Energy Applications
Surface Alloying with Tantalum
Technologies for IGT

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Recapping ITSC
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Chromalloy – Technologies For Industrial Gas Turbine Operators

Where's the News?
The dilemma – How relevant is the news section in a quarterly publication? Some of the best news stories could be as old as 3 months; by the time they are published, they are more history than news.
The solution – ASM has developed a Newswire service for distributing relevant news in a timely manner. ASM editors cull the news daily and choose the most important materials news stories for the thermal spray and other industries. News of interest to the thermal spray industry is posted directly to the TSS website!
Check it out on the ASM homepage (www.asminternational.org) and the ASM Thermal Spray Society website www.asminternational.org/tss
Let us know what you think!

Editor Christopher C. Berndt
Associate Editors Robert Gansert
William Jarosinski
Managing Editor Eileen De Guire
Art Director Barbara L. Brody
Production Manager Joanne Miller
Publisher Joe Zion

National Account Manager
Kelly Thomas, CEM, CMP
Materials Park, Ohio
tel: 440/338-1733
e-mail: kelly.thomas@asminternational.org

Thermal Spray Society Executive Committee
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Peter Hanneforth, Immediate Past President
Charles Kay, Vice President
William Lenling, Secretary/Treasurer
Thomas S. Passek, Executive Director

About the cover
A comparator is used to check blade surfaces for conformity to a master drawing, both for manufacturing and repair.
Photo courtesy of Chromalloy.
Dear Thermal Spray Colleague:

Thank you to all of the individuals and organizations who made the International Thermal Spray Conference and Exposition (ITSC 2009) in Las Vegas a success, and particularly to our attendees. It’s amazing the number of people you need to pull off an international gathering like ITSC!

The right programming and an attractive venue provided a positive learning and networking experience. We all have different ideas on how to grow markets in Europe, Asia and in the States, and how to get young professionals more involved in our societies and our industry. Perspectives from around the world came together in Vegas.

Our theme, “Expanding Thermal Spray Performance to New Markets and Applications,” touched on all aspects of the supply chain. Our featured events included the Legends of Thermal Spray, plenary talks by Tocalo and Messier-Dowty, market-focused talks by representatives from India, Korea and Nordic Europe, and a dedicated program on Reliability and Consistency.

There’s so much more to ITSC than the conference itself. There are also the conversations, the friendships, the board meetings and committee meetings, the United Nations of Thermal Spray! An ITSC is a constant stream of productive dialogue.

It was also tremendous to see the leaders of our industry – the Rolls-Royces, Praxairs, Lindes and Sulzers – coming together at the TSS Board meeting. Recommendations on safety and certification and programming were shared, not to benefit a company but for the good of our entire community.

ITSC was a success in every respect, from the technical sessions to the exhibits, and from our special events to the Annual Banquet, which featured a memorable performance by the legendary “Rat Pack.” From start to finish, it was an incredible experience. Thank you for being part of it.

Sincerely,

Mitch Dorfman
Sulzer Metco (US) Inc.
President, ASM Thermal Spray Society
General Co-Chair, ITSC 2009

Building on Success
Don’t forget about ITSC 2010 (www.dvs-ev.de/itsc2010/) in Singapore and the Cold Spray and Corrosion and Wear regional conferences in the fall of 2010.
Visit the TSS Community website (www.asminternational.org/tss) for updates on these exciting events.
TSS News

Successful ITSC 2009 event built on volunteer and staff effort

Take the leading thermal spray event in the world...add some challenging world economics...sprinkle in fears of a swine flu pandemic...and pour on the elbow grease. What do you get? ITSC “by the numbers” tells the story:

**ITSC 2009 by the Numbers**

- Total attendance: More than 800 from 30 countries
- Five technical tracks: Materials, Equipment & Processes, and Market Focused Symposia (Turbine, Semi-Conductor & Electronics, Technology, Biomedical; Applications and Case Studies) plus a general session
- 376 papers submitted and 250 presentations
- 210 published papers and 76 posters
- Technical conference comprised of:
  - 33 % papers from North America
  - 36 % from Europe
  - 26 % from Asia
  - 3 % from Oceania
  - 2 % from South America
- 88 exhibit booths, 55 companies from eight countries represented
- Key sponsors: Sulzer Metco, HAI Advanced Material Specialists, TOCALO Co., Ltd., HFW Industries
- Three inductees into the Thermal Spray Hall of Fame
  (Daryl Crammer, Akira Nakahira, Anatolii Papyrin)

**Special Thanks to Symposium Chairs and Volunteers**

The success of ITSC 2009 was the result of the vision and hard work of the symposium chairs. A special thanks is extended to the following symposium chairs.

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**Thank You Volunteers**

Behind the scenes, many TSS volunteers participated in the awards activities and special events that made ITSC 2009 a unique experience. These members include:

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<td>C. Berndt, P. Fauchais, D. Puerta, M. Boulus, J. Heberlein</td>
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**Building on Success**

Don’t forget about ITSC 2010 (www.dvs-ev.de/itsc2010/) in Singapore and the Cold Spray and Corrosion and Wear regional conferences in the fall of 2010. Visit the TSS Community website (www.asminternational.org/tss) for updates on these exciting events.
TSS Certification Update

May’s ITSC event in Las Vegas last month proved important to the ongoing progress of the ASM/TSS Certification Program for Thermal Spray Operators. “This was the first opportunity for the Thermal Spray Certification Committee (TSCC) to meet face-to-face, and we made substantial progress,” says Louise Wehrle, Ph.D., ASM manager for Certification Programs. The committee added two new members: Marc Froning of BASF and John Passmore of St. Louis Metallizing.

The TSCC determined the candidate profile for the Certified Thermal Spray Operator to be “a person who generally works under supervision to safely perform fundamental tasks for thermal spray that include taking a part from beginning to end of the spray process.”

The job/task analysis (what this candidate actually does) was outlined within areas of activity/responsibility:

- Safety and Environmental Compliance
- Set-up and Part Preparation
- Spray Equipment Operation and Maintenance
- Application of Coating
- Record Keeping and Quality.

Market research has identified certification as a priority for the thermal spray community. Eighty percent of respondents agreed that “Having thermal spray employees or contractors who are tested and certified will improve the quality and consistency of our thermal spray activities.”

JTST Best Paper Award

Dr. Roland Seals, chair of the Journal of Thermal Spray Technology Best Paper Subcommittee, announced the JTST Volume 17 Best Paper Award winners, as chosen by an international committee of expert judges. The awards were presented to the winning authors at International Thermal Spray Conference & Exposition 2009 in Las Vegas, Nevada.

Two papers tied for first place: “Parameters Controlling Liquid Plasma Spraying: Solutions, Sols, or Suspensions” by Pierre Fauchais, Ramuntxo Etchart-Salas, Vincent Rat, Jean-François Coudert, Nadège Caron, and Karine Wittmann-Ténèze; and “On the Role of Bubbles in Metallic Splat Nanopores and Adhesion” by Meng Qu and Andrew Gouldstone.

The Best Paper Honorable Mention was presented to “Room Temperature Impact Consolidation (RTIC) of Fine Ceramic Powder by Aerosol Deposition Method and Applications to Microdevices” by Jun Akedo.

Special thanks to the judging committee: Arvind Agarwal, David V. Bucci, Nadège Caron, Andrew Gouldstone, Vincent Guipont, David Hart, Jan Ilavsky, Bertrand Jodoin, George Kim, Jiri Matejicek, André McDonald, Tim McKechnie, Petri Vuoristo, James A. Rudd, Philip Shipway, Tsunekawa Yoshiki, Joel Voyer, and chair Roland D. Seals.

Congratulations are extended to the winning authors from the JTST Editorial Committee and the ASM Thermal Spray Society Board of Directors.

It pays to be a TSS member. Discover the member benefits.

Get the value only your professional society can give.

Chapters – Network and get involved with your local thermal spray community. Affiliation is free for all members.

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Quarterly iTSSe (International Thermal Spray & Engineering™) newsletter

FREE online, full-text access to Metallurgical Transactions A & B, going back to the first issue

Monthly ASM member magazine, Advanced Materials & Processes®, with special Thermal Spray focus issues and ASM eNews, including online access.

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Charles Kay
Vice President
ASB Industries, Inc.

“The value of TSS is something that I use almost every day.”

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MEMBER NEWS

Rick Knight receives TSS President’s Award

TSS president, Mitch Dorfman (left), presented the 2009 TSS President’s Award to Dr. Rick Knight, FASM (right), auxiliary professor at Drexel University, at the April meeting of the ASM Philadelphia (Liberty Bell) Chapter. Dr. Knight has been a tremendous advocate for TSS since its very beginnings. He served as a board member in 1996, and served on the society’s executive leadership team as secretary-treasurer in 1999, vice president in 2002, and president in 2004. Retired from the TSS Board after a full decade of service, he continues to serve the society as a member of the Program Committee and as a member of the Membership, Marketing and Outreach Committee.

Goodspeed named thermal spray market manager at Farr APC

Farr Air Pollution Control (APC) has appointed Scott R. Goodspeed to the newly created position of thermal spray market manager. With 36 years of sales, managerial, and technical experience in the thermal spray industry, Mr. Goodspeed will oversee all aspects of Farr APC’s growing thermal spray dust collection business. Farr APC manufactures a full line of dust and fume collectors and filters that improve operating efficiency, enhance safety, and solve environmental compliance challenges. In addition to ASM TSS, he has held leadership positions in the International Thermal Spray Assoc., is a member of the American Welding Society, and has served his community as a firefighter for 25 years.

In Memorium

The thermal spray community lost a promising young colleague with the untimely, accidental death of Materials Advantage student, Abhinav (Abhi) Parasmal Choudhari. A graduate student at the University of Michigan, Mr. Choudhari worked on cold spray research under the guidance of Prof. Pravansu Mohanty. Originally from India, Mr. Choudhari was 25 years old.


ITSC 2010 Singapore — Present, Exhibit, and Learn.

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Go to www.asminternational.org/itsc for details and registration.
Tantalum Surface Alloying of Parts for Corrosive Hydrogen Production Process

Dean Gambale
Americas for Tantaline Inc.
Waltham, Massachusetts

With increasing demand for energy and environmental concerns on the rise, there is a tremendous focus to develop the next generation of energy. Advanced processes for coal, natural gas, and especially hydrogen are being explored as possible alternatives to oil to serve the world’s ever-increasing needs. However, in many cases, there is one critical factor limiting the success of these next generation processes – corrosion. The wide range of process temperatures, pressures, and chemical concentrations required pushes beyond the engineering limits of standard materials. As a result, new revolutionary materials have been developed, which not only enable energy research to continue, but also open up the prospect of an abundant, affordable infrastructure to support and deliver a clean energy supply.

Tantaline, based in Waltham, Mass., is a recent newcomer to the growing market for new materials for energy applications. The company’s surface alloying process produces what is claimed to be the most highly corrosion resistant material commercially available and is especially suited for projects that work with hot acids or highly corrosive chemicals. With this process, engineers have higher performance at a cost less than specialty metals like nickel, titanium, and zirconium base alloys – a significant benefit in any economic environment.

Surface Alloying with Tantalum

The tantalum vapor surface alloying technology takes advantage of the superior corrosion resistance properties of tantalum, and can be applied to almost any OEM standard or stainless steel part. Common parts selected for treatment include valves, fittings, instrumentation, etc.

In a furnace heated to 700-900 °C, the tantalum metal is chemically reacted and vaporized. The gaseous tantalum diffuses into the substrate, typically stainless steel, creating a surface alloy approximately 50 µm thick. The gaseous tantalum atmosphere is maintained in the furnace so that a dense layer of pure tantalum grows on the surface of the part over the diffusion layer. The pure tantalum surface layer is also about 50 µm thick. The treated part has the original OEM part size and shape, but now has the same chemical properties and corrosion resistance as pure tantalum metal. The figure shows how the layers develop when a washer made of 316 stainless steel is subjected to the treatment.

Case Study – Hydrogen Production

Hydrogen fuel is an attractive alternative for the world’s energy problem. However, hydrogen currently is produced from fossil fuels, and, therefore, does not yet contribute to energy independence. General Atomics, a high-technology systems development company, turned to Tantaline as part of a demonstration to supply hydrogen for a hydrogen-based economy from a sulfur-iodine thermochemical process. The sulfur-iodine process involves hydrogen production by thermochromically decomposing water into hydrogen and oxygen without using fossil fuels (see sidebar). Heat and water are the only inputs while oxygen and hydrogen are the only outputs, resulting in no emissions.

A key challenge General Atomics faced was the exceedingly corrosive nature of the process. The sulfur-iodine thermochemical reactions are aggressive mechanically and chemically, requiring materials that can handle high temperatures and pressures along with concentrated, corrosive acids and chemicals. The combination of a severe operating environment and highly corrosive chemicals limits materials choices; even specialty materials like Hastelloy (Haynes International Inc.) struggled to survive a few days. General Atomics found that the tantalum surface alloy was the only material that could effectively resist the corrosive environment and make the process economically and technically feasible.

General Atomics has installed more than 1,500 parts that have been treated by Tantaline in the form of Swagelok (Solon, Ohio) fittings, valves, and instrumentation. The tantalum surface alloys enabled General Atomics to continue the project, demonstrating that the sulfur-iodine thermochemical process can be a viable commercial alternative for future hydrogen energy production.

For more information: Dean Gambale, CEO, Americas for Tantaline; 1050 Winter St., Suite 1000, Waltham, MA 02451; tel.: 1-888/268-2586; dgambale@tantaline.com; www.tantaline.com.
Written Programs an OSHA Inspector May Ask to See

Occupational Safety and Health Administration (OSHA) compliance involves maintaining several mandatory written programs and records. The following is a management checklist of five of the most common written programs and records that an OSHA inspector might ask to see.

1. OSHA 300 Log - If you have 10 or more employees, you need to keep an OSHA 300 Log (29CFR1904). The OSHA log is a uniform way of providing information to the Bureau of Labor Statistics (BLS). Make sure that whoever is in charge of keeping your OSHA 300 Log reads and understands the OSHA guidelines. In many cases, good case management and knowledge of the record-keeping rules can save you a recordable injury.

2. Lockout/Tagout Program - The purpose of a lockout/tagout program (CFR1910.147) is to ensure the safety of personnel by preventing equipment activation anytime maintenance or repair work is being performed. Programs must be designed to protect the safety of employees working on, or close to, equipment with the potential for unexpected operation, movement, release of energy, or release of hazardous materials.

3. Process Safety - OSHA’s Process Safety Management Standard (CFR1910.119) establishes requirements that employers must follow to prevent catastrophic losses associated with certain chemical processes. Some of these requirements include employee training, prestart safety reviews, mechanical integrity inspections, and emergency planning and response. The standard applies to any process involving one or more of the listed highly hazardous chemicals (such as ammonia, hydrochloric and hydrofluoric acids, hydrogen, and propylene) at or above the threshold quantity, or any process that involves a flammable liquid or gas in a quantity of 10,000 lb or more.

4. Emergency Action Plan - OSHA requires that action plans (CFR1910.38) be in writing and cover actions that designated employers and employees are expected to take to ensure employee safety from fire and other emergencies. The plans should identify potential emergency situations and convey to employees just what their responses should be.

5. Respirator Program - If respirators are necessary in your workplace to protect the health of employees, you must establish and implement a written respiratory protection program (CFR1910.134) with work site-specific procedures. The program must be updated as necessary to reflect changes in workplace conditions affecting respirator use.

Progressive Idea #18

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After several decades of developing gas turbine components, coatings and repair solutions targeting aerospace engine operators, Chromalloy’s focus on the industrial gas turbine (IGT) segment is now set to increase.

“Our main focus continues to be developing innovative solutions and collaborating with turbine engine original equipment manufacturers (OEMs),” said Komal Laul, Chromalloy repair development engineer. “Chromalloy has years of expertise in the industrial gas turbine segment – and we work closely with the OEMs as well as directly with power plant operators. In addition, we perform maintenance and repair work at our facilities around the world.”

Many Chromalloy technologies developed for aerospace applications are now fully integrated into the IGT components that are part of OEM manufacturing, as well as used in the repair of turbine components.

New Leadership

Chromalloy is the world’s largest independent supplier of technologically advanced repairs, coatings, and FAA approved replacement parts for turbine airfoils and other critical engine components for commercial airlines, the military, and industrial turbine engine applications. Chromalloy employs over 4,000 engineers, metallurgists, chemists, and highly trained technicians and operates 30 sales and production operations in 14 countries world wide.

Chromalloy was acquired by the Carlyle Group in 2007 and has a new president, Armand Lauzon, Jr.

“Lauzon’s leadership has brought a global mindset to the organization, as well as revitalized the company,” Laul said. “A key focus continues to be growing our IGT work – and that includes expanding relationships that we already have and forging new alliances with the OEMs, power plant operators and other customers.”

Coatings Tailored for Applications

“Chromalloy is a powerhouse for innovative diffusion and overlay coatings used in OEM manufacturing and IGT components,” Laul said.

For the last six decades, Chromalloy has pioneered protective coatings for turbine engine components from cone to tail.

“We continue to partner with customers around the world to develop the most advanced coatings, from aluminide and platinum aluminides to low-pressure plasma spray overlay and electron beam physical vapor deposition coatings,” Laul said.

“Our wide array of proprietary and patented coatings are available for manufacturing and repair of industrial gas turbine components,” he said. “This includes coatings such as pack and vapor aluminides, platinum aluminides, cubic boron nitride (CBN) based blade tip coatings, low pressure plasma spray (LPPS) applied metallic coatings, electron beam – physical vapor deposition (EB-PVD) applied coatings, as well as lower conductivity thermal barrier coatings, polyester enhanced abradable seal coatings, and other unique coating combinations.”

Other technologies include spray welding methods including vision-guided interactive laser welding and shrouded tungsten inert gas welding, vision-guided cooling hole reinstallation systems, laser installed conical and the more sophisticated “shaped cooling hole” systems, advanced conventional and electron discharge machining equipment.

Repair Solutions from Aerospace to Industrial

Chromalloy repairs extend the life of turbine engines, helping customers reduce their operating costs.

“On repairs, we again partner closely with customers to develop repairs for the entire engine that combine our engineering expertise with our world-class processes for component refurbishment, coating application, and cooling-hole installation. Our focus on quality and repeatability towards our repair processes add longevity to engine components, thereby reducing operating costs,” he said.

Chromalloy recently provided a solution regarding a vertically segmented coating for an operator that needed to find a lower cost solution.

“We offered the power plant operator an EB-PVD coating component that was at a discount compared to an OEM vertically segmented coating,” Laul said. “This solution helped the operator and provided a superior component for their need.”

The operator sought an alternative to the hardware that uses the segmented, vertically cracked air plasma sprayed (APS) thermal barrier coating (TBC). “The vertically cracked APS TBC tries to emulate the performance of an EB-PVD coating. By providing our customer an EB-PVD coating, we provided him with an outstanding value, which would improve the service life of the components because of the natural columnar structure of the EB-PVD coatings,” he added.

In another case, Chromalloy provided a solution for an operator for a brazing paste to close the cooling holes in the repair process.

Traditional repair methodology included coating over the cooling holes and then reopening the cooling holes after the coatings have been applied. “This process is time consuming
and also affects the cooling airflow from the holes, compromising the performance of the repaired components,” Laul said. “With the ability to fill in cooling holes with braze, we are allowed the opportunity to re-laser drill the existing cooling hole pattern, with OEM type airflow results, or the ability to drill new cooling hole patterns altogether thus improving the performance of a refurbished component.”

From Casting to Coating
Chromalloy has a wide range of services within its manufacturing and castings facilities - laser powder welding, directional welding, induction welding, superalloy brazing, machining, plasma coatings (low pressure plasma spraying for metallic coatings and APS for ceramic), newly developed thermal barrier coatings, innovative methods for cooling hole reinstallation for repairs, equiaxed, directionally solidified and single crystal castings - that provide operators the ability to rely on Chromalloy as a “one-stop shop.”

“Our customers can provide us with a single purchase order and we can deliver an end-product that is ready to be installed in the engine,” Laul said.

By combining casting, machining, coating, and laser drilling operations, Chromalloy simplifies repairs for operators, reduces the repair cycle time, and saves operators money that may have been spent on inventory costs. “This is a unique approach for component manufacturing. In the past, the components would require processing by three or four different vendors before reaching the operator. The cost savings from using single point manufacturing can be substantial,” he said.

Value-Added Parts
Chromalloy was the first manufacturer to provide non-OEM flight hardware including Parts Manufacturer Approval (PMA) parts for the high-pressure turbine section of an engine. “Chromalloy is adding to its product offerings for PMA-type components in the IGT market. Chromalloy’s OEM-alternate parts help operators control their expenses,” he added.

The company’s capabilities include single crystal, directionally solidified and equiaxed casting technology, advanced metallic, ceramic and abradable coatings, machining and cooling holes installation. “These enable us to produce components quickly and at a lower price than our competitors, providing value for operators, Laul said.

The company continues to make significant investments in its operations, including a $16.5 million investment in its casting operation in Tampa, Fla., several million dollars in conventional and electron discharge machining, and additional low pressure plasma spray and air plasma spray coating equipment at its facilities. These investments and new capability give Chromalloy the ability to offer a one-stop service for customers in the repair and production process.

Chromalloy’s 113,000 ft² turbine component manufacturing center in Tampa provides design, developing, machining and casting of turbine engine components. “We plan to stay on the leading edge.” Laul said.

For more information: Komal Laul, 4430 Director Dr., San Antonio, TX 78219; tel.: 210/333-6010; klaul@chromalloy.com; www.chromalloy.com.

For more information: Tekna, 819-620-2204, info@tekna.com; www.tekna.com.

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**JTST HIGHLIGHTS**

The Journal of Thermal Spray Technology (JTST), the official journal of the ASM Thermal Spray Society, publishes contributions on all aspects – fundamental and practical – of thermal spray science, including processes, feedstock manufacture, testing, and characterization. As the primary vehicle for thermal spray information transfer, its mission is to synthesize the rapidly advancing thermal spray industry and related industries by presenting research and development efforts leading to advancements in implementable engineering applications of the technology.

Several articles from the September issue 18(3), as selected by JTST editor Christian Moreau, are highlighted here.

In addition to the print publication, JTST is available online through www.springerlink.com. For more information, please visit www.asminternational.org/tss.

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**“Bonding Mechanisms in Cold Spraying – The Contributions of Metallurgical and Mechanical Components”**

Tanvir Hussain, D. Graham McCartney, Philip H. Shipway, and Deen Zhang

The mechanism of bonding in cold spraying is still a matter of some debate. In this work, copper has been cold sprayed onto aluminium alloy substrates, the surfaces of which had been prepared in a variety of ways. The coating-substrate bonding was assessed via a novel intermetallic growth method along with adhesive pull-off testing, and related to the substrate preparation method. The bond strength has been rationalised in terms of a modified composite strength model, with two operative bonding mechanisms, namely 1) metallurgical bonding and 2) mechanical interlocking of substrate material into the coating. In most cases, mechanical interlocking is able to account for a large proportion of the total bond strength, with metallurgical bonding only contributing significantly when the substrate had been polished and annealed prior to spraying. In addition, grit-blasting has been shown to significantly reduce the bond strength compared to other substrate preparation methods.

**“Microstructure of Suspension Plasma Spray and Air Plasma Spray Al2O3-ZrO2 Composite Coatings”**

Dianying Chen, Eric H. Jordan, and Maurice Gell

Al2O3-ZrO2 coatings were deposited by the suspension plasma spray (SPS) molecularly mixed amorphous powder and the conventional air plasma spray (APS) Al2O3-ZrO2 crystalline powder. The amorphous powder was produced by heat treatment of molecularly mixed chemical solution precursors below their crystallization temperatures. Phase composition and microstructure of the as-synthesized and heat-treated SPS and APS coatings were characterized by XRD and SEM. XRD analysis shows that the as-sprayed SPS coating is composed of α-Al2O3 and tetragonal ZrO2 phases; while the as-sprayed APS coating consists of tetragonal ZrO2, α-Al2O3, and γ-Al2O3 phases. Microstructure characterization revealed that the Al2O3 and ZrO2 phase distribution in SPS coatings is much more homogeneous than that of APS coatings.

**“Effects of Temperature of In-flight Particles on Bonding and Microstructure in Warm Sprayed Titanium Deposits”**

KeeHyun Kim, Makoto Watanabe, Jin Kawakita, and Seiji Kuroda

Micron-sized titanium particles were deposited on steel substrates by warm spraying, which is a modified high velocity oxy-fuel (HVOF) spraying technique. In the process, nitrogen gas is mixed with the HVOF flame jet to lower the temperature of injected powder particles. Observations of splats formed on polished substrates using SEM and TEM were conducted to investigate the effects of particle temperature on the bonding of splats with the substrate and the microstructure within the splats. At lower nitrogen flow rates, the particles were heavily deformed with diverse splat morphologies and microstructures. At higher flow rates, most of the particles were impacted in the solid state and the oxidation of particles was remarkably less. TEM revealed different microstructures within the splats and splat/substrate interfaces depending on whether the particle was molten or solid before the impact.

**“Microstructure and Properties Characterization of Silicon Coatings Prepared by Vacuum Plasma Spraying Technology”**

Yaran Niu, Xuan Yong Liu, Xuebin Zheng, Heng Ji, and Chuanxian Ding

Silicon coatings were fabricated by vacuum plasma spraying technology. The morphology, composition and microstructure of the coatings were investigated by FESEM, XRD, WDX and TEM. The physical, mechanical, and thermal properties of the coatings were characterized. Vacuum plasma sprayed silicon coatings were compact and consisted of well melted silicon splats. Oxidation introduced by the spray process was limited. Small ball-like particles less than 1µm existed both on the surface and inside the coatings. Silicon coatings consisted of silicon grains with irregular shapes and different sizes of 0.5-1µm. The longitudinal microstructure of silicon coatings exhibited typical two-layer microstructure of equiaxed nanometer grains and overlying columnar grains. The open porosity, density and surface roughness of silicon coatings were 3.2 %, 2.24 g·cm–3, 3.47 µm, respectively. Microhardness and bonding strength of silicon coating were 7.00 GPa and 20.6 MPa, respectively.
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