

LINKING RESEARCH TO PRACTICE

Going Beyond the Surface

Message from the Director

I am pleased to introduce our sixth annual Center for Thermal Spray Research newsletter "Going Beyond the Surface". This issue comes during a time of exciting developments and transitions. The *Consortium for Thermal Spray Technology*, the center led academic-industry partnership, is now entering its 6th year involving some 25 companies. Just in the last year alone some 7 companies have joined the forum, demonstrating the value of such a pre-competitive collaboration. The Consortium is becoming more international with the participation from Mitsubishi, Volvo Aero and Alstom Power.

Significant progress has been made over the last two years in various aspects of thermal spray processes and materials. These advancements are slowly but steadily being transitioned to industry. Notable is the progress in the development and implementation of the CTSR developed *insitu coating property* (ICP) sensor. Originally developed as a means to assess *in-plane* elastic properties of coatings and to monitor residual stresses, Center researchers have significantly increased the value of this tool in its ability to monitor coating formation repeatability, rapid assessment of parameters effects, and most notably non-linear and anelastic properties of ceramic coatings. CTSR students and staff have demonstrated the utility of this approach through field trips to industrial locations. Over the last year, ICP experiments have been carried out at Caterpillar, Stellite, Praxair, Sulzer, PTI, Tinker Air Force base and even Volvo Aero in Sweden. These interactions are not only beneficial to industry but also provide students and post docs with exposure to industrial practice.

We are now fully settled in our new facilities within the

expanded Heavy Engineering building, including the facilitation of a one-of-a-kind K-12 outreach center, the SPLAT center (Spraying, Learning and Teaching). Outreach coordinator Lysa Russo along with several teachers organized a trial summer camp for middle school kids which was very well received. (see following pages).

Over the last couple of years we have also had many opportunities to host international scientists and students. Prof. Ghislaine Bertrand from Univ of Belfort, France, Dr. Robert Vassen from Juelich Research Center Germany, Dr. Bryony James from University of Auckland, New Zealand to name a few. Several graduate students from Italy, Sweden, New Zealand and Czech republic have also participated in Center's programs and benefited from research interactions and access to unique facilities.

There have been people transitions over the last two years. A number of students have graduated and gone onto gainful employment while new students have joined to fill in their shoes. Prof. Andrew Gouldstone returned to Boston to pursue his interests in mechanics of biological systems, while Profs. Hui Zhang and Lili Zheng from the Mechanical Engineering department have moved back to more lucrative opportunities in China. We wish them well. We are fortunate to have been able to recruit Chris Weyant as an assistant professor. Chris brings solid background in thermal spray as well industrial experience having worked at Honeywell for two years. We look forward to Chris's contributions in the years to come.

As always, I invite you to join the CTSR team to realize our common goal: to make thermal spray a household word.

Sanjay Sampath
Director CTSR

CTSR Signs Memorandum of Understanding with NIMS Japan

Prof. Sampath had the opportunity to spend several weeks this past summer at the National Institute of Materials Science (NIMS) in Tsukuba, Japan, participating in research discussions and collaborative interactions. Prof. Sampath's trip was sponsored by the NIMS visiting researcher program through their international center. Dr. Seiji Kuroda, Managing Director of the coatings and composites center at NIMS hosted the visit. During his trip Prof. Sampath had the opportunity to meet Prof. Teruo Kishi, President of NIMS. Prof. Kishi has significantly expanded the role of NIMS through wide ranging international interactions. In fact Prof. Kishi is an old acquaintance of CTSR having visited the laboratory in the late 1990s while he was a Professor at University of Tokyo. The MoU will enable Stony Brook graduate students and researchers to spend extended periods at NIMS conducting experiments and accessing unique facilities. Dr. Kentaro Shinoda from NIMS is now a post-doctoral fellow at CTSR.



Pictured left to right: Prof. T. Kishi, Dr. S. Kuroda, Prof. Sampath and Dr. Takemura

INDUSTRIAL CONSORTIUM NEWS

The consortium for thermal spray technology continues to expand with the addition of 7 new companies in 2008. The precompetitive partnership now totals some 25 companies. The new companies include: Alstom Power, Volvo Aero Corporation, Federal Mogul Power Train, Nooter/St.Louis Metallizing, Chromalloy, TACR and National Grid. The consortium meets twice a year with approximately 40-50 industrial participants.

Each company contributes \$12,500/year through membership fees which partially supports the research and knowledge transfer activities. Complementary funding to the tune of \$1.7 M has been received from NSF and DoD to support CTSR/Consortium research activities.

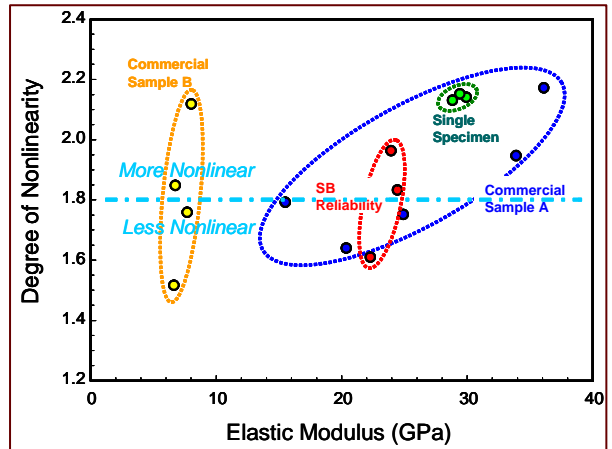


Non-Linear Properties of TBCs Used to Assess Reliability

Recent studies by CTSR researchers Prof. Toshio Nakamura and graduate student Yajie Liu, both of the Mechanical Engineering department, have shown that plasma sprayed YSZ coatings provide a non-linear thermo-mechanical response during low temperature cycling. Through recourse to substrate curvature measurements and applying non-linear bi-material analysis, Yajie and Toshio have been able to extract the “stress-strain curves for plasma sprayed YSZ coatings”. These non-linear stress-strain response appears to be strongly influenced by the microstructure and affected by process conditions.

A noteworthy development is the application of this novel behavior not only to optimize TBC compliance through processing strategies, but also as a means to assess process/deposition consistency and reliability. Specifically, the non-linear response can be quantified through two parameters, the non-linear degree and the coating elastic modulus. The figure shows how these two parameters can be tracked in commercial spray booths to assess coating consistency. Two sets of commercial samples produced during different spray days were thermal cycled at Stony Brook to extract these mechanical parameters. The results show that one set of samples shows consistency in modulus but variance in non-

linearity while the other shows variance in both parameters when sprayed over as many days. In contrast, process controlled samples at Stony Brook show a somewhat lower variability. For reference, a single specimen was measured which indicates the robustness of the method. Additional fundamental investigations are underway to make this procedure a robust measurement strategy.



Field Trips with ICP Sensor

Over the last year, CTSR students have been conducting field trips with the Center-developed *in situ* coating property (ICP) sensor. The goal of this activity was to examine the utility of the ICP method for assessment of industrial coating processes. During the summer of 2007, Alfredo Valarezo and Eduardo Mari visited Stellite, Praxair and Caterpillar. Over 80 HVOF spray runs were conducted during a period of 7 working days at the three locations. Wide ranging materials including NiCr, WC-Co and CrC-NiCr and an expansive set of process parameters were examined. The results of the initial field trips were shared with consortium members during the October 2007 meeting. Subsequently, students and post-docs have traveled near and far including visits to Sulzer Metco, Plasma Technology California, Tinker Air Force Base and even to Volvo Aero in Sweden. These field trips have been beneficial for both CTSR and industry. For CTSR, the visits have validated the utility of the ICP approach and provided critical design inputs to enable a more robust sensor development. For the host company, the technique allowed assessment of process-property relations as well as process/coating reliability evaluation. For the consortium membership as a whole, these visits demonstrated how fundamental knowledge derived through the Center’s interdisciplinary research can be linked to industrial practice. Finally, these field trips provide excellent opportunities for CTSR students and industrial personnel to interact.



CTSR—Mitsubishi Team



CTSR—Stellite

CTSR OUTREACH

SPLAT Center Hosts Summer Engineering Camp

The CTSR hosted a series of science and engineering week long camps during the past summer. Kids from throughout Long Island entering grades 4-10 spent the week exploring coating technology, engineering design, paleontology, marine biology, chromatography, DNA and rocket design. Each full day was broken down into morning and afternoon sessions with a sports break after lunch. The kids also toured campus visiting important University landmarks including Roth Pond, Seawolves Stadium, the Wang Asian Cultural Center and the Natural History Museum of Long Island.

"The goal of our camp was to expose kids to the scientific world around them and for them to gain confidence in their abilities through fun, hands-on experimentation", says Ms. Lysa Russo, camp director.

Over fifty future engineers and scientists participated in the camp which was run by four New York State Certified teachers and Ms. Russo.

Assessments were conducted before and after each topic was discussed to determine the effectiveness of the teaching methodology. On average, students from each grade level exhibited a thirty percent increase in understanding of the material discussed proving that kids really do learn better when they are having fun!



Collegiate Science and Technology Partnership

The Collegiate Science and Technology Partnership (CSTEP) program has been developed at various colleges and universities to promote interest in science and engineering among underrepresented minorities during their initial stage of college careers (among high school seniors and college freshman). CTSR is collaborating with Hofstra University in Long Island in their CSTEP efforts by offering a two day summer workshop. Typically 60-90 students participate in this program and the students rotate among various locations of interest including Brookhaven National Laboratory and Stony Brook University Hospital to explore opportunities in science and engineering. During summers of 2007 and 2008, Lysa Russo in coordination with Tyrone Bennett of Hofstra, mentored over 30 students within the center where they conducted thermal spray experiments and learned about robot technology. The participants enjoyed the hands-on aspect of the CTSR program. They were excited about the visual appeal of thermal spray ("so hot its cool") and were inspired by the diverse applications of these advanced materials and coatings in engineering. This program is now an annual event at CTSR and an important component of our NSF funded outreach initiative. Kudos to Lysa, Tyrone and Glenn for developing this activity and inspiring young minds.



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CTSR Postdoctoral Scientist and Student Accomplishments

CTSR is proud to announce Dr. Alfredo Valarezo won the Young Scientist award at the recent international thermal spray conference in Maastricht, Netherlands. During this event, some 20 young thermal spray scientists from all over the world were given an opportunity to make a 5 minute presentation to the ITSC audience. Alfredo's presentation titled "Understanding Coating Formation through Real Time Monitoring" was placed 1st by the judges. Alfredo has made breakthrough progress in integrating process science with materials science for HVOF coatings. His research has provided new insights into residual stress evolution and its implications with respect to coating and process design. He continues to make seminal contributions to our understanding of thermal spray processing. We look forward to his contributions in the years to come. Alfredo is pictured receiving the award from Prof. Erich Lugscheider.



Alfredo came to Stony Brook in the fall of 2005 from Ecuador through a Fulbright Scholarship. He successfully de-

fended his PhD this year and is currently leading the consortium integration efforts. He is also the winner of the ITSA student scholarship.

Second year graduate student Ms. Lorena Bejarano won the 2008 International Thermal Spray Association graduate scholarship. She received a cash award of \$2000 and a certificate from ITSA chairman and scholarship chairman respectively, Marc Froning and Alan Burgess. Lorena has a bachelor's degree in mechanical engineering from the National Polytechnic School in Ecuador. Lorena came to Stony Brook in 2005. For 2 years, she worked as a part time project aide at CTSR involved in coating while caring for her infant son. She formally joined the graduate program in 2007 in her quest to obtain a PhD. Lorena is now conducting research on thermal expansion studies of sprayed coatings. Her research is demonstrating several new findings including irreversible changes in many sprayed coatings during the 1st thermal cycle. We look forward to her contributions in the years to come.

CTSR Welcomes New Faculty Member: Dr. Christopher Weyant

In August 2008, Chris Weyant joined the Center for Thermal Spray Research as an Assistant Professor in the Department of Materials Science and Engineering. Chris earned his B.S. in Engineering Science at Pennsylvania State University in 1996 where his thesis research was conducted in the corrosion resistance of non-equilibrium aluminum-molybdenum alloys. With an interest in graduate education in materials science, he went to the Center for Electrochemical Science and Engineering at the University of Virginia to earn his M.S. degree.

After U.Va., Chris worked as a materials engineer at Capstone Turbine Corporation in Chatsworth, CA where he was involved with the materials issues of small gas turbine engines. In addition to conducting failure analysis and being part of the materials selection for a new gas turbine product, he had his first exposure to plasma sprayed thermal barrier coatings.

With a strong desire to continue his graduate education, in 2000, Chris started a Ph.D. program in Materials Science and Engineering at Northwestern University. His dissertation research concentrated on the development of a plasma-

sprayed tantalum oxide-based environmental barrier coating for silicon nitride-based gas turbine components. As part of this research, Chris investigated the effects of alloying additions on the coatings' microstructural evolution, and determined through-thickness residual stresses using high-energy X-rays at Argonne National Laboratory.

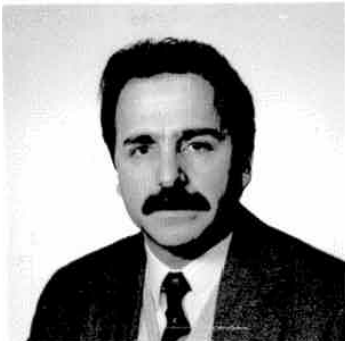
Upon completion of his Ph.D. in 2004, Chris began as a postdoctoral appointee at the Thermal Spray Research Laboratory of Sandia National Laboratories in Albuquerque, NM and subsequently accepted a position with Honeywell Aerospace's Advanced Materials and Processes Laboratory in Morristown, NJ. During his time at the lab, he was Honeywell's liaison to CTSR's industrial consortium. With a desire for a career in an academic research environment,

Chris returned to Northwestern University as a Research Associate in 2006.

Chris is excited to become part of the incredible legacy of thermal spray research at Stony Brook University. He looks forward to using his breadth of experience to broaden the research endeavors in CTSR while also continuing strong research ties with industry.



Alumni Focus: Dr. Saed Safai – Honeywell Aerospace



In this newsletter, we are pleased to introduce Dr. Saed Safai, a program manager at Honeywell Aerospace in Phoenix Arizona. Saed has been a long standing friend, supporter and well wisher of the Stony Brook thermal spray family. He has the notoriety of being one of the early thermal spray

graduates of Stony Brook. Saed along with Volker Wilms were among the first graduate students of Herb Herman in the field of thermal spraying in the late 1970s.

Saed was born in Iran and migrated to US in 1969 to pursue his college education. He graduated with a degree in Engineering Science from the City College of New York following which he joined the Materials Science program at Stony Brook. Saed was one of the early researchers investigating the complex phenomenon of melting and solidification of particulates in high temperature thermal environments such as combustion fuel and electric arc plasma sources. Saed pioneered the investigation and modeling of metallic and ceramic particles injected in hot plasma flame for the purpose of fabricating protective surface coatings. He received his Ph.D. in spring of 1979.

Saed's most notable contribution to thermal spray is understanding solidification of single droplets. In fact, the famous single splat picture which has proliferated the thermal spray science and engineering literature is attributed to Saed's PhD thesis.

Subsequently, he joined Metco/Perkin Elmer (now Sulzer Metco) where he was responsible for developing materials for industrial coating applications. After a short stint at Metco, he joined Pratt and Whitney Aircraft, United Technologies, where he led the engineering team responsible for development of compressor and turbine abradable seals for commercial and military fighter aircraft engines. He provided significant contributions to the technical advancements in high temperature gas path clearance control and abrasive blade tip materials, and is a patent holder on several inventions that are currently bill-of-material in advance aircraft engines. During his stint at Pratt he managed several Air Force ManTech contracts and company funded programs including feasibility demonstration for the first large scale automated coating production centers.

In pursuit of warm weather and new challenges, Saed moved out west in 1996 to Phoenix Arizona joining what was then Allied Signal Gas Turbine division, which was subsequently acquired by Honeywell Aerospace. Saed's tour of assignments during his long career in Honeywell Aerospace has included wide range of technical and organizational leadership responsibilities. He has provided technical expertise on many fronts in development of protective coatings for APU and other gas turbine products. His more recent efforts have been aimed at advanced manufacturing process control and digitization/application of web tools that enable suppliers to capture and comply with the engineering design intent and materials specification. He is a certified Six Sigma Green Belt and Certified Quality Engineer.

Saed lives in Phoenix with his wife Ellie and daughter Sabrina. He is involved in community youth activities and likes cycling and hiking.