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**Razieh Alikhanifaradonbeh,** Tampere University, Faculty of Engineering and Natural Sciences
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**Margherita Cescon,** University of Modena and Reggio Emilia
*Mechanical and Chemical Performance of Multilayered EBCs with Graded YbMS/YbDS Compositions*

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**Zhoukun Shi,** Université de technologie de Belfort Montbéliard (UTBM)
*Comparison of suspension plasma sprayed coatings fabricated with two torch configurations (conventional and cascade) and two injection methods (mechanical and atomizer)*

**Kaito Takagi,** TOCALO Co., Ltd
*Microstructural Control and Functional Properties of Columnar YSZ Coatings Deposited by Suspension Plasma Spraying*

**Margherita Cescon,** University of Modena and Reggio Emilia

***Mechanical and Chemical Performance of Multilayered EBCs with Graded YbMS/YbDS Compositions***

**Abstract:**
Silicon carbide (SiC)-based composites used in gas turbines require environmental barrier coatings (EBCs) to ensure durability under extreme conditions. These coatings must resist high-temperature water vapor, be chemically and thermally compatible with the substrate, and withstand corrosion from molten silicates (CMAS). Rare earth-based silicates, such as ytterbium monosilicate ($Yb_2SiO_5$, YbMS) and ytterbium disilicate ($Yb_2Si_2O_7$, YbDS), are promising EBC materials due to their phase stability at high temperature. YbMS provides excellent resistance to CMAS and water vapor but is more brittle and has a higher coefficient of thermal expansion (CTE). YbDS, while less resistant, offers better CTE compatibility with SiC substrates. Bi-layer coatings using both materials often fail due to cracking in the brittle YbMS layer. To overcome this, we developed advanced multilayered EBCs using air plasma spraying (APS), consisting of a silicon bond coat followed by up to five engineered layers with graded YbDS/YbMS compositions. This design aims to reduce internal stresses and improve mechanical integrity while maintaining environmental resistance. Depositions were carried out using a dual feeder system, adjusting the feed rates of pure YbDS and YbMS powders to achieve the desired proportions. The microstructural observations showed that the composition of each layer was consistent with the designed one. The coatings were further evaluated through adhesion, thermal cycling fatigue, CMAS corrosion, and water vapor corrosion tests. Additional testing was performed on five-layer systems that were heat-treated and on versions with asymmetric layer thicknesses, both designed to further enhance the performance and durability of the coating

**Zhoukun Shi,** Université de technologie de Belfort Montbéliard (UTBM)

***Comparison of suspension plasma sprayed coatings fabricated with two torch configurations (conventional and cascade) and two injection methods (mechanical and atomizer)***

**Abstract:**
This study investigates the effect of Suspension Plasma Spraying (SPS) yttria-stabilized zirconia (YSZ) thermal barrier coatings on the microstructure, porosity, and thermal performance. Two types of plasma torches were used: the ProPlasma torch and the cascade-type torch, each combined with two different injection methods: a mechanical injector and a twin-fluid atomizer. The objective of this research is to systematically analyze the combined influence of torch type and injection method on droplet behavior in the plasma jet, the structural characteristics of the deposited coatings, and their service performance.

A comprehensive experimental program was carried out, incorporating in-situ diagnostic techniques (SprayCam and Accuraspray) to observe and measure the characteristics of the suspension droplets within the plasma. These measurements helped define optimal injection pressures for each Torch/Injector combination. Significant differences were found in the morphology, microstructure, and properties of the YSZ coatings depending on the operating conditions.

Furthermore, the influence of five key process parameters on coating porosity was systematically investigated: suspension mass load, spray distance, plasma power, torch scanning step, and substrate roughness. Based on the experimental data, predictive models of coating porosity were developed using Response Surface Methodology (RSM) and Artificial Neural Networks (ANN).

Finally, thermal cycling tests (at 1150℃) revealed that the microstructure plays a crucial role in high-temperature performance: through-thickness vertical cracks promote oxygen diffusion into the substrate, leading to the formation of spinel phases at the edge of the thermally grown oxide (TGO), which tends to accelerate coating failure.

This work proposes a generalizable method for optimizing the SPS process, relying on numerical analysis to establish relationships between process parameters, coating microstructure, and porosity. The development of predictive models provides theoretical support and a useful database for the design of TBC-type coatings.

**Dr. Pavan Ravulaparthy,** U.S. Department of Energy

***Computationally Guided EBCs for High Temperature, Fuel Flexible $sCO_2$ Turbine Cycles—A DOE Perspective***

**Abstract:**
The U.S. Department of Energy's Advanced Turbine Systems effort targets step change efficiency and fuel flexibility (syngas blends and $sCO_2$ cycles), with temperature capability beyond today's limits—driving a materials challenge in turbine hot sections.

DOE's Advanced Energy Materials program addresses that challenge through integrated computational materials engineering, advanced manufacturing, and durability testing for extreme environments, with special emphasis on high temperature, corrosive service and hydrogen effects on materials.

To enable SiC/SiC CMC components, environmental barrier coatings (EBCs)—typically rare earth silicates over silicon bond coats—are essential to mitigate steam driven recession and oxide growth that limit lifetime. Recent DOE sponsored work refines phase field and lifetime modeling of thermally grown oxides (TGO) and demonstrates pathways to extend EBC durability in cyclic air steam environments toward industrial lifetime targets (≥25,000 h).

Parallel studies exploring bond coat free architectures illuminate failure modes at 1400–1600 °C and define requirements for next generation EBC chemistries and interfaces.

This contribution synthesizes DOE program insights with thermal spray process innovations—notably Suspension Plasma Spray (SPS) and Solution Precursor Plasma Spray (SPPS)—to achieve dense, phase stable Yb silicate EBCs while managing segmentation cracks and gas tightness, comparing oxidation kinetics versus conventional APS coatings.

We frame a computational to coating workflow (AEM/eXtremeMAT → spray process maps → microstructure → lifetime models) oriented to hydrogen ready and $sCO_2$ compatible turbine architectures, and we highlight Prague IPP lab capabilities (WSP/WSP H, RF/ICP torches, SPS facilities) as an ideal testbed for joint demonstrations.

Takeaway: a DOE informed, spray centric roadmap to accelerate EBC maturity for SiC/SiC CMCs, linking modeling, processing, and durability testing to meet next generation turbine performance goals with lower emissions and higher reliability.

**Razieh Alikhanifaradonbeh,** Tampere University,Faculty of Engineering and Natural Sciences

***Icephobic Polyethylene/Carbon Coating by Dual Suspension-Powder Flame Spray TechniqueIcephobic Polyethylene/Carbon Coating by Dual Suspension-Powder Flame Spray Technique***

**Abstract:**
Ice formation on solid surfaces can affect operations of aircraft, wind turbines, transmission lines, roads, ships, heat-exchange systems and cause economic losses and safety risks. Coating is one of the best ways to reduce ice adhesion and make ice removal easier. Flame-sprayed polyethylene coatings have improved icephobicity, which allows the ice to be removed more easily by external forces. However, polyethylene has very low thermal conductivity and light absorption, and this can limit its use in active de-icing methods such as heating and light irradiation. Carbon nano-powders cannot be directly used in conventional flame spraying because particle size is very small and the powder has low flowability, which leads to clogging of the spray torch. On the other hand, addition of carbon-based materials to PE can be done to enhance thermal conductivity and light absorption. In this research, polyethylene/carbon black composite coatings were produced by a dual suspension-powder flame spray process. While polyethylene was used as the main coating material in the powder form, carbon black was introduced to the flame as the suspension to enhance the functional properties of the composite coating. The final coating demonstrated low ice adhesion, strong light absorption, and better heat-transfer behavior. These properties helped faster and more efficient ice removal by several de-icing methods, for example mechanical removal, heating, and light irradiation. These results suggest that flame sprayed polyethylene/carbon black composite coatings can operate as multifunctional icephobic coatings for anti-icing and de-icing applications.

**Kieron Robinson,** University of Nottingham

***Suspension plasma spraying of $GdPO_4$ coatings: influence of process parameters on microstructure and performance***

**Abstract:**
Thermal barrier coatings (TBCs) protect Ni-based superalloy substrates from elevated operating temperatures and corrosion. The current state-of the-art material, yttria-stabilised zirconia (YSZ), undergoes a detrimental phase transformation around 1170 °C and has poor resistance to calcia-magnesia-alumino-silicate (CMAS), which makes it unsuitable for next generation gas turbine and aero engines that will operate in CMAS-prone environments. Rare-earth phosphates are an emerging family of materials which offer improvements over YSZ and common alternatives such as gadolinium zirconate ($Gd_2Zr_2O_7$). Gadolinium phosphate ($GdPO_4$) exhibits phase stability up to 1700 °C and has excellent CMAS resistance due to the fast formation of a dense apatite reaction layer, both contributing to a longer TBC lifetime. Suspension plasma spraying (SPS) is a promising route to deposit a range of microstructures such as columnar and dense vertically cracked (DVC) which have improved strain tolerance during thermal cycling. This study develops the first SPS $GdPO_4$ coatings and investigates how processing parameters - gas mixture, torch current, total gas flow, and stand-off distance (SoD) - affect their microstructure, phase composition, and performance during thermal cycling and CMAS exposure. A range of multi-phase $GdPO_4$ coatings were deposited with a range of columnar and DVC-like microstructures. Increasing net power resulted in more loss of phosphate and poorer CMAS performance with lower cycles to failure, whilst lower net power retained phosphate which significantly reduced Ca and Si infiltration compared to conventional SPS YSZ coatings. A single-layer SPS $GdPO_4$ coating could be used as a highly effective barrier for CMAS protection in TBC systems.

**Kaito Takagi,** TOCALO Co., Ltd

***Microstructural Control and Functional Properties of Columnar YSZ Coatings Deposited by Suspension Plasma Spraying***

**Abstract:**
Columnar yttria-stabilized zirconia coatings deposited by suspension plasma spraying are expected to exhibit extended thermal cycle lifetimes because vertical gaps within the coating mitigate thermal strain. Consequently, their application to thermal barrier coatings has been extensively studied. With recent advancements toward higher temperatures and efficiencies in gas turbines, thermal cycling environments have become increasingly severe. Therefore, aiming to further enhance thermal cycle resistance, this study focused on the effects of spray parameters on the columnar structure and its formation mechanism. Experimental results revealed that the interior of a single column consists of alternating dense layers formed by straight-flying particles and porous layers formed by particles following the gas stream. Under conditions with higher particle velocities, the intercolumnar gaps narrowed, and the interior of the columns became more densified. These coatings demonstrated superior thermal cycle resistance and wear resistance, suggesting high interparticle bonding strength. Conversely, lower particle velocity conditions led to a degradation in these properties. This was presumed to be due to an increased proportion of the porous layer within a single column resulting from a higher fraction of overspray particles, which led to a decrease in interparticle bonding strength and a consequent reduction in coating strength. This presentation reports in detail the effects of spraying parameters on the columnar structure, as well as on the coating microstructure, thermal cycle resistance, and wear resistance.

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**Beulah Ude,** Obafemi Awolowo University

***Machine Learning-Driven Predictive Modeling of Kinetic Degradation in Advanced Nano-Silica Enhanced Thermal Spray Coatings for Harsh Environments***

**Abstract:**
Advanced environmental and thermal barrier coatings (EBCs/TBCs) processed via suspension and solution thermal spraying offer unprecedented microstructural control for harsh operational environments. However, optimizing feedstock liquid chemistry and spray parameters to suppress sub-film degradation and corrosive kinetic behavior remains a complex, high-dimensional challenge. This study introduces an agile Materials Informatics framework leveraging ensemble machine learning (ML) architectures specifically Random Forest and Gradient Boosting regressions to map, model, and predict the long-term kinetic degradation pathways of nano-silica enhanced epoxy composite coating architectures.Utilizing a curated dataset of experimental corrosion rates, electrochemical impedance spectroscopy (EIS) data, and microstructural phase distributions under aggressive acidic conditions, our models successfully disentangled the non-linear coupling between nanoparticle weight fractions, processing temperatures, and electrolyte diffusion pathways. The Random Forest architecture provided high-fidelity spatial feature importance mapping, identifying critical thresholds for nano-silica dispersion that optimize barrier performance. Concurrently, the Gradient Boosting model achieved exceptional predictive accuracy for kinetic degradation trajectories, yielding an R^2 score greater than 0.92 and a minimized Root Mean Square Error (RMSE).Microstructural validations confirm that the ML-optimized processing window successfully suppresses localized pitting and under-film corrosion kinetics by facilitating a highly tortuous diffusion pathway. This research demonstrates a significant paradigm shift from conventional, iterative trial-and-error coating design to an accelerated, data-driven methodology. By unifying advanced nanomaterial synthesis with predictive kinetic modeling, this work establishes a scalable roadmap for engineering next-generation, high-durability surface coatings optimized for aggressive industrial and oilfield environments. The insights presented offer a framework directly transferable to the design and optimization of complex liquid-phase thermal spray architectures.

**Jade Orlandi,** IMERYS/IRCER

***Comparative study of particle behavior in aqueous and ethanol-based suspensions in suspension plasma spraying and the influence of powder chemistry from micrometric to nanometric scales***

**Abstract:**

YSZ thermal barrier coatings (TBCs), elaborated through suspension plasma spraying (SPS), are widely used in industry. This process presents many advantages, such as the versatility of the materials and microstructures, and its ability to process complex parts in large quantities. While numerous studies on TBCs have been conducted using ethanol-based suspensions due to their favorable spraying behavior, increasing attention is now being paid to water-based suspensions from an environmental perspective, as they reduce the use of volatile organic solvents (Ref 1,2). This implies a further understanding and a precise control of the thermokinetic behavior of the particles in the plasma plume, providing deeper insight into the factors that govern suspension formulation — a critical aspect for ensuring industrial reproducibility and for defining the intrinsic properties of the resulting deposit (Ref 3,4).
In thermal spraying, the solvent used in ceramic suspensions is a key parameter that strongly influences viscosity, colloidal stability, and surface tension, all of which govern jet behavior during spraying. In particular, water, which exhibits a higher surface tension and vaporization enthalpy than ethanol, shows a distinct evaporation behavior within the plasma plume, thereby significantly affecting particle fragmentation, heating, and acceleration, and ultimately the resulting coating characteristics (Ref 1,5,6).
In this work, coatings produced from ethanol and water-based suspensions are compared using on-line plasma measurements to better understand how suspension behavior within the plasma plume influences coating properties and performance. Special attention was also given to the role of formulation, from micrometric to nanometric powders, in modifying particle–plasma interactions, residence time, and in-flight evolution, and consequently the development of the coating microstructure. Resulting coatings and in-flight sampled particles were characterized by scanning electron microscopy and particle size analysis, allowing a detailed correlation between suspension properties, in-flight behavior, and final deposit morphology.

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**Ali Eskandari,** University West

***Toward Ultra-High Porous Gadolinium Zirconate Thermal Barrier Coatings by Suspension Plasma Spraying***

**Abstract:**

Suspension plasma-sprayed (SPS) gadolinium zirconate (GZO) coatings were developed for advanced thermal barrier coating (TBC) applications. The increasing industrial demand for lower thermal conductivity coatings for combustion engine applications has driven the development of highly porous coating architectures with improved thermal insulation performance.

In the present study, SPS processing parameters were systematically modified to produce ultra-high porous GZO coatings. The influence of spray conditions, including stand-off distance (SOD), plasma current, and nozzle size, on microstructural features, including porosity content and distribution, crack formation, and columnar morphology, together with thermophysical properties such as thermal conductivity, was investigated to identify processing conditions suitable for next-generation high-temperature thermal barrier coatings.

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**Gilles Mariaux,** Univ. Limoges, CNRS, IRCER, UMR7315, F-87000 Limoges, France

***Advanced modelling of Suspension Plasma Spraying: focus on the physical treatment of the suspension***

**Abstract:**

Suspension Plasma Spraying (SPS) process is being adopted by cutting-edge industrial sectors due to wide range of microstructures produced at atmospheric pressure and its relatively high deposition rate. Nevertheless, the resulting microstructures are highly sensitive to a large number of operating parameters (torch, injector and suspension, substrate, kinematics) making their control particularly challenging, especially for components with complex geometries. Furthermore, understanding the process remains complex because it involves numerous interdependent phenomena (Magneto-Hydro-Dynamic, turbulence, suspension fragmentation, heat transfer, etc.) occurring over a wide range of temporal and spatial scales, and there are few diagnostic tools available to characterize the treatment of the material in-flight, given the small size and high velocity of the agglomerates formed in the harsh plasma environment. Consequently, the Institute of Research for Ceramics (IRCER) and the Bordeaux Engineering and Mechanics Institute (I2M), in partnership with Safran Group, are developing advanced modelling of SPS as the first steps for developing a SPS digital twin in order to 1) enhance their understanding of the process and 2) reduce the costs of process development and 3) optimize new coatings by establishing the link between operating parameters and microstructures. This study focuses on the physical treatment of an already fragmented droplet. Indeed, an initial analysis of the time constants associated with the various phenomena has shown that the fragmentation of the liquid by the plasma jet is the fastest process, followed by the evaporation of the liquid and its recirculation, while the diffusion of submicrometric particles being the slowest. This model, developed as a 2D-axysmetric in-house code depicts the initial evaporation stage, before the viscoelastic shell forms as a result of particle agglomeration on the spherical droplet surface from an initial particles distribution within the droplet. It includes, the liquid recirculation, droplet heating and shrinking, submicronic particles movement and agglomeration.

**Karolina Płatek,** Wroclaw University of Science and Technology

***Comparative Study of TiO2 Photocatalytic Coatings Deposited by SPPS and SPS Using an Axial III Plasma Torch***

**Abstract:**

While the possibility of use of the thermal spray technologies for fabrication of photocatalytic coatings is already well examined, most of the studies focus on deposition from powder or suspension feedstocks, leaving solution precursor plasma spraying (SPPS) less explored. This is primarily due to the disadvantageous properties of most conventional precursors, such as aqueous titanium salts or alkoxides, of which high hydrophilicity and tendency toward premature precipitation lead to nozzle clogging and process destabilization.

In this study, we investigated the deposition of photocatalytic TiO2-based coatings using both SPPS and suspension plasma spraying (SPS) with an Axial III plasma torch. Titanium(IV) bis(ammonium lactato)dihydroxide (TALH) was used as the stable water-based solution precursor, while the suspension was formulated from 100% sub-micrometric anatase powder with a distilled water as a solvent. The coatings were further characterized in terms of their microstructure through scanning electron microscope (SEM). The phase composition was acquired using X-ray diffraction (XRD), and the mechanical properties of the coatings were also assessed. Finally, the photocatalytic performance of the coatings was evaluated through the degradation of a methylene blue solution under UV irradiation, and the results for both SPPS and SPS coatings were compared.

**Sara Mokhlesi,** IKMT - University of Stuttgart

***Inconel 625 coatings via Suspension-HVOF for resistance heating: Influence of oxygen scavengers***

**Abstract:**
The electrification of industrial high-temperature processes requires heating systems that combine efficient heat generation with long-term thermal stability. Thermally sprayed resistance heating coatings are a promising solution, enabling the direct integration of heating elements onto ceramic components. Among thermal spray technologies, High-Velocity Suspension Flame Spraying (Suspension-HVOF) offers the potential to produce thin, smooth, and homogeneous metallic coatings with reduced oxidation, making it particularly attractive for resistance heating applications.
In this study, Inconel 625 resistance heating coatings were deposited by Suspension-HVOF onto alumina-insulated substrates. The influence of the stoichiometric ratio ($\lambda$), which governs particle heating and oxidation during spraying, was investigated with respect to coating microstructure and functional properties. To further suppress oxidation, polyethylene glycol (PEG) was incorporated into the suspension as an oxygen scavenger, and its effect on coating formation and electrical performance was evaluated.

The resulting coatings were characterized in terms of microstructure, oxide content, and temperature-dependent electrical resistivity. In addition, the heating performance of structured resistance heater coatings was assessed to evaluate their suitability for electrically heated high-temperature applications. The results demonstrate that the use of oxygen scavengers can effectively reduce oxidation during Suspension-HVOF spraying. At the same time, the influence of PEG on suspension processing and coating formation highlights the importance of optimizing the suspension formulation to achieve both low oxidation and high coating quality. These findings demonstrate the potential of suspension chemistry as an additional tool for tailoring functional metallic coatings produced by Suspension-HVOF for integrated resistance heating applications.