EUROPEAN VIRTUAL INSTITUTE ON
KNOWLEDGE-BASED MULTIFUNCTIONAL MATERIALS AISBL

KMM-VIN Newsletter

Issue 22, Summer 2020

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EDITORIAL

The European Virtual Institute on Knowledge-based Multifunctional Materials (KMM-VIN) was established in 2007 as the key result of the Network of Excellence project KMM-NoE of the EU 6th Framework Programme. It is an international non-profit association (AISBL) based on Belgian law with the registered seat in Brussels and a branch in Warsaw, Poland.

KMM-VIN is a self-sustainable European network of universities, R&D institutes and industrial companies which was created to promote and facilitate cooperative research on advanced structural and multifunctional materials.

Joint research activities of the KMM-VIN members are being conducted within Working Groups (WGs). At present KMM-VIN consists of five WGs of different sizes and cooperation schemes: WG1. Materials for Transport, WG2. Materials for Energy, WG3. Biomaterials, WG4. Materials Modelling and Simulation, WG5. Graphene/2D Materials. They comprise materials development and processing, characterisation of microstructure and properties, modelling and simulation. The main industry sectors targeted by the KMM-VIN WGs are Transport, Energy and Healthcare.

Integration of research activities between network members is supported through the KMM-VIN Research Fellowship programme for PhD students and young researchers.

Thematic scope of KMM-VIN encompasses:

- metals and alloys
- advanced ceramics
- intermetallics and shape memory alloys
- composites of metal, ceramic or polymer matrices
- coatings, layered materials, surface modification
- biomaterials and bioinspired materials
- graphene and 2D materials
- joining of advanced materials
- modelling and simulation of materials.

Besides the networking activities for its members, KMM-VIN offers services for external customers such as integrated R&D solutions, access on market conditions to laboratory equipment, database of KMM-VIN materials and members' expertise, customised Specialised Courses, participation in KMM-VIN Industrial Workshops.

This Newsletter issue summarises the main activities of the KMM-VIN association in the first half of 2020 and the planned actions and events for the near future.

Due to COVID-19 restrictions the past months have been difficult for the network integration activities, which are by nature based on exchange and mobility of researchers. This is commented upon in "Latest News" containing up-to-date information on the membership as well as recent and forthcoming events. Despite the travelling constraints the research cooperation has been going on, mainly on bilateral basis, as reported in "News from the Working Groups". As you will see the amount of information obtained from the WGs is substantial. This makes us believe that the WGs will be back to normal cooperation activities (not only virtual) once the situation with COVID-19 is under control.

In the column "KMM Projects" a concise information is provided on selected European projects in which two or more KMM-VIN members are involved. Also, the participation of KMM-VIN representatives in the European Technology Platform on Advanced Engineering Materials and Technologies (EuMaT ETP) is mentioned.

Within the "Research Fellowships, Courses and Trainings" column the results of the 2020 call for KMM-VIN Research Fellowships for young researchers and PhD students are provided. An updated list of Specialised Courses which are offered by KMM-VIN members for external clients is also included.

Professional achievements of KMM-VIN members, such as scientific awards, promotion to high professional positions and alike are reported in "Personalia".

The up-to-date register of the KMM-VIN members and the contact details of the KMM-VIN office are provided at the end of the Newsletter.

More information about KMM-VIN can be found on the website: http://www.kmm-vin.eu

Katarzyna Kowalczyk-Gajewska, Editor

LATEST NEWS

GENERAL ASSEMBLY 2020

The 15th Annual General Assembly of KMM-VIN was held on February 25, 2020 in Brussels, just before the outbreak of COVID-19 virus in Europe. The annual activity and financial reports of 2019 and a provisional budget for 2020 were presented, voted and approved by the General Assembly. The financial situation of KMM-VIN at the end of 2019 was stable with almost 50 000 € as cash reserve on the bank account and a positive annual balance. According to the provisional budget for 2020 it is expected that the year 2020 will be another year of a positive annual balance and strengthening of the network financial viability.

During the GA meeting it was pointed out that KMM-VIN had evolved into a European network, whose core activities comprise (i) collaborative research projects (multipartner or bilateral) conducted within five Working Groups (WGs), (ii) mobility programme for young researchers (KMM-VIN Research Fellowships), and (iii) Industrial Workshops (IW) organised by the WGs. These three groups of interrelated activities were the highlights of KMM-VIN networking in 2019.

Besides the activity and financial reports, the GA has also approved an update of the KMM-VIN Operating Procedures including *inter alia* the membership fees for 2020, which remained unchanged relative to 2019.

The annual technical meetings of the five Working Groups were held from 24th to 26th Feb. 2020 in Brussels as satellite events of the General Assembly meeting. The primary aim of the WGs annual meetings is to report on the ongoing research collaborations between the WG members. These meetings also play a brokering role for the participants by giving them an opportunity to present new research topics on which new collaborations can be built.

PARTNERSHIP

The KMM-VIN association is currently composed of 61 core and associate members from 14 European States. Among them 54 are institutions (research centres, universities, large companies and SMEs) and 7 are individual members. For several years now the number of KMM-VIN members has been oscillating around 60. In 2020 three new organisations have joined the KMM-VIN: Università degli Studi di Modena e Reggio Emilia (Italy), Ecole normale supérieure Paris-Saclay (France), and European Technology Development Ltd (UK). There were also two withdrawals: Fundacion CIDETEC Centre for Electrochemical Technologies (Spain) and Universita degli Studi di Padova (Italy).

KMM-VIN is open for new members interested in collaborative research within the thematic scope of the five WGs. Applications for membership are being collected on a continuous basis but the final decision on accession is taken once a year by the General Assembly at its annual meeting in Brussels.

FORTHCOMING EVENTS

Due to the COVID-19 precautionary measures adopted throughout the world all conferences and workshops scheduled after 1st March 2020 have been either postponed or cancelled. The KMM-VIN Industrial Workshops 9 and 10 are no exception.

9th KMM-VIN Industrial Workshop (IW9) on Materials for Energy in Turin has been moved to **May 17-18, 2021**. The aim of IW9 is to gather a mixed audience of researchers and industrial players in the field of energy and to show the new opportunities offered by advanced materials (see "News from WG2" for more information on IW9).

10th KMM-VIN Industrial Workshop (IW10) on "Design and modeling of innovative biomaterials and bioinspired materials for industrial applications" was planned on January 18-19, 2021 in Vienna. The new date is **January 25-26, 2022** (see "News from WG4").

THERMEC'2020 – the 11th International Conference on Processing & Manufacturing of Advanced Materials - Processing, Fabrication, Properties, Applications, scheduled on May 31-June 5, 2020 in Vienna (http://www.thermec2020.tugraz.at) has been postponed to **May 9-14, 2021**. It is organised by TU Graz, with Christof Sommitsch (TUG) as the General co-Chair and Cecilia Poletti (TUG) as the Program co-Chair. Several KMM-VIN partners were invited to be topic Coordinators and/or Keynote Speakers: Peter Mayr (TU Munich), Cecilia Poletti (TUG), Michał Basista (IPPT) and Olaf Andersen (FRAUNHOFER).

ECCC2020 – 5th International ECCC Creep & Fracture Conference has been moved to **September 20-23, 2021**; venue remains as before (Edinburgh); http://eccc2020.com

ICTAM 2020 – 25th International Congress of Theoretical and Applied Mechanics has been postponed by one year and will be held from 22 to 27th August 2021 in Milan. For more information please visit the ICTAM website: https://www.ictam2020.org/

SolMech2020 – 42nd Solid Mechanics Conference originally scheduled on September 7-10, 2020 has been cancelled. It is not yet decided whether the conference will be postponed till 2021 or 2022. For updates please check the conference website: http://solmech2020.ippt.pan.pl/

LUBMAT 2020 – 7th Congress on Lubrication, Tribology and Condition Monitoring organized by IK4-TEKNIKER in Bilbao has been moved to 1st-2nd Dec. 2020. Interested participants are requested to visit the conference website http://www.lubmat.org

EUROMAT 2021 – will be held on 12-16th September 2021 in Graz. Christof Sommitsch (TUG) is the scientific chairman. For more information please visit: https://www.euromat2021.org

WHAT'S NEW IN WORKING GROUPS

Working Groups (WGs) constitute the internal research structure of KMM-VIN. Collaborative research supported by the KMM-VIN Research Fellowship programme, preparation of project proposals, and organisation of Industrial Workshops are currently the core activities carried out within the Working Groups. Since the internal collaborative projects within WGs receive no funding from KMM-VIN budget they are being formed bottom-up by the WG members without any imposed research agenda or work model from KMM-VIN. Therefore, the results of the collaborative work within WGs are mainly dependent on the members' commitment and the leadership of WG coordinators. In fact, each WG operates in a slightly different way with different intensity.

At present KMM-VIN is composed of five WGs as listed below.

WG1. Materials for Transport

Coordinators:

Pedro Egizabal, Fundación Tecnalia (TECNALIA), Donostia/SanSebastian, Spain

Thomas Weissgärber, Fraunhofer Institute for Manufacturing and Advanced Materials, (FRAUNHOFER-IFAM DD), Dresden, Germany

WG2. Materials for Energy

Coordinators:

Monica Ferraris, Politecnico di Torino (POLITO), Italy

Christof Sommitsch, Graz University of Technology (TUG), Austria

WG3. Biomaterials

Coordinators:

Aldo R. Boccaccini, Friedrich-Alexander Universität (FAU), Erlangen-Nürnberg, Germany

Christian Hellmich, Technische Universität Wien (TUW), Austria

WG4. Materials Modelling and Simulation

Coordinators:

Andrés Diaz-Lantada, Universidad Politécnica de Madrid (UPM), Spain

Katarzyna Kowalczyk-Gajewska, Institute of Fundamental Technological Research of Polish Academy of Sciences (IPPT), Warsaw, Poland

WG5. Graphene/2D Materials

Coordinators:

Peter Hansen, Ammanford, United Kingdom

Antonios Kanellopoulos, University of Hertfordshire (UH), Hatfield, United Kingdom

Any member of KMM-VIN (core or associate) can join any WG upon prior consent from the WG coordinators, with the exception of the WG2-EMEP (a subgroup of WG2. Materials for Energy), where special accession rules apply (cf. http://kmm-vin.eu/members_area/wg2/ after login). New WGs can be formed on themes not covered by the existing WGs, if requested by a group of minimum 7 members.

NEWS FROM WG1: MATERIALS FOR TRANSPORT

What´s new in WG1

The collaborative projects and contacts among members of WG1 have continued during the first half of 2020 and new collaboration opportunities were discussed during the General Assembly meeting of KMM-VIN held in Brussels at the end of February 2020 that should crystallize in new projects in the near future.

The long-standing collaboration between IMIM and TECNALIA continues through the internal collaborative project related to the development of new aluminium based particulate reinforced composites. The exchange of samples and discussion of the analysis of samples has continued and a new exchange of researchers is foreseen for September 2020 in the frame of the KMM-VIN Research Fellowships. Another internal project is being coordinated by IPPT with the goal of analysing ways to improve the strength and fracture toughness of NiAl intermetallics. The VSB TU Ostrava and IMIM have also continued their collaboration in a project related to the effect of severe plastic deformation on aluminium based composites.

A new round of brainstorming session for further collaborative projects will be opened by WG1 coordinators in the autumn of 2020 in order to boost new collaborations among members of WG1.

Internal collaborative projects

1. Effect of various severe plastic deformation parameters on grain refinement and mechanical properties of aluminium-based composites

The bilateral collaboration between VSB TU Ostrava and IMIM Kraków within the NAWA project PPN/BIL/2018/1/00118/U/ has continued during 2020. The aim of the project is to determine the influence of severe plastic deformation (SPD) process using a new construction of the ECAP-TC angular channel with helical exit geometry (intensifying deformation) on changes in the microstructure and mechanical properties of cast composites based on aluminium-silicon alloys with the addition of SiC and Al_2O_3 submicron particles. The main contractor for the Czech side is Miroslav Greger and from the Polish side is Wojciech Maziarz. During the last half year, the investigations were focused on determination of microstructure and mechanical properties of composite AlSi/SiC samples deformed by one pass in ECAP-TC at different temperatures i.e. 350, 400 and 450 °C. Microhardness measurements results (Fig. 1) revealed a decrease of microhardness with increasing temperature of the ECAP process. These phenomena can be associated with the dynamic recrystallization during the TCAP process.

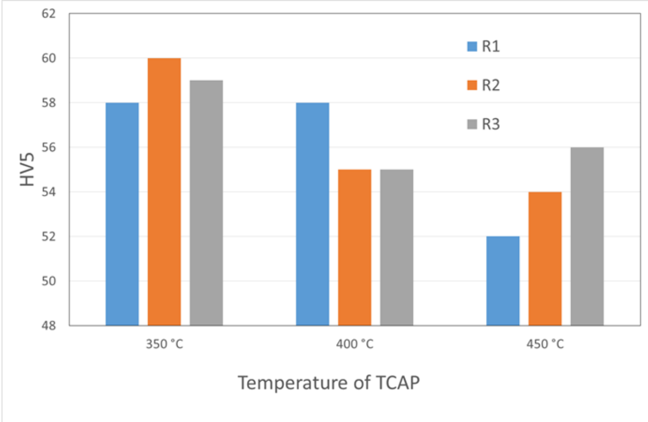


Fig. 1. *Results of microhardness HV5 measurements in different regions of samples TCAP at different temperatures (courtesy of IMIM).*

Taking into account the chemical composition of AlSi base alloy and the Al-Si phase diagram it can be stated that its melting point is T_t ~ 580 °C. According to the temperature criterion, a hot plastic deformation process occurs if $T_h > 0.4T_t$. In our case T_h = 232 °C and plastic deformation processes were conducted at 350, 400 and 450 °C, hence they can be considered hot plastic deformation processes. Additional criterion for dynamic recrystallization during hot plastic deformation is $T_{dr} > 0.6T_t$.

The calculated T_{dr} is 348 °C which is lower than all applied temperatures of the SPD process. Therefore, the main reason of existence of microstructural and micro-hardness phenomena in composite after TCPA is associated with the possible recrystallization process occurring in the investigated samples due to different time of exposition at the extrusion temperatures. However, the 350 °C is very close to the temperature of dynamic recrystallization, therefore it ensures the smallest grain growth.

TEM microstructure investigations were performed for samples extruded at 350 and 450 °C in order to confirm that dynamic recrystallization has taken place. Since the temperature of dynamic recrystallization for the investigated composite is around T_{dr}~ 348 °C, therefore significant differences in microstructure can be expected in selected samples for TEM observations.

A severe plastic deformation process is associated with the generation of large amounts of microstructural faults, in particular dislocations and changes in the shape of grains. On the other hand, the processes of recovery and recrystallization cause annihilation of dislocations and growth of grains. For that reason, the STEM-HAADF observation technique is very useful as it is sensitive to chemical composition and structural faults. Fig. 2 shows STEM-HAADF images of samples deformed by TCAP at 350 and 450 °C, respectively.

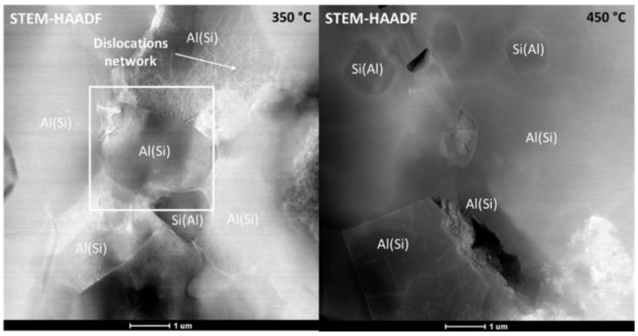


Fig. 2. *STEM-HAADF images of samples deformed by TCAP at 350 and 450 °C (courtesy of IMIM).*

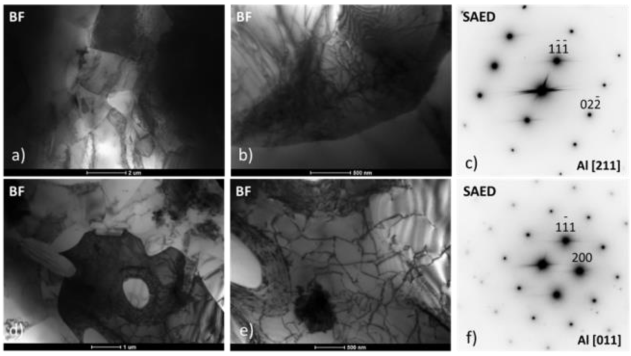


Fig. 3. *Set of BF microstructures images taken at different magnifications and corresponding SAED patterns of composite extruded by TECAP at 350 °C (a), (b), (c) and 450 °C (d), (e) and (f) (courtesy of IMIM).*

In both cases one can see equiaxed grains of Al(Si) and Si(Al) solid solutions. While the Si(Al) grains are practically the same for both cases, about 1 μm in size, the Al(Si) grains are fundamentally different. For a lower temperature of TCAP, smaller grains decorated with a large amount of dislocations forming a typical network microstructure characteristic for large plastic deformation can be seen. I case of higher temperature the grains of Al(Si) are significantly bigger and with lower amount of dislocations. Therefore, this is evident that during extrusion at 450 °C recrystallization and grain growth processes occurred. This is was also confirmed by observations performed in a bright field (BF) and selected area electron diffraction (SAED). Fig. 3 presents set of BF microstructures taken at different magnifications and corresponding SAED patterns of composite extruded by TCAP at 350 and 450 °C. One can see the deformed Al(Si) grains with [211] and [011] zone axis for composite extruded at 350 and 450 °C, respectively. The substantial differences in grains size is visible at lower magnifications and in densities of dislocations at higher one. Fig. 4 shows STEM-HAADF image and results of EDS point analyses and corresponding BF microstructure showing the SiC particle with a size of about 1 μm. Because thin foil in this area is not enough thin for electron diffraction conditions, existence of the SiC particle is confirmed only by EDS analyse. Moreover, identifications of SiC particles in AlSi/SiC composite is difficult since Si(Al) solid solution after TCAP process have a form of regular particles of size close to SiC initially introduced in to aluminium matrix.

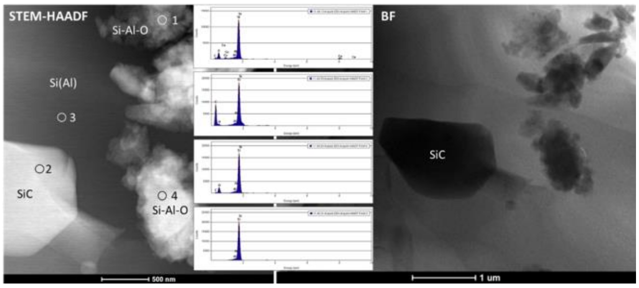


Fig. 4. *STEM-HAADF images, results of EDS point analyses and corresponding BF microstructure (courtesy of IMIM).*

When applying EDS analysis in the STEM-HAADF mode some amount of C is always present in spectrum due to contamination caused by interaction with the electron beam. Therefore, it is difficult to distinguish which particle we are dealing with. From the EDS spectra one can see a significant increase of intensity of C peak in point 2 corresponding to a SiC particle in comparison with point 1 corresponding to Si(Al) solid solution. Hence it can be stated that it is a SiC particle.

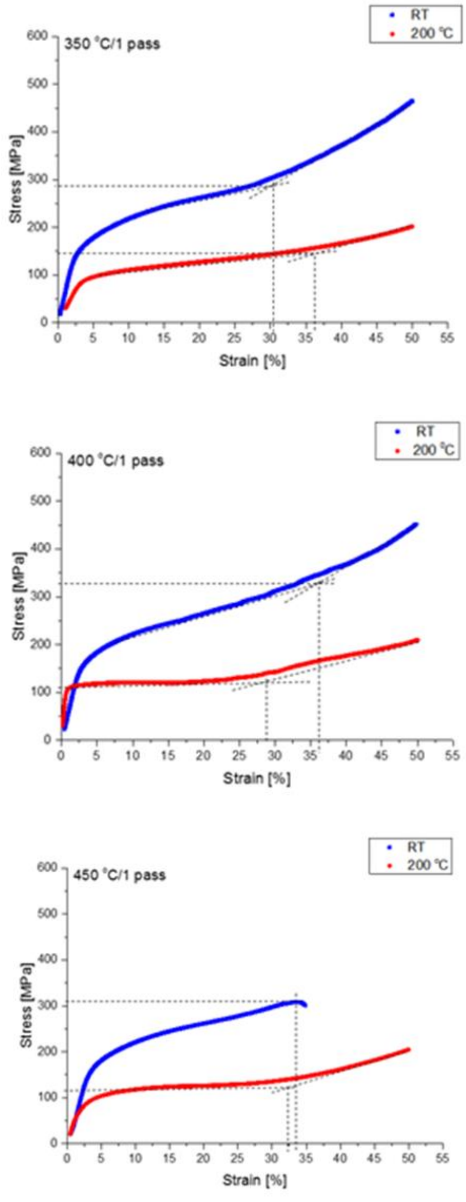


Fig. 5. *Stress-strain curves for AlSi/SiC composites after 1 pass of TCAP recorded at RT and 200 °C (courtesy of IMIM).*

Due to a small amount of the material obtained from TCAP the mechanical properties were determined by use of compression tests at two temperatures i.e. room temperature (RT) and 200 °C. Fig. 5 shows a set of stress-strain curves obtained for AlSi/SiC composites after one pass of TCAP recorded at RT and 200 °C. In all cases a similar character of the stress-strain curves is visible. For larger deformations (over 25%), a change in the slope of the strengthening curve is noted, which may be associated with achieving maximum deformation by the compressed samples and the contribution of the anvils of the testing machine to further deformation and increase in stress. Using the tangent method at the inflection point of the curves, the maximum plastic deformation and the compressive strength were determined. It can be seen that at the RT the maximum plastic deformation is about 35%, the compressive strength about 300 MPa and is similar for all the investigated samples. At 200°C, there is essentially no change in strength, only a decrease in strength between 100 and 150 MPa. Lower strength is exhibited by the samples after the TCAP performed at higher temperatures.

Wojciech Maziarz, IMIM
w.maziarz@imim.pl

2. Improvement of the fracture toughness and strength of NiAl intermetallic at room temperature

The IPPT and IMIM teams have continued their long-term collaboration on improving fracture toughness and strength of NiAl at room temperature in view of its potential use as a lightweight structural material replacing Ni-base superalloys in aero engines.

The preliminary idea reported in Newsletter 19 was to add rhenium to NiAl powder and consolidate the NiAl(Re) mixture by hot pressing or SPS technique. An addition of 1.53vol.% Re to NiAl almost doubled its flexural strength and increased its fracture toughness by 60%. More information about that processing route and properties of NiAl(Re) material can be found in [1].

Recently, this idea has been pursued further by adding alumina ceramic to NiAl(Re) powder mixture. Of several compositions of NiAl-Re-Al_2O_3 shown in Fig. 6 the best combination of fracture toughness and flexural strength was obtained for NiAl 0.73Re 0.5Al_2O_3 composite (material no. 6 in Fig. 6) showing 99.9% relative density. Mechanical properties of this material at room-temperature were as follows: fracture toughness 15.19 MPa$\sqrt{m}$, bending strength 1065.1 MPa, tensile strength 605 MPa, elongation 0.8%. The K_{IC} of NiAl 0.73Re 0.5Al_2O_3 is over two times higher than that of the as-received NiAl sintered under the same conditions (material no. 3). However, tensile ductility of NiAl 0.73Re 0.5Al_2O_3 is still insufficient for application in aero engines. Therefore, future investigations will be focused on ductility enhancing mechanisms in NiAl-Re-Al_2O_3 materials, while not compromising on toughness and strength. More information about NiAl-Re-Al_2O_3 materials developed within this IPPT-IMIM collaboration can be found in [2].

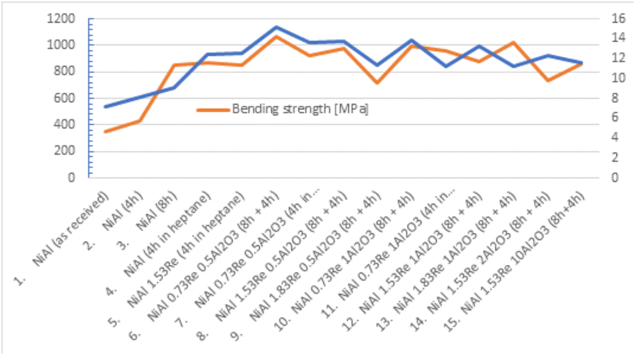


Fig. 6. *Fracture toughness and flexural strength of NiAl-based materials in four-point bending (courtesy of IPPT).*

[1] K. Bochenek, W. Węglewski, J. Morgiel, M. Basista Influence of rhenium addition on microstructure, mechanical properties and oxidation resistance of NiAl obtained by powder metallurgy, *Materials Science and Engineering A*, 735, 26, 121-130, 2018. 10.1016/j.msea.2018.08.032

[2] K. Bochenek, W. Węglewski, J. Morgiel, M. Maj, M. Basista, Enhancement of fracture toughness of hot-pressed NiAl-Re material by aluminum oxide addition, *Materials Science and Engineering A* 790, 139670-1-6, 2020. 10.1016/j.msea.2020.139670

Michał Basista, IPPT
mbasista@ippt.pan.pl

3. Development of new aluminium and magnesium based particulate reinforced composites with the help of ultrasound probes to disperse ceramic particulates

There is still running a fruitful collaboration between IMIM and TECNALIA concerning the investigation on the metal matrix composites reinforced with the ceramic nanoparticles. These materials are widely studied due to the combination of low density with high specific stiffness, high specific strength and high temperature stability, which are suitable for a variety of applications as functional and structural materials. Here, the type, size and distribution of the reinforcing particles are relevant taking into account the mechanical properties of the composites.

The metal matrix composites are fabricated by conventional *ex-situ* methods and *in-situ* techniques. In the first case, the reinforcement is added to the matrix externally while the second route includes the formation of reinforcement within the matrix by reaction during processing. The *in-situ* process is beneficial relative to the *ex-situ* one because it leads to finer particles uniformly distributed in the matrix. Additionally, good wettability of the reinforcement and clean interface strongly affect the high-temperature properties. In this work, composites were manufactured *in-situ* via casting process by Self-propagating high-temperature synthesis in bath (SHSB).

Here, the addition of powder moderator is a new issue, which promotes the creation of nano-TiC particles and may lead to pushing them from grain boundaries to grain inferiors. Several parameters on SHSB process were applied in order to obtain the optimal microstructure of composite composed of small (nanometre size) TiC particles homogenously distributed in the matrix without additional intermetallic phases.

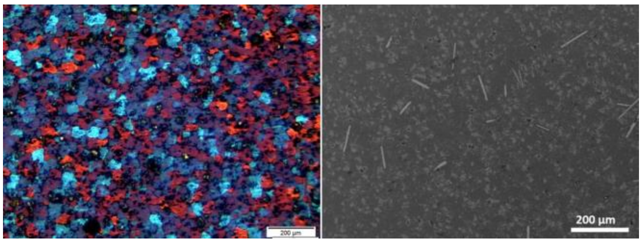


Fig. 7. *Optical and SEM images showing the microstructure of TiC/Al nanocomposites (courtesy of IMIM).*

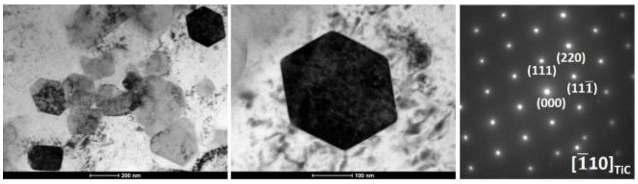


Fig. 8. *Bright field images and selected area diffraction patterns taken from the TiC particle (courtesy of IMIM).*

Fig. 7 shows both the optical and scanning electron microscopy images of the composite with high (80% of the whole mixture of reactants) content of moderator. What is important here, the microstructure is homogenous, without the clear division into the zones of small equiaxed grains, columnar grains and bigger grains in the middle of the cast, with the average grain size of around 30 µm. Moreover, the TiC particles are not clustered, but spread along the whole area in both grain boundaries and grain inferiors. The only disadvantage is an extra TiAl3 phase in a form of blocky-like plates. Transmission electron microscopy images show that TiC particles are well separated from each other, with the size between 150-299 nm (Fig. 8). Here, both the grain refinement and the addition of well distributed in the matrix and relatively small TiC particles lead to significant improvement of the mechanical properties of composites.

Anna Wójcik, IMIM
a.wojcik@imim.pl

News from AGH-UST

Bimetallic Au-Ni nanoparticles for catalysis applications

Bimetallic nanoparticles have attracted considerable interest in a variety of fields related to catalysis, energy storage and conversion, magnetic storage, and biotechnology. Manipulating the nanoparticle size, shape and composition enable one to control and enhance the catalytic performance of these materials. Core-shell, Janus-like, and hollow-structure nanoparticles are exciting examples of the engineered nanomaterials. Furthermore, combining several chemical elements in a single nanoparticle enables the development of materials with hybrid properties. Thus, for example, Au–Ni nanoparticles provide a combination of non-toxic gold and magnetic nickel, which substantially broadens the potential of their applications. However, for successful development and long-term, degradation-free performance of such nanostructures, one needs to firmly understand the interaction between components of the particle at the nanometer scale.

The International Centre of Electron Microscopy for Materials Science, AGH-UST has started bilateral research cooperation with the group for Thin Film Physics of V. N. Karazin Kharkiv National University (KhNU) on studies of interface interactions in bimetallic nanoparticles down to the atomic level. The cooperation has already been supported by joint Ukraine - Poland R&D project “Towards understanding equilibrium phase diagrams at nanoscale”, the Horizon 2020: H2020-INFRAIA-2018-2020 Enabling Science and Technology through European Electron Microscopy (ESTEEM3) through the transnational access activity and international exchange PROM NAWA program.

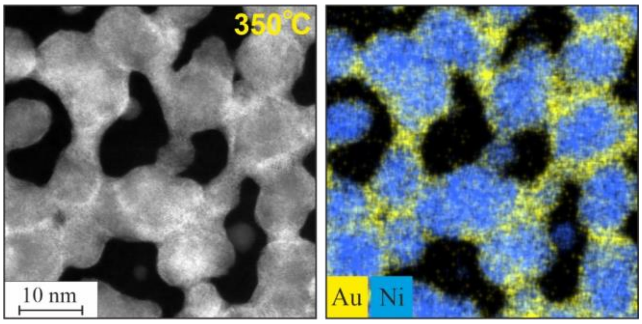


Fig. 9. *HAADF-STEM image and the corresponding EDX elemental distribution map of the Au–Ni islands at 350°C (courtesy of AGH-UST).*

Advanced electron microscopy techniques have been applied to investigate the kinetics of mixing of Au and Ni in nanoparticles and to visualize the equilibrium morphology of the AuNi nanosized alloy. Fig. 9 exemplifies AuNi nanosized alloy revealing Au segregation to the surface of homogeneous nickel-based solid solution particles at 350°C. Moreover, we were able to fully mix Au and Ni in nanoparticles with a diameter of 13 nm already at a temperature of 550°C, which is more than 250°C below the homogenization temperature of the bulk alloy.

Further details can be found in:

S. Bogatyrenko, A.P. Kryshtal, A. Minenkov, A. Kruk, Miscibility gap narrowing on the phase diagram of Au-Ni nanoparticles, *Scripta Materialia* 170, 57-61, 2019. https://doi.org/10.1016/j.scriptamat.2019.05.023

Oleksandr Kryshtal, AGH-UST
kryshtal@agh.edu.pl

Interfacial stability of $CoSb_3$ in contact with metal

One of the most promising applications of thermoelectric generators is waste heat recovery from exhaust lines in the automotive industry. Thermoelectric properties of materials are strongly dependent on chemical composition. Even a small deviation from stoichiometry can cause a significant drop in thermoelectric performance. Unfortunately, since thermoelectrics often work at elevated temperatures, they undergo changes in chemical composition as a result of diffusion around interfaces. Thermal stability of interfaces, including electrical connections and protective coatings, is likely to be one of the key issues for an efficient thermoelectric conversion. To get more in-depth knowledge on the interfacial phenomena in metal/thermoelectric material systems, the Cr-$CoSb_3$ joints were studied at AGH-UST (Fig. 10).

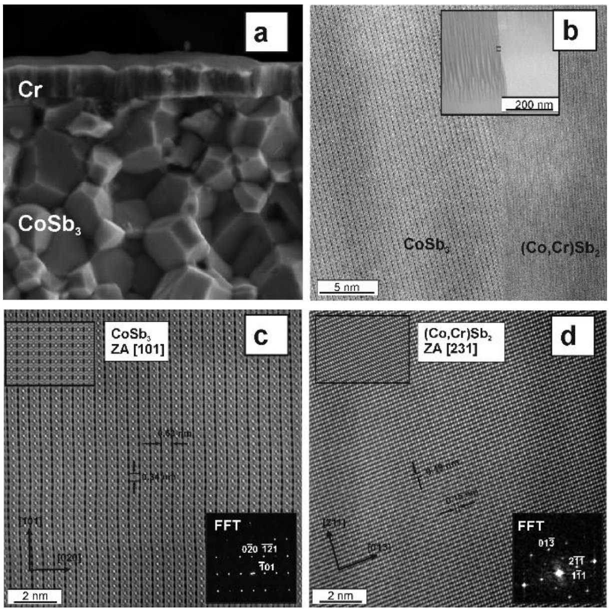


Fig. 10. The Cr/$CoSb_3$ interface: (a) fracture before annealing (SEM, SE); (b) interdiffusion zone/$CoSb_3$ interface after annealing at 600ºC for 24h (HR-STEM); (c) $CoSb_3$ (HR-STEM) and (d) (Co,Cr)Sb_2 grain (HR-STEM) with corresponding HR-STEM image simulations (left-top insets); (courtesy of AGH-UST).

Phenomena occurring at the $CoSb_3$/Cr interface are particularly important for the lifetime of some oxidation resistant coatings on the $CoSb_3$-based components of thermoelectric modules. Investigations on reactivity and diffusion in a Cr-$CoSb_3$ couple under vacuum were carried out in the temperature range 500°C – 600°C. The performed studies were focused on evolution of microstructure, chemical and phase composition over time. Complex microstructure of the interdiffusion zone was visualized by means of a 3D model using FIB-SEM tomography (Fig. 11). Some general kinetic parameters, such as growth rate of layers and corresponding activation energy, were determined. As a result, explanation of the interdiffusion zone formation was proposed.

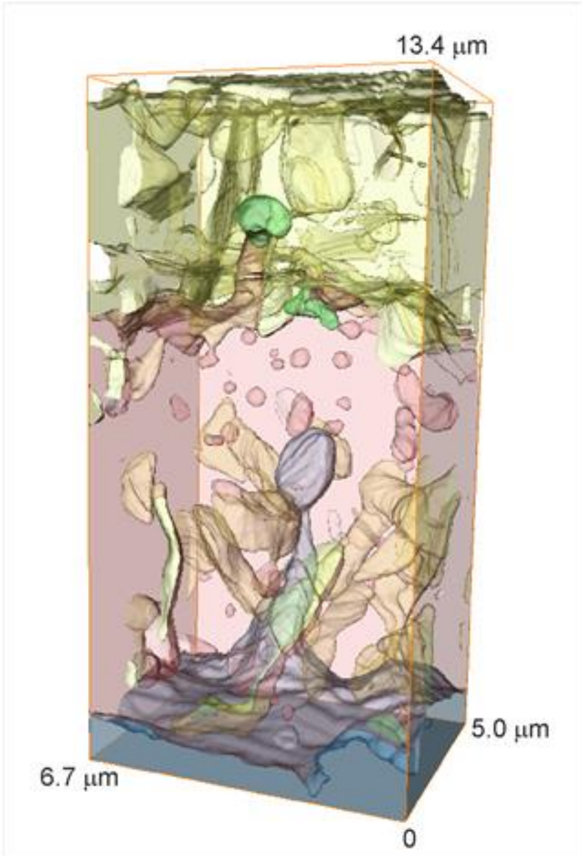


Fig. 11. 3D reconstruction of interdiffusion zone: yellow – (Cr,Co)Sb, green – CoSb, red – (Co,Cr)Sb_2, blue – $CoSb_3$ (courtesy of AGH-UST).

More detailed information can be found in:

K. Zawadzka, E. Godlewska, K. Mars, A. Kryshtal, A. Kruk, Interfacial stability of $CoSb_3$ in contact with chromium: Reactive diffusion and microstructure evolution, *Journal of Alloys and Compounds*, 843 155862, 2020. https://doi.org/10.1016/j.jallcom.2020.155862

Kinga Zawadzka, AGH-UST
kinga@agh.edu.pl

ESTEEM3 Transnational access possible at AGH-UST

The ESTEEM3 project, in which AG-UST is one of the partners, gives a possibility of a transnational access to the most advanced Transmission Electron Microscopy (TEM) installations offering world-class expertise in many different fields of electron microscopy. ESTEEM3 is a European project funded by the European Commission's Horizon 2020 Programme. It is a network of European laboratories and SMEs in electron microscopy. The main objective of ESTEEM3 is to facilitate access to electron microscopes in Europe. The project, which takes over from ESTEEM1 and ESTEEM2, started in January 2019 for a duration of 4.5 years. Transnational access (also called TA) is the central feature of the project and allows European and International researchers to access state-of-the-art European facilities of electron microscopy. Thus, researchers can apply in the laboratory of their choice from a list of 15 facilities in Europe (Fig. 12) for all what is necessary to perform investigations: Sample preparation, Transmission electron microscopy (TEM) and also Data analysis. Only user groups that are allowed to disseminate the results they have generated under the action may benefit from the access, unless the users are working for SMEs. Access for user groups with a majority of users not working in an EU or associated country is allowed but limited to 20% of the total amount.

Fig. 12. *Map of TA providers within ESTEEM3 (courtesy of AGH-UST).*

Fig. 13. *Scientists from Transylvania University of Brasov, Romania during TA visit at AGH-UST (courtesy of AGH-UST).*

More information about ESTEEM3 TA can be found at www.esteem3.eu

Grzegorz Cempura, AGH-UST
cempura@agh.edu.pl

News from IMBAS

The scientific group from the Institute of Mechanics of Bulgarian Academy of Sciences (IMBAS) continues to work within the framework of WG1. Our recent research is related to the study of the properties of light alloys, foams and other high porosity materials.

This year, analytical models have been developed for the homogenization of porous media based on the generalized mixture rule. When comparing theoretical results and experiments, it was found that among the main elastic characteristics, a change in the Poisson coefficient is the most difficult to predict. We consider the future investigations in this direction very important, since Poisson's ratio of metal-based materials is directly related to the fragility or ductility of such composites. We also derived a new yield condition for the transition from elastic to plastic state of a porous medium, which depends on the pore size. It is applicable for materials with a matrix at a positive Poisson ratio.

There are indicators in the work showing that it belongs to the KMM-VIN frame and it has been developed under support of the Bulgarian Foundation for Scientific Research through “Digital Materials Laboratory - an innovative interdisciplinary approach for multiscale modelling and characterization of porous media”, No KP-06-27/6-2018.

Applying into practice the idea of KMM-VIN about a closer relationship with industry, some results were presented at the scientific forum of the Bulgarian Section of the Society for Industrial and Applied Mathematics (SIAM).

L. Parashkevova, Characterization of porous materials by homogenization models based on a generalized mixture rule, 14th Annual Meeting of the Bulgarian Section of SIAM, December 17-19, 2019, Sofia, *BGSIAM’19 Extended abstracts*, pp.73-74, Fastumprint, ISSN: 1313-3357 (print) ISSN: 1314-7145 (electronic).

News from FRAUNHOFER IKTS

Ceramic rotor for a micro gas turbine

Micro gas turbines are very versatile machines to provide electric energy and heat from various fuel gases. They are used to secure the local energy supply in hospitals or other critical infrastructure, but also as range extender in electrically driven busses for public transportation.

To achieve a remarkable increase of efficiency, the combustion temperature must be raised in combination with less cooling effort, resulting in very high demands for the materials in the hot section. In a project called “Bonokeram” (03EE5032A, Federal Ministry of Economic Affairs and Energy, BMWI) Fraunhofer IKTS is developing a new type of silicon nitride that shall withstand temperatures up to 1400 °C under very high mechanical loading. In collaboration with other partners from Fraunhofer (IPK, SCAI) and industry (Euro-K GmbH, Ceramaret GmbH) an impeller (Fig. 14) with an outer diameter of 126 mm will be optimized, fabricated, installed and tested to evaluate its long-term behaviour. Thus, in combination with the already existing ceramic combustion chamber and the ceramic vanes, the next important step to a new generation of micro gas turbines will be taken.

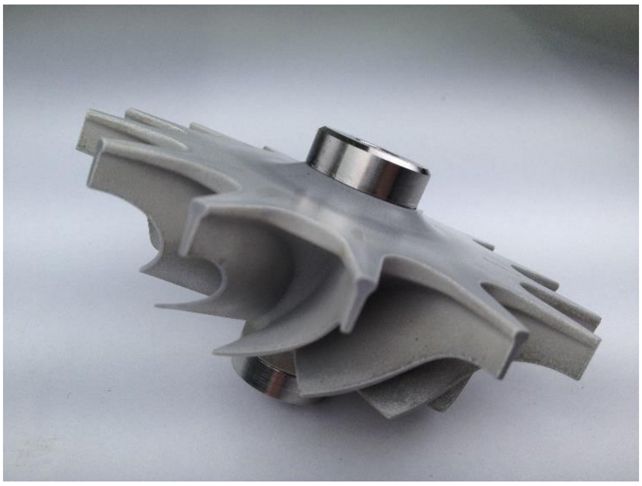


Fig. 14. *Impeller of the first generation with temperature capability in oxidizing atmospheres up to 1200 °C (courtesy of Fraunhofer IKTS).*

News from TECNALIA

The OASIS Open Innovation Test Bed has launched an Open Call for Democases with the objective of providing support to institutions in the development of lightweight multifunctional products based on aluminium and polymer composites. Successful applicants to the OASIS Open Call will get free access to an ecosystem of 12 nanotechnology manufacturing pilot lines, providing nanomaterials, nano-intermediates, nano-enabled products and associated services. The selected applicants will be provided with customized support through a complete set of services integrating technical and business expertise which will enable them to build up sustainable business cases.

If interested, please check OASIS' website: (https://project-oasis.eu/), browse through its Catalogue of service (https://lnkd.in/geBBduf), read the conditions of the Call (https://lnkd.in/gu8VWu3), and eventually apply with your Democase here – https://lnkd.in/gRCtSK3

https://project-oasis.eu/

OASIS was funded by the EC in the frame of the NMBP-01-2018 call under the topic of Open-innovation test beds for lightweight, nano-enabled multifunctional composite materials and components with GRANT Agreement ID 814581 and will run for 42 months up to August 2022.

Open access single entry point for scale-up of innovative Smart lightweight composite materials and components.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814581.

NEWS FROM WG2: MATERIALS FOR ENERGY

There are two thematic subgroups in WG2 called "EMEP" and "non-EMEP". The EMEP partners follow the work model and research programme of the former COST proposal "Engineered Micro- and nanostructures for Enhanced long-term high-temperature materials Performance" (EMEP). The internal work programme EMEP consists of Work Topics (WT): WT1. Advanced Materials Modelling & Design, WT2. Materials Development and Manufacturing (A. Pipework and Tubing, B. Castings, C. Forgings), WT3. Materials Process Development and WT4. Testing and Validation. The non-EMEP subgroup deals with other topics related to energy materials, especially the low-carbon energy materials. The WG2 EMEP is coordinated by Christof Sommitsch (TUG), whereas the WG2 non-EMEP by Monica Ferraris (POLITO).

The 9th KMM-VIN Industrial Workshop (**IW9**) on "Advanced Materials for Energy: challenges and opportunities" in Turin has been moved to new dates 17-18th May 2021.

This workshop, originally scheduled in May 2020, had a complete list of keynote lectures. Most of the invited speakers expressed an intention to participate in IW9 in 2021. The workshop programme and organisational details can be found on http://kmm-vin.eu/workshops/

News from FRAUNHOFER IKTS

Cost-effective hot-side interconnects for thermoelectric generators

Using waste heat to generate power results in significant energy efficiency potentials. Thermoelectric generators (TEGs) offer the advantage of directly converting thermal energy into electricity without the use of high-maintenance moving components. However, conventional TEGs use cost-intensive and toxic substances, such as bismuth or lead telluride, as active materials. In addition, TEGs are still cost-intensive to manufacture due to multi-stage process steps.

As part of the EU INTEGRAL project, Fraunhofer IKTS has developed a high-temperature interconnect technology using environmentally friendly materials and the cost-effective ceramic screen printing technology (Fig. 15). In this process, inexpensive steel substrates are provided with dielectric coatings based on structured glass ceramics. The developed glass ceramic materials, with a high coefficient of thermal expansion, are particularly suitable for use at temperatures up to 600 °C. They can be applied as pastes using screen printing technology in layer thicknesses of approx. 50 µm and serve as a dielectric insulation layer. As contact layers for the thermoelectrically active materials, copper and silver-based pastes are then applied in thicknesses of up to 200 µm. Thus, even multiple connectors with increased reliability as well as segmented and wireable hot-side contacts can be realized.

Fig. 15. *Hot-side interconnect elements for thermoelectric modules consisting of copper contact layer, glass ceramic dielectric layer and steel substrate (courtesy of Fraunhofer IKTS).*

Seasonal heat storage system with bodies formed out of zeolites

Hydrophilic zeolites have a high water adsorption capacity combined with a high adsorption enthalpy. For these reasons, zeolites are commercially used for short-term heat storage and for cooling. However, zeolite-based long-term heat storage solutions for using solar energy or waste energy from industrial processes have not yet reached the market.

As part of a BMBF project, Fraunhofer IKTS researchers systematically investigated the adsorption properties of binder-free zeolite granules and zeolite honeycombs in order to determine under which conditions they can be used as seasonal heat accumulators. At a drying temperature of 300 °C and remoistening in a saturated steam atmosphere, a high adsorption capacity of 26 wt % H2O was achieved for binder-free zeolite NaY granules. Temperatures of up to 80 °C were maintained for more than five hours. As expected, the adsorption capacity was lower at lower drying temperatures, which led to a shorter period of heat development. Nevertheless, the granules reached temperatures of 70 to 80 °C during water adsorption. In addition, constructive aspects were also examined.

Fig. 16. *Zeolite beads in a seasonal heat storage system (courtesy of Fraunhofer IKTS).*

Based on these results, a prototype zeolite heat storage system was designed and built (Fig. 16). 900 litres of NaYBF zeolite granulate with a thermal capacity of 150 kWh were filled in between the closely spaced heat exchanger plates of the storage unit. In this closed system, energy could be thermochemically bound at an optimal temperature of 200 °C and in a 50 mbar vacuum. The temperature required for the activation of the zeolites can be provided in the summer by solar heat collectors or through electrical heating with solar power. In this way, the thermochemical energy can be stored seasonally in the zeolite structure.

Hans-Peter Martin, Fraunhofer IKTS
hans-peter.martin@ikts.fraunhofer.de

News from AGH-UST

Three-dimensional characterization of an oxide scale on ATI 718Plus® superalloy

ATI 718Plus® (718Plus) is a polycrystalline nickel-based superalloy designed to replace in certain applications the widely used Inconel 718 superalloy. The 718Plus exhibits improved chemical composition compared to conventional Inconel 718, which stems from its optimized microstructure and allows to operate at higher temperatures.

In our study, multiscale 2D and 3D characterizations were used to explore the complexity of the oxide scale and near-surface region formed in the 718Plus superalloy during up to 4000 h oxidation in synthetic air at 850 °C. We used an original approach to the characterization of oxide scale grown on the 718Plus superalloy utilizing FIB-SEM tomography combined with advanced electron microscopic and spectroscopic techniques. The large volume of tomographic data provided detailed information about the morphology and distribution of phases in three-dimensional space.

Fig. 17 (top) shows a 3D tomographic reconstruction of the microstructural features of the near-surface area of 718Plus oxidized for 1000 hours, while Fig. 17 (bottom) limits the data to Cr_2O_3 and Al_2O_3 only. This reconstruction shows that chromium oxide present within the internal oxidation zone of aluminium remained in contact with the previously formed Al_2O_3 precipitates in the vast majority of them. Sometimes these oxides remained in contact with the scale, forming deep intrusions; however, a significant number had formed separate precipitates. It was presumed that the local concentration of chromium in the γ matrix had been so low that the oxidation in this area was interrupted. Thus, the oxygen dissolved in the solid solution of the γ phase had to diffuse to deeper parts of the bulk material, where the chromium concentration was higher. It is via this mechanism that separate Cr_2O_3 particles had formed despite having no contact with the scale. This can be supported by the fact that the interface of the Al_2O_3 phase seems to be a nucleation site for the Cr_2O_3 phase.

More information about this study may be found in recent publications [1–4]. It is worth mentioning, that all these publications result from Sebastian Lech research stay at INTA supervised by Alina Agüero and granted by KMM-VIN within 2016 Research Fellowship programme.

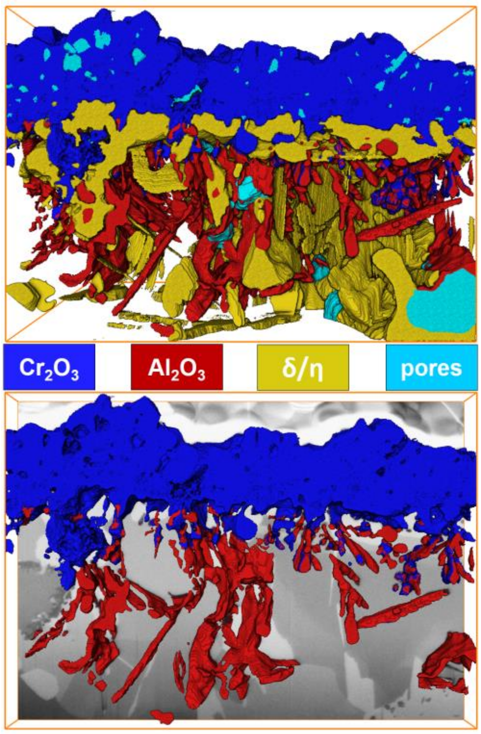


Fig. 17. *(top) 3D tomographic reconstruction of the microstructural features of the near-surface area (front view); (bottom) the same image as top figure, but limited to Cr_2O_3 and Al_2O_3, with an orthoslice inserted at a distance of 3 μm along the z-axis (courtesy of AGH-UST).*

[1] S. Lech, A. Gil, G. Cempura, A. Agüero, A. Kruk, A. Czyrska-Filemonowicz, Microstructure of an oxide scale formed on ATI 718Plus superalloy during oxidation at 850 °C characterised using analytical electron microscopy, *International Journal of Materials Research*, 110, 42–48, 2019. https://doi.org/10.3139/146.111675

[2] S. Lech, A. Kruk, A. Gil, G. Cempura, A. Agüero, A. Czyrska-Filemonowicz, Three-dimensional imaging and characterization of the oxide scale formed on a polycrystalline nickel-based superalloy, *Scripta Materialia* 167, 16–20, 2019. https://doi.org/10.1016/j.scriptamat.2019.03.027

[3] S. Lech, A. Kruk, G. Cempura, A. Gruszczyński, A. Gil, A. Agüero, A.M. Wusatowska-Sarnek, A. Czyrska-Filemonowicz, Influence of High-Temperature Exposure on the Microstructure of ATI 718Plus Superalloy Studied by Electron Microscopy and Tomography Techniques, *Journal of Materials Engineering and Performance*, 29, 1453–1459, 2020. https://doi.org/10.1007/s11665-019-04474-5

[4] A. Kruk, S. Lech, A. Gil, G. Cempura, A. Agüero, A.M. Wusatowska-Sarnek, A. Czyrska-Filemonowicz, Three-dimensional characterization of an oxide scale on ATI 718Plus® superalloy, *Corrosion Science*, 169, 108634, 2020. https://doi.org/10.1016/j.corsci.2020.108634

Sebastian Lech, AGH-UST
slech@agh.edu.pl

From POLITO to FAU

(KMM–VIN Research Fellowship call 2019)

POLITO-FAU-AGH

The KMM-VIN fellowship, call 2019 gave the possibility to strengthen the fruitful and long-lasting collaboration between POLITO, FAU and AGH-UST.
During the research stay at FAU under the supervision of Aldo R. Boccaccini, Elisa Zanchi (Ph.D. student at POLITO, supervised by F. Smeacetto) optimised and deposited innovative cobalt-free spinel coatings for Solid Oxide Fuel Cell (SOFC) interconnects.
The coatings were put by electrophoretic deposition (EPD) technique in DC mode: various metallic oxides selected as the spinel precursors were simultaneously co-deposited. In particular, $Mn_{1.7}Cu_{1.3}O_4$ and $Mn_{1.5}Cu_{1.2}Fe_{0.3}O_4$ spinels were obtained using Mn_2O_3, CuO and Fe_2O_3.

The stability of the EPD suspensions were first assessed by Z-potential measurements of the precursors in different mixtures of solvents; pH adjustments were made in order to reach the best formulations. Then, the quality of the deposited coatings was evaluated by SEM (Fig. 18, Fig. 19).

EDS	At.%
O	58.2
Mn	27.0
Cu	14.8

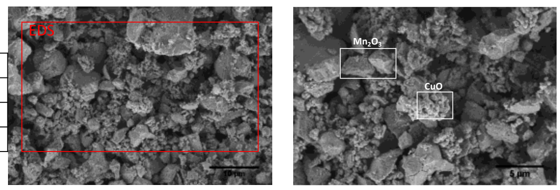


Fig. 18. *Top view scanning electron microscope (SEM) images of "as-deposited" samples and energy dispersive X-Ray analysis (EDX) results of the $Mn_{1.7}Cu_{1.3}O_4$ coating (courtesy of POLITO).*

EDS	At.%
O	61.1
Mn	18.4
Cu	7.3
Fe	13.2

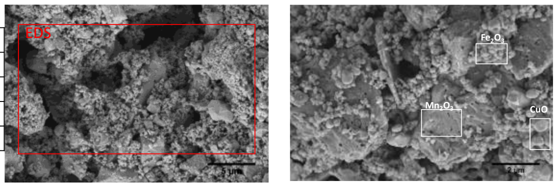


Fig. 19. *Top view scanning electron microscope (SEM) images of "as-deposited" samples and energy dispersive X-Ray analysis (EDX) results of the $Mn_{1.5}Cu_{1.2}Fe_{0.3}O_4$ coating (courtesy of POLITO).*

The optimal sintering parameters were subsequently investigated at POLITO. The coatings were treated following a two-step procedure: first a heat treatment in reducing atmosphere (Ar/H2) to reduce the oxide precursors in MnO, Cu and Fe, followed by a heat treatment in an oxidizing atmosphere to form the desired spinel structure, as confirmed by X-ray diffraction (Fig. 20).

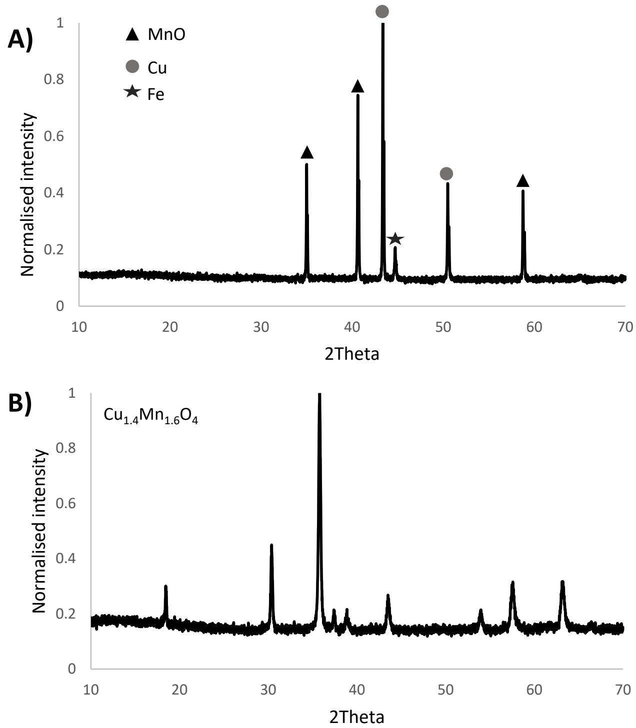


Fig. 20*. XRD patters of $Mn_{1.5}Cu_{1.2}Fe_{0.3}O_4$ after the reducing treatment (A) and after the re-oxidation step (B) (courtesy of POLITO).*

Highly dense and homogeneous coatings were obtained in all cases (Fig. 21).

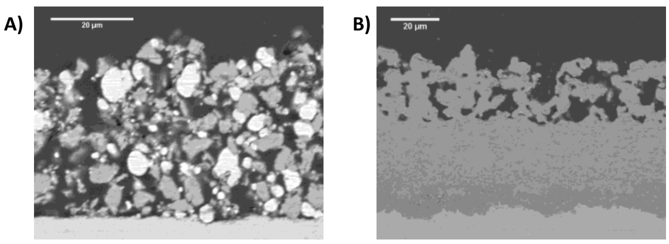


Fig. 21. *Cross section SEM (backscatter electron mode) images of the coatings after the reducing heat treatment (A) and after the re-oxidation step (B) (courtesy of POLITO).*

The KMM-VIN research stay gave the opportunity to establish further discussion on the electrophoretic deposition technique, resulting in a relevant publication [1]. This new article focuses on the characterization of the oxidation and conductive properties of iron doped manganese cobaltite spinel coatings up to 3200h at 750°C. It brings the valuable contribution of the advanced TEM characterization techniques from AGH-UST (Grzegorz Cempura and Adam Kruk) resulting from the KMM-VIN fellowship (call 2018) granted to Antonio Sabato (POLITO) and the ESTEEM3 program (call 2019) between AGH-UST and POLITO.

Fig. 22 shows the morphology and composition of Fe-doped coatings on Crofer 22 APU after ASR tests, conducted by transmission electron microscopy (TEM) methods, supported by STEM-EDX and SAED analysis.

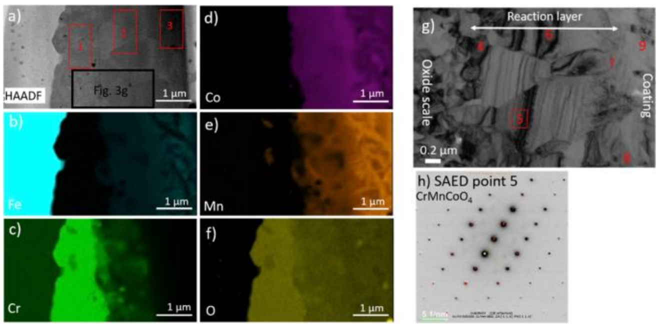


Fig. 22. *Cross section SEM (backscatter electron mode) images of the coatings after the reducing heat treatment (A) and after the re-oxidation step (B) (courtesy of POLITO).*

[1] E. Zanchi, S. Molin, A.G. Sabato, B. Talic, G. Cempura, A.R. Boccaccini, F. Smeacetto, Iron doped manganese cobaltite spinel coatings produced by electrophoretic co-deposition on interconnects for solid oxide cells: Microstructural and electrical characterization, *Journal of Power Sources*, 455, 227910, 2020. https://doi.org/10.1016/j.jpowsour.2020.227910

Federico Smeacetto, POLITO
federico.smeacetto@polito.it

NEWS FROM WG3: BIOMATERIALS

Introducing UNIMORE to KMM-VIN and WG3

Biomaterials Research Group at the University of Modena and Reggio Emilia, Italy

The Biomaterials Research Group @ the University of Modena and Reggio Emilia is located at the Department of Engineering "Enzo Ferrari" and it is directed by Valeria Cannillo.

The University of Modena and Reggio Emilia (UNIMORE) has been created in 1998, from the merging of the University of Modena (one of the oldest Universities in Europe founded in 1598) with that of Reggio Emilia. UNIMORE is organized on a "site network" model embracing the cities of Modena and

Reggio Emilia. Department and Schools based in Modena are Humanities, Natural Sciences, Life Sciences, Economy, Law, Engineering, Medicine; in Reggio Emilia Education, Agriculture, Engineering, Communication Science and Economy. It counts about 24000 students, including 3500 postgraduates, 900 faculty members and over 300 international exchange and cooperation programs. It currently offers 81 bachelor and master classes and 14 PhD schools in its 14 departments.

The Biomaterials Research Group works on the design, production and characterisation of innovative biomaterials, including bioceramics, bioactive glasses, composites and Functionally Graded Materials (FGM).

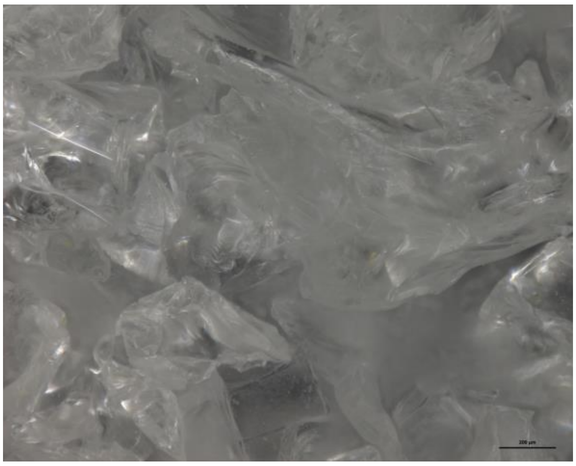
A remarkable array of facilities ranging from traditional milling system to kilns and high temperature oven is available for materials production. Moreover, the group is equipped with the most up-to-date instrumentation for materials characterisation, such as SEM, ESEM, TEM, XRD, DTA/TGA (and other equipment for thermal characterisation), heating microscopy, mechanical and optical dilatometry, AFM, Raman, Nuclear Magnetic Resonance, FTIR, depth-sensing micro and nano indentation, mechanical testing, wear testing, corrosion testing, as well as computational tools (e.g. finite element analysis - FEA).

Additionally, a lab is equipped for in-vitro testing (SBF experiments, and cells tests); in vivo testing is carried out with the collaboration of other colleagues in UNIMORE with expertise in Medicine. The interdisciplinary group offers a stimulating working context, bringing together chemists, biologists, and material engineers with various backgrounds, covering a wide range of materials systems.

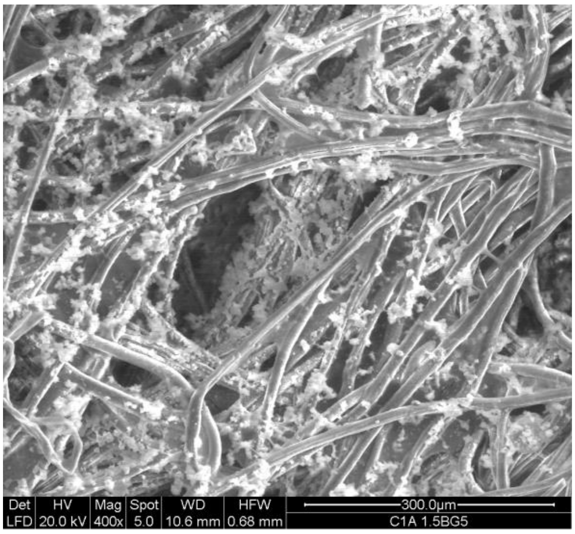
The research group has been working on the development of new biomaterials, ranging from new bioactive glass, to novel composites (including several combination of bioactive glasses, bioceramics and different polymers), to bioactive coatings, novel scaffolds, wound healing devices, and materials processed with innovative techniques (e.g. SPS-Spark Plasma Sintering).

In particular, it is worth mentioning that several novel bioactive glass compositions have been developed (some of which have been patented), with specific properties such as ultra-high crystallization temperature, enhanced bioactivity, etc. Moreover, the group has a sound expertise on the production of bioactive glass coatings by means of thermal spraying.

In Fig. 23 some examples of the investigated materials are illustrated: (a) bioactive glass granules (patented composition); (b) wound dressing.



(a)



(b)

***Fig. 23**. Examples of materials investigated at UNIMORE: (a) bioactive glass granules (patented composition); (b) wound dressing (courtesy of UNIMORE).*

Valeria Cannillo, UNIMORE
valeria.cannillo@unimore.it

From AGH-UST to POLITO

(KMM-VIN Research Fellowship, call 2019)

Investigation of zeta potential of electrospun fiber for medical applications

The purpose of the research stay was to measure the zeta potential to evaluate surface charge of poly(3-hydroxybutyric acid-co-3-hydrovaleric acid) (PHBV) samples. The study included measurement of zeta potential on spin – coated thin PHBV films and electrospun PHBV fibres produced with positive and negative voltage polarities. The zeta potential was determined by streaming potential, measured in standard solution. Although the fibre morphologies did not change during electrospinning (Fig. 24), measurement of zeta potential showed a slight difference between fibre produced with positive and negative voltage polarity. Then, the surface properties of electrospun fibres were correlated with in vitro studies. Cellular responses to zeta potential variations were evaluated using NIH 3T3 fibroblast. This investigation allowed to verify cellular responses to the controlled zeta potential of electrospun PHBV fibres mats in biomedical applications.

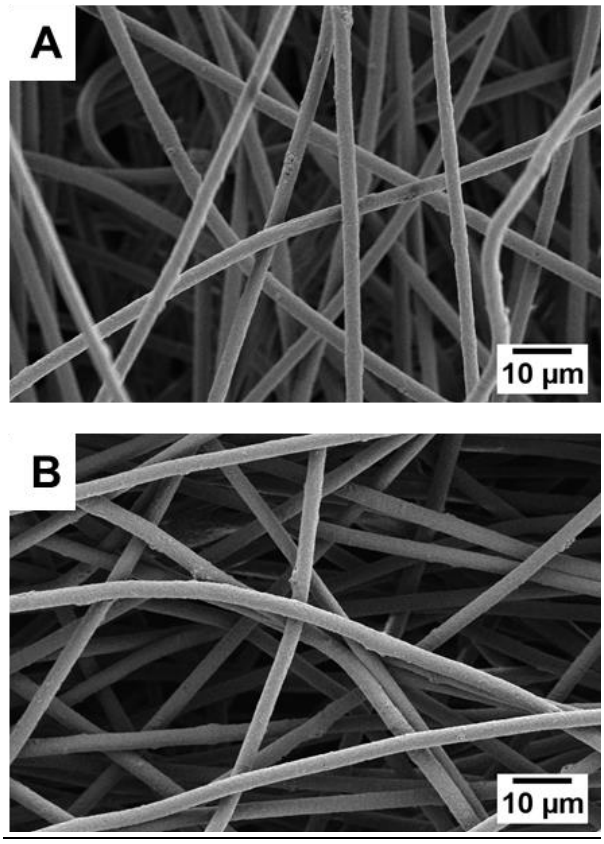


Fig. 24. *SEM images of PHBV fibres produced applying positive (A) and negative (B) electrical polarity (courtesy of AGH-UST).*

The zeta potential measurements at Politecnico di Torino within the KMM-VIN Fellowship 2019 were performed under the supervision of Silvia Spriano. The research stay contributed to development of the cooperation between the International Centre of Electron Microscopy for Materials Science at AGH-UST and Department of Applied Science and Technology at POLITO.

Lukasz Kaniuk, AGH-UST
kaniuk@agh.edu.pl

From FAU to IPM

(KMM-VIN Research Fellowship, call 2019)

Assessment of mechanical properties of metal ion – chitosan antibacterial coatings deposited by electrophoretic deposition

In the framework of the KMM-VIN research fellowship program Muhammad Asim Akhtar, PhD student of Aldo R. Boccaccini at the Institute of Biomaterials, University of Erlangen-Nuremberg, Germany (FAU), visited Institute of Physics of Materials, ASCR, Brno, Czech Republic (IPM) to conduct research under the supervision of Ivo Dlouhý.

The evolution of hardness and scratch resistance properties of copper (II)-chitosan (Cu(II)-CS) and gallium (III)-chitosan (Ga(III)-CS) bioactive coatings developed by electrophoretic deposition (EPD) at FAU were analysed in the laboratory at IPM.

Electrophoretic deposition (EPD) has been established at the Institute of Biomaterials at FAU for the development of bioactive and antibacterial coatings based on chitosan for medical applications [1]. This project is investigating the development of metal ion chitosan complexes as a new family of antibacterial coatings on metallic substrates for orthopaedic applications. Cu and Ga are the ions being investigated given their proven antibacterial effects.

A series of coatings was successfully prepared at FAU by an optimised EPD process [2], which were characterised by instrumented nanomechanical tests at IPM. In particular, nan-indention was performed at IPM using a Zwick/Roell ZHN Universal Nanomechanical Testing System. A pyramidal diamond indenter was used for the indentation experiments. Different loads from 1 mN to 200 mN were applied on the coating to make sure that the substrate would not affect the coating hardness values. It was found that in the range of 1 mN to 5 mN the hardness values were constant, however at higher loads the hardness increased that was clearly due to the substrate effect on the measurement. The maximum load of 5 mN was therefore used for this study.

The scratch test on coatings was performed at the Faculty of Mechanical Engineering, Brno University of Technology, by using a CSM Instruments scratch tester. A controlled scratch with a Rockwell diamond tip (radius: 200 μm) was used under a linear progressive load (from 1 N to 10 N) with loading rate of 3.6 N/min and speed of 2 mm/min over the scratch length of 5 mm (Fig. 25). The load at which the coatings start to break is known as critical load, this load was observed by optical photographs. Furthermore, scanning electron microscopy (SEM) was performed to obtain high resolution images of the scratched surfaces.

It was interesting to note that the mechanical properties of chitosan change with the different concentration of added therapeutic metal ions, i.e. Cu(II) and Ga(III). The hardness of the chitosan coatings increased up to a certain concentration of Cu(II) and Ga(III) ions, i.e. 12 %. However, with further increase in the concentration of ions in the complexation process cracks appear in the coatings, leading to a reduction in the hardness values. The same behaviour was confirmed by the scratch test results: the critical load of the coatings increased up to certain concentrations of Cu(II) and Ga(III), however further increase in concentration decreased the adhesive property of the coatings.

These results are important as they provide guidance for the design of the coating composition, given the relevance of the assessment of the mechanical properties of such “soft” coatings must fulfil for the intended applications in orthopaedic and dental implants. The results have been published in peer-reviewed open access journals [2, 3].

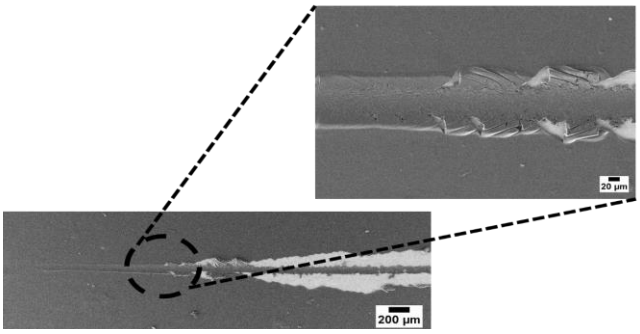


Fig. 25. *Images showing a scratch made by a Rockwell diamond tip (radius: 200 µm) on a chitosan based coating at low and high magnifications (courtesy of FAU).*

[1] E. Avcu, F. E. Bastan, H. Z. B. Abdullah, M. A. Ur Rehman, Y. Y. Avcu, A. R. Boccaccini, Electrophoretic deposition of chitosan-based composite coatings for biomedical applications: A review, *Progress in Materials Sciences*, 103, 69-108, 2019. https://doi.org/10.1016/j.pmatsci.2019.01.001

[2] M. A. Akhtar, K. Ilyas, I. Dlouhý, F. Siska, A. R. Boccaccini, Electrophoretic deposition of copper(II)–chitosan complexes for antibacterial coatings. *International Journal of Molecular* Sciences, 21, 2637, 2020. https://doi.org/10.3390/ijms21072637

[3] M. A. Akhtar, Z. Hadzhieva, I. Dlouhý, A.R. Boccaccini, Electrophoretic deposition and characterization of functional coatings based on an antibacterial gallium (III)-chitosan complex. *Coatings* 10, 483, 2020. https://doi.org/10.3390/coatings10050483

Muhammad Asim Akhtar, FAU
asim.akhtar@fau.de

News from POLITO

NEW EU project with participation of POLITO

A new EU project has been launched in January 2020: “Precision medicine formusculoskeletal regeneration, prosthetics, and active ageing” (PREMUROSA) (https://premurosa.eu/), in the framework of the “Marie Sklodowska-Curie Innovative Training Network-European Joint Doctorates” programme, funded by Horizon 2020, where POLITO is a partner (scientific responsible for POLITO: Enrica Verné).

More details on the project can be found at: https://poliflash.polito.it/en/research_innovation/premurosa_the_project_that_will_improve_the_treatment_of_musculoskeletal_disorders

Invention of a coating with anti-Covid 19 properties at POLITO

A coating that can be applied to any surface and has antibacterial, antifungal, and antiviral properties that can destroy the Coronavirus has been invented and patented by the research group of Monica Ferraris of DISAT (the Department of Applied Science and Technology) of POLITO.

Thanks to a coating based on silica and silver nanoparticles, on which Monica Ferraris’ team has been working for more than ten years, safer and more reliable filters can be created to eliminate any external pathogens, including the virus that causes Covid-19. This has been demonstrated in tests conducted by Elena Percivalle, at the Fondazione IRCCS Policlinico San Matteo in Pavia. Respective results are published in [1].

The technology and the most recent patent (PCT/IB2018/057639, Monica Ferraris, Cristina Balagna, Sergio Perero) associated with it, sparked the interest of GV Filtri of Baldissero Torinese, a company that has specialised in the development and production of industrial filters for more than 30 years. The synergy between the university and company brought the public research results to fruition, opening the way to the manufacture of an innovative product with a high economic and social impact.

The agreement reached between Politecnico di Torino and GV Filtri is essential for completing the knowledge transfer process for the invention. It enables GV Filtri to industrialise the applied development of the coating on its own industrial filters, with the aim of bringing the technology onto the market, thus introducing a significant innovation to existing products or creating entirely new ones.

Source:https://poliflash.polito.it/en/research_innovation/invention_of_a_coating_with_anti_covid_19_properties_at_politecnico_di_torino

[1] C. Balagna, S. Perero, E. Percivalle, E. Vecchio Nepita, M. Ferraris, Virucidal effect against Coronavirus SARS-CoV-2 of a silver nanocluster/silica composite sputtered coating, *Open Ceramics*, 100006, 2020. https://doi.org/10.1016/j.oceram.2020.100006

NEWS FROM WG4: MATERIALS MODELLING AND SIMULATION

10th KMM-VIN Industrial Workshop on “Design and modelling of innovative biomaterials and bioinspired materials for industrial applications”

The IW 10 was planned to be held at the Technical University of Vienna from 18th to 19th January 2021. Due to COVID pandemic it has been decided to postpone the event for 2022. The new date has already been fixed: **25-26 January 2022**.

Co-chairs: Christian Hellmich (TUW, IW10 local organiser), Katarzyna Kowalczyk-Gajewska (IPPT), Andrés Díaz Lantada (UPC).

The workshop is the tenth in a series of industrially oriented workshops organized by KMM-VIN in collaboration with leading research centres and industries. The most recent advances in material science and technology with high industrial potential are presented in this series. These workshops provide a unique opportunity to start and intensify the communication and cooperation between scientists and engineers for reshaping several industrial sectors with the help of knowledge-based multifunctional materials. The 10th KMM-VIN Industrial Workshop will cover the following topics:

- Design and modelling of biomaterials for medical devices and other biomedical applications.
- Design and modelling of bioinspired materials for industrial applications.
- Multi-scale / multi-physical modelling of the synthesis, processing and application of biomaterials and bioinspired materials.
- Modelling methods of microstructure-property relationship for hierarchical materials.
- Artificial intelligence-aided design of innovative biomaterials and bioinspired materials.
- Manufacturing hierarchical biomaterials and bioinspired materials towards final applications
- Promotion of knowledge-based biomaterials and bioinspired materials for enhanced industrial performance.
- Cases of success in different industrial sectors: health, energy, transport, space, construction and

All participants are invited to present a poster or oral presentation to show and discuss their work on materials modelling and process simulation. Invited keynote speakers will present research directions and recent breakthroughs in the aforementioned topics.

Contact:

Katarzyna Kowalczyk-Gajewska
kkowalcz@ippt.pan.pl
Andrés Díaz Lantada, adiaz@etsii.upm.es

Introducing LMT to KMM-VIN and WG4

LMT is an academic laboratory located in the south of Paris, France. The lab is associated to Université Paris-Saclay, Ecole Normale Supérieure Paris-Saclay and CNRS. Founded in 1975 by J. Lemaitre, 40 academics, 17 technicians and 65 PhD students are working on the modelling, the characterization and the simulation of solid materials and structures.

The lab is divided into three parts: Mechanics and Materials, Structures and Systems, Civil Engineering and Environment and two shared technical platforms: Testing Center, Computational Center. The activity of the first two units will be illustrated in the following with several examples.

For forty years, LMT has been developing constitutive models based on damage mechanics for concrete, metals or composite materials. For example, for ceramic matrix composites, anisotropic damage models based on tensorial damage variables have been built to take into account unilateral contact and friction in an array of micro-cracks multi-axially loaded. Additional mechanisms such as fatigue, creep and oxidizing are also described. The model has been tested on complex loadings such as the one presented in Fig. 26.

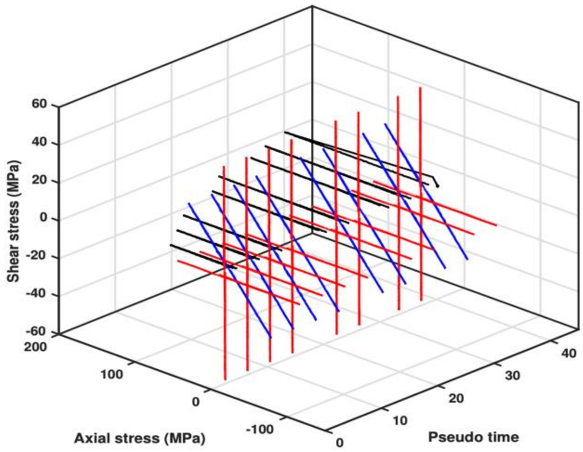


Fig. 26. *Complex loadings used for testing developed damage model (E. Baranger, Int. J. Damage Mech., 2019).*

In order to better understand the mechanical behaviour of materials or to feed complex constitutive models, full field measurements based on digital image or volume correlation techniques are very interesting tools. Such a tool has been developed at LMT based on a global finite element approximation or on modal reduced representations. It allows to measure displacement and strain fields or directly identify mechanical or loading parameters in an integrated approach. In that case, a numerical model helps to regularize the identification strategy. Recently, it has been applied to the identification of crack propagation with *in-situ* testing (CT scan). The classical 3D reconstruction step has been avoided and a direct exploitation of some radiographs used to decrease the acquisition /reconstruction time. A residual is shown in Fig. 27.

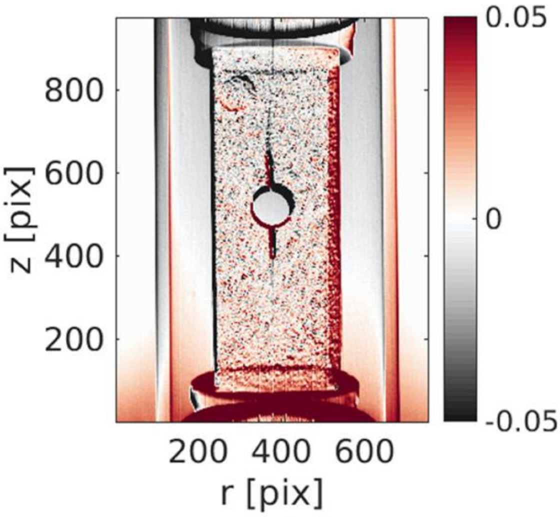
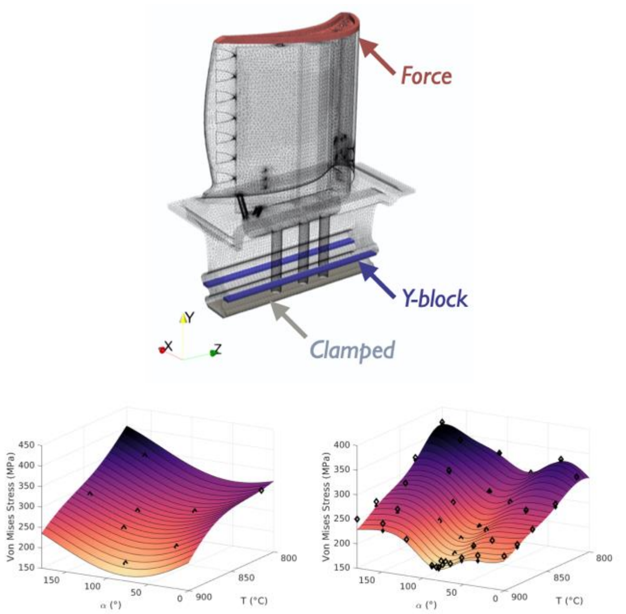


Fig. 27. *A direct exploitation of radiographs is used to decrease the acquisition/reconstruction time with in-situ testing (CT scan). A residual is shown (Jailin et al., Experimental Mechanics, 2017).*

The last presented example focuses on high performance computing in the context of a multi-parametric study of a turbine blade (Nachar et al. 2019). A meta model that can be used for optimization is built from numerical data. These data are obtained via a dedicated nonlinear solver relying on the so-called proper generalized decomposition. It allows the control of the error and the reuse of the previously obtained information with different qualities. Low quality simulations are used to define the global shape of the meta model and then refined near extremums for example using high quality simulations. Fig. 28 shows the finite element mesh of the blade and the response surface built on low and high-fidelity numerical data.



(a) The initial one (with only low-fidelity data)   (b) The final one (High-fidelity data are filled diamonds)

Fig. 28. *The finite element mesh of the blade and the response surface built on low and high-fidelity numerical data (courtesy of LMT).*

Emmanuel Baranger, LMT
emmanuel.baranger@ens-paris-saclay.fr

News from IPPT

Experimental and numerical studies of micro- and macromechanical properties of modified copper–silicon carbide composites

Recently in IPPT, in cooperation with Warsaw University of Technology and Institute of Electronic Materials Technology, the research on mechanical properties of modified copper-silicon carbide composites at the micro- and macroscopic scale has been conducted in the frame of the National Science Centre project. The improvement of a copper-silicon carbide composite refers to the addition of a protective layer at the ceramic reinforcement in order to prevent the dissolution of silicon in the copper matrix. The macromechanical behaviour has been evaluated by the performance in a small punch test. The investigation has been carried out with samples with varying volume content of ceramic reinforcement and different protective layers of the silicon carbide particles. The results have been referred to the interfacial bonding strength of Cu and SiC particles. SEM characterization of samples has been performed to link the composites' microstructure with the mechanical behaviour (Fig. 29).

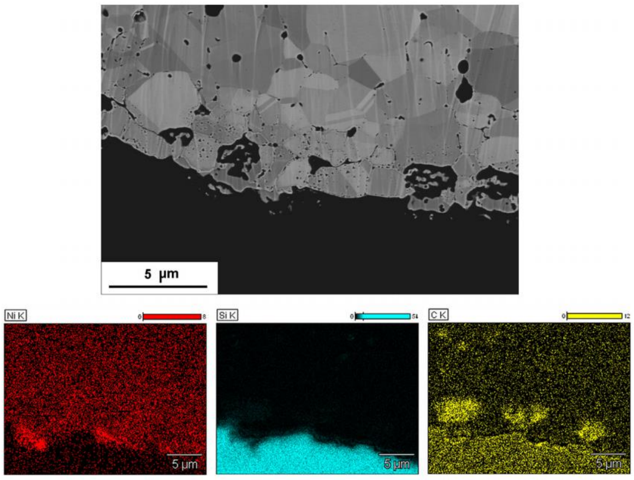


Fig. 29. *SEM/EDS maps of surface distribution of elements for Cu-SiC composite with nickel coating (courtesy of IPPT).*

Finally, in order to perform a comprehensive analysis of the behaviour of macroscopic mechanical properties of copper - silicon carbide composites, numerical modelling has been applied. The purpose of the numerical study was to obtain the best possible representation of characteristics of composite mechanical properties via the finite element approach (Fig. 30).

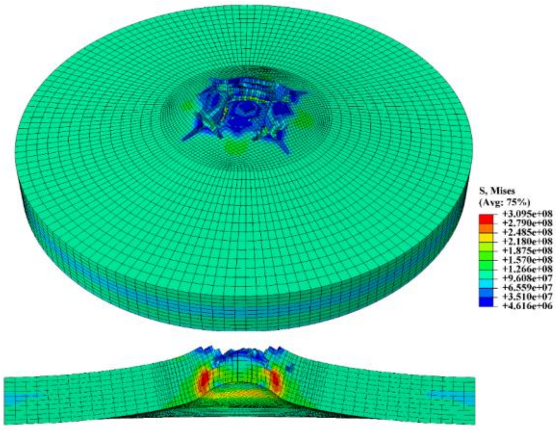


Fig. 30. *FEA results shows the von Mises stress distribution (in Pa) at the end of the simulation (courtesy of IPPT).*

The numerical model used the simplified homogenized approach of modelling metal matrix composites described by the Gurson-Tvergaard-Needleman (GTN) constitutive material law. Basing on the following assumptions, the finite element model correctly reproduced the behaviour of composite materials during the small punch test. Adequate correspondence has been achieved in all stages until the material softening (Fig. 31).

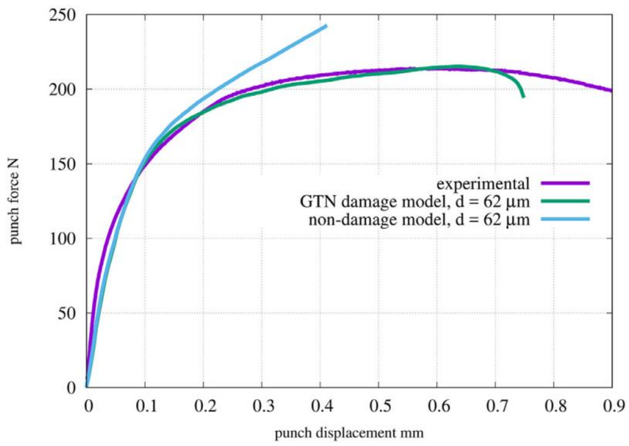


Fig. 31. *Comparison between the experimental and numerical force vs. deflection curves of Cu-30%SiC composite without the protective layer (courtesy of IPPT).*

More detailed presentation of the methodology and results can be found in [1].

[1] S. Nosewicz, B. Romelczyk-Baishya, D. Lumelskyj, M. Chmielewski, P. Bazarnik, D. M. Jarząbek, K. Pietrzak, K. Kaszyca, Z. Pakieła, Experimental and numerical studies of micro- and macromechanical properties of modified copper–silicon carbide composites, *International Journal of Solids and Structures*, 160, 187-200, 2019. https://doi.org/10.1016/j.ijsolstr.2018.10.025

Szymon Nosewicz, IPPT
snosew@ippt.pan.pl

EU PROJECTS and COOPERATION

In several EU projects two or more KMM-VIN members are currently involved as partners, which is a form of integration stemming from their collaboration within KMM-VIN. Two examples of the ongoing projects are given below.

Besides the EU projects, representatives of KMM-VIN members are participating in the governing bodies of the European Technology Platform for Advanced Engineering Materials and Technologies (**EuMaT**), namely: Amaya Igartua (TEKNIKER), Pedro Egizabal (TECNALIA), Arnaldo Moreno (ITC) and Michal Basista (IPPT) are members of the EuMaT Steering Committee (SC). Amaya Igartua also serves as the co-secretary of EuMaT ETP.

BIONECA COST Action "Biomaterials and advanced physical techniques for regenerative cardiology and neurology" (2016-2020). This COST action involves three KMM-VIN members: UNIVPM (coordinator), AGH-UST and TUW as project partners.

NICRRE – "Innovative Ni-Cr-Re coatings with enhanced corrosion and erosion resistance for high temperature applications in power generation industry" (2017-2021). This MERA-Net consortium is composed of four KMM-VIN members: ITME (coordinator), IPPT, WUT (all based in Warsaw, PL) and IMRSAS from Kosice (SK).

The project has entered the final stage of execution where the new NiCrRe coatings deposited by the HVOF technique on steel plates will be tested in an industrial environment (boiler in a running power plant).

KMM-VIN RESEARCH FELLOWSHIPS, COURSES and TRAININGS

KMM-VIN Research Fellowships 2020

The KMM Mobility Programme offers Research Fellowships on a competitive basis for PhD students and early stage researchers from the KMM-VIN members to do research at other KMM-VIN member institutions.

Joint publications of the fellowship holder and the host are expected as a result of the KMM-VIN Research Fellowship within 12 months after the research stay completion. The up-to-date published papers resulting from KMM-VIN RF stays are listed on http://kmm-vin.eu/fellowships/. More information on KMM-VIN Research Fellowships is available in the Members' Area of KMM-VIN website.

The 12th Call for KMM-VIN Research Fellowships was opened right after the General Assembly annual meeting 2020 (end of February 2020) and closed on March 31, 2020. The submitted eligible applications were reviewed by the Research Fellowship Committee, consisting of the Chair of the KMM-VIN Mobility Programme and of Coordinators of the KMM-VIN Working Groups.

Similarly, as most international mobility programmes, the 12th Call of KMM-VIN Research Fellowships has been affected by the COVID-19 virus. The number of submitted applications was significantly lower than in the past. The four eligible applications were evaluated by the RF Committee and recommended for funding.

The following applicants were granted with 5.5 person months in total:

Applicant	Host	Duration (months)	Start date (provisional)
Z. Hadzhieva (FAU)	I. Dlouhy (IPM)	1.5	Oct. 2020
K. Bochenek (IPPT)	Ch. Sommitsch (TUG)	1.5	Oct. 2020
L. Rakoczy (AGH)	C. Poletti (TUG)	1.5	Sep. 2020
A. Wójcik (IMIM)	P. Egizabal (TECNALIA)	1.0	Sep. 2020

Due to the COVID-19 situation the applicants were offered to (i) extend their research stays to 1.5 months and (ii) to move the start date of the fellowship from 2020 to 2021, if the situation with COVID-19 in Europe does not improve. Moreover, an extra call is planned for autumn 2020 (to be decided by the RF Committee and the KMM-VIN Board)

KMM-VIN Specialized Courses

KMM-VIN offers customer-tailored Specialized Courses in the fields of materials design, processing technologies, fundamentals of chemical and physical processes, thermodynamics of complex materials, characterization of materials microstructure and properties, modelling of material properties and response to in-service conditions. The courses entail lectures, practices and case studies. They can be delivered at company's premises, at KMM-VIN members' location, or as e-learning.

These courses are designed for experienced staff members, who want to improve their skills in a selected field, but also for non-experienced employees, who would like to gain basic knowledge in the field. The courses are offered on a continuous basis upon individual arrangement with the interested parties. The fees depend on the type and extent of the course and can be agreed upon with the customers on case by case basis. More information on the courses can be found on KMM-VIN webpage (a detailed booklet to be downloaded) using the following link: http://kmm-vin.eu/for_industry/courses_and_trainings/

Interested companies can contact the coordinator of KMM-VIN trainings, Arnaldo Moreno (ITC) amoreno@itc.uji.es

Current list of Specialised Courses

MATERIALS

- Adhesive bonding (LU)
- Biomaterials (FAU)
- Development and applications of micro-structured and micro-textured materials (UPM)
- Light alloys and composites (IOD)
- Materials for energy systems and advanced steam power plants (AGH-UST)
- Materials for aerospace (AGH-UST)
- Materials science and technology (POLITO)
- Nanomaterials for biomedical applications (FAU)
- Nickel based superalloys (AGH-UST)
- Sustainable use of materials (LU)

PRODUCTION PROCESSES

- Automotive body materials (UH)
- Colloidal processing (FAU)
- Electrophoretic deposition (FAU)
- Foundry (TECNALIA)
- Heat treatment of welded joints (IS)
- International / European Welding Engineer / Technologist / Specialist (IS)
- International welder (IS)
- Plastics processing technology (LU)
- Rubber compounding and processing (LU)

CHARACTERIZATION TECHNIQUES

- Joining of dissimilar materials and mechanical tests of joints (POLITO)
- Electron microscopy (AGH-UST)
- High-temperature materials characterization in liquid and semi-liquid states (IOD)
- Material characterization via depth sensing indentation tests (IMBAS)
- Microstructural analysis and characterization by microscopy and tomography (AGH-UST and TECNALIA)
- Stress analysis of texturized materials by X-ray diffraction technique (IMIM)
- Testing methods for materials at high temperature and in aggressive environments (IOD)

MODELLING TOOLS

- Advanced multiphase and multi-scale material modelling (IMBAS)
- Design and modelling of micro-structured and micro-textured materials (UPM)
- Fracture mechanics of piezoelectric composites (IMBAS)
- Modelling and numerical simulations of multiphase composites (IMBAS)
- Sintering of metal-ceramic composites: modelling of the process, measurement and prediction of residual stresses (IPPT)
- Tissue engineering: biomaterials and cardiovascular systems (BIOIRC)

RISK MANAGEMENT

- Risks in Industry (R-TECH)
- Asset/plant Oriented Risk Management (R-TECH)
- Health, Safety, Security and Environment (R-TECH)
- Risk Governance (R-TECH)
- Risk Based Inspection (R-TECH)

PERSONALIA

Aldo R. Boccaccini, Head, Institute of Biomaterials, University of Erlangen-Nuremberg (FAU), celebrates 10 years as Editor-in-Chief (EiC) of Materials Letters: https://www.journals.elsevier.com/materials-letters

The journal is one of the "classical" journals in the field of materials science and engineering. It was founded in 1982 and has seen a continuous increase of the impact factor (IF) over the years, the current IF is 3.019. The journal belongs to the Materials Today extended family of journals in Materials Science, (https://www.materialstoday.com/journals) published by Elsevier.

Marking 10 years as EiC of Materials Letters, Aldo Boccaccini said:

"It is a great honour and a responsibility to be the Editor-in-Chief of Materials Letters, one of the most recognised journals in the materials science field. In the last 10 years the journal has continued to grow, in terms of the number of papers published and citations received. Indeed, our editors' team has grown accordingly - we have now an excellent team of 12 editors and two managing editors - whose expertise covers the most varied areas in the materials field. The journal published 1,650 papers in 2019 with around 50,000 total citations, articles published in Materials Letters were downloaded 2,227,422 times in 2019, highlighting the impact of the journal. I look forward to continue serving the materials science community as editor of one of the most respected journals in the field".

According to the category "Materials Science, Multidisciplinary" in the Web of Science(R) data base, the journal featured in position 24 (out of 293 journals) in terms of total number of citations (2018 data).

Arnaldo Moreno, Technical Director of KMM-VIN AISBL, has been appointed as Full Professor of Chemical Engineering at the University Jaume I of Castellón (Spain).

In the last years he has been teaching in the Degree of Chemical Engineering as well as in the Master's Degree in Science, Technology and Application of Ceramic Materials, and in the Master's Degree in Energy Efficiency and Sustainability in Industrial Installations and Buildings. He is a senior researcher at Instituto de Tecnología Cerámica (ITC) of the University Jaume I since January 1987. His research lines are related to raw materials, ceramic compositions, stages of the manufacturing process of ceramic products, heat transfer mechanisms, properties and application of glazes, melting and sintering, glaze-body interaction, new ceramic coatings using nanometric raw materials, and, recently, additive manufacturing of ceramic-based materials. He established the Spain Chapter of the American Ceramic Society in July 2019 and is its Chair since that date.

Michał Basista, Chief Executive Officer of KMM-VIN, professor of mechanical engineering and Head of Division of Advanced Composite Materials at IPPT (Warsaw), has been granted the professor title by the President of the Republic of Poland.

His research is focused on modelling of deformation, damage and fracture, micromechanics, thermal residual stresses. His current research interests also include processing of metal-ceramic composites, characterization of properties on micro and macroscale. He has spent over 8 years at foreign universities, mainly in Germany and USA.

KMM-VIN Core Members

Institutions

1. **AGH-UST** AGH-University of Science and Technology, Krakow, Poland
2. **BioIRC** Bioengineering Research and Developing Centre, Kragujevac**,** Serbia
3. **FAU** Friedrich-Alexander Universität Erlangen-Nürnberg, Germany
4. **FRAUNHOFER** Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., Germany
   - **IFAM** Fraunhofer Institute for Manufacturing and Advanced Materials, Bremen,
   - **IFAM-DD** Fraunhofer Institute for Manufacturing and Advanced Materials, Dresden,
   - **IWM** Fraunhofer Institute for Mechanics of Materials, Freiburg
   - **IKTS** Fraunhofer Institute for Ceramic Technologies and Systems, Dresden,
5. **IK4-TEKNIKER** Foundación TEKNIKER, Eibar, Spain
6. **IMBAS** Institute of Mechanics, Bulgarian Academy of Sciences, Sophia, Bulgaria
7. **IMIM** Institute of Metallurgy and Materials Science, Polish Academy of Sciences, Krakow, Poland
8. **IMRSAS** Institute of Materials Research, Slovak Academy of Sciences, Kosice, Slovakia
9. **INTA** Instituto Nacional de Técnica Aeroespacial, Torrejón de Ardoz, Spain
10. **IOD** Foundry Research Institute, Krakow, Poland
11. **IPM** Institute of Physics of Materials, Brno, Czech Republic
12. **IPPT** Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland
13. **ITC** Instituto de Tecnología Cerámica - AICE, Castellón, Spain
14. **ITME** ŁUKASIEWICZ-Institute of Electronic Materials Technology, Warsaw, Poland
15. **MCL** Werkstoff-Kompetenzzentrum-Leoben Forschungsgesellschaft m.b.H. (Materials Centre Leoben), Leoben, Austria
16. **POLITO** Politecnico di Torino, Torino, Italy
17. **R-TECH** Steinbeis Advanced Risk Technologies GmbH, Stuttgart, Germany
18. **TECNALIA** Fundación Tecnalia, Donostia-San Sebastian, Spain
19. **TUD** Technische Universität Darmstadt, Darmstadt, Germany
20. **TUG** Graz University of Technology, Graz, Austria
21. **TUW** Technische Universität Wien, Wien, Austria
22. **UH** University of Hertfordshire, Hatfield, Herts, UK
23. **UNIVPM** Università Politecnica delle Marche, Ancona, Italy
24. **UPM** Universidad Politécnica de Madrid, Madrid, Spain
25. **WRUT** Wroclaw University of Technology, Wroclaw, Poland
26. **WUT** Warsaw University of Technology, Warsaw, Poland

Individual members

1. **Katarzyna Pietrzak** Warsaw, Poland
2. **Michał Basista** Warsaw, Poland
3. **Krzysztof Doliński** Warsaw, Poland
4. **Michał Urzynicok** Koszęcin, Poland
5. **Peter Hansen** Ammanford, UK

KMM-VIN Associate Members

Institutions

1. **BEG** Böhler Edelstahl GmbH & Co KG, Kapfenberg, Austria
2. **BSGA** Böhler Schweißtechnik Austria GmbH, Kapfenberg, Austria
3. **CSM** Centro Sviluppo Materiali S.p.A., Rome, Italy
4. **GE Power** General Electric Power Ltd, Rugby, UK
5. **UNIMORE** Università degli Studi di Modena e Reggio Emilia, Italy
6. **UNIPER** Uniper Technologies Limited., Coventry, UK
7. **ENS P-S** Ecole Normale Supérieure Paris-Saclay, France
8. **ETD** European Technology Development Ltd, UK
9. **ETE** Energietechnik Essen GmbH, Essen, Germany
10. **EU-VRi** European Virtual Institute for Integrated Risk Management, Stuttgart, Germany
11. **GSC Ltd** Goodwin Steel Castings Ltd, Hanley, UK
12. **IMSETHC** Institute of Metal Science, Equipment and Technologies with HydroAerodynamics Centre of the Bulgarian Academy of Sciences, Sofia, Bulgaria
13. **IS** ŁUKASIEWICZ-Instytut Spawalnictwa, Gliwice, Poland
14. **LU** Loughborough University, Loughborough, UK
15. **MPA** Materialprüfungsanstalt Universität Stuttgart, Germany
16. **NOMASICO** Nomasico Ltd, Nikosia, Cyprus
17. **NUIG** National University of Ireland, Galway, Ireland
18. **NTUA** National Technical University of Athens, Athens, Greece
19. **SIEMENS** Siemens AG, München, Germany
20. **SSF** Saarschmiede GmbH Freiformschmiede, Völklingen, Germany
21. **SWG** Schmiedewerke Gröditz GmbH, Gröditz, Germany
22. **TUBAF** TU Bergakademie Freiberg, Germany
23. **UCM** Universidad Complutense de Madrid, Spain
24. **UL** University of Limerick, Limerick, Ireland
25. **VAGL** Voestalpine Giesserei Linz GmbH, Linz, Austria
26. **V&MD** Vallourec & Mannesmann Tubes, V&M Deutschland GmbH, Düsseldorf, Germany
27. **VTT** VTT Technical Research Centre of Finland, Espoo, Finland
28. **VZU** Výzkumný a zkušební ústav Plzeň s.r.o., Plzeň, Czech Republic

Individual members

1. **Peter Mayr**, Munich, Germany
2. **Alex Lanzutti**, Udine, Italy

European Virtual Institute on Knowledge-based Multifunctional Materials (KMM-VIN AISBL)
rue du Trône 98, 1050 Brussels, Belgium
Phone: +32 2 213 4160, +48 668 160 300
Fax: +32 2 791 5536
Email: office@kmm-vin.eu
http://www.kmm-vin.eu

KMM-VIN Branch Poland
Pawińskiego 5 B, 02-106 Warsaw, Poland
Phone: +48 22 122 8528
Fax: +32 2 791 5536

Newsletter Editor: Katarzyna Kowalczyk-Gajewska
kkowalcz@ippt.pan.pl
http://kmm-vin.eu/newsletter/