Volume 2, Issue 2
Fall 2012

Center for Thermal Spray Research

www.ctsr-sunysb.org

STONY BROOK
STATE UNIVERSITY OF NEW YORK

Going Beyond the Surface

LINKING RESEARCH TO PRACTICE

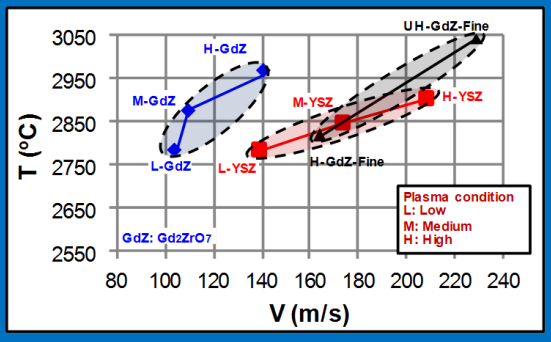
Message from the Director

Our 10th annual newsletter began development the day after hurricane Sandy has ravaged through our part of the world. We are all fortunate that there is no loss of life or injuries, but the area around Stony Brook has experienced significant damage resulting in disruptions in power and communications. Fortunately, Stony Brook campus has its own gas turbine co-gen and as such most of us have sought refuge here in our offices on this "day-after". It is ironic that since there is no internet, students and staff have gone back to the old fashioned way of communicating i.e. talking. We will get through this one in the next few days. As this newsletter goes to press, we are preparing for our fall consortium meeting which will be held at the Boeing Museum of Flight in Seattle. This meeting is co-hosted by friends at Boeing Company, Marc Froning and CTSR alumnus Arash Ghabchi. Over the last few years, together with our industrial friends we have sought to rotate the fall meeting around the country in conjunction with OEM partners. More details on the next page. We have continued to make substantial progress in research, scholarship, knowledge transfer and mentoring. 2011-2012 was a blockbuster year in terms of our federally sponsored research activity as well as consortium efforts. Our NSF, DoE, ONR and the Transportation Research programs have all produced exciting new results. Some of the salient accomplishments are highlighted in this newsletter. Our thermal spray facility continues to evolve as we have added two new spray cells in the high bay area and are currently incorporating advanced diagnostics within the cells. These new spray cells will allow us to enhance our student training programs. We are grateful to Sulzer Metco for their generous support of equipment and service to get these facilities operational. CTSR also welcomes two new affiliate faculty members. Molly Gentleman and Jason Trelewicz joined the materials department as assistant professors in September. Molly comes to us from Texas A&M University. She received her PhD in Materials from University of California Santa Barbara following which she spent 3 years working at GE Research on advanced coating development. Jason is an alumnus of our program receiving his BS degree from Stony Brook engineering and subsequently obtained a PhD in materials from MIT. Following his doctoral work, Jason worked for 4 years at MesoScribe Technologies involved in advanced sensor fabrication. We welcome Molly and Jason to the team and look forward to their contributions to the Center. More details about their research are profiled in the following pages. Our consortium program continues to thrive with some 36 members. The meetings are very well attended with significant interaction both with the Center as well as among the participants. The consortium is slowly but steadily elevating the knowledge in the field, perhaps more importantly providing utilization of advanced scientific concepts in industrial practice for improved coating design, enhanced efficiency and reliability. As always, I invite you to join the CTSR team to realize our common goal, to make thermal spray a household word.

- Sanjay Sampath

Optimizing Compliance and Conductivity of New Thermal Barrier Oxides

Through sponsorship from the Department of Energy's University Turbine Systems program, CTSR researchers have been applying advanced diagnostics, process maps and non-linear property measurements to new thermal barrier oxides. The main focus is exploring new oxides that can potentially enable TBC application in coal gasified high hydrogen turbines. In coal gas operations, the TBCs are subjected to significantly higher heat loads, exposure to higher moisture content, fly ash erosion and lignite deposits. Current understanding suggests YSZ TBCs may not provide requisite performance under these conditions and hence the quest for new oxides. CTSR work has focused on exploring Gadolinium Zirconate ($Gd_2Zr_2O_7$) and NASA developed cluster doped compositions (with Y, Yb and Gd). Several processing challenges arise with the zirconates Although they are resistant to ash attack, these have lower toughness and thus lower erosion resistance. Secondly, the zirconates are incompatible with the thermally grown alumina layer and thus requires a two layer top coat solution incorporating a YSZ interlayer. Reliable fabrication of such multilayers imparts new challenges to the plasma spray community however , work to date has shown that knowledge gained from the YSZ processing science can be readily translated to the new systems. The CTSR group in collaboration with industrial partners is integrating process science with property and performance characterization to provide generic tools for process and coating design. Advances from this work can also enhance TBC application in natural gas turbines.



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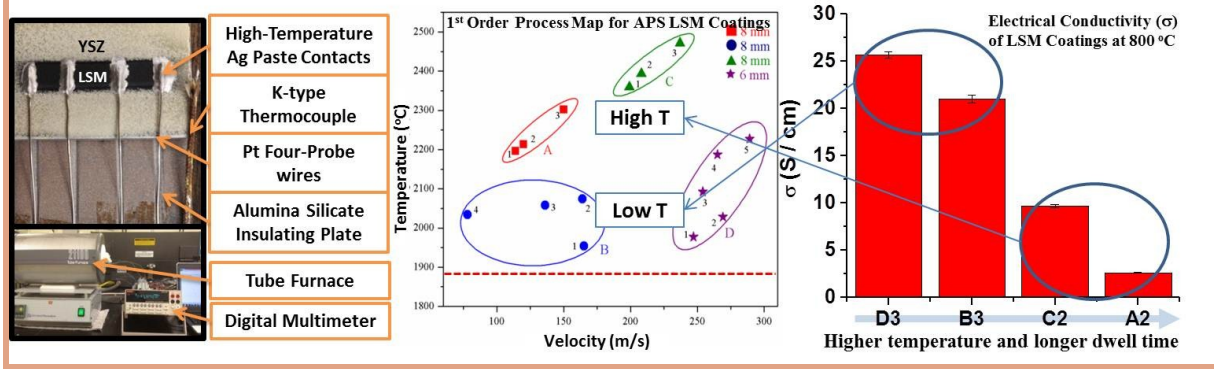
Industrial Consortium News

The Consortium for Thermal Spray Technology hosted by CTSR continues to expand and provide benefits to industry across the supply chain. 2012 saw the addition of Pratt and Whitney to the membership. We welcome their participation and look forward to productive interactions in the coming years. The fall 2011 meeting was hosted by GE Aviation at their facilities in Evandale, OH. GE hosted a reception for the participants at their learning center site which has an impressive display for GE engine products starting from the 1950s to present day. It was not only an enjoyable and interactive evening but also a treat to see these advanced systems on display. We are grateful to GE for supporting this event. The spring 2012 consortium was held at Stony Brook campus and was our largest event with some 80+ participants over 2 days. As this newsletter goes to press, we will be gathering for our fall 2012 meeting in Seattle, hosted by our friends at the Boeing company.

Our consortium strategy going forward will seek to rotate the fall meetings around strategic partner sites with an emphasis to involve our OEM partners. This allows larger participation of design and manufacturing engineers from these organizations which will be crucial to enhance thermal spray coating utilization in engineering systems. Each company contributes $12,500/year through membership fees which enable self-sustaining operation of CTSR following its 11-year National Science Foundation grant enabling continued research, knowledge transfer and human resource development activities. Complementary funding to the tune of $5M has been received through NSF, DoE, DoD and the University enabling CTSR to thrive and continue to be the focal point of thermal spray research

Measuring High Temperature Electrical Properties of Thermal Sprayed Oxides

Functional ceramic oxides are important classes of multi-component materials that display resistive, semiconductive and conductive electrical behavior. They find extensive applications in RF/microwave systems, power electronics, sensors, batteries and fuel cells. Fabrication of these oxide materials is a challenge due to their refractory nature and requirement for high temperature processing. Thermal spray offers a novel processing pathway for the synthesis and fabrication of these materials. However, the nature of the thermal spray process in terms of rapid quenching, layered assemblage and porosity all result in complex defected microstructure and significantly affect electrical response. As opportunities for thermal sprayed functional oxides arise, it is of importance to understand their electrical properties from the perspective of extrinsic (pores/interfaces) and intrinsic (disorder, metastability, stoichiometry) defects. CTSR, under the sponsorship of the National Science Foundation Partnership for Innovation program is examining critical attributes of the process-structure-property relationships in functional oxides. One element of this work is establishing tools and methods to fabricate and characterize the electrical properties at temperature. In the figure below we show design of a test structure along with measurement and correlation to process condition. This initial work was conducted for plasma sprayed La (Sr)MnO_3 material which is of significant interest to the fuel cell community. The figure on the left shows a test sample comprising of an insulating undercoat of YSZ onto stainless steel , followed by strip of plasma sprayed LSM deposited with a mask onto which platinum wires (4 probe) are attached with silver paste. Center shows a first order process map for APS LSM along with high temperature conductivity measured via the above mentioned set-up. The results on the right show strong correlation between conductivity and process condition, thus providing the connection between process-microstructure and functional properties.



CTSR Welcomes New Affiliate Faculty Members

Professor Molly Gentleman: Molly's research group focuses on the characterization of coatings using optical and surface techniques including Raman and luminescence spectroscopy as well as surface energy measurements. She has been pioneering the observation and measurement of ferroelastic properties of TBC coatings using Raman spectroscopy. With her lab, she brings a Raman microprobe spectrometer with mapping capabilities from the ultraviolet to near infrared at temperatures as high as 1500 °C. These capabilities will allow for in depth studies of the toughening mechanisms in individual splats and how they interact with the TBC as a whole. Her lab also works on developing ceramic coatings with superhydrophobic/water shedding properties for steam turbines and biocompatible surfaces for medical implants.

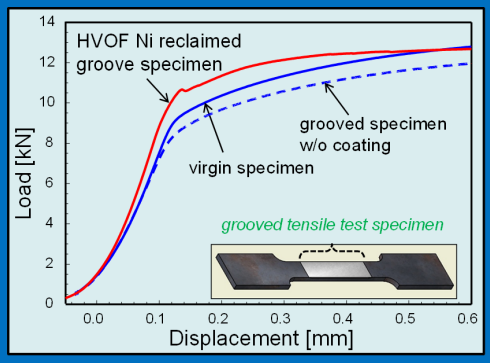
Professor Jason Trelewicz: Jason's research group studies the science and engineering of nanostructured and amorphous alloy coatings deposited by a variety of non-equilibrium deposition techniques. Particular emphasis is being placed on understanding the fundamental physics responsible for the breakdown of physical scaling laws as characteristic microstructural length scales approach the nanometer regime. Using this knowledge, unique microstructures are being designed to simultaneously optimize multiple material properties and develop novel multifunctional nanocomposite coatings. He is establishing a new electrodeposition laboratory on campus, which will be used in electroforming of amorphous, nanocrystalline, and advanced nanocomposite alloys. These materials will be compared with thermal spray coatings of nominally identical composition to study the role of alloying in nanostructure stabilization and how hierarchal defect structures influence the mechanical and corrosion behavior of nanostructured materials.

Professor Sampath Promoted to SUNY Distinguished Professor

CTSR Director, Professor Sampath was recently appointed to the rank of Distinguished Professor by the State University of New York Board of Trustees. The rank of Distinguished Professor is the University's highest faculty designation. "Sanjay's leadership, research and dedication make him truly deserving of the Distinguished Professor designation," said Samuel L. Stanley Jr., MD, President, Stony Brook University. "For more than 20 years he has enriched the Materials Science and Engineering department and the entire University. Stony Brook is fortunate to have him on our faculty and looks forward to many more contributions from him in teaching, research and discovery." "We are truly delighted that Sanjay joins the prestigious rank of SUNY Distinguished Professors in recognition of his sustained commitment to excellence in interdisciplinary research transcending the boundaries of materials science and engineering," said Dennis N. Assanis, Provost, and Senior Vice President for Academic Affairs. "He has made an unusual impact in this field, not only through his basic discoveries, but also through their translation into innovative applications."

Structurally Integrated Coatings Takes Center Stage in CTSR Research Programs

Structurally integrated coatings, a term coined by our colleagues at Caterpillar in the early 1990s, led to a joint research program between Caterpillar, CTSR and other partners as part of a US Government Advanced Technology program. The goal therein was to design and build thick overlay graded metal-carbide coatings onto steel structures that would impart step change in wear and corrosion resistance of materials used in high contact stress earth moving heavy machinery. Almost two decades since, the term has taken new meaning in CTSR's research involving thin thermal sprayed overlays, where the coating and its application process can be sensitive to the parent metal structure. For instance, in the recent work on chrome plate replacement for aero-landing gear any fatigue debit of the parent structure associated with coatings and its applique needs to be carefully examined. Results indicate that HVOF sprayed coatings can enhance the fatigue life of hardened steel alloys, but some sensitivity to process condition and materials selection is noted. Recent research has shown that these sensitivities arise due to differences in state of residual stress in the coating and substrate due to both deposition parameters (e.g. extent of peening stress) as well as thermal excursion during coating application. As additional applications for such chrome plate replacements are contemplated onto light metal substrates (Al and Ti alloys), and confined geometry ID components, the interplay between processing, material addition and thermal exposure on both static and dynamic mechanical properties are becoming of interest. In addition, opportunities in structural reclamation using thermal spray and cold spray processes can also lead to potential (beneficial) modifications of the structural properties of the parent metal or coated composite. For instance, CTSR, through support from the Transportation Research Board has been researching the concept of *in situ* repair of corroded steel in bridge structures as a temporary method for reclaiming the structural strength while reducing further propensity for corrosion. Systematic static (see figure) and dynamic mechanical testing studies are underway in conjunction with process map strategy for coating optimization and in situ and ex situ characterization of residual stresses. Robust explanation of process induced changes will enable realization of the "structurally integrated coatings" paradigm for both thick layers as envisioned in the past and thin coatings of current interest.



CTSR Hosts Alumni Reunion

Following the spring 2012 consortium, CTSR hosted a day long alumni workshop and reunion. Some 30 of our alumni from the 1970s to the present gathered for this festive event. Several of our international alumni made it a point to make the long journey for this momentous occasion. The event began with lab tours and demonstrations in the morning show casing the growth of the center especially the new facilities and programs.

Following lunch, an alumni workshop was held, featuring presentations from several of our accomplished alumni with topics ranging from advanced thermal spray coatings to novel building materials and even design/manufacturing of stents. The event concluded with a dinner gathering in Port Jefferson harbor involving alumni and their families. Some 90 people joined in the festivities completing a memorable reunion.

Photographs courtesy of Frank Fumelli of Sulzer Metco, a Stony Brook University alumnus

Alumni Focus: Dr.Jan Ilavsky

In this newsletter, we are pleased to recognize, Dr. Jan Ilavsky of the Advanced Photon Source at Argonne National Laboratory. Jan came to Stony Brook to pursue graduate work in 1991 from the Czech Republic. Following the political changes in Eastern Europe a relationship developed between the Institute of Plasma Physics in Prague and the Thermal Spray Laboratory at Stony Brook facilitated by the respective directors at that time Dr. Pavel Chraska and Prof. Herman. Jan not only came to study at Stony Brook but also facilitated the installation and operation of the Water Stabilized Plasma system donated by the institute to Stony Brook. Jan with fellow colleagues at that time Bob Gansert were instrumental in establishing industrial interest for the water plasma in the US. Jan was the trail blazer of this period of great collaboration between Stony Brook and our Czech colleagues resulting in several young Czech students joining our advanced degree programs and concurrent opportunities for Stony Brook students to visit Czech Republic for extended research visits. Jan's greatest contribution to the field of thermal spray was the development and application of advanced x-ray and neutron scattering techniques to characterize pores in thermal spray coatings. In many respect, he made Prof. Herman's dream come true as Herb always thought neutrons offered a 3D/large volume technique to characterize porosity. Jan shuttled numerous times between Brookhaven Lab (working with the late Dr. Goland) and to NIST Gaithersburg (with Drs. Andrew Allen and Gabrielle Long) and together they established appropriate small angle scattering models to describe thermal spray coating defects. In many ways, this was a game changer in our understanding of thermal spray process and materials. After a brief return to Prague for a couple of years in the late 1990s, Jan returned to US to further catalyze collaborations between Stony Brook and NIST, resulting in a highly productive period of research with some 20 journal publications in just two years. Jan then went onto the Advanced Photon Source at Argonne, where he extended small angle scattering with high energy synchrotron X-rays. AS a beam line scientist, he not only continues to study spray coatings as a personal interest but also supports characterization of a variety of engineering materials. In addition to continuing collaborations with Prof. Herman, Jan expanded his collaborations by facilitating partnership with the thermal spray groups at both University of Limoges and Belfort (in France) to apply scattering concepts to suspension sprayed coatings. Jan is always open to collaboration with both industry and academia especially if it can further enhance our knowledge of coatings. Jan and his wife, Irena have two children; son, David, 21, is currently a bachelor of Chemical and Electrical Engineering student at IIT in Chicago and daughter, Veronika, 15, is a high school student. He lives in Naperville and enjoys sports and travel, when his busy experimental schedule allows.