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Center for Thermal Spray Research

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Stony Brook University

Linking Research to Practice

Going Beyond the Surface

Message from the Director

I am pleased to introduce our annual newsletter “Going Beyond the Surface”. Typically we introduce this newsletter coincident with the fall industrial consortium meeting usually held in November of each year. Of course COVID has disrupted so many things in 2020 that it has required significant adaptation and reconfiguration of our plans. We began 2020 with great promise. We had our last fall consortium meeting at GE Energy in Schenectady last November with significant enthusiasm and excitement about the thermal spray industry. All of us were planning for a year of great successes until COVID hit. As you all know New York was the epicenter of the infection March through May of this year. Our activities were shut down in mid March due to the Governors imposed lock down. All the students were sent home and all classes were quickly moved online. The CTSR team learned to adapt quickly making sure that all the data was accessible for remote work. After a few weeks of adjustment, we were able to organize ourselves quite effectively. Of course many of our projects were set back or delayed especially those that involved collaborative work in the laboratory. Things were surreal in April and May. In fact US Army built a 5 tent, 1000 bed field hospital in our soccer fields anticipating huge waves of COVID patients. Luckily this didn’t materialize and they are now being removed.

New York opened slowly in June, with research initiated at 30% capacity in late June/Early July to allow us to restart our equipment and processes in a controlled setting. Essential staff were able to keep tabs on the equipment throughout the shut down period which allowed us to quickly restart. By late summer the lab was operating at about 80% capacity with appropriate precautions to allow people to work in a socially distanced setting. We are pleased to report that through this entire process no one in the group was affected by COVID. We are hoping that we will continue to operate safely and creatively through the winter.

Throughout the process, our work was not compromised. The CTSR staff worked staggered schedules including weekends to meet our project milestones. The team showed significant creativity by moving the Consortium events online, including our very successful webinar formats. Over the last 8 months over a dozen webinars were held where students and staff presented their developments to the Consortium group. Anywhere from 50-120 people have routinely joined these sessions. The sessions were also recorded and shared with the membership. We were gratified at the interest and support. It appears that such a consortium format is likely here to stay in the future. The 1 hour topical sessions seems to be of great value especially from the point of education and reviews. Of course, we miss the social interaction of the face to face meetings and we will endeavor to resume that activity as soon as possible. We are hoping to organize our spring 2021 meeting next June for an in-person-event.

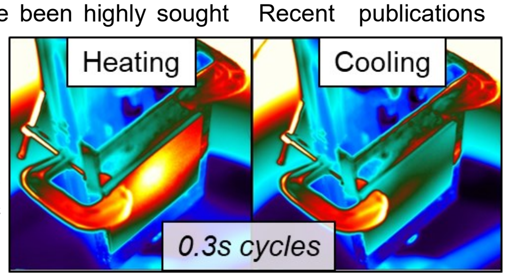
Interest in thermal spray science and technology continues despite the COVID related economic challenges. Some sectors have been more resilient than others. We are hopeful that once the vaccines become common, people will restart travels which can boost both air and automotive transport with concomitant impact on energy sector.

Meanwhile, the team here continues to innovate in both science and technology. In this newsletter we feature key accomplishments in science and technology including our newly initiated efforts aimed at understanding cracking and delamination, novel methods to look thermal transient behavior in coatings and understanding abradable coating dynamics.

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

Thermal Swing in Insulating Coatings

Thermal swing coatings for increased efficiency in internal combustion engines have been highly sought after by automotive researchers in the last half decade. These coatings are intended to insulate combustion facing surfaces by having the instantaneous wall temperatures match the combustion temperature at every point through periodic combustion cycles. Despite numerous theoretical investigations into ideal combinations of material properties for optimal performance in this application, little experimental work has been performed directed at producing such coatings. Work at the CTSR has broadly investigated the feasibility of manufacturing thermal swing coatings through spray processes, with the effects of microstructure and deliberate process variation in key materials explored. Recent publications demonstrate that the coatings effusivity, the combined effects of conductivity, density, and specific heat, is a primary concern in this application through a novel in laboratory developed test. A HVOF torch is used to expose coated samples at heat flux conditions relevant to engine operation with high frequency transient heating and cooling cycles. These results indicate that lowering effusivity through the inclusion of intrinsically low-density silicates in YSZ based composites may serve as a better pathway for achieving these goals than simply using the process to reduce conductivity.



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Industrial Consortium News

The Consortium for Thermal Spray Technology, hosted by CTSR, continues to expand and provide benefits to our industry across the supply chain. This past year has seen the addition of Sandia National Laboratories. Sandia has been a leading participant in Thermal Spray technology for some time, providing academic contributions as well as hosting a number of Center alumni and we are happy to welcome them to the Consortium membership. The Consortium is now completing its 18th year, starting from some 10 companies in 2002-03 to the present membership of 30 leading international companies.

The Consortium is a pre-competitive research and knowledge transfer partnership between CTSR Researchers and Industrial Partners. The goal is to provide Methods, Measurements, and Models that will allow the industry to more effectively design and manufacture with Thermal Spray. Each company contributes $12,500 annually as membership fees to the Consortium/CTSR, enabling self-sustaining operations following the 11-year National Science Foundation Materials Research Science and Engineering Center grant from 1996 to 2007.

While we did not have a face-to-face Consortium Meeting this year, the meetings continued through a virtual platform (details in a separate section). Despite the challenges of 2020, the Consortium nevertheless had a successful year. We look forward and are hopeful to hosting a face-to-face meeting in 2021 with the members and continuing to find innovative and unique ways to implement the highly successful virtual platform in the future.

CTSR WEBINARS—Virtual Consortium Meetings

In response to the rapidly evolving global trend of virtual meetings and webinars, CTSR has successfully hosted its first year of Consortium Webinar Discussions through Skype for Business and Zoom. From March 2020, the CTSR team organized sixteen Webinar sessions which allowed the sharing of recent work and developments in several key areas of Thermal Spray Technology (shown below). As a consequence of hosting online Webinar sessions, these meetings were all successfully recorded and stored in a SharePoint location for Consortium Members to access anytime from any device for post-meeting viewing. Since initiating this feature, past Webinar presentations have had anywhere from 20 to 40 views per recording by members of the Consortium. This shows the versatility and broad scope of application these Virtual Consortiums have had on our membership.

Additionally, the virtual consortium platform has allowed for the CTSR team to experiment with features that allow members to retain their anonymity while still actively engaging in the discussion. Such elements as anonymous polling and anonymous Q&A sessions have proven highly successful with the Consortium membership. This platform has also facilitated the establishment of new industrial collaborations between CTSR team members and member companies, for example in Round Robin Testing for the Center's Tensile Adhesion initiative.

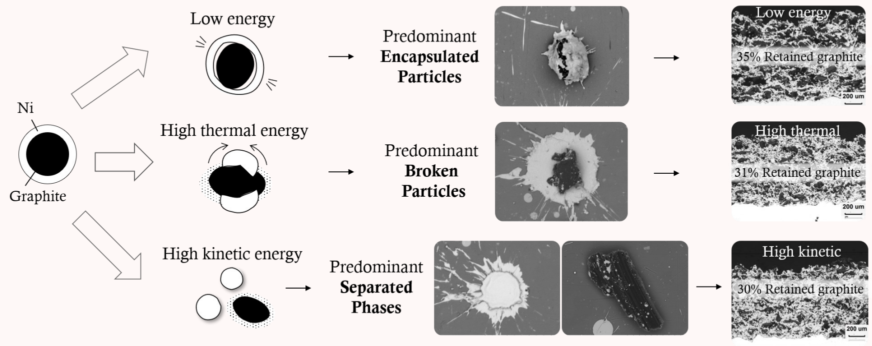
The growth and success of CTSR's virtual consortium series over 2020 has been proven by the membership's continued attendance and participation in the 1-hour topical presentations that have been given this year. The virtual consortium webinars have drawn numbers from as high as 150 attendees for more broad presentations to a more modest 50+ attendees in the specific topical discussions. The success and seamless integration of the virtual platform could not have been achieved without the dedicated effort from the CTSR Team. We thank Shalaka Shinde and Edward Gildersleeve for their steadfast efforts in ensuring the membership had a professional-grade experience in our first year of Webinars. We look forward to continuing to offer the membership a high-quality experience through new and innovative ways to utilize this technology.

Consortium 2020 Webinar Topics

Structurally Integrated Damage Tolerant Coatings	Interplay Between Delamination and Cracking in TS Coatings	Overview of Thermal Properties of TS Coatings
Geometry Effects on TS Coatings	MultiLayer Manufacturing & Design of TS Coatings	Contemporary Overview of the Tensile Adhesion Test (x3)
Formation Dynamics of Abradable TS Coatings	Synthesis of Functional Metal Oxide TS Coatings	Thermal Expansion Nuances in TS Coatings

Formation Dynamics of Ni-Graphite Abradable Coatings

The Center has started a quest for a more fundamental understanding on the formation dynamics of abradable coatings, used for clearance control in turbomachinery, steam turbines, labyrinth seals, among others. Abradable coatings are engineered to be readily worn out during contact with a mating counterpart, which promotes the creation of a tight sealing, in situations involving thermal expansions, vibrations, and distortions.



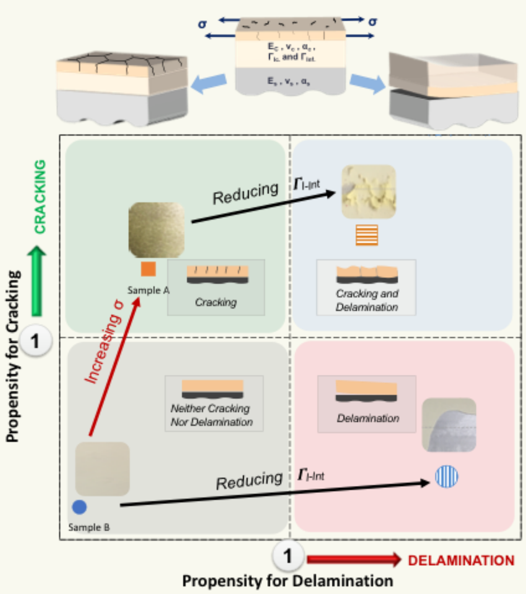
To simultaneously impart sufficient abradability and sufficient mechanical integrity, abradable coatings are generated composed of composite materials (such as blended AlSi-polyester and Ni-cladded graphite), whose contrasting properties pose a particular challenge to understand the intricacies of the interaction between the different materials during processing, and between them and the surrounding environment.

This investigation starts off addressing in-flight particle dynamics of Ni-graphite abradable coatings processed by APS, where the effect of thermal energy increment (current from 300 to 400A), kinetic energy increment (primary Ar gas from 50 to 80 lpm) and stand-off distance (100 and 160 mm) were assessed. A detailed microscopy study of particle transformations in-flight, showed that Ni and Graphite are susceptible to separation in flight. Results suggest that the process starts with debonding between the Ni-cladded graphite interface. This is followed by the agglomeration of molten Ni and, ultimately, by shearing and detachment between the two phases. Particle diagnostics and splat analysis for each of the studied conditions indicate that this separation effect progressively increases with thermal and subsequent kinetic energy increment and is more accentuated for higher spray distances.

Splat analysis also showed that detached graphite particles are unlikely to adhere to the substrate, leading to an increase in the Ni content, density and hardness. These efforts shed light to better understand the effect of processing parameters on the formation of Ni-Graphite coatings and help develop the science behind the engineering of these important coatings.

Interplay between Cracking and Delamination

Cracking within a sprayed coating and delamination from the interface have been widely recognized as the two most important phenomenon that affect the mechanical attributes of Thermal Sprayed coatings. These phenomena can be observed during processing of such coatings or can progressively evolve over time during service. Cracking in the coating can be advantageous for certain applications- for example the Dense Vertically Cracked (DVC) structure improves strain tolerance and thus enhances durability of TBCs. Therefore, the ability to deliberately incorporate such cracks during processing can be a significant step towards optimizing both the performance and production of optimal Thermal Spray coatings. On the contrary, delamination of the coating from the substrate is undesirable, creating the need for a framework for predictive modeling.



The Center research is aimed at adapting well established knowledge of such phenomena in these films to the thermal spray situation. The difference being thermal spray involves progressive assemblage of thin films with significant thermal dynamics during the coating build (heating and cooling due to rastering and material build-up). Preliminary linkages between analytical models and experimental observations show promise that thin film mechanics can be adopted to explain cracking and delamination in progressively deposited spray coatings. Figure shown is an example of a 4 quadrant map (based on quantitative parameters derived from modified thin film fracture analysis) along with examples of experimentally observed phenomena for air plasma sprayed zirconia coatings where all of the variants of delamination, cracking, and combined events are possible. This fundamental work is being rigorously validated both analytically and experimentally.

Awards and Honors

CTSR continues to make an impact in the materials and thermal spray world.

Over the past two years CTSR students John Saputo and Carl Schmidt both received the International Thermal Spray Association scholarship which is awarded annually to students pursuing interest in thermal spray. CTSR students have always been on the frontline to receive this award given their dedication and commitment to thermal spray technology.

CTSR paper "*Sustainability of metal structures via spray-clad manufacturing*" received the TMS-JOM award from the light metal division. This paper led by CTSR graduate Dr. Greg Smith presented innovations on the way thermal spray/cold spray remanufacturing metallic systems can be characterized to assess structural performance.

Following last year John Jeppson Award from the American Ceramic Society, Prof. Sampath was honored by ASM International through the **Albert Sauveur Achievement Award for 2020**. Established in 1934 in honor of a distinguished teacher, metallographer and metallurgist, this award recognizes pioneering materials science and engineering achievements that have stimulated organized work along similar lines to such an extent that a marked basic advance has been made in the knowledge of materials science and engineering. Prof. Sampath's award citation reads "*For identifying impediments to knowledge in thermal spray technology which led to his developing improved tools for wide industrial adoption of in-situ process diagnostics and coating property measurements*".

Alumni Focus: Daren Gansert

In this newsletter, we are pleased to feature Daren Gansert, founder and CEO of HAI Advanced Materials in Placentia CA. Daren graduated his Bachelor's in Mechanical Engineering followed by Masters in Materials Science at Stony Brook in 1987 focusing his thesis on high velocity thermal spray technologies. He started working with Prof. Herman as an undergraduate researcher and went on to develop passion and expertise in thermal spray technology. This was the period of significant interest in the Jet Kote™ HVOF process which was introduced into the market only a few years prior. Daren was responsible for setting up the Jet Kote system at Stony Brook and among the first students to operate the system and spray coatings. This was the period of "handheld thermal sprays" and all of the energy he put in the gym lifting weights came in handy during his thesis work. Concurrent to his work with Jet Kote, Daren also played around with the Fuel Air Repetitive Explosion detonation spray process. The so-called FARE gun was developed in the 70's as detonation spray technology which used a unique ribbon powder delivery process to apply coatings. Daren spent many hours trying to get this system operational ultimately succeeding in producing coatings. Daren brought lot of humor along with his hard work. His body building skills came in handy in moving things around the laboratory but that would extend to lifting other students over the head and do some 'squatting' routines. He was also a gifted caricature artist, often setting up drawings on the black board overnight for people to discover.

Following graduation, Daren set off to sunny California (he is originally from upstate New York) to pursue an engineering career at Bender Machine Co. who specialized in field thermal spray applications for Yankee Dryer paper machines. He developed significant experiences in nuances of technology, applications, and business of thermal spray, which then led him to entrepreneurial pursuits with the development of HAI. He has been at the helm of HAI for the past 28 years where he has tirelessly pursued technology and business opportunities in thermal spray materials, equipment and systems. Since its founding in 1992, HAI has grown to a significant company with some $20M in annual revenue with some 40 or more staff members and sales representatives. HAI has built numerous thermal spray systems, innovated in novel materials developed strategic partnerships with key customers. Notable, also is his partnership with the Czech Republic in the area of Water Stabilized Plasma Technology. This technology was brought into US by Prof. Herman in the late 1980s through his collaboration with the Institute of Plasma Physics (IPP) and tested extensively at Stony Brook as part of major governmental programs. Daren and HAI established a link with the commercial wing of the institute and has successfully commercialized this technology around the world.

To say Daren is a highly energetic individual is an understatement. He has an intense work ethic and passionate leader, technologist and entrepreneur. Daren is very adept at launching new ideas and brands and creatively finds methods for the benefit of all. As he notes in his company motto "Combine a passion for your services and commit to your customers and that result will be the benefit to everyone's prosperity".

Daren remains very active in the thermal spray community. He has presented numerous technical papers in some 17 countries, was a recipient of an outstanding Alumni Award from Stony Brook in 1999. He continues to reach out and offer his assistance to Stony Brook students and Alumni. During his free time, he enjoys spending weekends on his boat with his partner Irene in Newport Beach area. Daren enjoys many hobbies, he is a Certified PADI Diver and particularly enjoys hunting lobsters during the season, fishing and golfing.