Volume 1, Issue 2

Summer 2001

NSF Materials Research Science and Engineering Center

CENTER FOR THERMAL SPRAY RESEARCH

Going Beyond The Surface

Message from the Director: Dr. Herbert Herman

This issue of the *Center for Thermal Spray Research* newsletter can be no more than a snapshot of our activities in the world of functional and protective coatings. In fact, the notable successes and visibility of the *Center* go beyond Stony Brook and reflect the enormous strides made by industrial researchers and practitioners. Thermal spray technology has evolved well beyond the bounds of a decade ago into a diversity of applications, some mundane, but essential and widely accepted by industry, and some exotic and futuristic, showing great promise for tomorrow. We believe that the *Center* has played an important role in this evolution.

The SUNY Stony Brook *Center* is now supported by funds from the National Science Foundations (the second award of a five year Materials Research Science and Engineering Center was made in August of 2000), a three year multi-million dollar award on electronics from the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research, and a variety of industrial concerns. Carrying out this research is an accomplished team of graduate students, post-doctoral researches, visiting engineers and scientists, and staff engineers. Additionally, the *Center* has cooperative research agreements with numerous universities, national laboratories and industrial organizations. An Academic-Military Alliance Memorandum of Agreement has also been established.

This second issue of the newsletter will highlight certain of our activities and hopefully, give the readership ideas on how to interact with the *Center*.

New CTSR Center Under Construction

Perennial complaints about space limitations will soon end with the completion in April, 2002, of a new building extension for the College of Engineering. $18 Million in funds has been acquired from the State of New York in recognition of the *Center's* success in attracting federal and industrial funding to the SUNY Stony Brook campus. This designed-for-use modern space will allow us to install new thermal spray and analysis equipment in appropriate laboratory facilities. The new space will add an additional 10,000 sq. feet of lab space and offices to the present Thermal Spray Laboratory.

Inside this issue:

Special points of interest:

- *CTSR Receives Major DoD Award*
- *New Industrial Liaison Manager*
- *New Approaches in Pore Detection and Characterization*
- *Advances in Process Science and Mapping*
- *Collaborative Residual Stress Study*
- *Alumni Highlights: Dr. Richard Neiser*

CTSR Receives Major Department of Defense Award

The Center for Thermal Spray Research is at the forefront of a technological revolution. Since 1998, the *Center* has enjoyed tremendous success with their cutting-edge research into thermal spay applications in the area of electronics. In just over two years the *Center* has acquired nearly 5 million dollars from the Defense Advanced Research Project Association (DARPA) and the Office of Naval Research (ONR) to pursue research in this fast expanding field.

This research promises to carry the field of thermal spay technology into innovative new directions beyond thermal spray's traditional uses as a protectant against the wear and corrosion of metals. Recent advances in process science have shown that specialized thermal spray can be used in the rapid prototyping and manufacturing of high-density, multi-layer electronic substrates, also known as meso-electronic circuits. This new application dramatically reduces the amount of time needed to turn a computer-aided circuit design into a prototype and ultimately into a manufactured product. If successful, the less expensive, more versatile, and more efficient processing methods could result in yet another wave of functionally-improved electronics. Developing electronic circuits through this new method, which does not involve the use of solvents with PCBs, would also be a more environmentally friendly process than current manufacturing methods.

Although it is an extraordinarily challenging endeavor, the *Center's* efforts in electronics research quickly paid dividends. "We have made significant progress at the *Center* and are confident that we will effectively develop this revolutionary application, " reports Professor Sanjay Sampath, a researcher at the *Center* and the principal investigator for the *Center's* electronics research grants. "Since beginning our work in this area, we have demonstrated that high quality electronic multi-layers can be produced by thermal spray technology. We believe the technology will have important applications in the emerging industry of sensor technology." Indeed, since beginning this research, CTSR has designed, fabricated, and tested several circuits.

> *"The Stony Brook team has significant knowledge in the area of thermal spray deposition of materials and the sensor user community has significant knowledge in sensor technology. Together, this is a very efficient way to insert a new technology into the market place"*

Their success with research into sensors underscores the practical benefits of the *Center's* efforts. "Sensors are something that people come into contact with everyday, although they don't often realize it," Dr. Sampath explains. "For example, temperature sensors regulate the climate in a building, but you never see them." In this respect, the environmentally-friendly nature of thermal spray gains added value considering sensor technology's increasing importance as a fundamental tool of modern life.

The *Center's* growing success in electronics research mirrors their growing success in obtaining lucrative grants. In December 1998, the *Center* earned a modest $115,000 grant through DARPA. With research quickly showing impressive results, CTSR received another $640,000 the following autumn from the ONR to expand their efforts in electronics research. A year later, DARPA and ONR provided in excess of $4.2 million to support the *Center's* efforts. Thanks to this multi-million dollar grant, the future for CTSR's electronics research looks bright. As part of the *Center's* current research, a Sensor and Electronic Fabrication/Prototyping Facility will be set-up in the Heavy Engineering building on the Stony Brook Campus. The facility will be used for the creation of prototype embedded sensors and electronic sensors for communication systems and engineering components to be used in harsh environments, such as turbines. In the process, the *Center* is currently working toward developing thermal spray electronics technology into a full scale commercialized system.

Importantly, industry has been receptive to the *Center's* work. Last autumn the CTSR hosted an industry user group, which was attended by representatives from 18 different companies, including General Electric, United Technology, Northrop-Grumman, and Electric Boat. The meeting was coordinated by the commercialization leader of the project Terry Feeley, President of Laser Fare. Feeley believes the *Center* is on the cusp of introducing new technological applications with fantastic commercial potential. "The purpose of the meeting was to provide a forum to discuss real world applications where this developing technology may be used in the near future," Feeley noted. "The Stony Brook team has significant knowledge in the area of thermal spray deposition of materials and the sensor user community has significant knowledge in sensor technology. Together, this is a very efficient way to insert a new technology into the market place." If the *Center* continues its research and industrial outreach at its current pace, it will not be long until before this new technology is indeed making strides in the market place.

For additional information, or if interested in participating in project, please contact *The Center for Thermal Spray Research*.

For more information on DARPA and ONR, log onto: www.darpa.mil and/or www.onr.navy.mil

Industrial Outreach Initiative Launched

Expanding the partnerships between the *Center for Thermal Spray Research* and the leaders of the thermal spray industry is critical to the ongoing success of the CTSR's research endeavors. Mutually beneficial relationships between the CTSR and industry enable the *Center* to learn from industry with its vast array of resources and experts. Industry, in turn, can benefit from the variety of physical and intellectual resources possessed by the *Center*, as well as through consultation and long-term research programs it offers. In light of the mutually valuable benefits offered through academic-industrial partnerships, the CTSR has dedicated itself to forging strong alliances with a broad range of key industrial companies. To date, the CTSR enjoys productive relationships with industrial leaders such as Alcoa, Caterpillar, Praxair, Sulzer Metco, Textron, Northrup Grumman, and Siemens Westinghouse, to name just a few. These efforts have allowed the CTSR to establish itself as a dynamic center of development within the thermal spray community. Indeed, the *Center's* outreach activities reflect its commitment to ntegrated, interdisciplinary approach to thermal spray research and linking research to practice

Increasing its strategic alliances with industrial associates is the natural next step for the CTSR. Since the *Center's* establishment in 1998 the interdisciplinary groups that form the core of the CTSR have explored the fundamentals of process-structure-property relationships. These groups are currently developing ways to integrate design, materials, and processes. Their findings have established the CTSR at the cutting edge of coating design and processing science. New strategic alliances with industry are critical in allowing the *Center* to apply these research successes in commercially viable enterprises. For its industrial partners, the CTSR can offer extensive facilities that are available for exploratory research, materials processing, product development and materials testing.

The *Center's* on-going commitment to industrial outreach will be on display when it hosts its tri-annual workshop on August 8-9, 2001.

Lysa Russo Joins CTSR Staff as Industrial Liaison Manager

In 2001, Lysa Russo joined the *Center for Thermal Spray Research* as the industrial Liaison Manager. At CTSR, Lysa will be responsible for the coordination of the *Center's* industrial and government outreach activities. One of her initial tasks will be to develop an "Industrial Alliance". The Alliance will allow industry and the CTSR to form mutually valuable partnerships that provide industry with access to the *Center's* intellectual and equipment resources. In addition, Lysa will also be planning a workshop for this August on "Linking Research to Practice" a key theme to the *Center*. In joining the CTSR, Ms. Russo is returning to her alma mater, having earned her B.E. and M.S. at Stony Brook in 1990 and 1992, respectively.

"It is a privilege to be working at Stony Brook, not only because it is where I first received my education in TS, but because the CTSR is involved in R&D that will revolutionize the thermal spray industry"

Ms. Russo is returning to Stony Brook with an impressive resume to her name. For the past nine years, Ms. Russo was with Sulzer Metco working as a Project Engineer in the Materials R&D Department. At Sulzer Metco, her activities focused on new abradable and superalloy powder developments. She has also been an active member in both ITSA and ASM's TSS where she is currently serving as co-chairman of the Recommended Practices Subcommittee on Safety. Now back at Stony Brook, Ms. Russo has come full circle.

"Linking Research to Practice" Workshop—August 8-9, 2001 hosted by CTSR

Thermal Spray has undoubtedly emerged as an innovative and cost effective means for the processing of high performance and functional surfaces. Much of the current thrust seen within the industry owes itself to the extensive research and development which has been conducted by both the academic and industrial users of this highly diverse technology. Many significant advances have been made within the industry, from process science and modeling to standardization of testing, that are directly responsible for propelling thermal spray processing into non-traditional, highly technical application areas.

It is the objective of this workshop to introduce some of these novel and exciting applications and industries that are reaping the benefits of TS processing.

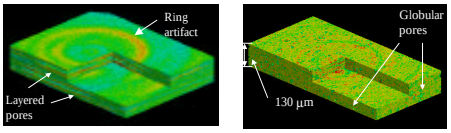
Each session will bring together industrial leaders and academics that have been at the forefront of high performance processing and characterization of thermal spray overlays.

Major Research Highlights

New Approaches in Pore Detection and Characterization:

Two advanced methods of evaluating the pores and micro-cracks of thermal sprayed materials have been exploited by the CTSR working with the National Institutes of Science and Technology (NIST) and Brookhaven National Laboratory (BNL). As members of BNL's X27A X-Ray High Intensity Computed Microtomography (CMT) beamline, we have imaged gross porosity and, together with results from Small-Angle Neutron Scattering (SANS) studies from NIST, have compared these results with thermal conductivity measurements for alumina. These measurements allowed us to accurately determine overall deviations from theoretical density and to detect and to characterize pores in the deposit and relate these imperfections to thermal spray processing parameters. CMT measurements show that HVOF (high velocity) deposits of alumina have flat, in-plane layered pores, where-as the plasma sprayed (low velocity) oxides display globular pores. These results have explained in a dramatic fashion the apparently anomalous difference between thermal conductivity for HVOF and plasma sprayed oxides: although the overall porosity is smaller for the HVOF deposit, it has a much lower thermal conductivity, due presumably to the flat insulating layers normal to the heat transfer direction. These results say much about the microstructure of the ceramic spray deposit. Modeling studies, off-angle spraying and further experimentation are proceeding and will be reported in future Newsletter issues.

Figure 1: 3D Visualization of Thermal Spray Alumina



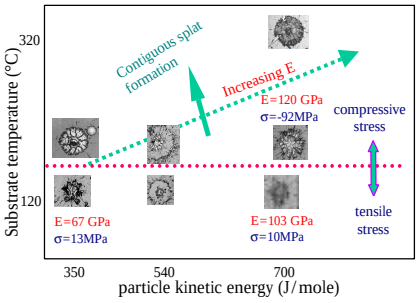
Porosity:	4%	8%
TC	3 W/m K	5.3 W/m K

Advances in Process Science and Mapping:

A process map, linking processing to performance, can consist of both experimental and computational data. Several types of relationships comprise a TS process map. In the SUNY-SB and Sandia National Laboratory joint study, efforts were made to find relationships among spray parameters, in-flight particle characteristics and deposit microstructures and properties. Process maps were synthesized for the plasma spraying of Mo. Two key parameters were used in the construction of the map: Particle energy which captures in-flight spray particle behavior and Tsub which allows modification of fragmentation.

Figure 2 exemplifies the second order process maps of properties generated from the first order particle behavior map. These types of maps offer unique scientific and engineering insight into the process.

Figure 2: Process Map Illustration for TS of Mo.

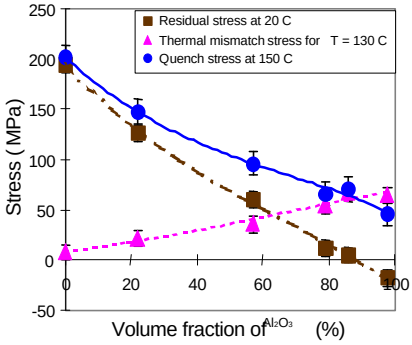


Collaborative Residual Stress Study:

Process induced residual stresses were studied to examine spray-related intrinsic residual stresses, which influences coating performance. A joint program between SUNY-SB and MIT involved two graduate students working closely to integrate results obtained by a variety of techniques. The stresses arise from two sources: solidification shrinkage and thermal mismatch due to deposition temperature gradients. Effects of processing on residual stresses were measured and related to microstructure and properties.

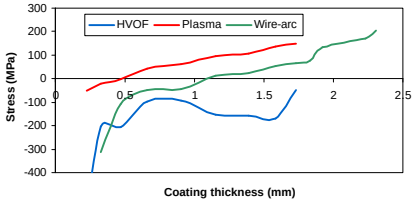
Two approaches have been used to study intrinsic process-induced stresses. MIT has developed a method fro determining such stresses in layered and graded deposits employing *ex situ* measurements of curvature through highly precise laser techniques (Figure 3) along with analytical and numerical modeling.

Figure 3: Curvature based stress measurements in graded deposits.



In parallel, neutron (NIST) and XRD were used to evaluate the intrinsic lattice stresses. The technique is phase-distinctive, allowing for both surface and through-thickness stress profiling. For the first time, through-thickness profiles on the deposits produced by various TS processes were investigated, offering important new insights (Figure 4).

Figure 4: Through-thickness stress in Thermal Spray Ni-5Al.



Partnerships Formed with Industry through SPIR/Industrial Consortiums

Industrial outreach has been of vital importance to the success of the CTSR. Given the industrial significance of thermal spray, it is difficult to speak of research in the absence of applications. Therefore the *Center* has sought council from industrial partners in establishing their research agenda and explore new strategies for industry-university programs.

SUNY-SB actively engages in New York *State's Strategic Partnerships for Industrial Resurgence* (SPIR). SPIR aids many large and small high technology New York based companies and helps them to utilize the vast intellectual, equipment and educational resources provided by the University. The *Center* has been very aggressive in outreaching to the large industrial base of Long Island. Through these intense activities, about ten companies have contracted with the *Center* through the SPIR program to address a wide variety of problems within their manufacturing scheme.

In addition to SPIR programs, the *Center* has been very active in the formation of industrial consortiums, or user groups, that brings together several companies sharing a common R&D goal. This approach not only allows for the sharing of combined resources, but for the exchange of ideas and concepts as to what the real issues are that need to be addressed.

Alumni Focus: Dr. Richard Neiser—Sandia National Laboratory

Rich Neiser's involvement in thermal spray science began 15 years ago when he enrolled in the doctoral program at SUNY Stony Brook under Prof. Herbert Herman. The thermal spray lab had about ten graduate students at the time, most of whom continue to be active members of the thermal spray community. After completing his Ph.D work in late 1989, Rich moved to Germany with his family as a Fellow of the Alexander von Humboldt Foundation. He spent over a year at the University of the Federal Armed Forces in Hamburg and at Aachen Technical University studying the properties of vac-

uum plasma sprayed nickel-aluminum intermetallics. In the summer of 1991, Rich accepted a position in the Materials Science and Process Center at Sandia National Laboratory. In 1999, Rich took over management of the Thermal Spray Research Laboratory (TSRL). Today, Sandia's TSRL is a 3000 square foot facility specializing in advanced modeling, diagnostics and pioneering research into new deposition technologies. There are seven full-time and numerous part-time employees and an annual budget of ~$2 M. A couple of interesting research projects being explored at the lab at this time include cold spray processing, feedback control of particle temperature and velocity for a production application, and a new type of vacuum plasma spray process called Thin Film Low Pressure Plasma Spray.

STONY BROOK
STATE UNIVERSITY OF NEW YORK

A Long History of Producing World Class Thermal Spray Engineers and Scientists

1970-1980

Mitchell Dorfman MS '79(Sulzer Metco), Saed Safai Ph.D '79(Allied Signal), Subramanian Rangaswamy MS '80 (Wall Chomalloy)

1981-1990

Subramanian Rangaswamy Ph.D '87 (Wall Chomalloy), John Nerz MS '87(Motorola), Keith Kowalsky MS '88(Flame Spray Industries), Tuck Chon MS '88(Motorola), Daren Gansert MS '88(Hardface Alloys Inc), Xiao-Xi-Guo Ph.D' 88(Applied Materials), Richard Neiser Ph.D '89(Sandia National Lab), Sanjay Sampath Ph.D '89 (SUNY Stony Brook), Hougong Wang Ph.D '89 (Applied Materials).

1991-2001

Rajesh Tiwari Ph.D '92 (Texas Instruments), Lysa Wasielesky-Russo MS '92 (SUNY Stony Brook), Christos Perdikaris MS '93(Bender Machine), Sang-Ha Leigh MS '93(Caterpillar), Jan Ilavsky Ph.D '94(NIST), Srikanth Reddy MS '94 (Ford), Robert Greenlaw MS '95(Integrated Coatings Inc.), Raphael Benary MS '95 (Sulzer Metco), Zhong-Jian Chen Ph.D '95 (Chromalloy), Karlis Gross Ph.D '95 (Monash University), Sang-Ha Leigh Ph.D '96 (Caterpillar), Robert Gansert '96 (Hardface Alloys Inc), Klaus Dobler MS '96 (St. Louis Metallizing), Jeff Brogan Ph.D '96,(Poly Therm) Saifi Usmani Ph.d '97(Motorola), Joshua Margolies MS '98(SUNY Stony Brook), William Smith MS '98(Caterpillar), Ahmed Ibrahim Ph.D '99 (SUNY Farmingdale), Jiri Matejicek Ph.D '99 (IPP– Prague), Tomas Chraska Ph.D '99 (IPP-Prague), Rogerio Lima Ph.D '01 (SUNY Stony Brook), David Cook Ph.D '01 (Ford), Ashish Patel MS '01 (Sulzer Metco)

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Going Beyond the Surface

For More Information:
www.stonybrook.edu/ctsr

Calendar of Events

AUGUST 2001

5-9 Long Beach, CA USA *Microscopy & Microanalysis 2001*– Microscopy Society of America, www.msa.microscopy

7-9 Stony Brook, NY USA CTSR "*Linking Research to Practice*" 631-632-4567, web: www.stonybrook.edu/ctsr

SEPTEMBER 2001

18-20 Edinburgh, Scotland *NACE United Kingdom Joint Conference with ICORR*, 44-1525-851771, web: www.icorr.org

18-21 Madrid, Spain *Advanced Materials Processing Technology Congress (AMPT)* 34-91-6249142, e-mail: congrega@fund.uc3m.es

OCTOBER 2001

3-4 Albuquerque, NM USA *Cold Spray, New Horizons in Surfacing Technology*– ASM International 800-336-5152, web: www.asminternational.org

4-7 Albuquerque, NM USA *Int'l Thermal Spray Assoc. Fall Membership Meeting*—ITSA members and guests only; 440-338-1950, web: www.thermalspray.org

15-17 Orlando, FL USA *Coating 2001 Conference & Expo*—Goyer Mgt. 513-624-9988, web: www.finishing.com/coating

NOVEMBER 2001

4-8 Seattle, WA USA *33rd Int'l SAMPE Technical Conference*– Soc. For the Advancement of Materials & Process Engineering, 800-562-7630, web: www.sampe.org

5-8 Indianaplis, IN USA *ASM Int'l Materials Solutions Conference & Expo and 21st Heat Treating Society Conference & Expo*, 800-336-5152, web: www.asminternational.org

DECEMBER 2001

4-6 Kenner, LA USA *8th NACE New Orleans Offshore Corrosion Conference*, 504-728-4145

FEBRUARY 2002

17-21 Seattle, WA USA *TMS Annual Meeting & Exhibition* (The Minerals, Metals & Materials Society), 724-776-9000 ext.270, web: www.tms.org/meetings

MARCH 2002

4-6 Essen, Germany Int'l *Thermal Spray Conference & Exposition (ITSC 2002)*-**DVS (German Welding Society), 49-211-15910,** e-mail dvs_hg@compuserve.com

19-23 Las Vegas, Nevada *SAE International Off-Highway Congress CONEXPO-CON/AGG*, fax: 724-776-1830, e-mail: kpurnell@sae.org

JUNE 2002

10-13 Orlando, FL USA 13th *AeroMat Conference & Exposition*, ASM Int'l, 800-336-5152, web: www.asminternational.org