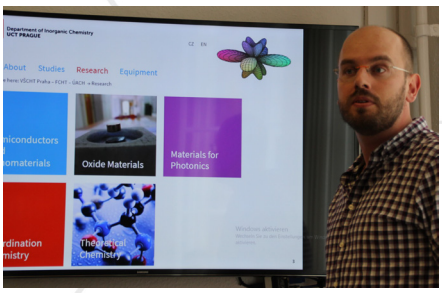


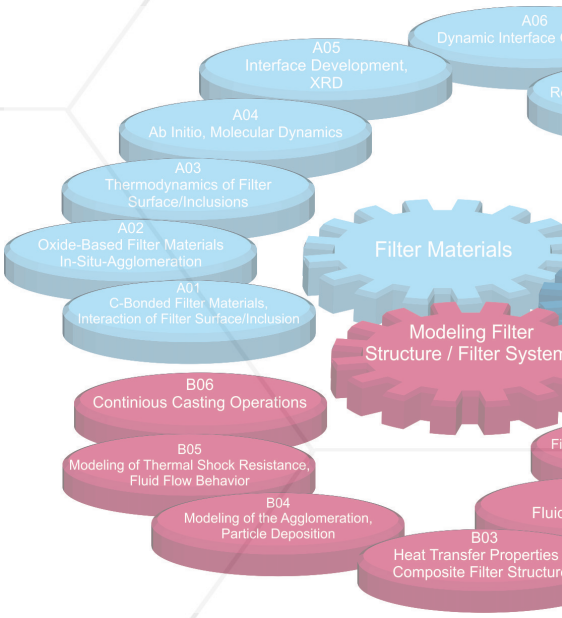
Photo: PhD Ondrej Jankovsky presenting at the Institute for Ceramics, Glass and Cosntruction Materials (IKGB).

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.

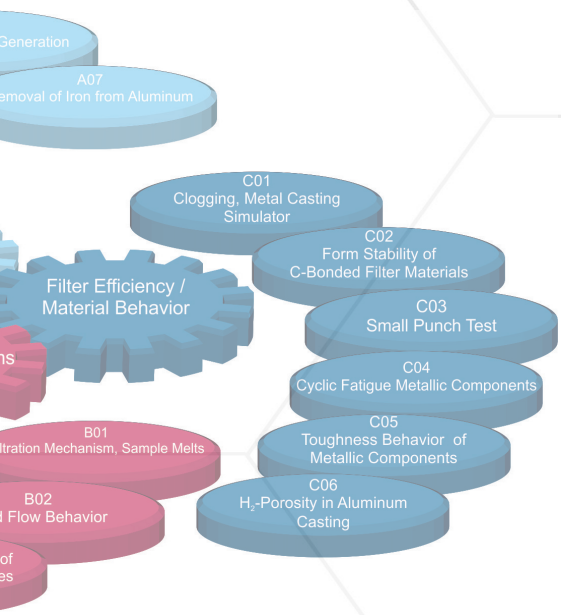
Working Group 1: "Metal melt/inclusions, active/reactive filter material, boundary surface design" (Coordination: Dr.-Ing. Claudia Voigt)

- Verification of an amorphous intermediate layer with embedded crystalline fractions on Al_2O_3-4 Ma.% C and on pure corundum after contact with molten 42CrMo4 steel for 1 min at 1600 °C in SPS complements similar results of TEM analyses for samples produced in the steel casting simulator (A06),
- Characterization of the large-sized filter for the application in the tundish according to strength, porosity, filter structure and behavior with steel melt contact in a steel casting simulator trial (T01, C01),
- Preparation and characterization of 7 inch continuous casting filter for the filtration of aluminum melt (A02). Testing of these filter in a long term filtration trial at Hydro (Bonn, Germany) with Al99.5 (A02, S03),
- Preparation and characterization of with environmentally friendly Al_2O_3-C filter according to strength and behavior with steel contact (small impingement test with 42MoCr4). Besides first analyses with Raman spectroscopy were conducted (A01, S03, A04),
- Determination of the influence of different parameters (for example the alloying elements Cr, Mn and Mg, different holding times and different cooling rates) on the formation of iron-containing, intermetallic precipitates in AlSi-alloys with Fe-impurity (A07, S03) and the robust phase identification (A07),
- Analysis of the crystal structures of low temperature phases which are formed from the η-Al-Fe high temperature-phase at low temperatures (< 350 °C) (A07, A04)
- Comparative study of Alpha-Al_2O_3 surface energies by DFT and MD simulations (A04),
- Completion of the programs sluzzle, rubik and cuDebye for the simulation of 3D planar defect networks in cubic structures. Simulated diffraction patterns verify the existence of anti-phase and rotational boundaries in Gamma-Al_2O_3, which play an important role concerning the thermal stability and the structural evolution at high temperatures (A05),
- Investigation of interactions between temperature stable colloidal probe cantilevers and the developed substrate surfaces via HT – atomic force microscope up to 500 °C and development of an analysis routine for the HT-AFM data (B01),
- Several trials with ceramic fibers have been carried out. The aim was the implementation of these fibers into the filter system for increasing the separation efficiency. All trials have been performed on the water based pilot plant (B01),
- Investigations concerning the reactivity of $LiAlO_2$ for the application as reactive filter material for the removal of hydrogen from the aluminum melt (C06, A02),
- Experimental investigations of the MgO-TiO_2 system and thermodynamic assessment; experimental study of the MgO-TiO_2-Al_2O_3 system as basis for the development of a corresponding thermodynamic database (A03),
- Update of Al-Mg-Fe-Si description with new assessment of Al-Fe, Al-Fe-Si, Al-Fe-Mg and Fe-Mg-Si (A03).



Working Group 3: "Thermomechanical properties of the filter material and structures" (Coordination: M. Sc. Henry Zielke)

- Specimen manufacturing in subproject A02 to determine the size dependency of the strength of the filter material Al_2O_3 employing experimental tests (C03),
- FEM-Simulation of a real foam geometry and comparison with results of artificially generated foams (B05),
- Comparison of experimental results of the effective high-temperature creep behavior of foams at 1350 °C (C02) with numerical simulations (B05),
- Manufacturing of Al_2O_3-C foam filter with CNT coating (+ alumina nano sheets, + alumina nano spheres) (A01) and determination of compressive strength at 1100 °C and 1400 °C (C02),
- Determination of residual compressive strength of CA6/2 finger test samples (A01) after immersion in metal melt (C02),
- Room and high temperature bending test with acoustic emission on compact Al_2O_3-C bars (C02),
- Fracture mechanical bending tests on Al_2O_3-C compact specimens at room and high temperature (C02),
- Determination of the influence of carbon content and cooking regime on the strength of carbon-bonded alumina (Al_2O_3-C) at different temperatures (C03), specimen manufacturing in A01,
- Implementation of a B3B-test set-up with possible testing-temperatures up to 1500 °C (C03).



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

- Experimental investigation of the agglomeration of hydrophobic particles with low density as well as the heteroagglomeration with microbubbles in the water system (B04) and numerical prediction of agglomeration of non-metallic inclusions in turbulent shear flow considering the lubrication force between the inclusions (B06, B04),
- Further investigation of the impact of roughness on adhesion force distributions using samples from A01 and A02 with varying roughness, showing that poor-wetting rough filters are more suitable because of higher adhesion forces (B01),
- Experimental study on the variation of the filter loading with respect to the filter depth in the water model (B01),
- Numerical investigation of filters comprising Kelvin cells of variable width regarding pressure drop and filtration efficiency (B02)
- Strength assessment of new filter designs on the basis of effective homogenized properties (B05, B02),
- Numerical prediction of the influence of the filter on the flow inside the tundish as well as its positioning on the filtration (T01) and validation of the numerical model through velocity measurements in the water experiment (B06),
- Modification of the test facility for measuring the volumetric heat transfer coefficient for preheating temperatures of 650 °C (B03) and comparison of two measurement techniques for determining hemispherical transmission (B03),
- Visualization of different flow structures inside open-cell foams on the basis of in-situ compressed data from detailed LBM simulations using an in situ index of flow velocity and vorticity inside ParaView and the Cave (S02, B05, B02).

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

- Mechanical characterization of the "finger tests" FT3 to FT6 (42CrMo4) with respect to strength, ductility, fracture toughness, fatigue lifetime and damaging inclusions (C04, C05).
- Experiment-based determination of the NMI's clustering distance from the fractured surfaces of specimens after VHCF-testing.
- Statistical-based determination of the NMI's clustering distance from the optical NMI patterns dataset.
- Excellent correlation between fractographic and statistical approaches, both showed NMI's clustering distance to be 10 µm.
- Development of a clustering algorithm, based on the determined clustering distance.
- Application of a simple point process statistical function showed it to be an effective instrument for NBI's clustering detection from the optical patterns.
- Investigation of ductile damage of 42CrMo4 steel during tensile loading by combination of non-destructive testing methods (acoustic emission analysis, thermography, and digital image correlation) (C05).
- Microstructural analysis of metallographic sections taken from an additional cast steel slab (18CrNiMo7-6) treated in a carbon-bonded alumina crucible (C01, C04, S01).
- Improvement of the developed rule-file, for a better classification of the non-metallic inclusions regarding their chemical composition and inclusion types analyzed with ASPEX (C04).
- Detailed microstructural investigation of the in the 18CrNiMo7-6 slabs contained nonmetallic inclusions using SEM in combination with EBSD and EDS and acidic extraction revealing the 3D inclusion morphology (C04, S01).
- Nonmetallic inclusions in 18CrNiMo7-6 are mainly globular, and either multi crystalline sulfides of alpha-MnS-type or duplex inclusions composed of an oxide core, which is potentially amorphous silica that is often accompanied by an individual mullite crystal and a multi crystalline MnS shell.
- Investigation of damage evolution of the hot work tool steel AISI H13 (X40CrMoV5-1) with and without 20 Vol% TiC particles by analysis of acoustic emissions. For the steel with the TiC particles, cleavage fracture event rate significantly increase at relatively low loads of 79 % of the fracture toughness. In contrast, the pure steel without TiC additions exhibits an increasing cleavage fracture event rate just before final brittle fracture (96 % of fracture toughness) (C05).
- The fracture surface roughness of the X40CrMoV5-1 steel depends on the content of the TiC particles. A higher content results in lower fracture surface roughness. Hence, less crack path deflection is observed, which was confirmed by scanning electron microscopy.

INTERFACES BETWEEN FUNCTIONALIZED FILTER SURFACE AND METAL MELT

Author: Anton Salomon (Subproject A06)

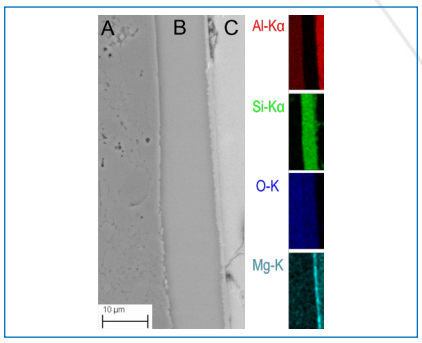


Abb. 1: Left: SEM micrograph (BSE contrast) of the amorphous SiO_2 coating (B) on the Al_2O_3 substrate (A) after 1 min dwell at 750 °C in contact with the solidified AlSi7Mg0.6 alloy (C); Right: Results of EDX element mapping of the area on the left showing Mg enrichment on the interface SiO_2/alloy. [1].

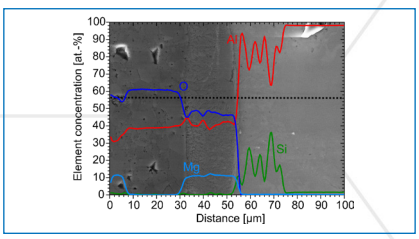


Abb. 2: SEM micrograph (SE contrast) and overlaid EPMA line scan track (cross-centred black dashed line) with corresponding quantitative elemental analysis showing the α-Al_2O_3 substrate with an $MgAl_2O_4$ precipitate (left side) covered with a newly formed, Mg-enriched, Al- and O-containing and Si-free layer (middle) that replaces the SiO_2 coating after contact with the AlSi7Mg0.6 alloy (right side) at 750 °C for 30 min. The composite structure grows columnar-like [1].

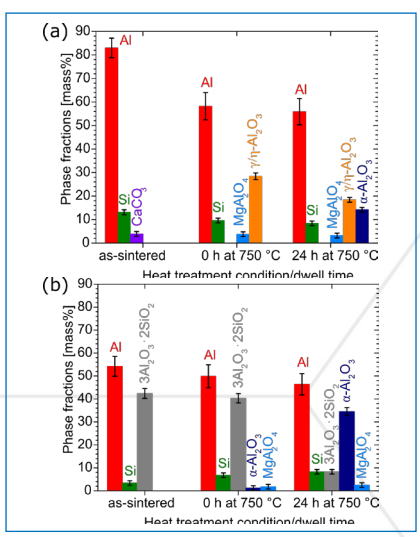


Fig. 3: Phase composition of the powder mixtures of AlSi7Mg0.6 and amorphous SiO_2 (a) and AlSi7Mg0.6 and mullite (b) in the as-sintered state, after heat treatment at 750 °C without dwell (0 h)and after 24 h at 750 °C (24 h) [1].

Subproject A06 deals with the analysis of interfaces between the functionalised filter surface and the respective metallic melt. The analyses focus on the chemical interactions possibly leading to phase forming reactions. The interface generation is performed in a Spark Plasma Sintering device to minimise any melt-flow-related effects.

The phase composition and the chemical composition of the functionalised filter surfaces are of crucial importance for the CRC 920, as they influence the intended deposition of non-metallic inclusions during the passage of the metal melt through the filter ceramic. Due to the high casting temperatures, such chemical interactions between the filter ceramic surface and the metal melt are likely to occur, whereby the chemical and phase composition of the individual coating are changed. In this regard, the targeted use of a functional coating can be applied to selectively modify the filter surface in situ via these interactions and to enhance the deposition of inclusions. For aluminium alloys, corundum (α-Al_2O_3), magnesium aluminate spinel ($MgAl_2O_4$) and metastable phases like η-, γ- or θ-Al_2O_3 are among the most commonly found inclusion phases. The latter ones are especially difficult to apply as a coating. Since the oxide phase formation additionally consumes oxygen dissolved in the melt, a reactive contribution could also be accomplished.

For this study, mullite ($3Al_2O_3{\cdot}2SiO_2$) and amorphous silicon dioxide (SiO_2, fused silica) as reactive coatings on corundum were exposed to melt of the aluminium alloy AlSi7Mg0.6 without melt convection using Spark Plasma Sintering. Experiments were conducted at 750 °C with 1 min, 30 min and 60 min dwell. Complementary, powder mixtures of the aluminium alloy and each of both oxides were pressed to tablets and heat-treated at 750 °C for up to 24 h. These later samples with increased metal-ceramic contact area showed faster reaction kinetics and were used for the quantitative XRD analysis. Thermodynamic calculations were performed to obtain reference equilibrium data [1].

The analyses revealed that both oxides react with the AlSi7Mg0.6 alloy. SiO_2 is reduced by Al and Mg of the melt to Si, which precipitates in the alloy melt. Released oxygen in combination with Al and Mg leads to the formation of $MgAl_2O_4$ (cf. Fig. 1). The low amount of Mg in the alloy (0.61 m.%) and the small thickness of the coating result in a complete replacement of the former SiO_2 by a composite of $MgAl_2O_4$ and Al_2O_3 after 60 min (Fig. 2). During the reaction of mullite with molten AlSi7Mg0.6, the phase firstly decomposes into Al_2O_3 and SiO_2. Again, SiO_2 is reduced and dissolved, whereas Al_2O_3 survives and builds a scaffold for the formation of $MgAl_2O_4$ and additional Al_2O_3stemming from SiO_2 reduction. The decomposition process retards the degradation of mullite in comparison to amorphous SiO_2. In addition, the analysis of the auxiliary powder mixtures revealed that Al_2O_3 growing during the SiO_2 reduction in fused silica coating appears first in its metastable form (η/γ-Al_2O_3) and transforms to thermodynamically stable corundum after longer dwell times. However, aluminium oxide stemming from the reaction between SiO_2 and AlSi7Mg0.6 melt in the mullite coatings grows on the Al_2O_3 scaffold and thus directly in its corundum modification (Fig. 3). The general reaction paths agree well with the calculated thermodynamic equilibria [1].

In the frame of this study, the growth of favourable oxide phases ($MgAl_2O_4$, η/γ-Al_2O_3), that were shown to form in situ, was verified. These newly formed phases were generated within dwell times of relevance for aluminium casting and could contribute to an enhanced active and especially reactive filtration [1]. ■

[1] Salomon, A.; Zienert, T.; Voigt, C.; Dopita, M.; Fabrichnaya, O.; Aneziris, C. G. & Rafaja, D., Formation of different alumina phases and magnesium aluminate spinel during contact of molten AlSi7Mg0.6 alloy with mullite and amorphous silica, Corrosion Science, 2017, 114, 79 - 87

SURFACE FUNCTIONALIZATION OF AL_2O_3-C FILTERS IN STEEL MELT FILTRATION

Author: Anne Schmidt (Subproject A01)

In subproject A01, novel carbon-bonded filter materials and filters with active and reactive coatings for steel melt filtration are investigated. The interactions with the steel melt lead to an in-situ layer formation (reactive stage) on the surface of carbon-bonded alumina filters (Al_2O_3-C filter), which supports deposition of, in particular, very fine nonmetallic inclusions (active stage).

Due to its thermal properties, carbon-bonded alumina is a promising filter material for the steel melt filtration. These filters can be optimized using functional surface coatings, e.g alumina. Thereby, the conscious change of the surface chemistry had distinctly influenced the amount of deposited inclusions at the filter surface. Alumina coated Al_2O_3–C filters had performed best regarding alumina based inclusions smaller than 50 µm. [1]

Furthermore, interactions between the ceramic metal melt filter and the molten steel as well as their time dependence play an essential role. In order to understand these interactions, investigations were carried out between alumina coated Al_2O_3–C filters and Al-killed steel under quasi static conditions by using a spark plasma sintering device (SPS). Immersion tests in a steel casting simulator, which provides close to reality conditions, complement these investigations. [2]

Microstructure and phase analyses reveal that interfacial reactions between filter and molten steel lead to characteristic thin in situ formed layers on the Al_2O_3–C filter surface, Fig. 1a-c. The scheme in Fig. 2 provide a closer look at the formed layers and exemplify the time dependent layer buildup on the filter surface. According to the present state of knowledge, this layer formation could take place in two successive stages. During a first "reactive" stage, large polycrystalline plate-like alumina structures (E) are formed on top of the in situ layer (D). That is, polycrystalline alumina structures arising from heterogeneous nucleation formed on the in situ formed layer surface as a result of dissolution and precipitation reactions. Thereby, carbon and gas phases from the carbon-bonded filter material (A), dissolved oxygen of the steel, iron as catalyst, and probably endogenous inclusions from the steel were involved. Likely due to sintering of the alumina coating (C), these interactions stopped. In a subsequent second „active" stage, fine endogenous inclusions from the molten steel are deposited and sintered on them polycrystalline alumina structure (F).

The results implicate that a porous structure of the alumina coating should be essential to provide the filter / steel interface with sufficient carbon and gaseous phases to trigger the reactive behavior. The surface functionalized Al_2O_3-C filters were most efficient during the "reactive" stage, that is, as long as the interfacial reactions take place. Thereby, the amount of inclusions remaining in steel was reduced to 50 % down to 30 % after immersion tests at 120 sec and 60 sec. This is double to triple the efficiency than predict by numerical simulations by Asad et al. [3]. ■

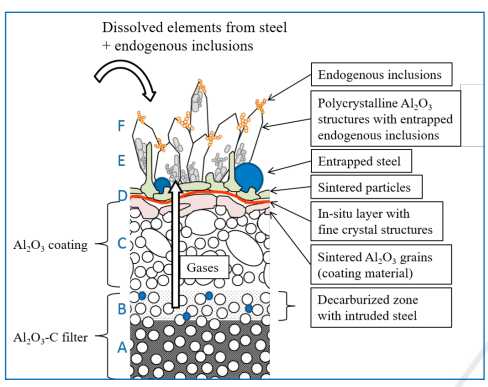


Fig. 2: Scheme of the formed layers buildup on the filter surface [2].

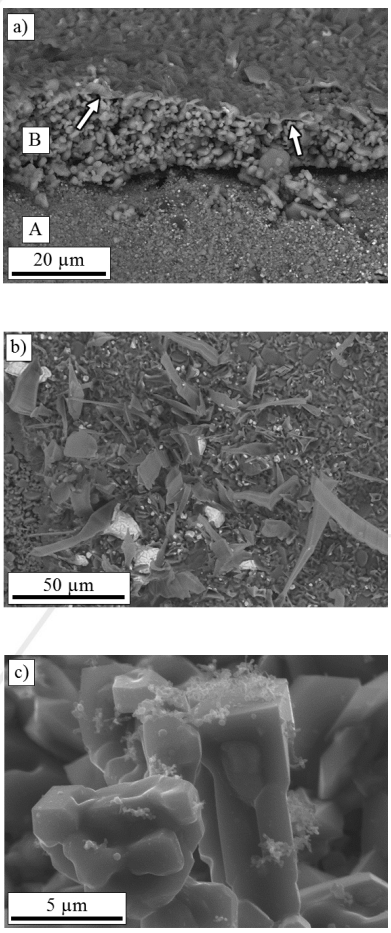


Fig. 1 a) Cross-sectional view on the filter surface after 10 s immersion, BSE mode, A: carbon-bonded filter, B: alumina coating, white arrows: new in situ formed layer; b) top view on the filter surface after 30 s immersion, BSE mode, steel droplets are entrapped by plate-like polycrystalline alumina structures; c) detail of deposited fine clusters on polycrystalline alumina after 60 s immersion, SE mode [2].

[1] Emmel, M., Aneziris, C. G. Schmidt, G., Krewerth, D., Biermann, H.: Influence of the chemistry of ceramic foam filters on the filtration of alumina based non-metallic inclusions. Advanced Engineering Materials, 15 [12] (2013), pp. 1188-1196.
[2] Schmidt, A., Salomon, A., Dudczig, S., Berek, H., Rafaja, D., Aneziris, C. G.. Functionalized carbon-bonded filters with an open porous alumina coating: impact of time on interactions and steel cleanliness. Advanced Engineering Materials, 19 [9] (2017), pp. 1700170 (1-12)
[3] Asad, A., Werzner, E., Demuth, C., Dudczig, S., Schmidt, A., Ray, S., Aneziris, C. G., Schwarze, R.: Numerical modeling of flow conditions during steel filtration experiments. Advanced Engineering Materials, 19 [9] (2017), pp. 1700085 (1-10)

DFG Deutsche Forschungsgemeinschaft
BERGAKADEMIE FREIBERG TECHNISCHE UNIVERSITÄT

CURRENT PUBLICATIONS (MAY - NOVEMBER 2017)

Further information about the currently 221 publications from the second program period until November 2017 as well as about the currently 17 patents and patent applications are available http://tu-freiberg.de/forschung/sfb920.

Projectarea A - Filter materials

Subproject A01

Aneziris, C. G., Gehre, P., Schmidt, A., Storti, E., Dudczig, S., Hubálková, J. (2017): Interactions of refractory filtering materials with steel melt, a contribution to clean steel technologies. 19th conference on modern refractory materials and key achievements in high temperature technologies - REFRA PRAGUE 2017, Prague, Czech Republic, Vortrag Nr. 01, S. 1-5.

Storti, E., Schmidt, A., Dudczig, S., Aneziris, C. G. (2017): Impact of surface functionalization of carbon-bonded filters on steel cleanliness. EcerS 2017 - 15th Conference & Exhibition of the European Ceramic Society, Budapest, Hungary, oral presentation, abstract book, p. 672.

Gehre, P., Schmidt, A., Dudczig, S., Aneziris, C. G., Child, N., Delaney, I., Rancoule, G., DeBastiani, D. (2017): Contribution of molten metal filters with thermal and slip sprayed alumina coatings to the cleanliness of steel. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O109, pp. 414-417.

Schmidt, A., Dudczig, S., Salomon, A., Zienert, T., Storti, E., Rafaja, D., Aneziris, C. G. (2017): Time Dependent Interaction between Carbon-Bonded Alumina Filters and Molten Steel. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O066, pp. 250-253.

Schmidt, A., Salomon, A., Dudczig, S., Berek, H., Rafaja, D., Aneziris, C. G. (2017): Functionalized Carbon-Bonded Filters with an Open Porous Alumina Coating: Impact of Time on Interactions and Steel Cleanliness. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700170 (1-12), DOI 10.1002/adem.201700170.

Schröder, C., Fischer, U., Schmidt, A., Schmidt, G., Volkova, O., Aneziris, C. G. (2017): Interactions between exogenous magnesia inclusions with endogenous inclusions in a high alloyed steel melt. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700146 (1-9), DOI 10.1002.201700146.

Storti, E., Dudczig, S., Hubálková, J., Gleinig, J., Weidner, A., Biermann, H., Aneziris, C. G. (2017): Impact of Nanoengineered Surfaces of Carbon-Bonded Alumina Filters on Steel Cleanliness. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700153 (1-10), DOI 10.1002/adem.201700153.

Storti, E., Dudczig, S., Schmidt, G., Aneziris, C. G. (2017): Comparison of Carbon-Bonded Alumina Filters with Addition of Titania and Nanomaterials in Contact with a Steel Melt. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O067, pp. 254-257.

Storti, E., Dudczig, S., Schmidt, A., Schmidt, G., Aneziris, C. G. (2017): Filter functionalization with carbon nanotubes and alumina nanosheets for advanced steel filtration. Steel Research International, Vol. 88, Iss. 10, pp. 1700142 (1-9), DOI 10.1002/srin.201700142.

Storti, E., Farhani, M., Aneziris, C. G., Wöhrmeyer, C., Parr, C. (2017): Calcium aluminates reactive filter coatings on carbon-bonded alumina filters for clean steel approaches. Steel Research International, DOI 10.1002/srin.201700247.

Storti, E., Schmidt, A., Dudczig, S., Hubálková, J., Aneziris, C. G. (2017): Advanced ceramic filtering materials: a contribution to clean steel technologies, Refractories Worldforum, Vol. 9, Iss. 4, pp. 117-120.

Storti, E., Veres, D., Aneziris, C.G., Wöhrmeyer, C., Parr, C. (2017): Reactive filter collectors based on calcium aluminates with carbon for clean steel approaches. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O108, pp. 410-413.

Subproject A02

Liang, X., Li, W., Sang, S., Xu, Y., Chen, Y., Li, B., Aneziris, C. G. (2017): Enhanced mechanical properties of SiC reticulated porous ceramics via adjustment of residual stress within the strut. International Journal of Applied Ceramic Technology, DOI 10.1111/ijac.12766.

Voigt, C., Taina, F., Aneziris, C. G., Le Brun, P. (2017): Surface Functionalized Ceramic Foam Filter for the Filtration of Aluminum. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O126, pp. 481-484.

Subproject A03

Zienert, T., Leineweber, A., Fabrichnaya, O. (2017): Heat capacity of Fe-Al intermetallics: B_2-FeAl, $FeAl_2$, Fe_2Al_5 and Fe_4Al_{13}. Journal of Alloys and Compounds, Vol. 725, pp. 848-859, DOI 10.1016/j.jallcom.2017.07.199.

Subproject A05

Rudolph, M., Salomon, A., Schmidt, A., Motylenko, M., Zienert, T., Stöcker, H., Himcinschi, C., Amirkhanyan, L., Kortus, J., Aneziris, C. G., Rafaja, D. (2017): Thermally Induced Formation of Transition Aluminas from Boehmite. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700141 (1-10), DOI 10.1002/adem.201700141.

Subproject A06

Salomon, A., Voigt, C., Fabrichnaya, O., Aneziris, C. G., Rafaja, D. (2017): Formation of Corundum, Magnesium Titanate and Titanium(III) Oxide at the Interface between Rutile and Molten Al or AlSi7Mg0.6 Alloy. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700106 (1-8), DOI 10.1002/adem.201700106.

Subproject A07

Becker, H., Leineweber, A. (2017): Atomic channel occupation in disordered η-Al_5Fe_2 and in two of its low-temperatures phases, η'' and η'''. Intermetallics, accepted: 29.09.2017, DOI 10.1016/j.intermet.2017.09.021.

Becker, H., Leineweber, A., Amirkhanyan, L., Kortus, J. (2017): Powder-X-ray diffraction analysis of the crystal structure of the η'-Al_8Fe_3 (η'-Al2.67Fe) phase. Journal of Alloys and Compounds, accepted: 31.05.2017, DOI 10.1016/j.jallcom.2017.05.336.

Project area B - Modeling of filter structures/ filter systems

Subproject B01

Ditscherlein, L., Schmidt, A., Storti, E., Aneziris, C. G., Peuker, U. A. (2017): Impact of the roughness of alumina and Al_2O_3-C substrates on the adhesion mechanisms in a model system. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700088 (1-11), DOI 10.1002/adem.201700088.

Subproject B02

Demuth, C., Werzner, E., Mendes, M. A. A., Krause, H., Trimis, D., Ray, S. (2017): Non-isothermal simulations of aluminum depth filtration. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700238 (1-11), DOI 10.1002/adem.201700238.

Werzner, E., Abendroth, M., Demuth, C., Settgast, C. Trimis, D., Krause, H., Ray, S. (2017): Influence of foam morphology on effective properties related to metal melt filtration. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700085 (1-10), DOI 10.1002/adem.201700240.

Subproject B04

Knüpfer, P., Ditscherlein, L., Peuker, U. A. (2017): Nanobubble enhanced agglomeration of hydrophobic powders. Colloids and Surfaces A, Vol. 530, pp. 117-123, DOI 10.1016/j.colsurfa.2017.07.056.

Subproject B05

Abendroth, M., Werzner, E., Settgast, C., Ray, S. (2017): An approach toward numerical investigation of the mechanical behaviour of ceramic foams during metal melt filtration processes. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700080 (1-10), DOI 10.1002/adem.201700080.

Settgast, C., Abendroth, M., Kuna, M. (2017): Investigation of creep behavior of open cell ceramic Kelvin foam. In: Proceedings of the International Conference on Creep and Fracture of Engineering Materials and Structures (Creep2017), JSt. Petersburg, Russia, SPbPU Publisher, St. Petersburg, pp. 167-168, ISBN: 978-5-7422-5799-8.

Settgast, C., Solarek, J., Klemm, Y., Abendroth, M., Kuna, M., Biermann, H. (2017): Prediction

of High Temperature Behavior of Open-Cell Ceramic Foams Using an Experimental-Numerical Approach. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700082 (1-9), DOI 10.1002/adem.201700082.

Subproject B06

Asad, A., Werzner, E., Demuth, C., Dudczig, S., Schmidt, A., Ray, S., Aneziris, C. G., Schwarze, R. (2017): Numerical modeling of flow conditions during steel filtration experiments. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700085 (1-10), DOI 10.1002/adem201700085.

Project area C - Filter performance, materials properties

Subproject C01

Dudczig, S., Schmidt, G., Hubalkova, J., Aneziris, C. G. (2017): Evaluation of Interactions between Refractory Materials and Steel Melt by using a Steel Casting Simulator. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O112, pp. 426-429.

Fruhstorfer, J., Aneziris, C. G. (2017): Influence of particle size distributions on the density and density gradients in uniaxial compacts. Ceramics International. DOI 10.1016/j.ceramint.2017.07.011.

Fruhstorfer, J., Aneziris, C. G. (2017): Influence of particle size distributions with grain size of 1mm on the density, density gradients and strength og uniaxially die-pressed refractories. InterCeram, Refractories Manual (2017), pp. 41-46.

Fruhstorfer, J., Demuth, C., Götze, P., Aneziris, C. G., Ray, S., Groß, U., Trimis, D. (2017): How the coarse fraction influences the microstructure and the effective thermal conductivity of alumina castables - an experimental and numerical study. Journal of the European Ceramic Society, DOI 10.1016/j.jeurceramsoc.2017.07.038.

Fruhstorfer, J., Dudczig, S., Schöttler, L., Aneziris, C. G. (2017): Inclusions in steel with high Al content and casting temperature after corrosion tests in carbon free and containing refractories. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O041, pp. 150-153.

Subproject C02

Burkhardt, C., Solarek, J., Aneziris, C. G., Biermann, H. (2017): Mechanical Behaviour of Carbon Bonded Magnesia (MgO-C) at Temperatures up to 1500 °. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O133, pp. 509-512.

Solarek, J., Aneziris, C. G., Biermann, H. (2017): A new Method for Manufacturing Graded Refractories by Localized Hot Uniaxial Pressing. Ceramic International, Vol. 43, Iss. 17, pp. 14636 - 14641, DOI 10.1016/j.ceramint.2017.07.167.

Solarek, J., Himcinschi, C., Klemm, Y., Aneziris, C. G., Biermann, H. (2017): Ductile behavior of fine-grained, carbon-bonded materials at elevated temperatures. Carbon, Vol. 122, pp. 141–149, DOI 10.1016/j.carbon.2017.06.041.

Solarek, J., Klemm, Y., Aneziris, C. G., Biermann, H. (2017): High Temperature Behavior of Carbon-Bonded Filter Structures. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O134, pp. 513-516.

Subproject C03

Zielke, H., Abendroth, M., Kuna, M. (2017): Fracture toughness characterization of carbon bonded alumina using chevron notched specimens. Key Engineering Materials, Vol. 754, pp. 71-74, DOI 10.4028/www.scienti c.net/KEM.754.71.

Zielke, H., Schmidt, A., Abendroth, M., Kuna, M., Aneziris, C. G. (2017): Determining the strength of carbon-bonded alumina using the ball on three balls test. Proceedings of the 60th International Colloquium on Refractories 2017 – Supplier Industries enabling REFRACTORIES, 18.-19.10.2017, Aachen, pp. 194-198, ISBN 978-3-9815813-3-1.

Zielke, H., Schmidt, A., Abendroth, M., Kuna, M., Aneziris, C. G. (2017): Influence of the specimen manufacturing process on the strength of carbon bonded alumina (Al_2O_3-C). Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700083 (1-7), DOI 10.1002/adem.201700083.

Subproject C04

Weidner, A., Lippmann, T., Biermann, H. (2017): Crack initiation in the very high cycle fatigue regime of nitrided 42CrMo4 steel. Journal of Materials Research, pp. 1-12, DOI 10.1557/jmr.2017.308.

Subproject C05

Henschel, S., Gleinig, J., Lippmann, T., Dudczig, S., Aneziris C. G., Biermann, H., Krüger, L., Weidner, A. (2017): Effect of crucible material for ingot casting on detrimental non-metallic inclusions and the resulting mechanical properties of 18CrNiMo7-6 steel. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700199 (1-12), DOI 10.1002/adem.201700199.

Henschel, S., Kietov, V. Deirmina, F., Pellizzari, M., Krüger, L. (2017): Fracture toughness of a hot work tool steel-TiC composite produced by mechanical milling and Spark Plasma Sintering, Material Science & Engineering A, Vol. 709, pp. 152-159, DOI 10.1016/j.msea.2017.10.053.

Kietov, V., Henschel, S., Krüger, L. (2017): Study of dynamic crack formation in nodular cast iron using the acoustic emission technique. Engineering Fracture Mechanics, DOI 10.1016/j.engfracmech.2017.07.009.

Subproject C06

Fankhänel, B., Stelter, M., Voigt, C., Aneziris, C.G. (2017): Interaction of AlSi7Mg with oxide ceramics. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700084 (1-8), DOI 10.1002/adem.201700084.

Transfer projects

Transfer project T01

Wetzig, T., Ode, C., Dudczig, S., Aneziris, C. G. (2017): Carbon-Bonded Alumina Filters for Steel Melt Filtration by a Gel-Casting Processing Route Based on Sodium Alginate. UNITECR 2017 - 15th Biennial Worldwide Congress on Refractories, Santiago, Chile, Proceeding No. O068, pp. 258-261.

Service projects

Service project S01

Hubálková, J., Voigt, C., Schmidt, A., Moritz, K., Aneziris, C. G. (2017): Comparative phenomenological study of fracture behavior of ceramic and glass foams under compressive stress using in-situ X-ray microtomography. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700286 (1-9), DOI 10.1002/adem.201700286.

Service project S03

Dietrich, B., Becker, H., Smolka, M., Keßler, A., Leineweber, A., Wolf, G. (2017): Intermetallic sludge formation in Fe containing secondary Al-Si alloys influenced by Cr and Mn as preparative tool for metal melt filtration. Advanced Engineering Materials, Vol. 19, No. 9, pp. 1700161 (1-7), DOI 10.1002/adem.201700161.

Complementary projects

Aneziris, C. G., Fischer, U., Dudczig, S. (2017): Beiträge von funktionalisierten Hochtemperaturfilterwerkstoffen zur Leichtbaufertigung, Qualitätssteigerung und Recyclingfähigkeit von metallischen Produkten. Zur 250. Wiederkehr des Geburtstags von Wilhelm von Humboldt, Abhandlung der Humboldt-Gesellschaft für Wissenschaft, Kunst und Bildung e.V., Band 39, pp.197-208, ISBN 978-3-940456-81-6.

Fischer, U., Dudczig, S., Aneziris, C. G. (2017): Unsichtbare Helden: Keramische Filter für die Metallschmelzefiltration; ein Beitrag zu Zero Defect Materials. DGM im Blickpunkt „Hochleistungskeramik“ 2017, Hrsg.: DGM, IWV, Verlag: ALPHA Informationsgesellschaft mbH, Projekt-Nr. Nr. 103-021, S. 46-52.

Patents and patent applications

Subproject A02

Silica-based aluminium melt filter. Patent application Nro PCT/10 2017 216 964.8 (25.09.2017).

GUESTS FROM INDUSTRY

In July, representatives from **Nippon Steel & Sumitomo Metal Corporation** visited TU Freiberg. The guests demonstrated substantial interest in applications of refractory materials and components, improvements of refractories' lifecycle as well as the development of refractory materials for improving the purity of steel. In terms of productions volume, the Nippon Steel & Sumitomo Metal Corporation is the world's second largest steel manufacturer.

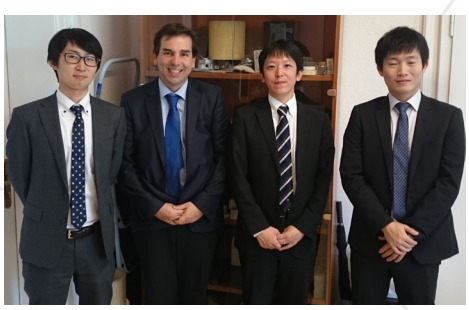


Photo (from left to right): Satoshi Taniguchi (Steelmaking Division), Prof. C. G. Aneziris, Dr. Kenji Taguchi (Senior Researcher at Nagoya R & D Lab.), Kohhei Nishikawa (Manager).

For the CRC 920 collaborations with the industry are of great value. Among others, an external industry advisory board is assigned to the CRC as a strategic advisory council to ensure early discussions of findings and experiences as well as succesful transfers of knowledge into applications. ■

AWARDS AND DISSERTATIONS

Again three doctoral students of the CRC's research training group defended sucessfully their dissertations. **Dipl.-Math. Jakob Teichmann** received his PhD for his work on „Stochastic Modeling of Brownian and Turbulent Coagulation." **Elahe Saboor Bagherzadeh M. Sc.** finished succesfully her dissertation on "Improvement of Wettability by Mechanical Coating".

Dipl.-Ing. Steffen Dudczig was assigned the title Dr.-Ing. for his dissertation on

Photo (from left to right): Prof. Christos G. Aneziris, Dr.-Ing. Steffen Dudczig, Prof. Olena Volkova, Prof. Horst Biermann, Prof. Thomas Graule (EMPA, Schweiz), Prof. Thomas Bier.

"Development of refractory castables for key components able to capture mutual reactions between steel melts and refractory materials in a metal melt simulator." ■

CONFERENCES AND CALLS FOR PAPERS

8. Freiberger Feuerfestforum: 13.12.2017 in Freiberg.

3. DKG Annual Conferece: 10.-13.04.2018, Munich Trade Fair; more information available at http://www.2018.dkg.de.

CIMTEC 2018 - 14th International Conference on Modern Materials and Technologies: 04.-08.06.2018, Perugia, Italy; more information available athttp://2018.cimtec-congress.org.

ICC 2018 - 7th International Congress on Ceramics: 17.-21.06.2017, Foz do Iguaçú, Brasil; more information available at http://www.icc7.com.br.

WCPT 2018 - 8th World Congress on Particle Technology: 22.-26.04.2018, Orlando, USA; more information available at http://www.wcpt8.org.

IMPRESSUM

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PHOTOS
TU Bergakademie Freiberg, CRC "Multi-Functional Filters for Metal Melt Filtration - A Contribution towards Zero Defect Materials," Detlev Müller; UNITECR 2017.

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