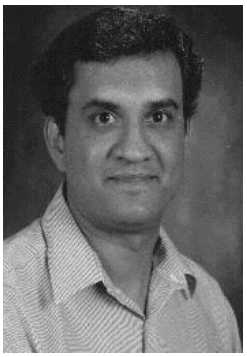
Volume 1, Issue 5

Spring 2006

CENTER FOR THERMAL SPRAY RESEARCH

Going Beyond The Surface

Message from the Director:
Dr. Sanjay Sampath



It gives me great pleasure to introduce our fourth annual newsletter, just in time for the International Thermal Spray Conference in Seattle. A lot has happened since our previous newsletter. The Center has made progress in many fronts. Our research enterprise has made significant and important contributions, the Consortium for Thermal Spray Technology is now entering its 4th year and we have (finally!) moved into our new building. Needless to say, these exciting events have kept us very busy over the last couple of years.

As of January 1, 2006, the Center made the transition to our new facility which has been under construction for the last few years. This new building features some 10,000 sq. feet of space dedicated to thermal spray including an elegant high bay thermal spray lab, coating characterization facility and office facilities for faculty and staff. We are now in the final phase of occupancy and expect our spray labs to come on line in the summer of 2006. We welcome you to visit the laboratory.

Our NSF and University support continues through 2007 and we are exploring new opportunities to grow the Center beyond support from the National Science Foundation.

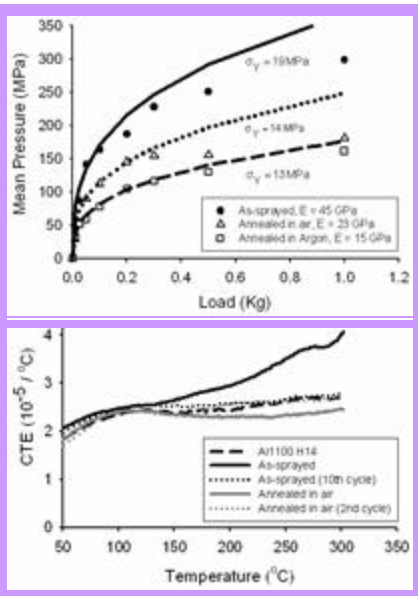
The Consortium for Thermal Spray Technology comprising of 14 companies is now entering its 4th year and has made valuable contributions to knowledge transfer between academia and industry. The initial phase focused on thermal barrier coatings but now the research is expanding to include wear resistant coatings for applications in Cr-replacement, expanded applicability of process maps for coating reliability as well new methods for characterization of coatings. The founding members of the consortium continue to support our research efforts and the many networking opportunities. More details are presented within this newsletter.

This past year we have seen significant turn over of our graduate students with many obtaining gainful employments within our consortium partners' organizations. We have also welcomed several new students to the group who show much enthusiasm towards thermal spray technology. Our ability to groom the 'next generation' of thermal spray engineers and scientists is a significant attribute of our university based research program and perhaps the most important contribution that we make to our industry.

We look forward to seeing you in Seattle and hope to welcome you more formally to our new facility in the near future.

Integrated Property Characterization

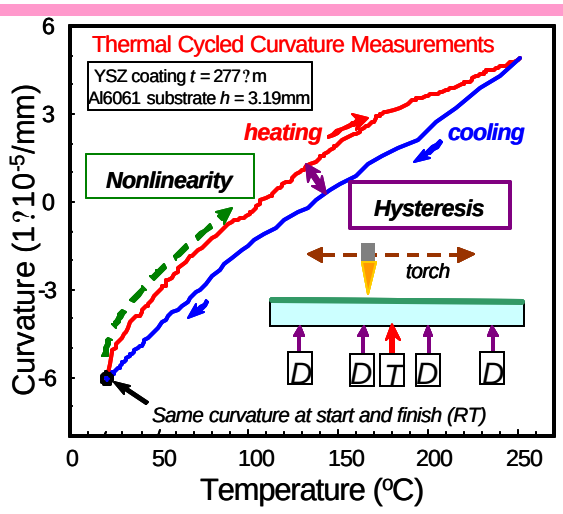
After progress in process science and advanced microstructural characterization, we have turned much of our effort to the fundamental understanding of splat-splat interfaces. Although a long time cited reason for the deviation of TS coating properties from bulk materials, interfaces have not yet been analyzed quantitatively (this is in contrast to the large number of successful models to describe the effects of porosity). However, the investigation of the roles of interfaces is non-trivial, and given the complexity of TS materials, isolated property measurements tend to fall short of providing comprehensive physical mechanisms. Thus, we have adopted an integrated approach to our functional characterization schemes, measuring mechanical, electrical, and thermo-mechanical properties on the same specimens, allowing us to isolate, e.g., splat-based, pore-based and interface-based contributions to observed behavior. This has most recently been useful in experiments on cold-sprayed (CS) Al in which indentation, dilatometry and 4-point probe tests were used to clarify the role of oxidation in as-sprayed and annealed specimens. Specifically, we have seen that annealing of CS Al causes a marked decrease in mechanical properties, the extent of which is strongly dependent on whether the atmosphere is oxidizing or noble. In Ar, thermal mismatch at interfaces causes cracking, but in air, this effect is decreased due to oxidation-induced crack closure.



(top) Modulus and yield strength results from indentation, (bottom) CTE measurements.

Anelastic and Non-Linear Behaviour in Ceramics

We have used the substrate curvature technique, in essence a thermally-driven test for in-plane mechanical properties, to reveal interesting behavior of TS ceramic coatings. Curvature-temperature measurements obtained during a thermal cycle test, shown in the adjacent figure, clearly illustrate *anelastic* mechanical behavior of plasma sprayed YSZ coatings on metal substrates. That is to say, although ceramics are nominally elastic, the curvature-temperature (stress-strain) paths during heating and cooling (loading and unloading in tension) are non-linear, and hysteretic. We postulate that the hysteretic behavior is associated with energy-dissipative mechanisms. Initial investigations suggest micro-cracks and weak splat interfaces provide the source of such behavior, through friction during interfacial sliding. The implications of this are interesting, as energy dissipation can act as a toughening mechanism under cyclic loading.



Measured temperature and curvature of YSZ coating/Al substrate during a thermal cycle test. During loading and unloading, the coating exhibits nonlinear and hysteretic stress-strain behavior. Curvature measurement system is shown at inset; thermal cycling tests are accomplished by heating the bi-layer with a torch and continuously recording backside displacement.

Excite - Inspire - Connect - Sustain: Recipe for Success in Developing Future Corps of Engineers and Scientists

A critical goal of the *Center* is the development of next generation materials researchers, engineers and scientists that are capable of providing global leadership in the advancement of materials science and, in particular, TS processing. Our outreach philosophy has been to:

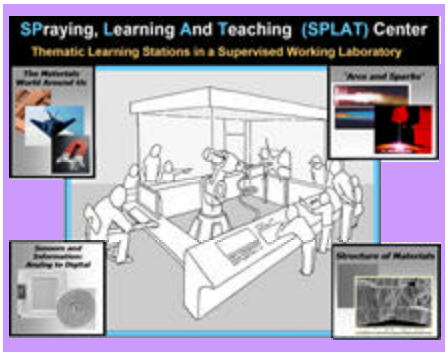
?? **Excite** kids about engineering and science with activities that offer a high degree of sensory simulation. The "arcs and sparks" of TS is extremely exciting and appealing to young students.

?? **Inspire** kids with real-world relevance and historical significance and the future role that they can play.

?? **Connect** them by relating their current education to the world around them.

?? **Sustain** their intellectual growth with continuous support for both students and teachers and foster an environment of 'lifelong learning'.

The **SPLAT (SPraying, Learning and Testing) Center,** a specially designed, "kid-friendly" dedicated interactive research laboratory that is currently under development. Demonstrations and hands-on experiments will be part of the immersive nature of this lab which will be housed in the *Center's* new spray facility. The laboratory will literally offer thousands of young people and their teachers a space of their own where they can explore and discover a wide range of exciting and highly relevant topics.



Consortium on Thermal Spray Technology Expands to Include Four New Industrial Members

The Consortium on Thermal Spray Technology was founded four years ago on the premise that TS technology offered a perfect platform for pre-competitive, collaborative research projects between end-users (OEMS), applicators, material and equipment developers and leading research institutions. Through combined resources and expertise the group has tackled projects ranging in scope from plasma optimization and mapping of yttria stabilized zirconia ceramics to elastic/plastic properties of HVOF, APS and VPS sprayed superalloy bond coats.

The annual research agenda is set by the membership and meetings are held throughout the year to keep the group up to date on status and achievements made. Annual training workshops and classes are also used as a mechanism of keeping the group abreast of the latest advances being made not only in thermal spray but surface engineering as a whole. The coming year's work expands the use of process maps into hard chrome replacement coatings, namely HVOF and APS applied tungsten carbide / cobalt and nickel chrome / chrome carbide materials. The goal is to understand parameter variables and their influence upon resulting coating properties as they relate to a given application.

The Consortium also provides a mechanism to explore novel TS applications, such as those in the electronics and silicon chip manufacturing facilities and military installations.

For additional information on activities or membership, please contact Lysa Russo at lysa.russo@stonybrook.edu.

CENTER FOR THERMAL SPRAY RESEARCH

State University of New York at Stony Brook
Department of Materials Science & Engineering
Room 130 Heavy Engineering
Stony Brook, New York 11794-2275

Phone: 631-632-4567
Fax: 631-632-7878
Email: lysa.russo@stonybrook.edu

Going Beyond the Surface

CTSR Alumni Reunion, July 2004

For More Information:
www.stonybrook.edu/ctsr

Alumni Focus: Dr. Xiangyang Jiang—Caterpillar

In this issue of "Going Beyond the Surface", we are pleased to recognize Dr. Xiangyang Jiang. Xiangyang is currently a senior engineer at Caterpillar's Technical Center located in Peoria IL

Xiangyang was born and raised in Guilin, China . He completed his undergraduate education in Materials Science and Engineering at the Central South University of China in Changsha. He spent one year at the University of Cambridge in England with Prof. Greer and by chance met Prof. Sampath at a conference in Slovakia in 1996. He joined CTSR Stony Brook in spring of 1997 and obtained a Ph.D. in 2000. His Ph.D. thesis investigated splat and coating microstructures during thermal spraying. Xiangyang made seminal contributions to the field and in fact was the architect of the "adsorbate theory" of splat fragmentation. Essentially showing that when thermal spray droplets hit cold, untreated substrates the adsorbates present on the substrate interact with the splat formation leading to breaking-up and "bubbling". This has profound implications for adhesion and in fact the suggestions of his work are now becoming more and more apparent. He collaborated with many individuals within and outside the Center and contributed significantly to the industry. Xiangyang was the recipient of the ITSA graduate student scholarship in 1999.

At Caterpillar, Xiangyang works in the Advanced Materials Technology, Technology Solution Division. He is active in thermal spray coating and materials development for wear and corrosion control including chrome plating replacement. His work also extends to wear coatings using weld overlay hardfacing, dimensional restoration/salvage technology for remanufacturing of used engine and machine components. The primary focus of his work is in earth moving machinery. Xiangyang also holds a license to drive a D6~D8 size track type tractors, mining trucks and excavators.

Xiangyang lives in Dunlap IL with wife Zhengchun and daughters Ruixuan and Huimin. His hobbies include photography, fishing, and most important spending time with his family.