

LINKING RESEARCH TO PRACTICE

Going Beyond the Surface

Message from the Director

It is with a great sense of excitement that I present this 8th annual CTSR newsletter "Going Beyond the Surface". By all measures 2010 has been a blockbuster year. We managed to swim through the recession with limited impact and have made significant strides in science, technology, funding and human resource development. I am pleased to report that our NSF GOALI grant was renewed for an additional three years, with a commitment of over \$600K from NSF and added contributions from the University. This is quite an extraordinary achievement by the team especially in light of the highly competitive environment. In large part this grant was possible due to some extraordinary discoveries related to novel mechanical properties of thermal sprayed coatings (more inside this newsletter).

The GOALI grant complements our highly successful industrial consortium for thermal spray technology now entering its 8th year. We have some 30 member companies at present with continuing interest in our program. The biannual meetings have attracted 60+ industrial participants. As this newsletter is being developed we are preparing for the Fall 2010 meeting which, for the first time, will be held off site in Key West, Florida on Dec. 1 and 2. This meeting is being co-hosted by the Naval Research Laboratory's Key West Corrosion Center. This meeting's theme will be corrosion mitigation coatings with invited presentations from industry, government and academia. A tour of the corrosion center is also planned during this two day event.

The CTSR team was also chosen by the Dept. of Energy's National Energy Technology Laboratory for a three year grant to examine materials-processing-performance linkages for thermal barrier systems exposed to coal gasified turbine environments. Sponsored through the clean coal initiative, this

project will for the first time introduce processing ideologies and novel materials into the performance assessment criteria. The outcome of this project will not only impact the design of TBCs for such a harsh environment but also provide feedback into traditional TBC applications in gas turbines.

CTSR is also working on several novel application initiatives for coatings and layered materials. The most notable is the Office of Naval Research's thermal management program for ship decks susceptible to high heat loads from engine exhaust of vertical landing aircrafts. Corrosion will be a big factor in such large area marine applications and as such we are also interacting with Navy personnel to examine corrosion performance in layered, heterogeneous thermal sprayed systems.

Our collaborations with U.S. and International organizations continue to provide rich dividends in terms of both science and technology. In partnership with Oak Ridge National Laboratory (High Temperature Materials Laboratory) we have introduced novel characterization schemes for sprayed coatings in thermal and mechanical property measurements. ORNL is also a close collaborator in the clean coal coatings program. We continue to interact with VTT Finland in areas of tribology, process maps and tribo-corrosion of coatings. The NSF program will provide additional support to foster student travel between Stony Brook and Scandinavia. Such interactions provide great opportunity for students to be exposed to new technical and cultural exchanges.

This newsletter provides a snap-shot of some recent developments and as always, I look forward to our continued efforts to make thermal spray a house-hold word in engineering.

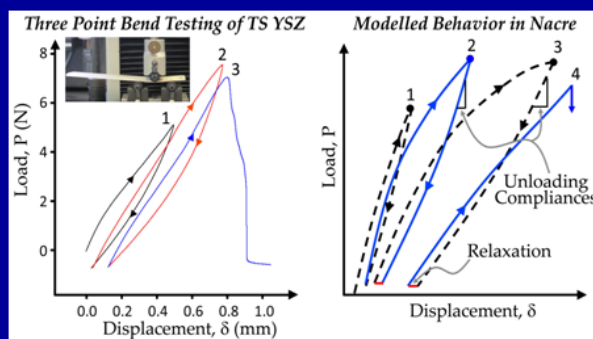
Sanjay Sampath
Director CTSR

Nature-Inspired Thermal Spray: Large Scale Processing of Biomimetic Structures

An NSF GOALI partnership between the Center for Thermal Spray Research at Stony Brook University and the Consortium for Thermal Spray Technology was recently funded to continue this highly productive collaboration. The project seeks to harness recently discovered biomimetic mechanical response of thermal sprayed ceramics due to their unique "brick and mortar" morphology. The microstructural geometry produces non-linear elastic and hysteretic stress-strain response during mechanical and thermo-mechanical loading. The anelastic attributes are similar to those seen for Nacre (mother of pearl) despite the absence of any organic matter within the thermal sprayed interfaces.

The project seeks to develop a fundamental understanding of the mechanical, thermo-mechanical and electro-mechanical behavior of TS fabricated meso-scale structures rationalized through contemporary analysis of the natural counterparts. Concurrent efforts aimed at process engi-

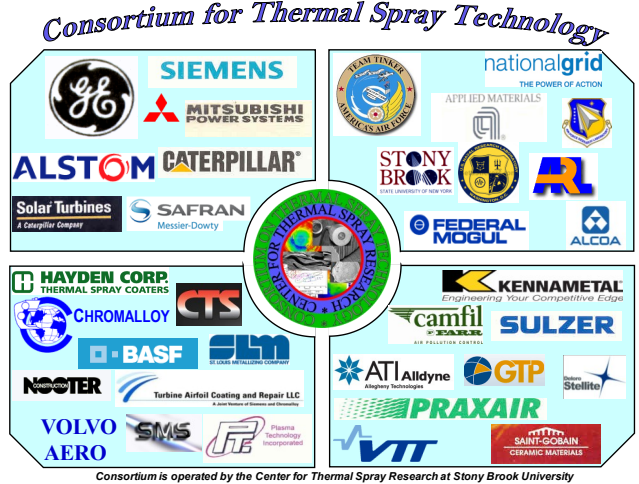
neering of interfacial structures will enable tailoring of elastic and damage tolerant properties. The goal is to model, design, fabricate, and analyze engineered materials and coatings, considering natural structural principles, guided by pervasive and technologically relevant applications.



Industrial Consortium News

The Consortium for Thermal Spray technology is pleased to introduce three of its newest members: Cincinnati Thermal Spray, Hayden Corporation and Camfil FARR. This brings the total members to 30 companies, a major milestone since the formation of the consortium in 2002-2003. The consortium held meetings in November 2009 and in early June of 2010 with participation from some 60 industrial engineers. The spring meeting included a focused session on application of thermal spray coatings in defense and energy systems with presentations from key government researchers and program managers.

The growth in consortium membership and leveraged partnership with other federal funded programs, has allowed us to keep the membership cost at the same level for the last several years (\$12,500/year per member company). Concurrently, we have expanded research activities, collaborations and field trips over the last year. We expect continued growth in our programs over the coming years.



Field Trips to Consortium Members' Sites

Our consortium field trip programs have continued to generate a lot of interest among the members. Since the last newsletter, several field trips have been conducted. During March 2010, a field trip was conducted at **Praxair Tafa** in Concord, NH with observers from the Naval Research Laboratory. More recently, sensor demonstration and property extraction field trips were conducted at **Howmet Corporation** in White Hall, Michigan, at **Sulzer Metco** in Westbury, NY, at our new member site **Hayden Corporation** in Springfield, MA and even **St. Gobain Research** in Avignon, France.

A variety of different materials (oxides, metallic alloys and carbides) were processed using a wide range of spray devices including HVOF, conventional APS, Pro-Plasma™ and Triplex Pro™. Both particle diagnostics and ICP measure-

ments were conducted.

Each field trips lasts 2-3 days involving about 1/2 day for set-up, training and safety analysis at the member site. Typically one or two people from CTSR visit the member site and work closely with spray operators, technicians and engineers in conducting the spray investigations. Within minutes after the deposition, initial results are analyzed and the advances are shared with the various stakeholders. Typically, a follow-up activity in terms of a more detailed analysis and ex situ characterization is completed upon returning to Stony Brook.

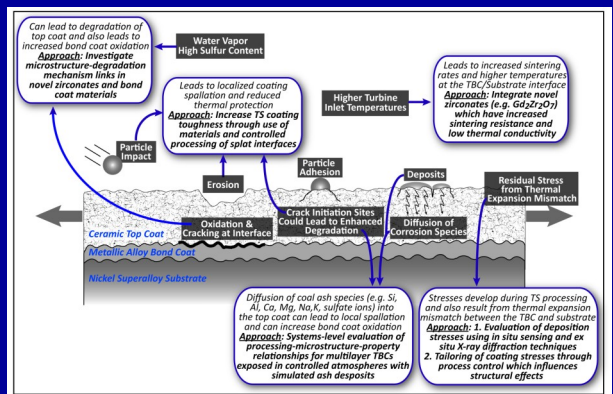
This series of field trips in the U.S. and Europe started in 2007, and have proven to be very beneficial not only for students and associates at CTSR, but also for researchers and engineers at akin research facilities at universities, specialized labs, and industries.

University Turbine Systems Research: TBCs and Gasified Coal

The Dept. of Energy through NETL has recently funded a CTSR proposal in the University Turbine Systems Research (UTSR) program. The overall objective of the research is to provide enabling science and technology for increased viability of TS multilayer coatings (metallic alloys and ceramics) in integrated gasification combined cycle (IGCC) gas turbine systems. To address the requirements for providing effective thermal protection in the moisture-rich hydrogen fuel environment, a system using functional coating architectures and state-of-the-art materials will be investigated. As such, an important goal will be to develop a sound scientific understanding of the material-microstructure-property-performance linkage for these multifunctional coatings in relevant environments.

Far beyond intrinsic properties associated with bulk materials, this work will address the complexity associated with the layered assemblage and defect hierarchy of TS structures and assess how variations in processes affect properties and performance. It is important to note that such a systematic

approach is lacking in the literature. Several degradation mechanisms affect the viability of TS coatings. This research will elucidate how several of these mechanisms (high temperature, water vapor, sulfur, deposits, and residual stress) degrade multilayer, multifunction coatings.



Focus on CTSR Students & Postdocs

Dr. Alfredo Valarezo and **Lorena Bejarano** returned to their native Ecuador and have joined as faculty members at the Universidad San Francisco de Quito. Lorena is continuing her Ph.D. work long distance and expects to get her degree from Stony Brook sometime in 2011.

Jose Colmenares-Angulo completed his PhD defense in Sept. 2010 and has joined Sulzer Metco as a process engineer. Prior to joining Sulzer, Jose spent 2 months as a summer intern there. He also had the opportunity to spend 6 months working on his PhD at NIMS Japan and one month as a DAAD fellow (German science foundation) at the Energy Institute in Juelich.

Dr. Yang Tan, CTSR post-doctoral associate, has joined as a process engineer at Turbine Airfoil Coating and Repair in Middletown, NY. He received his Ph.D. in Mechanical Engineering in 2005 at Stony Brook and worked as a post-doctoral fellow afterwards.

We wish Alfredo, Lorena, Jose and Yang the best!

These transitions mean a new generation of postdocs and students will join Stony Brook in the coming years. CTSR has recruited several new students and postdocs this year. We are pleased to report that **Dr. Yikai Chen** from Shanghai Institute of Ceramics has joined the group earlier this summer. **Dr. Dimitrios Zois** from Greece will join in January pending visa approval. They will both work on consortium efforts

Gopal Dwivedi was selected through a competitive process to participate in the Stony Brook Provost's graduate student lecture series. He presented findings on the biomimetic linkages between thermal sprayed ceramics and nacre.

Claire Maxey, a recent mechanical engineering graduate of Stony Brook, is participating in the Volvo Aero internship program. She will spend a year in Trollhattan working within the Volvo Aero thermal spray group from August of 2010 to August of 2011.

ONR: Ship Deck Thermal Management

Since June of this year, CTSR has embarked on an ambitious new project to develop thermal management solutions for ship decks on amphibious assault ships. The advent of short-take off vertical landing aircraft operation (STOVL) based on JSF and the MV-22 Osprey aircrafts have imposed several thermal loads on the structural deck material and the non-skid coatings present on the surface. CTSR

is developing a novel hybrid multifunctional material strategy to address the many conflicting issues of thermal load, corrosion and manufacturing. Aspects of this program are proprietary but if successful, it can be a significant coating application opportunity for the thermal spray industry. Stay tuned.



JSF-35b



MV-22 Osprey

NSF/DOE: TS Thermoelectrics

CTSR in partnership with colleagues from the Mechanical Engineering Department and Brookhaven National Laboratory were recently awarded an interdisciplinary research grant to pursue fabrication of thermoelectric materials onto tubular sections for exhaust heat recovery from engines. The goal here is to integrate materials advances (e.g. Mg₂Si), novel processing schemes and integrated wiring to produce a high performance functional device. This is a challenging project, but has the potential to propel thermal spray technology into new territories. The review committee found the thermal spray based manufacturing concept particularly appealing and the funding will seek to enhance the material and device characteristics. The three year award will provide NSF funds to the tune of \$550K with additional \$300K support from various organizations within the University.

In Memoriam

We are deeply saddened by the sudden passing of two of our colleagues, Dr. Allen Goland and Dr. Leslie Seigle. Allen was founding member of the CTSR and served on its executive committee during the NSF MRSEC program. He was deeply involved in application of advanced scattering techniques to characterize the complex pore structure of thermal sprayed coatings. Prior to his retirement in 1996, Allen spent most of his career as a physicist at Brookhaven National Laboratory. He applied innovative techniques to study defects in materials culminating in his work on defects in thermal spray coatings. He has co-advised/mentored numerous students and post-docs. We will miss him dearly.

Dr. Les Seigle, Professor of Materials Science at Stony Brook, was tour de force in diffusion coatings and built a legacy for coatings research at Stony Brook. Many of his graduates went on to positions of great stature in the aerospace industry. He was an outstanding teacher, researcher and colleague. He was 93. A scholarship fund is being developed with initial contribution from alumni Raj Bamola.

CTSR Research Earns Best Paper Award from JTST

CTSR publication "Sensing Control and In situ Measurement of Coating Properties: An Integrated Approach toward Establishing Process-Property Correlations" was selected as the best paper for the Journal of Thermal Spray Technology Volume 18, 2009. The contributors include Prof. Sampath, Dr. Vasu Srinivasan, Dr. Alfredo Valarezo, Dr. Anirudha Vaidya and Dr. Tilo Streibl. The selection committee cited "very high impact on our understanding of a process-property correlation" and should be "required reading for future thermal sprayers". This is wonderful recognition of the hard work and innovation by the CTSR team.

Prof. Sampath Elected Fellow of the American Ceramic Society

Prof. Sanjay Sampath was elected fellow of the American Ceramic Society in 2010 for his contributions to ceramic science and engineering. Elected by peers, this distinct honor is provided to a handful of scientists and engineers each year. Prof. Sampath received his award from ACERS president Ed Fuller during the society's awards dinner held in October 2010 at the Materials Science and Technology meeting in Houston. Prof. Sampath is now fellow of two materials societies ASM and ACERS. Congratulations!



Professor Sanjay Sampath was appointed as a guest professor at University West in Trollhatten, Sweden. The Univer-

sity is a relatively new institution in Sweden having turned a young 20 years old this year. The university's technical pro-



grams were created to develop research and education partnerships with local industries such as Volvo Aero and Saab. In his role as a guest professor, Sanjay will advise graduate students conducting research in thermal spray at the university, promote student and faculty exchanges between Stony Brook and Trollhatten and participate in both basic and industrial research programs. Prof. Sampath will work closely with Prof. Per Nylén, director of the Production Technology Center at University West.

Dr. Curt Johnson, Adjunct Professor at Stony Brook University

Dr. Curtis Johnson joins CTSR and the Department of Materials Science and Engineering at Stony Brook University as an adjunct professor. He earned his B.S. and Ph.D. degrees in Metallurgy from Penn State. In 1973, he joined General Electric Research, Niskayuna, where he has worked on a wide variety of challenges related to the development and application of ceramics. In early 2008, Curt retired from his position of Principal Scientist within the Ceramics and Metallurgy Technologies organization at GE Research. He is currently a part-time consultant with GE.



Over the last 37 years, Curt has worked on the development, fabrication, characterization, life prediction and reliability assessment of advanced ceramics and coatings. He helped develop processes for sintering and near-net-shape fabrication of sintered silicon carbide. He helped advance analytical techniques for probabilistic strength and failure

prediction of brittle materials and has applied those techniques to many products and practical problems. Curt's recent research interests include thermal barrier coatings and environmental barrier coatings with emphasis on fabrication-microstructure-property-performance relationships.

Curt has been recognized with three GE Dushman Awards, the Distinguished Career Award from the Hudson-Mohawk Section of TMS in 2008 and the James I. Mueller Award from the American Ceramic Society in 2009. He has authored or co-authored over 25 publications and has 39 issued U.S. patents.

Even during his GE days, Curt has been an external research advisor to CTSR students. Adjunct professor status will allow Curt more active engagements in teaching and research. Welcome Curt!

Alumni Focus: Rajan Bamola

Rajan (Raj) was born in the Fiji Islands and came to SBU in 1979 for undergraduate studies. He completed a combined BS/MS in engineering chemistry and material science under the late Dr. Seigle. His research concerned extracting diffusion coefficients using the pack aluminizing process. His Ph.D. work was under Prof. Herman studying corrosion resistant VPS zirconium and inert chamber arc spray graduating in 1993.



His first job was as an engineer for Turbine Metal Technologies, Inc. developing and optimizing thermal spray, diffusion, electrospark and epoxide coatings mainly for the aero- and land-based turbine industry. He became the VP for Research and Development and eventually the VP and General Manager for the Houston facility working with steam and gas turbines, petroleum and chemical process industries. Raj moved back to Los Angeles working with Bender Machine as the senior engineer for the next 1½ years. This work involved mostly the pulp and paper and steel industries.

Raj founded Surface Modification Systems Inc. in 1993. The shop is one of the most comprehensive on the west coast offering LPPS, APS, HVOF, wire arc, cold spray (redesigned Dymet), combustion wire and powder. Diffusion coatings offered are aluminizing, chromizing, boronizing, vanadizing and siliconizing. Other less known processes in place or being developed are electrospark, spray forming and casting. Coating services are complemented by machining and grinding. SMS Inc. is an FAA and ISO certified facility. Recently another building was purchased bring manufacturing space to 36,000 sq. ft.

Raj is married to Yashica and has two girls Aarti, 15 and Megha, 13. He was involved actively in Martial Arts and competed in kickboxing for the United States in France while at SUNY. He was also the New York State Amateur Bantamweight kickboxing champion in 1984. Nowadays racquetball is his new passion. Raj also serves on the Industry Action Council at Cal State Poly Pomona.