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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, address: Los Alamos National Laboratory, P.O. Box 1663, MS G-770, Los Alamos, NM 87544; e-mail: kjhollis@lanl.gov.

Cold Spray Club

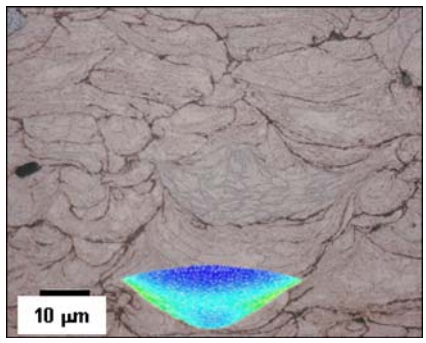
The Ecole des Mines de Paris (School of Mines—Paris, France) has recently launched a new research consortium focusing on the cold gas dynamic spray process (cold spray). Named ''The Cold Spray Club,'' the consortium is aimed at industry, R&D centers, and laboratories that are interested in aspects of cold spray ranging from fundamental understanding to industrial production. Even though cold spray has been developed recently, it is gaining interest and finding applications rapidly. The development of cold spray dates back to the early 2000s and has shown potential for achieving thick, high-density, low-oxygen coatings of metallic or composite materials. Interest in cold spray has been expressed from many sectors of industry including the aeronautical, biomedical, energy, and repair fields.

In spite of the recent interest in cold spray, most of the basic mechanisms that govern the cold spray processing of coatings through the deposition of solid-state, high-velocity (from 400 to 1000 m/s, typically) particles, are far from being fully elucidated. The task of the Club is to help in the understanding of this innovative process and related coatings. For this, the Club keeps up actively with scientific and technological advances in the field. This is carried out through conventional literature studies and the networking of actors in the cold spray scene. In addition, an internal experimental program called the ''Liaison Program'' conducts cold spray experiments as decided by the Club members collectively.

The Cold Spray Club uses cold spray facilities that began operation in early 2006 at the Ecole des Mines de Paris Materials Research Center (www.mat.ensmp.fr) in Evry (on the outskirts of Paris, France). The cold spray equipment includes a CGT Kinetiks 3000, which can utilize nitrogen or helium gases at temperatures up to 550 °C and pressures up to 3 MPa. These facilities were purchased with the support of the Essonne Department General Council and industrial companies in the Essonne Department region of France. These facilities are available for the Liaison Program and for any applied specific program at partners' request (within or outside of the Club).

These cold spray facilities complement the other thermal spray facilities at the Competence Center for Spray Processing (www.mat.ensmp.fr/C2P). Moreover, cold spray deposition can take place in the controlled-atmosphere chamber (large-sized CAPS chamber by Sulzer Metco). This extends the capabilities of conventional cold spray and opens opportunities for innovative applications. R&D studies are currently in progress using this unique equipment in addition to the whole range of facilities for analysis, mechanical testing, and computing at the Ecole des Mines de Paris Materials Research Center. Some of the topics to be investigated are:

- Pretreatment for cold spray coatings (collaboration with labs in France, C2P-Paris, LERMPS-Sevenans, CRITT M2T-Nancy) and lab in Canada (NRC-Boucherville)
- Composite coating by cold spray (NT University of Athens/Pyrogenesis, Greece; Urodelia, France; CIVEN, Italy)
- Experimental simulation of cold spray by LASERFLEX (C2P and University of Tohoku, Japan)



Cold-sprayed copper and (inset) related computer simulation using Radioss (commercial, finite element code for modeling of highly deformed material, as in automobile crash simulations). In this figure, the image of a calculated, highly deformed cold-sprayed particle was artificially inserted in an actual image of a coating's cross section (optical + chemical etching) to illustrate both experimental and modeling activities developed at C2P and within the Club

Some recent results of research from the Club were presented at ITSC 07 in Beijing in the paper ''Deposition Mechanisms of Cold Gas Dynamic Sprayed MCrAlY Coating'' by Y. Ichikawa, K. Sakaguchi, K. Ogawa, T. Shoji, S. Barradas, M. Jeandin, and M. Boustie.

The Cold Spray Club is run through a formal 1-year renewable agreement. In 2006, the Club included 24 members, half of which were from industry. These members include: CGT company (Germany), MD Consultant (France), Advanced Coating (Belgium), CEA Ripault (France), Chpolansky (France), Civen (Italy), Critt M2T Lorius (France), DCN (France), Mines Paris-C2P (France), UT Belfort-Montbelliard-LERMPS (France), NTU Athens (Greece), Pyro-Genesis (Greece), Renault (France), Schlumberger (France), SNECMA (France), Sulzer Metco (Switzerland), T L S Medical (France), UMICORE (Belgium), CSIRO (Australia), University of Tohoku (Japan), NRC/IMI (Canada), and University of Michigan-Dearborn (USA).

For joining the Club and/or for information, please contact Club Cold Spray, Mines, Paris, Competence Center for Spray Processing (C2P), BP 87, Evry Cedex 91003, France; Tel: +33-1-60-763000; fax: +33-1-60763150; e-mail: michel.jeandin@ensmpfr or vincent.guipont@ensmp.fr.

Industry News

New Technology from Air Products Takes the Heat Off During Thermal Spray Coating Applications

Air Products (Lehigh Valley, PA; NYSE:APD) has introduced a new thermal spray cooling technology to the North American market that uses cryogenic nitrogen vapor (−320 °F) to maintain part temperature during thermal spray coating applications. The company's United States patent-pending technology makes high-quality thermal spray coatings possible by maintaining part temperature within a predefined narrow range, even for heat-intensive spraying processes. The technology can enable the user to apply coatings faster and at a lower cost than traditional cooling methods.

Exposing a part to too much heat can negatively impact coating adhesion, substrate and coating hardness, fatigue life, corrosion resistance, and dimensional tolerances. One method used by thermal spray applicators to keep part temperatures within a closely set range is forced air cooling combined with interpass breaks. This traditional practice, however, increases downtime and reduces productivity as well as wastes powder and process gases.

"Air Products recognized that thermal spray applicators needed a better solution to maintaining part temperature," said Dr. Rana Ghosh, Project Manager, cryogenic cooling applications at Air Products. "In response, we developed a thermal spray cooling technology that can maintain a part's temperature within a much tighter range during the spray operation versus traditional cooling methods by varying the cooling intensity to match the heat generated in the spraying process. Use of our technology can improve part quality, lower costs by reducing powder and process gas waste and enabling the use of inexpensive flexible masking, and allow better utilization of the thermal spray equipment and booth."

Air Products' thermal spray cooling nozzles can be mounted directly on the robotic arm next to the thermal spraying gun. During spray application, the cryogenic vapor jet follows the thermal spray plume to maintain the part's temperature within the specified range. Multiple cooling lines can provide additional part cooling, if needed. The part is continuously monitored by a thermal imaging camera and/or infrared sensors that provide temperature feedback to the computer-controlled cooling nozzles, which allows the cooling system to automatically maintain the substrate temperature set by the spray booth operator. The part temperature history also can be recorded and archived for future audit purposes.

Compatible with existing thermal spray systems, Air Products' technology offers a variety of system designs for application-specific use. The technology can be used in the aerospace, automotive, and heavy industries; oil fields; and job shops. Currently used by a major aircraft parts service facility, Air Products' technology has cut in half the spraying time and the amount of powder and process gases consumed in the coating of aircraft landing gear axles.

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News from NASA

Delamination-Indicating Thermal Barrier Coatings

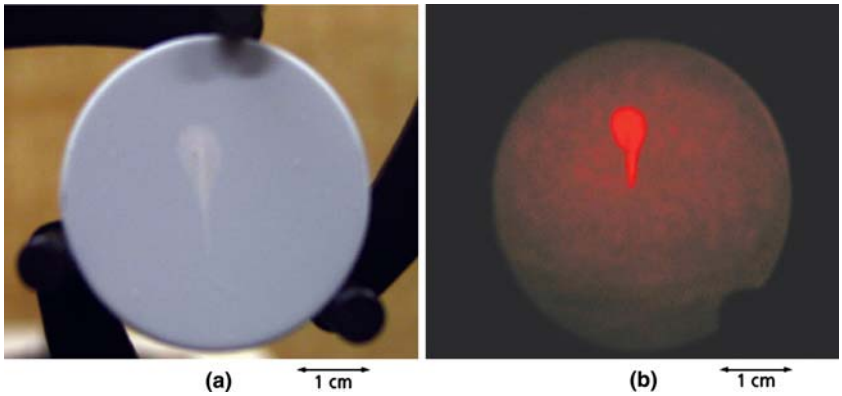
The risk of premature failure of thermal barrier coatings (TBCs), typically composed of yttria-stabilized zirconia (YSZ), compromises the reliability of TBCs used to provide thermal protection for turbine engine components. Unfortunately, TBC delamination proceeds well beneath the TBC surface and cannot be monitored by visible inspection. Nondestructive diagnostic tools that could reliably probe the subsurface damage state of TBCs would alleviate the risk of TBC premature failure by indicating when the TBC needs to be replaced before the level of TBC damage threatens engine performance or safety. To meet this need, a new coating design for TBCs that is self-indicating for delamination has been successfully implemented by incorporating a europium-doped luminescent sublayer at the base of a TBC composed of YSZ. The luminescent sublayer has the same YSZ composition as the rest of the TBC except for the addition of low-level europium doping and therefore does not alter TBC performance.

The strategy for producing delamination-indicating TBCs relies on the enhanced luminescence produced by regions of the TBC where subsurface cracks are propagating. This enhanced luminescence is caused by a large fraction of the excited luminescence that is incident upon the crack at an angle beyond the angle for total internal reflection. Deposition of 125-μm thick TBCs above a 7-μm thick europium-doped layer was performed in collaboration with Penn State University. These self-indicating TBCs were deposited by multiple-ingot electron-beam physical vapor deposition without disrupting TBC growth so as not to alter the usual columnar growth that gives these TBCs many of their desirable properties. To demonstrate delamination indication, localized TBC delamination was induced by scratching the coating with a stylus.

While the delaminated region can be faintly discriminated in a standard whitelight image [part (a) in the figure], the delaminated region stands out strongly in a luminescence image because of the greatly enhanced red emission originating from that area [part (b) in the figure]. The enhanced luminescence from the europium-doped sublayer was caused by total internal reflection of a large fraction of both the 532 nm excitation and the 606 nm emission wavelengths at the TBC/crack interface. Typically, luminescence is

enhanced from delaminated regions by about a factor of three for electron-beam physical vapor deposited TBCs and by an incredible factor of about 100 for plasma sprayed TBCs. Luminescence imaging was very simple to implement and can be achieved using only light-emitting-diode illumination source and a camera with a band-pass filter. High-resolution luminescence images were obtained within a few seconds that immediately identified regions of TBC delamination that would otherwise be difficult to detect, thereby showing great promise for routine inspection of TBCs.

Future work will concentrate on developing delamination indicating TBCs with near-infrared-luminescent sublayers. Because TBCs are much more transparent at near-infrared wavelengths than at visible wavelengths, luminescence can then be detected with less attenuation and from much greater coating depths. The prime candidate dopants for near-infrared luminescence are erbium and neodymium, which luminescence at 1.55 and 1.06 μm wavelength, respectively.



Delamination-indicating thermal barrier coating is examined as (a) white-light image and (b) Eu^{3+} luminescence image. Enhanced Eu^{3+} 606 nm (*red*) luminescence detected from scratched region of TBC readily reveals subsurface delamination

This work was performed by Jeffrey I. Eldridge of NASA Glenn Research Center. Adapted from http://www.techbriefs.com.

News from ITSA and TSS

News from ITSA: Marc James Froning Elected New ITSA Chairman

Marc James Froning was elected the 2007–2009 International Thermal Spray Association Chairman at their recent meeting in Chandler, AZ. Marc is employed by BASF Surface Technologies (formerly Engelhard) and has served as Materials Manager responsible for coating development and New Product Development Manager; he is currently the Manager of Engineering Development. Marc has focused on formulations of new coating systems/applications and improving the reliability of existing industrial standards. His previous experience in the thermal spray industry includes employment at GE Aircraft Engines, Plasma Technology, Inc., and H.C. Starck. Marc received BS (1984) and MS (1986) degrees in Metallurgical Engineering from the University of Cincinnati.

Adapted with permission from *SPRAY TIME* 14(3); Web: www.spraytime.org.

News from TSS: Purdue Makes Precision Parts Using Laser and Machining

Researchers at Purdue University, West Lafayette, IN, are perfecting a technique to manufacture parts that have complex shapes and precision internal features by depositing layers of powder materials, melting the powder with a laser, and immediately machining each layer. The method is suitable for producing parts made of advanced materials such as ceramics according to Yung Shin, Professor of Mechanical Engineering and Director of Purdue's Center for Laser-Based Manufacturing.

Although the basic laser deposition technique is not new, the researchers have increased its precision by adding the machining step. The method is about 20 times more accurate than deposition without machining. Purdue University researchers have developed a facility that can deposit the powder, heat it with a laser, and machine it at the same time. The technique might be used for producing finished parts in small lot sizes more economically than by building traditional tooling such as dies.

Purdue's Office of Technology Commercialization has filed patent applications in connection with the laser-deposition-machining technique. The technique is available for licensing. For more information see: www.purdue.edu.

This information was adapted from the TSS publication *International Thermal Spray & Surface Engineering*, 2(4).

People in the News

2007 ASM Fellows Thermal Spray Field

ASM International inducted 25 new members into the 2007 Class of Fellows during the Annual Awards Dinner, which took place on September 18, 2007 in Detroit, MI. Dr. Richard A. Neiser and Dr. Jeganathan Karthikeyan are the members recognized by their colleagues in the Thermal Spray Field.

Richard A. Neiser

Dr. Richard A. Neiser, Principal Member of Technical Staff, works at Sandia National Laboratories, Albuquerque, NM. His citation reads ''For pioneering contributions in innovative process diagnostics and modeling to enhance fundamental understanding and improve control technology for thermal spray processes, and for exceptional leadership in thermal spray safety education.''

Jeganathan Karthikeyan

Dr. Jeganathan Karthikeyan, Director of Research & Development, works at ASB Industries, Barberton, OH. His citation reads ''For significant technical contributions to thermal spray technology ranging from superconducting coatings to thermal barriers and nanomaterials.''

Albert Kay Receives the GTS Ring of Honor

Albert Kay, president of ASB Industries, Barberton, OH, was awarded the GTS Ring of Honor at the recent Cold Spray 2007 conference held on October 8–9 in in Akron, Ohio. This award recognizes those people who have made a great contribution to thermal spraying and have committed themselves to the ideas of GTS. These ideas are: to set a high-quality standard for thermal spraying, to actively promote innovation, and to spread the thermal spray word and the GTS highlights of solidarity, sincerity, and state of the art.

The award was presented by Peter Heinrich, who, in his remarks stated ''Albert Kay has given the GTS ideas his full support in the United States and also worldwide. However, it is not only Albert Kay's contribution to thermal spraying which distinguishes him; he also excels in the way he takes on new challenges and achieves the objectives he sets for himself with a tremendous farsightedness. We only need think of cold spraying, for example. For me personally, Albert Kay, with his wealth of experience, warm-hearted manner, and above all his generosity has—if I may take this liberty—become a true friend. Al, I am very proud to award this ring to you today.''

Peter Heinrich (*right*) awards the GTS Ring of Honor to Albert Kay

Maher Boulos Awarded the *Prix du Québec*

Professor Maher Boulos of Sherbrooke University, Quebec, Canada, was awarded the *Prix du Québec* ''Lionel Boulet'' prize by the Government of Quebec on November 6, 2007.

The *Prix du Québec* is the most prestigious award attributed by the Government of Quebec in all fields of culture and science. Each year, the government attributes six such awards in the cultural field and five in the scientific field. The purpose of this tribute is to recognize the career of women and men who have demonstrated a passion for their calling. It is given to individuals who have stood out by their creative or innovative spirit and whose work has contributed to the influence of Quebec around the world and to the evolution of Quebec society in their respective fields.

Maher Boulos (*left*) receiving the 2007 *Prix du Québec*