

Dr. Ann Bolcavage, FASM, Rolls-Royce Corporation, USA

Title: “Surface Engineering - Challenges and Solutions for Sustainable Aviation”

Abstract:

Gas turbine engine propulsion solutions will play a fundamental role in the transition to a low carbon economy for the aerospace industry. At Rolls-Royce, the decarbonization strategy is comprised of continued reductions in fuel consumption and emissions, incorporation of sustainable aviation fuels, and the development of innovative power alternatives such as electrification and hydrogen. Coating materials and surface engineering solutions will play a key part in enabling this transition. Challenges will include continued dependency on critical raw materials, increasing engine performance requirements in hot and harsh environments, and understanding how coatings will perform within novel propulsion systems. Sustainable manufacturing methods for coatings which reduce energy intensity, emissions, and environmental impacts will also require identification and incorporation in operations and the supply chain.

Biography:

Ann Bolcavage is an Engineering Fellow at Rolls-Royce and leads the strategic development of critical coating materials and advanced manufacturing technologies for high-value gas turbine engine components, incorporating products for the Civil Aerospace and Defense businesses.

Dr Bolcavage joined Rolls-Royce Corporation in Indianapolis in 2006, and her expertise includes hot section coatings for metallic and CMC components, thermal spray processing technology, and materials and manufacturing capability acquisition and industrialization. She was appointed Fellow of ASM International in 2011 and is currently a member of the ASM International Board of Trustees. Dr. Bolcavage is an honors graduate of Lehigh University and received her advanced degrees in Metallurgical Engineering at the University of Wisconsin-Madison.

Thomas Klassen, Hamburg University

Title: “Refurbishment and Lifetime Enhancement of Aircraft Components”

Authors: Thomas Klassen, Levke Wiehler, Markus Steierl, Sören Nielsen, Julio Gutierrez, Zahra Arabgol, Dhruvit Gabani, Marcel Lewke, Hongjian Wu, Alexander List, Hamid Assadi, Nikolai Kashayev, Benjamin Klusemann, Frank Gärtner

Abstract:

Aircraft components are typically replaced with new parts as soon as they show localized damage. Kinetic spraying has the potential to successively rebuild defective areas, thus saving considerable costs and resources in aviation. However, process parameters have complex interdependencies and must be individually adjusted. This includes primary parameters related to material and impact conditions, as reflected by the ratio between impact and critical velocity, but also secondary influences related to robotics, like transversal velocity of the gun over the substrate. Computer-based trajectory planning will be presented for different model repair geometries. Resulting critical mechanical properties like adhesion and cohesive strength are analyzed and discussed. Temperature gradients during deposition have a significant influence on stress distribution and potential crack propagation. Based on a comprehensive knowledge of mechanisms and processes, properties and stress states may be tailored to obtain as new properties in repair. These concepts can also be applied to new parts to control crack pathways and enhance service life.

Biography:

currently,	Full Professor/Shared Professorship:	
since 2010	Director of the Institute of Hydrogen Technology, Helmholtz-Zentrum Hereon, Geesthacht, Germany	
since 2005	Full Professor, Director of the Institute of Materials Technology, Helmut Schmidt University, University of the Federal Armed Forces Hamburg	
1 to 6/2016 & 3 to 6/2014	Harris German/Dartmouth Distinguished Visiting Professor, School of Engineering at Dartmouth College, New Hampshire, U.S.A.	Thayer
2011	Founding start-up company: Kinetic Spray Solutions GmbH, Buchholz	
2005	Habilitation in Material Science, Technical University Hamburg, „Nanocrystalline Materials: Mechanisms, Properties, and Potential Applications“	
1996 – 2005	Institute of Materials Research, GKSS Research Centre Geesthacht Director of the Department Powder and Nanotechnology	
1994 – 1995	Post-Doc at the Institute of Materials Science and Engineering, University of Illinois at Urbana-Champaign, U.S.A.	
1990 – 1993	Dr.-Ing. (Ph.D. in Engineering), Technical University Hamburg Institute of Materials Research, GKSS Research Centre Geesthacht	
1990	Diploma in Physics, Technical University of Dortmund, Germany	

Ludvik Martinu, Polytechnique Montreal

Title: “Vapor-deposited functional coatings: Impactful opportunities for aerospace applications”

Authors: Ludvik Martinu and Jolanta E. Klemberg-Sapieha

Department of Engineering Physics, Polytechnique Montreal, QC, Canada

Abstract:

Synthesis of films and coatings by vacuum-based vapor deposition processes allows one to tailor the microstructure and composition in order to obtain well-controlled functional and multifunctional characteristics combining the mechanical, tribological, electro-chemical, optical, electrical and other properties, as well as the coating system durability in the harsh environments. This presentation will describe a holistic approach to functional coatings and surface engineering relying on an in-depth knowledge of the interplay between the material, process and microstructure with respect to the final performance. In the first part, we will provide a brief overview of the advances in film fabrication technologies employing physical vapor deposition (PVD, in particular, magnetron sputtering including HiPIMS, and vacuum arc deposition) and chemical vapor deposition (CVD, in particular, plasma enhanced CVD (PECVD), and atomic layer deposition (ALD)), with a particular emphasis on the understanding of energetic surface interactions for controlling the evolution of coating microstructure on the nanoscale. In the second part, we will illustrate the challenges, progress and new opportunities in the development of functional coatings for aerospace and outer space applications by specific examples and case studies considering different components of aircraft and satellites. Selected examples will include:

- a) Nano-structured and duplex protective coatings against solid particle erosion, high temperature oxidation, and ice accretion;
- b) Near-infrared optical properties of thermal barrier coatings subjected to CMAS infiltration;
- c) Static and dynamic optical coatings for enhanced vision and energy control using electrochromic and thermochromic systems for smart windows and smart radiators.

Future perspectives with respect to process and material optimization for coating 2D and 3D components, as well as increasingly demanding performance, durability and sustainability will be discussed.

Biography:

Ludvik Martinu is Professor at Polytechnique Montreal, Canada, in the Department of Engineering Physics, Polytechnique Chair in Multifunctional Coatings and Surface Engineering, and Director of the Thin Film Science and Technology Research Center on the Campus of the University of Montreal. He obtained his Master's and PhD degrees from Charles University in Prague. After joining Polytechnique Montreal, Canada in 1988, he became Professor in 1994, and he served as Head of the Department of Engineering Physics in 2004-2010. He has been strongly involved in the scientific societies, in particular as President and Vice-President of the Society of Vacuum Coaters (2010-2016). His main research interests are surface engineering, optical, tribological and multifunctional thin films and coatings, plasma processing of materials, and development of university-industry partnerships. His activities resulted in more than 420 publications in refereed journals, book chapters, and conference proceedings, and in 22 patents and more than 80 invited, keynote and plenary lectures at international conferences. He is recipient of numerous special awards including those from the SVC, AVS, NSERC, and recently the Polytechnique's Award for Excellence in Research and Innovation.

Cédric Poupon, AIRBUS

Title: “Robust & Eco-Efficient Design Toward Innovative Coatings”

Abstract:

AIRBUS' vision to sustainable design is born from a combination of robust design principles and eco-efficient Materials and Processes.

Core material properties have been leading material developments during the last century, nowadays innovation is driven by the interface knowledge and development of reliable surface technologies, this is key to long term success. Better knowledge of interface requirements and continuous improvement of coatings are essential to fine tune optimal design and allow better control of Aircraft maintenance intervals. The quasi-infinite metal refilling opportunity offered by thermal spray coatings is also enabling us to re-think our spare parts strategy, and reshape the global landscape of operational maintenance.

New challenges, such as Pioneering the H2 energy in commercial aircraft, are driving innovation in new alloys, new material compositions and more ...

Serge Selezneff, Safran Group

Title: “Decarbonization of aviation: focus on coatings and surface treatments”

Authors: Serge Selezneff, Safran Tech, Materials and Processes, Rue des Jeunes Bois, 78772 Magny-les-Hameaux, France

Abstract

Safran road map for decarbonization addresses specific actions to tackle emissions regarding the 3 scopes of the Green House Gas protocol. When applied to coatings, the decarbonization objectives are mainly focus on scope 2, how to produce coating with low environmental impacts, and scope 3 where coating can participate improving engine efficiency for example. In this second case, coatings can help on the following requirements:

- An extend time on wing with coating solutions to limit detrimental effect of environment (high temperature, corrosion, erosion, impact...)
- coatings, or materials, compatibles with low carbon fuels (SAF, H2)
- Repair solutions for complex parts such as bonded parts

For each of these objectives, results from current studies will be shared with development around the help of process modeling (mainly thermal spray and PVD) to accelerated development and optimize fabrication.

Biography

Following a PhD on high temperature oxidation of thermal barrier coating, Serge Selezneff joins Safran Aircraft Engines Material and Processes department in 2012. Initially, in charge of mechanical aspects of coatings, especially abradables coating, Serge evolves to a position more focus on M&P support to industrial division and development of new coatings and surface treatments for aeronautical applications.

Since 2020, Serge joins the Safran research center, Safran tech, to lead a research team on the development of new coatings for the different business units of Safran group.

Robert Vaßen, Forschungszentrum Jülich GmbH

Title: “Manufacture and testing of advanced environmental barrier coatings”

Authors: Robert Vaßen^{1,2}, Emine Bakan¹, Daniel Emil Mack¹, Dmitry Naumenko³, Olivier Guillon^{1,4}

¹Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research: Materials Synthesis and Processing (IEK-1), Jülich, Germany.

²Institut für Werkstoffe, Ruhr-Universität Bochum, Bochum, Germany

³Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research: Materials Structure and Function of Materials (IEK-2), Jülich, Germany

⁴Jülich Aachen Research Alliance, JARA-Energy, Germany

Keywords: atmospheric plasma spraying, ytterbium disilicate, water vapor recession

Abstract:

The paper will describe recent results on the APS deposition and characterization of advanced EBCs based mainly on YbDS. Here the impact of processing conditions on crack formation will be discussed. Results of thermogravimetric measurements of SiC samples coated with silicon bond coat and dense ytterbium disilicate topcoat will give insight in the protection of the silicon bond coat from oxidation by the top layer. The comparison with samples only coated with a silicon bond coat showed a reduced oxidation rate of the sample revealing the low permeation rate of the top coat. In addition, the effect of the heat treatment of the topcoat on the oxidation rate of the bond coat will be shown.

Finally, advanced characterization tools for investigating water vapor recession will be shown. In addition to furnace tests performed under slow flowing water vapor, the gas burner test rigs already allow testing with higher gas velocities (above 10m/s). The highest gas velocities are available with our high velocity oxygen fuel (HVOF) torch. The impact of the different test conditions on the recession rates will be discussed.

Biography:

Robert Vaßen made a diploma in physics and received a PhD at RWTH Aachen University (1990). In 2004 he finished his habilitation on the “development of new oxide thermal barrier coatings for applications in stationary gas turbines“. In 2009 he received an appointment as professor at the Ruhr University Bochum, from 2010 on he is also a guest professorship at University West in Trollhättan, Sweden. He is the head of the section “materials for high temperature technologies” and deputy head of IEK-1, Forschungszentrum Jülich GmbH. His major research topics are thermal spray and powder technology, protective high-temperature coatings especially thermal and environmental barrier coatings, membranes, repair technologies, and ceramics in general. His work is mainly focused on materials development for energy conversion systems including gas turbines, solid oxide fuel cells, hydrogen systems, and concentrated solar power. He published more than 300 papers, about 200 in peer-reviewed journals having an H-index of 77 and more than 20000 citations (google scholar). In 2017 he was introduced into the ASM/TSS Hall of Fame of Thermal Spray and since 2019 he is fellow of both ASM International and the American Ceramic Society. He was elected in 2019 into the evaluation board of the German science foundation (DFG) and reelected 2023. In 2022 he received the SOFT innovation award for the development of graded tungsten/steal coatings for fusion reactor applications and will receive in 2024 the ASM International Albert Sauveur award.

Bala Balachander, Delta Air Lines Limited

Title: “Thermal Spray from a perspective of a Maintenance Repair and Overhaul Organization”

Authors: Bala Balachander*, Komal Laul Delta Air Lines Limited, Atlanta, USA

Abstract: Thermal Spray Process despite being a century old special process continues to be an essential core process in aerospace and industrial gas turbines finding applications from legacy to the modern futuristic engines in multitude of components. The flexibility to use a variety of feed stock materials to satisfy the typical needs such as component restoration for dimensional restoration, abrasability, wear resistance, and thermal protection on various substrates along with its robustness and cost-effective nature makes it an attractive remanufacturing process. The ability to repair and rebuild components, extending its service life is attractive in terms of maintenance cost and sustainability. The focus of this presentation is providing an overview of thermal spray process from a perspective of a Maintenance, Repair, and Overhaul Organization. This review would cover topics of applications, evolving technologies, opportunities, challenges, and a need for research to improve the sustainability and technology.

Biography:

Bala Balachander currently works as a Principal Engineer for Delta Air Lines Limited at the Delta Technical Operations, Atlanta facility with a focus on coatings and related special processes. He has completed his Ph.D. from University of Manitoba, Canada. His prior work experience includes Engineering, R&D, Quality and Business Management functions. He currently serves as a Secretary and Treasurer in the ASM-TSS board.

Dominique Billieres, Saint-Gobain Coating Solutions

Title: “Introducing Cord Plasma Spray (CPS) : A possible alternative to Suspension Plasma Spray (SPS)”

Co-Authors:

- Mr Dominique Billieres, Saint-Gobain Coating Solutions, France
- Dr Geoffrey Celeste, Saint-Gobain Coating Solutions, France
- Mr Cédric Bricquet, Saint-Gobain Coating Solutions, France
- Prof. Shrikant Joshi, University West, Sweden
- Mr Stefan Björklund, University West, Sweden

Abstract:

Feeding very fine particles into the plasma spray process has been the main motivation for working on the suspension plasma spray (SPS) process since more than 2 decades and it has delivered exciting advances such as columnar microstructures, fine and dense layers, or also coatings with specific crystalline phases that cannot usually be retained via thermal spray. All these results led to a constantly growing interest of the research community and to many

potential industrial applications. But the implementation at industrial scale of SPS technology can also be challenging, due to a greater process complexity than APS and to challenges related to suspensions formulation, stability, liquid solvent handling or process instabilities.

This presentation will introduce a breakthrough technology in thermal spraying of very fine and non-flowable powders spraying: the cord plasma spray (CPS). The authors could obtain all the spectrum of interesting microstructures by combining specifically developed YSZ cords (containing very fine powders) with the axial injection torch AXIAL III® (from *Northwest Mettech Corp.*) and a specific feeding device. The expected advantages of this new approach could be confirmed and will be presented, as well as its perspectives and potential for industrial applications.

Biography:

Mr Dominique BILLIERES – Having an Engineering degree in Ceramics & a Master of Science from Limoges University, Mr Dominique BILLIERES has 32 years of experience in the Thermal Spray industry. During his career, he has been involved in developments related to thermal spray processes, equipment design, and feedstock materials. He has authored or co- authored 11 patents in the field of Thermal Spray and has participated to several industrial developments involving thermal spray process.

Mr Dominique BILLIERES has held several positions since he joined Saint-Gobain in 2000, within the Coating Solutions Business Unit such as R&D manager, Europe Business Manager and is now Director of Business Development for this business unit and is also member of the board of TSS since 2022.

Sophie Costil, Université De Technologie De Belfort-Montbéliard

Title: “Strategies to increase the functional temperature of aeroparts in respect with the environmental challenges”

Authors: Sophie Costil, Cécile Langlade, Geoffrey Darut, Pierre Bertrand, UTBM, CNRS, ICB, F-90010 Belfort cedex, France

Abstract:

To meet environmental challenges, it is necessary to reduce fuel usage, NO_x and CO/CO₂ emissions of aero-engines or to change propellants composition. A way to achieve all these elements is generally to increase the functional temperature for better engine efficiency.

Consequently, new thermal barrier coatings systems must be developed to ensure the maximum lifetime. Two strategies can be followed regarding the interface pre-treatment as well as the coating composition. Coating adhesion by thermal spraying method requires sufficient surface roughness on the scale of the particles impacting the surface, particularly in the case of plasma spraying with particle melting state. The grit blasting process is mainly used to create the fine asperities required for the spread particles to adhere. To further increase adhesion, the use of laser texturing for metallic substrates is benefit. A second way may consist in adjusting thermal expansion coefficient by spraying ceramic/metal Functionally Graded Materials (FGM). Different types of FGM can be elaborated to assess the influence of the compositional profiles showing an excellent resistance with limited degradation signs.

Some results illustrating these two different approaches will be given.

Charlotte Dupressoire, Airbus Operations SAS

Title: “Wear protection for aircraft Wing to Pylon engine attachment”

Authors: C. Dupressoire, C. Poupon

Abstract:

In an aeronautic industry driven by performance, durability is one of the main objectives. It is consequently of major importance to understand the in-service issues to improve parts' lifetime. Many of these challenges are linked to wear and fretting as the one experienced in early 2000's on the wing to pylon front attachment of A380 aircraft. This interface is key to ensure loads transmission (engine weight) and have high requirements for maintenance.

A wear failure analysis was then conducted to determine the mechanism involved. It showed that a fretting wear phenomenon was responsible of damages found at the interface. An elementary test campaign was performed to investigate alternative combinations of material and coating. The most promising solution was then validated on full scale tests leading to its qualification.

During the maintenance inspection after 12 years in service, the qualified meets the expectations in terms of function and maintenance requirements. This good practice was even applied to other new programs.

Biography:

PhD in Materials Science on High temperature behaviour of titanium-based alloys 2 post-doctorates on Additive Manufacturing of TA6V alloy

Now, working on tribological (Wear & Fretting) topics for 2 years

Julien Escobar, IRT Saint-Exupéry

Title: “Development of anti-erosion and anti-icing coatings by suspension plasma spray for aeronautical parts”

Authors: Julien Escobar¹, Maxence Gombault^{1,2}, Simon Goutier², Christophe Chazelas², Armelle Vardelle², Sophie Senani³, Aurélien Joulia³

¹, *IRT Saint-Exupéry, Toulouse*

², *IRCER, Limoges*

³, *SAFRAN TECH, Châteaufort*

Abstract

In the field of aeronautics, the external parts of aircraft are subjected to significant stresses and harsh environments that cause material degradation. These in-service stresses can be thermal, chemical, or physical. The development of coatings and other surface treatments has notably addressed these issues and thus enhanced the durability of the parts.

In the frame of the FREEzING project, the objective was to create coatings that protect parts from erosion (due to water and solid particles) and also from ice accretion, which can respectively damage engine blades and lead to aerodynamic performance losses.

One of the strategies considered is the development of a ceramic coating based on a mixture of alumina-titanium dioxide through suspension plasma spraying. This technique involves spraying a suspension and allows the creation of coatings with highly varied microstructures (dense, columnar, etc.), whose optimization is likely to meet the dual protection requirement.

The first part of this work focused on understanding and influencing the process parameters on the microstructure and composition of the deposits created using diagnostic tools (collecting particles in flight, etc.).

The second part was focused on evaluating the performance of the various coatings produced through standardised tests, as the Pulsating Jet Erosion Test PJET to characterize water erosion. The icephobic properties were characterised by measuring the force required to remove ice previously formed on the coatings thanks to a pull-off test.

Promising results were obtained, notably dense microstructures exhibiting superior erosion resistance. The icephobic properties also proved to be interesting but still somewhat distant from the required standards.

Biography

Julien ESCOBAR is a R&T engineer in surface treatment at IRT Saint Exupery in Toulouse. He has a PhD in Material Science achieved in the CIRIMAT laboratory in Toulouse working on lubricating coatings for aeronautic applications. He then proceeds to make post-doctoral researches in Mons, Belgium on self-healing paints on a European project.

Since 2016, he is working at IRT Saint Exupery in the surface treatment team and he is involved in several research projects regarding wet and dry surface treatments for aeronautic and space applications.

Marc Froning, The Boeing Company

Title: "Introduction of HVOF-applied CrC-NiCr as a Hard Chrome replacement for Landing Gear"

Authors:

Marc Froning, The Boeing Company Ben Evans,
Collins Aerospace

Abstract:

High Velocity Oxygen Fuel (HVOF) applied tungsten carbide cobalt chrome (WC-Co-Cr) coatings have been successfully used as a replacement coating for electrolytic hard chrome plating on aircraft landing gear (LG) for over two decades.

Market volatility of tungsten and cobalt have driven the need for an alternative lower cost option. Chrome carbide nickel chrome (CrC-NiCr) powders have been shown to be lower cost and less susceptible to market swings. This paper will describe the recent collaboration between The Boeing Company and Collin Aerospace to comply with the European Union's Registration, Evaluation, Authorization and Restriction of Chemicals (EU-REACH) by converting all 737 and 767 LG produced in Poland from hard chrome plate to HVOF applied WC-Co-Cr and CrC-NiCr coatings and portions of the testing to support it.

Mohit Gupta, University West

Title: “Liquid Feedstock Plasma Sprayed Coatings for Improved Engine Performance”

Abstract

Increased functional, environmental and economic demands on today’s gas turbines require improved coatings that are capable of withstanding higher operating temperatures, show increased durability, and at the same time, are cheaper to produce.

Liquid feedstock plasma spraying involves usage of a liquid feedstock in form of a suspension or solution precursor to deposit fine droplets ranging from sub-microns to a few microns in size. Employing a liquid feedstock can produce a variety of coating microstructures over a wide range of porosity typically not possible with conventional powder plasma spraying. The columnar structure produced by suspension plasma spraying (SPS) has been of particular interest for thermal barrier coating (TBC) applications as it could provide both low thermal conductivity and high durability along with possibly lower manufacturing cost. Solution precursor plasma spraying (SPPS) also needs to be explored if it could achieve these microstructures. In case of environmental barrier coating (EBC) applications, SPS has the potential to create highly dense coatings.

In this presentation, latest developments in liquid feedstock plasma sprayed TBCs and EBCs will be included. Recent work on the influence of bondcoat fabrication process and topcoat- bondcoat interface characteristics on lifetime of SPS TBCs will be also presented.

Biography

Mohit Gupta is employed as Associate Professor at University West, Trollhättan, Sweden since September 2018, and is Head of Division of Mechanical Engineering since March 2024. He graduated from University West as a PhD in Production Technology in January 2015 by defending his thesis titled 'Design of Thermal Barrier Coatings – A modelling approach'. Prior to that, he obtained his Master of Science Degree in Mechanical Engineering from University West in 2010 and Bachelor of Technology Degree in Mechanical Engineering from Indian Institute of Technology Kanpur, India in 2009. His current research interests include Suspension Plasma Spraying (SPS) and High Velocity Air-Fuel (HVOF) spraying of ceramic and metallic materials for a wide range of applications such as thermal barrier coatings (TBCs), wear resistant coatings and multifunctional coatings.

Professor Tanvir Hussain FSAM FIMMM FHEA CEng

Professor of Coatings & Surface Engineering, University of Nottingham, UK

tanvir.hussain@nottingham.ac.uk

Title Clearance coatings in lower emission aviation gas turbines: Ytterbium disilicate abradable coatings spraying and combined steam-CMAS performance

Abstract

As efficiency gains are sought within gas turbines through ceramic matrix composites (CMCs), ytterbium disilicate coatings, as both abradable and environmental barriers, are seriously considered to achieve the desired performance. The paper will present a story on plasma spray parameters for developing a range of abradable coatings and their performance in abradable test rigs. It will then present how abradable coatings perform when exposed to steam, molten calcium magnesium alumino-silicates (CMAS) and combined steam and CMAS. Three ytterbium disilicate (Yb₂Si₂O₇ or YbDS) abradable EBCs containing 8, 15 and 22 % porosity by area were deposited using atmospheric plasma spraying. These coatings were then exposed to steam, CMAS (35 CaO – 10 MgO – 7 Al₂O₃ – 48 SiO₂ mol. %) and combined steam and CMAS at 1350 °C for 100 hrs. Exposure to steam caused the formation of a thin ytterbium monosilicate (Yb₂SiO₅ or YbMS) reaction layer. Reaction with the CMAS occurred by a dissolution-precipitation mechanism, with a reprecipitated ytterbium disilicate phase and Yb-apatite (Ca₂Yb₈(SiO₄)₆O₂) crystals noted as the only reaction products. After the combined exposure, the CMAS infiltration depth was higher than that observed in the standalone CMAS exposure. Also, an increased amount of Yb-apatite formation was observed within with YbMS reaction layer, and an ytterbium aluminium garnet (Yb₃Al₅O₁₂ or YbAG) phase was also observed

Biography

Prof Hussain FASM FIMMM FHEA CEng is a Professor of coating and Surface Engineering at the Faculty of Engineering, University of Nottingham and he holds a prestigious Engineering and Physical Sciences Research Council (EPSRC) Fellowship (£2.1 m) to develop Advanced Coatings for Aerospace Propulsion using artificial intelligence. He is a Co-Director of EPSRC Network Plus IGNITE+ to increase equality, diversity and inclusion in the Energy Sector (£1.25 m) and a Co-Director of the newly launched Centre for Doctoral Training (CDT) in Digital Metal with 4 other UK Universities from the Midlands to train 80 PhD candidates over the next 8 years. He is also one of the founding members of the Marie Skłodowska-Curie Actions Doctoral Training Programme on (Re-MAKE) Refurbishment and Additive Manufacturing Accomplished by Kinetic Deposition with 17 EU partners.

Over the last 20 years, he has built a solid scientific foundation in understanding novel materials processing techniques, especially **thermal spray** and **cold gas dynamic spray**. The process-microstructure-properties relationship is at the heart of his research. His research has directly impacted aerospace, automotive, renewable energy and healthcare sectors. He received a PhD in Materials Engineering from the University of Nottingham in 2010 and a Masters in Manufacturing Engineering and Management in 2007.

He is also recognised worldwide for his suspension and solution precursor thermal spraying to manufacture functional coatings from sub-micron to nanometer range feedstock particles. His team in the EPSRC Fellowship with 20 industrial partners and 7 academic partners are developing new compositions using artificial intelligence and novel processing routes for thermal barrier coatings, environmental barrier coatings, wear-resistant coatings, corrosion-resistant coatings, insulating coatings and functional coatings for electrification.

He is the Director of the Centre of Excellence in Coatings and Surface Engineering at the University of Nottingham, supported by £2.1 m investment from EPSRC and £1 m investment in infrastructure by Propulsion Future Beacon. Total funding since joining the UoN in 2013 is over £17 M (as PI or Co-I). He has published 150 peer-reviewed international journal papers and 2 book chapters on thermal and cold spray research. He has an h-index of 37 with over 4300 citations. He is in the top 2% of cited researchers worldwide for several years, which Stanford University compiled in a database of the top 100,000 scholars.

He is an appointed member of the EPSRC Strategic Advisory Team (SAT) in Manufacturing the Future and Circular Economy and sits on the Special Advisory Group (SAG) on EDI at EPSRC. He is currently an editor of the community's flagship journal, the Journal of the European Ceramic Society, Elsevier and was an Associate Editor for the Journal of Thermal Spray Technology, Springer-Nature, the journal of ASM-Thermal Spray Society (TSS). He also provides input to national and international standards committees as an expert in the BSI STI/40 committee.

Rogério S. Lima, National Research Council of Canada

Title: “SPS *versus* EB-PVD YSZ TBCs: Durability under Thermal Cycle in Thermal Gradient Environment”

Authors: Rogério S. Lima (speaker) and Bruno M. H. Guerreiro

Abstract:

One important question lasting in the thermal spray community is the knowledge if suspension plasma spray (SPS) ZrO₂-8wt%Y₂O₃ (YSZ) thermal barrier coatings (TBCs) can reach the performance levels of their electron-beam physical vapour deposition (EB-PVD) counterparts, and to eventually replace them as the state-of-the-art TBC for aviation gas turbine engine blades. This work aims at bringing some important clarifications on this subject. The SPS YSZ TBCs were engineered using industry-produced ethanol-based suspensions (from 25wt% to 75wt%) provided Innovnano, Saint-Gobain and Treibacher. The Mettech Axial III plasma spray torch and the Polycontrols M40 suspension feeder were employed to manufacture the SPS YSZ TBCs. The benchmark EB-PVD YSZ TBCs (including the Pt/Al bond coat) were manufactured by a private industrial contractor. All TBCs were deposited on single-crystal Rene N515 substrates. The bond coat material for the SPS YSZ TBCs was the NiCoCrAlY+HfSi; produced via air plasma spray (APS). The performance comparison amongst all these TBCs in thermal gradient cycling (5 min hot & 2 min cool cycles) was undertaken via a thermal gradient laser-rig testing system. These are released results from the Surftec Thermal Spray Industrial R&D Group of the National Research Council of Canada (NRC).

Biography:

Dr. Rogério Lima obtained his PhD degree in Materials Science & Engineering at the Center for Thermal Spray Research of the State University of New York at Stony Brook (USA); studying under the mentorship of Prof. Chris Berndt (now Distinguished Professor at Swinburne University of Technology – Australia). Right after his PhD graduation in 2001, Dr. Lima joined the Thermal Spray Team of the National Research Council of Canada (NRC) as a Research Associate and was awarded permanent position in 2006. He currently holds the position of Senior Research Officer at the NRC. Dr Lima’s main scientific interest is R&D of thermally sprayed thermal barrier coatings (TBCs) and environmental barrier coatings (EBCs) for aerospace applications.

Jürgen Ramm, Oerlikon Surface Solutions AG

Title: “PVD⁺ - Combination of PVD and PECVD deposition processes to synthesize EBC structures for SiC-based CMC materials”

Jürgen Ramm, Oerlikon Surface Solutions AG, Iramali 18, LI-9496 Balzers, Liechtenstein
Daniele Casari, Laboratory for Mechanics of Materials and Nanostructures, Empa, Feuerwerkerstrasse 39, CH-3602 Thun, Switzerland
Dianying Chen, Oerlikon Metco (US) Inc., Westbury, NY 11590, USA
Kerstin Glaentz, Oerlikon Surface Solutions AG, Iramali 18, LI-9496 Balzers, Liechtenstein
Xavier Maeder, Laboratory for Mechanics of Materials and Nanostructures, Empa, Feuerwerkerstrasse 39, CH-3602 Thun, Switzerland
Helmut Schoech, Oerlikon Surface Solutions AG, Iramali 18, LI-9496 Balzers, Liechtenstein
Benno Widrig, Oerlikon Surface Solutions AG, Iramali 18, LI-9496 Balzers, Liechtenstein

Abstract:

SiC-based substrate materials require protective coatings to suppress volatilization in water vapour at high temperatures. In addition, concepts need to be developed which allow thermal barrier coatings to extend the operating temperature beyond the melting temperature of silicon which is utilized as bond coat in current EBC layer stacks. This work describes a hybrid deposition technology developed for EBC relevant class of coating materials which combines PVD and PECVD processes. The presentation will discuss this new PVD⁺ approach and show representative coating materials which have been synthesized. The technology allows for the deposition of EBC layers in a single uninterrupted and economical process. The thermal stability and adhesion of Si-based coatings has been tested on SiC substrates. The TGO formation on a simple SiC/Si/Yb-Si-O EBC layer stack was investigated in isothermal and thermal cycling water vapour tests at 1316°C. Possibilities to reduce the TGO growth at Si bond coat or avoid elemental Si in the bond coat are discussed.

Biography:

Jürgen Ramm received his diploma in Experimental Physics in 1972 from Technical University in Dresden (Germany) and worked there subsequently in the field of Pattern Recognition based on Discrete Walsh Transformations. In 1981 he obtained his Ph.D. in Nuclear Physics from University of Zurich (Switzerland). Since 1984 he has been working at different positions at Oerlikon company in the field of thin film material development and PVD and CVD process development in semiconductor industry as well as for wear resistant coatings. During last years, his work focused on the synthesis of oxides, aluminides and superalloys by reactive cathodic arc evaporation and protective coatings in high-temperature applications. Recently, he is investigating Environmental Barrier Coatings for SiC-based substrate material utilizing a combination of PVD and CVD process. He is author and co-author of about 50 patents and more than 80 publications.

Céline Ruelle, Safran Tech

Title: “Development of abradables and abrasives coating solutions for turbojet engines applications”

Abstract:

Turbojet engines performances and specific fuel consumption are affected by the operating gap between static and rotating parts. To limit leakage flows, abradables coatings are applied to all stator stages, allowing sacrificial wear, conservation of blade tip integrity and consequently, limiting the gap opening after a mechanical contact. Moreover, the continuous improvement of aeronautical engines efficiency imposes materials to evolve in harsh environment. Erosion resistance of abradable coating is therefore crucial, but this property is antagonistic to porosity rate, usually high in abradable coatings. One way of achieving this challenge is to incorporate an abrasive coating at the top of the blade, on rotor part.

In this context, the multi-partner RAPTOR project was launched, and its objective is to develop abradable-abrasive coating pairs. Different processes and materials are investigated for each turbojet engine stages (compressor and turbine), such as thermal spray and Physical Vapour Deposition (PVD). Basic coating properties such as microstructure and adhesion will be characterized, and erosion and abradability testing will be performed to evaluate coatings performance.

Biography:

Céline RUELLE is a researcher engineering at Safran Tech, Safran Group’s research centre. Graduated from Limoges engineering school ENSIL with a speciality in Materials and Surface Treatments, she started her carrier as a research engineering at IRCER laboratory. Her missions were to develop an anti-erosion coating on a composite by thermal spray. In 2021, she started a PhD thesis at IRCER laboratory in collaboration with the French Alternative Energies and Atomic Energy Commission (CEA) on segmented plasma torch characterization. She defended her PhD in February 2024 and is now working on abradables coating applications at Safran Tech.

Uwe Schulz, DLR, German Aerospace Center

Title: “PVD coatings for protection of aero engine components under challenging environments“

Abstract:

Advanced aero engines operate under extreme conditions. This ultimately calls for materials with increased high temperature capability and lightweight components that are pushed to its limits. Usage of coatings offers the potential to prolong lifetime, to increase operating temperatures, and to protect turbine components. Several PVD coating techniques that are used to protect turbine parts will be presented. Thermal barrier coatings (TBCs) are applied to increase lifetime and efficiency of turbine blades and vanes in aero-engines and land-based gas turbines by reducing the average metal temperature and mitigating the detrimental effects of hot spots. The presentation highlights the behaviour of coatings that are produced by electron beam-physical vapor deposition (EB-PVD) especially under high loadings of dust, commonly described as CMAS deposits, that are ingested in aero-engines during the flight. The presentation provides results on several new TBCs, especially their improved behaviour under the influence of deposits. PVD methods are also capable to protect TiAl against oxidation. Magnetron Sputtering is a suitable method to manufacture the desired complex coatings that are either multi-element coatings such as TiAlCrY, TiSiAl, or complex MAX-phases. Finally, for very challenging conditions in terms of temperature that can be present in engines and hypersonic flight applications, CMC (Ceramic Matrix Composites) and Ultra High Temperature Ceramics (UHTCs) are potential solutions. Both ceramic materials need complex and demanding coatings to provide an adequate service life. The presentation will show results on promising PVD-based metallic and ceramic coatings for these materials.

Biography:

Prof. Dr. Uwe Schulz

German Aerospace Center, Institute of Materials Research, Cologne, Germany

Uwe Schulz studied materials science at the Technical University Mining Academy Freiberg. He is working at the German Aerospace Center (DLR) on development, manufacture, characterisation, and testing of protective coatings for turbine applications, deposited mainly by PVD methods. He is head of the department “High temperature and functional coatings” at

DLR’s Institute of Materials Research and in charge of various in-house, national and European projects, funded by industry and government. His major research focus is on oxidation, thermal and environmental protection for TiAl, Ni-based and new silicide-based alloys, CMCs, and for other space and energy applications. He holds several patents and is the author of 50+ papers and co-author of more than 80 further papers and holds an appointment as lecturer professor at Technical University in Dresden, Germany.

Kentaro Shinoda, National Institute of Advanced Industrial Science and Technology (AIST)

Title: “Hybrid aerosol deposition process: bridging the gap between thermal spray and vapor deposition processes”

Authors: Kentaro Shinoda, Mohammed Shahien, Masato Suzuki, Takashi Nagoshi, Kenji Nishimura
Advanced Manufacturing Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

Abstract:

Hybrid aerosol deposition (HAD) process is a kinetic spray deposition process of solid particles with the enhancement of particle surface by a mesoplasma jet. HAD can deposit dense ceramic coatings to porous ceramic coatings of which thicknesses are about a few micrometer to a hundred micrometer. Impacted particles are mainly deposited with a phenomenon called a room temperature impact consolidation. The starting powder particle size ranges sub micrometer to micrometer, which is much smaller than that of conventional ceramic plasma spray (a few tens of micrometer). On the contrary, in physical vapor deposition, deposition unit is an atom or a cluster (angstrom to nanometer scale). Therefore, the deposition unit of HAD comes in the middle size, and the deposition process of HAD can also be regarded between thin film technology and thick film technology. This difference can indicate some interesting points. For example, the surface roughness of the substrate is an important factor. In thermal spray, the substrate is grit-blasted before spraying, while in physical vapor deposition, the substrate is usually flat. Then, what is the suitable substrate surface for HAD process? In this presentation, we would like to discuss the size effect of deposition unit on the coating deposition process. Based on the current understanding of HAD process, vapor deposition, cluster deposition, aerosol deposition, and melt quenching deposition will be compared.

Biography:

Dr. Kentaro Shinoda is the Leader, Advanced Functional Surface Group of the Advanced Manufacturing Research Institute at the National Institute of Advanced Industrial Science and Technology (AIST), Japan. He received his Ph.D. in Engineering from the University of Tokyo in 2006. After two postdoctoral fellowships at the National Institute for Materials Science (NIMS) and the Center for Thermal Spray Research (CTSR) at Stony Brook University, Dr. Shinoda joined in AIST in 2011. His research interest is on the coating deposition process widely from chemical solution to kinetic spray to plasma spray depositions. Especially, he has developed a hybrid aerosol deposition process and try to expand its applicability to industrial research fields. He is also appointed as an Adjunct Professor at Shibaura Institute of Technology. He serves as the member of the director board of the Japan Thermal Spray Society and the member of ASM Thermal Spray Society Programming Committee.

Dr. Thorsten Stoltenhoff, Linde Advanced Material Technologies Title:

“ExoGard™ – Recent Achievements in Hard Chrome Substitution“

Abstract:

Since the entry into force of the EU Chemicals Regulation 1907/2006 - REACH on 1 June 2007 at the latest, many industrial sectors have been working increasingly on the substitution of electrodeposited chromium coatings, as the by-product – hexavalent chromium – is one of the prohibited substances. The substitution of g/a chrome coatings poses major challenges for both manufacturers and users due to their widespread use for decorative and technical purposes.

Many attempts to replace hard chrome coatings with Thermal Spray coatings have failed, as it was tried at the same time to achieve a significant improvement in the coating properties. Finally, the production costs of the resulting TS coatings got simply too high. A most suitable coating system as hard chrome substitute should therefore provide good protection against mechanical wear paired with sufficient corrosion resistance at a lowest possible total coating thickness. In addition, the as-coated surface should require lowest mechanical post-processing only. The extent to which this can be achieved with known or new technologies of thermal spraying will be presented here.

Biography:

Biography

Dr. Thorsten Stoltenhoff

Linde Advanced Material Technologies

Associate Director Technology Europe

Thorsten received his MSc in Mechanical Engineering with a major in Fluid Dynamics at the Helmut-Schmidt-University in Hamburg, Germany in 1996, during his 10 years service in the German Federal Armed Forces.

Subsequently, Thorsten completed his doctoral thesis in the field of cold spraying at the Institute of Material Science of the HSU in 2004, followed by his first industrial position at Praxair Surface Technologies GmbH in Ratingen, Germany, as head of process and application development. All in all, Thorsten can look back on more than 25 years of experience in the field of thermal spraying and cold spraying.

Aurélie Vande Put, CIRIMAT - ENSIACET Toulouse

Title: “Protective PVD coatings for improved high temperature oxidation resistance of titanium-based alloys”

Co-Authors:

Hugo Enjalbert ^a, Aurélie Vande Put ^a, Daniel Monceau ^a, Simon Belvezes ^b, Eric Males ^b, Benjamin Dod ^c, Elodie Delon ^c, Coralie Parrens ^c

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Abstract:

To increase engine efficiency and meet environmental norms, the aircraft industry has been looking for higher in-service temperatures and lighter structures for many years and even more nowadays. With their high specific strength at low or moderate temperatures (<650 °C), Ti- based alloys are good candidates for such applications. However, when exposed to oxidizing environments at high temperatures, they undergo a large oxygen dissolution while forming an oxide scale, which can greatly affect their mechanical properties. To maintain a high creep strength and ductility of these alloys while preventing large oxygen diffusion, the benefit of a thin protective PVD coating was assessed. In this aim, a few PVD coatings were deposited on two titanium-based alloys which were then subjected to high temperature oxidation test. The coated materials were characterized before and after oxidation to evaluate their influence on oxygen diffusion and any microstructure evolution at the coating/alloy interface.

Biography:

After a PhD on the effect of Pt on the high temperature oxidation resistance of a TBC system composed of a NiCoCrAlYTa bond-coating, co-financed by CNRS and Safran Helicopter Engines, and after a short post-doctorate at Oak Ridge National Laboratory (TN, USA) on the resistance to metal dusting of alumina-forming austenitic stainless steels, Aurélie Vande Put became an assistant professor at Toulouse-INP in 2010. Since then, she carries out research activities on the resistance and protection to high temperature oxidation and corrosion of metallic alloys for different application domains (aeronautics and chemical industry). She has been working on the durability of materials such as TBC systems, nickel-based superalloys, titanium-based alloys, FeNiCr alloys and protective coatings under various oxidizing environments like dry air or H₂O-rich air (resulting in the volatilization of the protective chromia layer) and more complex atmospheres leading to a degradation by metal dusting.

Scott Wilson, Oerlikon Metco

Abstract:

The Aviation industry is embracing the challenge of making air travel more sustainable with a key drive towards reductions in Specific Fuel Consumption (SFC) and eliminating unwanted emissions. To meet these goals, engine OEMs need and use advanced coating technologies on their engine components to enable the following:

- Less fuel wastage, especially for transient engine conditions such as take-off and landing
- Robust performance in complex cyclic thermal and environmental conditions
- Fewer maintenance intervals, with shorter engine overhaul turnaround times.

A snapshot of published Commercial Aero Engine fleet gas and other regulated emissions ratings as a function of Engine Thrust, and Engine Pressure Ratio (EPR) is presented, with insights on key challenges faced to lower these. Examples will be given on how existing and new coating technologies from Oerlikon have helped OEMs improve engine SFC and lower emissions. A focus on engine sealing technologies provided by thermally sprayed abrasion-resistant (clearance control) coatings is made, together with some examples of other coating systems used on advanced aero engine components, which are subjected to increasingly higher temperatures and complex environmental exposure attack.

Biography:

Scott Wilson is Global Product Manager for Abradable (clearance control) coatings at Oerlikon Metco, Switzerland. After completing his PhD in materials engineering at the University of Cape Town, he held a postdoc and research fellowship position at the University of Windsor, Canada, followed by a research officer position in the Tribology group at the National Research Council of Canada, in Vancouver. He then worked as Project Leader at Sulzer Innotec in Winterthur, Switzerland from 2001 to 2008, responsible mostly for abrasion-resistant testing and tribology programs. In 2009 he took up a Competence Leader R&D position at Metco and then migrated over to application & product management for Oerlikon from 2017.

Ping Xiao, The University of Manchester

Title: “Characterisation techniques for investigating thermal barrier coating and environmental barrier coating failure”

Abstract:

Materials characterisation plays a crucial role in developing thermal barrier coatings (TBCs) and environmental barrier coatings (EBCs) for gas-turbine engines. The failure of thermal barrier coatings and environmental barrier coatings is influenced by a complex interdependence of microstructure, residual stress, and thermomechanical properties. Validating our mechanistic understanding of each of these factors that contribute to failure requires a selection of suitable characterisation techniques. Presented in this talk are characterisation techniques that have advanced the understanding of thermal barrier coating and environmental barrier coating failure. Examples of characterization studies at University of Manchester will be given to present on 1) how electron microscopy together with optical microscopy and X-ray tomography can be used to examine degradation of TBCs and EBCs; 2) 4 point bending coupled with micro-mechanical study have been used to measure mechanical properties of TBCs; 3) Raman spectroscopy, XRD and synchron X-ray diffraction have been explored to examine residual stresses in TBCs and EBCs. Targeted coating development that is both effective and efficient depends on these characterisation techniques to obtain superior coatings with improved performance and lifetime.

Biography:

Ping Xiao currently holds the Rolls-Royce/Royal Academy of Engineering Research Chair in Advanced Coating Technology, maintaining a collaborative relationship with Rolls-Royce plc spanning over two decades. He has made a significant impact on introduction of TBCs into service in aero-engines.

Presently, Xiao is closely engaged with Rolls-Royce to develop environmental

barrier coatings for aero-engines, aimed at achieving higher operational temperatures and lighter components. His work has garnered international recognition, with features in *The Economist* and the American Society of Mechanical Engineers website. In 2017, he was interviewed by the Canada Business Network. Appointed by the UK Government's BEIS in 2019, Xiao serves as the UK representative on ceramics for the Generation IV Nuclear Reactor International Forum (GIF), interacting with representatives from the USA, EU, Japan, Canada, Australia, China, and the UK. Since 2020, Xiao is Chair of the Surface Engineering Division of the Institute of Materials, Mining, and Minerals (IOM3) in the UK. In 2024, he has been awarded the Institute of Materials, Minerals & Mining (IOM3) Tom Bell Surface Engineering Medal in recognition of excellence and outstanding contribution in surface engineering.