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# In The News

## News from Research and Technology Institutes Worldwide

This column informs *JTST* readers of activities in research and technology institutes active in the field of thermal spray technology. Technical overviews help the reader to understand the primary focus of the institution and the needs driving their thermal spray research and development. Getting to know the research interests and professional experience of our thermal spray colleagues allows us to better recognize experts in specific fields of study. Knowledge of institutional expertise is important for developing complementary partnering relationships to increase the fundamental understanding of thermally sprayed materials and increase the quality and breadth of practical applications.

This column includes articles giving an overview of current activities or a focus on a significant breakthrough. To submit an article for this column, please contact Kendall Hollis, *JTST* Associate Editor at: Los Alamos National Laboratory, P.O. Box 1663, MS G-770, Los Alamos, NM 87544; e-mail: kjhollis@lanl.gov.

## Thermal Spray Research at Forschungszentrum Jülich GmbH, Germany

The Forschungszentrum Jülich GmbH pursues interdisciplinary research on solving grand challenges facing society in the fields of health, energy, and the environment, and also information technologies. In combination with its two key competencies—physics and supercomputing—work at Jülich focuses both on long-term, fundamental, and multidisciplinary contributions to science and technology and on specific technological applications. With a staff of about 4400, Jülich, a member of the Helmholtz Association, is one of the largest research centers in Europe.

As a part of the Forschungszentrum Jülich GmbH, the Institute of Energy Research (IEF) investigates modern energy conversion technologies. The topics it covers range from photovoltaics and fuel cells, through nuclear fusion and nuclear safety research, right up to innovative coal and gas power plants. This gives rise to a large breadth of research topics, all bound together by scientific methods and systems analysis.

The Institute of Energy Research (IEF) consists of several sections, whereas the thermal spray research is located at the IEF-1: Materials Synthesis and Processing, being directed by Prof. Dr. Detlev Stöver. It deals with the development of materials, structural elements, and components for innovative systems of energy conversion, particularly in the areas of solid oxide fuel cells (SOFCs), gas separation membranes, and thermal barrier coatings (TBCs) for advanced power plants. Within the latter, which Dr. Robert Vaßen is responsible for, thermal spray research has grown in the past two decades as an important area of expertise that is supported by comprehensive equipment.

Overall scientific goals of the research done on thermal spray in Jülich are:

- Improved process control and reliability
- Development of new processes
- Targeted process design for new materials and to provide determined coating characteristics (structure, thermomechanics, optics, etc.)
- Combination of thermal spray technology with other surface and coating technologies

### Coating Process Reliability

Current activities in the research on process reliability of thermal spraying are focused on the atmospheric (APS) and vacuum plasma spraying (VPS), as well as the high-velocity oxyfuel spraying (HVOF). The industrial standard equipment includes one Sulzer Multicoat facility for APS and HVOF (F4, 9MB, F100 Connex, Triplex II, TriplexPro guns (Ref 1), and DJ2600, DJ2700 guns, respectively) and one Sulzer A3000 facility for APS (F4 and Triplex I guns). The reproducible manufacture of coatings deserves special attention. Therefore, an integral part of the thermal spray activities is diagnostics covering the plasma (Tekna enthalpy probe) as well as the particles (Tecnar DPV-2000 and Accuraspray-g3). The goal is to gain understanding of the processes and to manage quality (Ref 2-4).

Thermal spray process development is supported by the characterization of feedstock materials and coatings. For example, the microstructures are investigated by means of SEM, XRD, metallography, Hg porosimetry, and specific surface analysis. Another supporting research activity is the modeling of the plasma spraying process. The principal goal is the improvement in understanding concerning the relation between process parameters and performance of coating systems. Thus, modeling yields basic information that can lead to the optimization of the process (Ref 5).

### New Plasma Spraying Processes

The Sulzer VPS facility (Ref 6) has been recently upgraded for low-pressure plasma spraying (LPPS) so that the working pressure range is extended down to 1 mbar. Figure 1 shows this unit. During 2008, it will be equipped with higher output power supplies. This will allow the operation of the O3CP gun with up to 180 kW plasma power in addition to the F4 and the TriplexPro guns currently used. The objective is to establish thin-film processes (LPPS-TF) to provide TBCs with strain-tolerant columnar microstructures as well as thin and dense coatings for SOFC applications and gas separation membranes.

Another example of research projects being performed in the field of process development is the processing of nanosized powders by the improved

**Fig. 1** Vacuum plasma spray unit at Forschungszentrum Jülich GmbH that recently has been upgraded for low-pressure plasma spraying (LPPS) with working pressure range down to 1 mbar

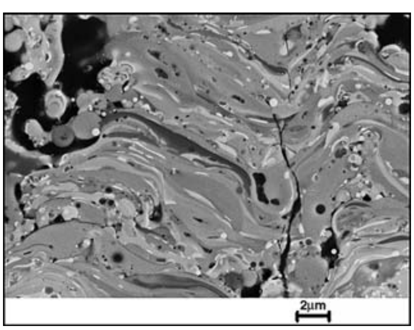


**Fig. 2** Example of a suspension plasma sprayed nanomultilayered $Al_2O_3$/5P-YSZ coating

suspension plasma spraying (SPS) technique (Ref 7). Further information on this method is given in the "Meet Our New Colleagues" column in this issue of *JTST*, which features Holger Kaßner. Figure 2 shows an example of a suspension plasma sprayed nanolayered coating.

### Coating Systems for Application in Energy Systems

The main application field of thermal spraying technology in Jülich is currently the development of advanced thermal barrier coatings (TBC) for use in gas turbines. Based on the institute's expertise with powder technology and functional ceramics, materials such as pyrochlores, perovskites, and hexa-aluminates as well as composites made from metal/glass or ceramic/ceramic are synthesized and characterized with respect to their potential use in TBC applications. IEF-1 operates two spray drying facilities that allow the manufacture of new, advanced oxide ceramics for plasma spraying.

The experience and know-how in the research areas of thermal spraying (processing, characterization, and modeling) are intensively used for the further development of coating systems made of these new materials. TBC systems that presently possess the best high-temperature capabilities and durability are produced as double-layer systems comprising a lower layer of conventional yttria-stabilized zirconia (YSZ) and a top layer of a high-temperature stable ceramic (e.g., YSZ/$La_2Zr_2O_7$ or YSZ/$LaLiAl_{11}O_{18.5}$, Ref 8, 9). Considering the design of these kinds of multilayer structures, control and optimization of the microstructure of each layer by means of process control is essential (Fig. 3).

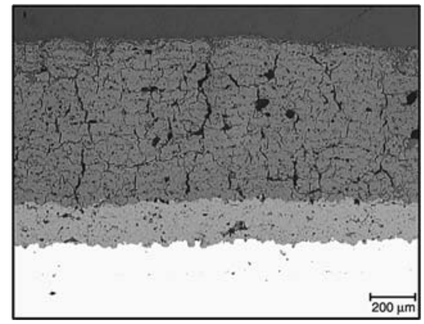


**Fig. 3** Cross section of an APS double-layer TBC system consisting of 150 µm thick interlayer of standard YSZ and a top-layer made from $LaLiAl_{11}O_{18.5}$ on a superalloy substrate with MCrAlY bondcoat

Other projects focus directly on the optimization of TBC microstructures made from standard YSZ. Examples are:

- The modification of the APS processing of YSZ to generate segmentation cracks that improve the thermal shock stability of the coatings (Ref 10). Research on increased crack densities and an adaptation of this technique for complex shaped components is ongoing.
- The use of the aforementioned SPS technique to produce advanced TBCs with a high porosity level adapted to reduce the optical transmittance that can reduce the overall thermal load of the turbine-base material (Ref 11).
- The manufacture of coatings with graded microstructures for use in abradable coatings or with incorporation of luminescent materials into the TBC that provide additional functionality, e.g., in sensor applications.

Following the institute's approach of integrated research on materials synthesis and processing, five thermal gradient cycling rigs are used to assess TBC coating quality. Different gas burner rigs for the testing of samples with flat or cylindrical geometries with the simultaneous application of corrosive agents can be used to study the combined impact of temperature gradients, substrate curvature, and chemical attack on the lifetime of the coating systems. To get maximum insight into the evolution of coating failure from microscopic cracking growth to macroscopic delamination, nondestructive techniques (acoustic emission and infrared thermography) are used to monitor the cycling experiments (Ref 12). The cycling experiment data are also used to improve a lifetime model based on the microstructure that has been developed at the institute (Ref 13).

The second important field of energy research in the IEF-1 is the solid oxide fuel cell (SOFC). The main manufacturing route used for SOFC components is sintering technology. However, the potential of atmospheric plasma spraying (APS) technology is also investigated for the manufacture of anode, electrolyte, and cathode functional layers as well as chromium evaporation barrier layers or isolative layers. Based on the understanding of the formation of defects during spraying, an optimized spraying process could be developed that leads to highly dense coatings with the appearance of a bulk, sintered electrolyte ceramic. A plasma sprayed diffusion barrier between the substrate and anode is very effective in reducing the degradation rate of the cells (Ref 14). It is worth mentioning that, for the manufacture of cells reaching the output power of 800 mW/cm, a substrate of tape-cast FeCr alloy and a screen-printed cathode layer have been used. The latter is mainly due to the currently superior performance of screen-printed cathodes and demonstrates the successful combination of thermal spray technology with other surface and coating technologies. The recently added availability of facilities for thin-film techniques such as PVD, CVD, and LPPS within the institute IEF-1 offers new prospects to use the combination of different coating techniques for improved coatings systems and new applications.

Thus, the technological expertise in thermal spray technology at Jülich is developing in close connection with material science as well as applied energy research. Emphasis is given to fundamental work on up-to-date technological standards and to intense cooperation with industrial partners.

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# News from NASA

## Atomized $BaF_2$-$CaF_2$ for Better Flowing Plasma Spray Feedstock

Christopher DellaCorte of NASA Glen Research Center, Cleveland, OH, and Malcolm K. Stanford of the University of Dayton have found that atomization of a molten mixture of $BaF_2$ and $CaF_2$ is superior to crushing of bulk solid $BaF_2$-$CaF_2$ as a means of producing eutectic $BaF_2$-$CaF_2$ powder for use as an ingredient in the powder feedstock of a high-temperature solid lubricant material known as PS304. The PS304 material was developed to reduce friction and wear in turbomachines that incorporate foil air bearings and is applied to metal substrates using plasma spray.

PS304 consists of an 80Ni-20Cr alloy, $Cr_2O_3$, Ag, and the $BaF_2$-$CaF_2$ eutectic (62$BaF_2$-38$CaF_2$).

The superiority of atomization as a means of producing the eutectic $BaF_2$-$CaF_2$ powder lies in (1) the shapes of the $BaF_2$-$CaF_2$ particles produced and (2) the resulting flow properties of the PS304 feedstock powder. The particles produced through crushing are angular, whereas those produced through atomization are more rounded. PS304 feedstock powder containing the more rounded $BaF_2$-$CaF_2$ particles flows more freely and more predictably, as is preferable for plasma spraying.

As shown in the figure, gas-atomized powder was nearly spherical but had a low yield in the desired 20-100 μm particle diameter range. Water-atomized powder was less spherical and did not flow as well as the gas-atomized powder, but yielded a greater portion of usable particles. Because water atomization is less expensive and better suited to high-volume production than gas atomization, water atomization could be preferable for applications in which the shapes of the eutectic $BaF_2$-$CaF_2$ particles are not required to closely approximate spheres and the intermediate flow properties are acceptable.

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## News from ITSA and TSS

### News from TSS International Thermal Spray & Surface Engineering: Synthetic Diamond Coating Helps Jet Engines Withstand Hostile Environment

Professor Nitin Padture and engineers at Ohio State University are developing a technology to coat jet engine turbine blades with $ZrO_2$ containing embedded aluminum and titanium to protect the components against high-temperature corrosion in environments containing sand. In the desert, sand is sucked into the engines during takeoffs and landings. When sand hits a hot engine blade, it melts and becomes glass, which is extremely aggressive and can dissolve nearly any material.

The hot glass attacks the ceramic thermal barrier coating on engine blades, but the real damage occurs after the engine cools and the glass solidifies to an inflexible glaze on top of the ceramic. When the engine heats up again, the metal blades expand but the ceramic coating cannot expand because the glaze has locked it in place. The result is that the ceramic breaks off, shortening the life of the engine blades.

The new diamondlike coating forces the glass to absorb aluminum and titanium atoms contained in the $ZrO_2$ coating. Once the glass accumulates enough of these elements, it changes from a molten material into a stable crystal, and it stops eating away the ceramic. The glass becomes a new ceramic coating on top of the old one. When new glass is formed, the process repeats itself, continually renewing the coating on the surface of the turbine blade.

The technology is in its infancy and has not been applied to complex shapes. Process costs and energy consumption are also issues to be addressed. However, the possibility of self-healing surfaces and higher combustion temperatures for aircraft engines, power-generating turbine engines, and even automobiles could bring great advantages. Prof. Padture is currently partnering with Inframat Corp., a nanotechnology company, to further develop the technology.

This information was adapted from the TSS publication *International Thermal Spray & Surface Engineering*, **3**(2).

### News from ITSA: OSHA Information

Two recent publications may be helpful in preparing for a United States Department of Labor Occupational Safety & Health Administration (OSHA) inspection of your facility. The first is a new compliance directive for occupational exposure to hexavalent chromium (hex chrome). This directive provides guidance to OSHA's compliance staff when inspecting a facility where hex chrome may be present. It will be helpful to know specifics about such an inspection. The directive can be found on OSHA's web site at: http://www.osha.gov/OshDoc/Directive_pdf/CPL_02-02-074.pdf.

*Occupational Safety* magazine recently published an informative article, ''When OSHA Knocks,'' that gives a very good list of steps that you should take when an inspector shows up at your door. Advanced preparation and following these steps could help minimize adverse results of an inspection. The article can be found at: http://www.occupationalhazards.com/Issue/Article/78870/When_OSHA_Knocks.aspx.

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