SEAM
ARC TRAINING CENTRE
Surface Engineering for Advanced Materials

ANNUAL REPORT

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Australian Government
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The ARC Training Centre in Surface Engineering for Advanced Materials (SEAM) is funded by the Australian Research Council (ARC) through the ARC Industrial Transformation Training Centre (ITTC) scheme via Award IC180100005. SEAM is a partnership between Swinburne University of Technology (host institution, headquarters to SEAM), RMIT University and University of South Australia, along with other collaborating organisations in Australia and overseas. We are grateful for the support of the industrial, university and other organisation partners who have contributed to the establishment of SEAM.

We respectfully acknowledge the Wurundjeri People of the Kulin Nation, their Elders past, present and emerging, as Traditional Owners of the land on which Swinburne's campuses are located in Melbourne. We are honoured to recognise our connection to Wurundjeri Country, history, culture and spirituality through these locations, and strive to ensure that we operate in a manner that respects and honours the Elders and Ancestors of these lands.

We also acknowledge the Traditional Owners of lands across Australia, their Elders, Ancestors, cultures and heritage.

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DIRECTORS MESSAGE

SEAM truly 'got off the ground' in 2019. SEAM built its profile and identity by cementing our research capacity and strength in the areas of surface engineering and advanced materials. We are excited to have recruited 17 Early Career Researchers (ECRs) in our first year and look forward to welcoming new talents who will contribute to the global manufacturing industry.

It has been an exciting first year and I am proud to say that SEAM has transitioned quickly into the reality of a multidisciplinary research institution. A highlight was execution of the Participants Agreement on 14 March 2019 in record time after the Australian Research Council (ARC) announced the Award in the 4th quarter of 2018. We have an exceptional team of 19 Chief Investigators (CIs), 22 Partners Investigators (PIs) from 15 Partner Organisations (POs), and 14 Other Organisations (OOs) with whom we have developed a collaborative research program based around three themes: (i) Thin films, (ii) Thick films, and (iii) Additive manufacturing.

The SEAM team across our three nodes; Swinburne University of Technology, RMIT University and University of South Australia (UniSA), provides exceptional training for ECRs, while also building capacity for a skilled workforce that will enable Australia to transition as a global leader in manufacturing.

In our first year, we were successful in attracting world-class researchers, research scientists and engineers to join our Centre. This team was assembled for the first time at our inaugural Annual Workshop (page 40-41) on 27-28 August 2019, which brought together our staff, students and stakeholders as well as research leaders from Singapore (represented by Oerlikon Metco), Canada (represented by Polycontrols) and Thailand (represented by SCG Chemicals).

SEAM has relied on the support and encouragement of Professor Aleksandar Subic, Swinburne's Deputy Vice-Chancellor (Research and Development), throughout the conception of SEAM to the post-award process. It was a distinct pleasure to have Prof Subic at the SEAM Launch (page 38-39) where he welcomed

Professor Sue Thomas, the ARC Chief Executive Officer, where she eloquently launched SEAM with 150 people in attendance. Emeritus Professor Derry Doyle was the Master of Ceremony of this wonderful event that established SEAM as a Centre that lived up to its moniker of '**SEAM Covers it All'**.

The SEAM Inaugural Executive Committee (EC) met throughout in 2019 to ensure professional governance of SEAM during its foundation year. I personally thank the Directors of the SEAM EC for their guidance, advice, and key recommendations as we begin our journey of 13 core research programs.

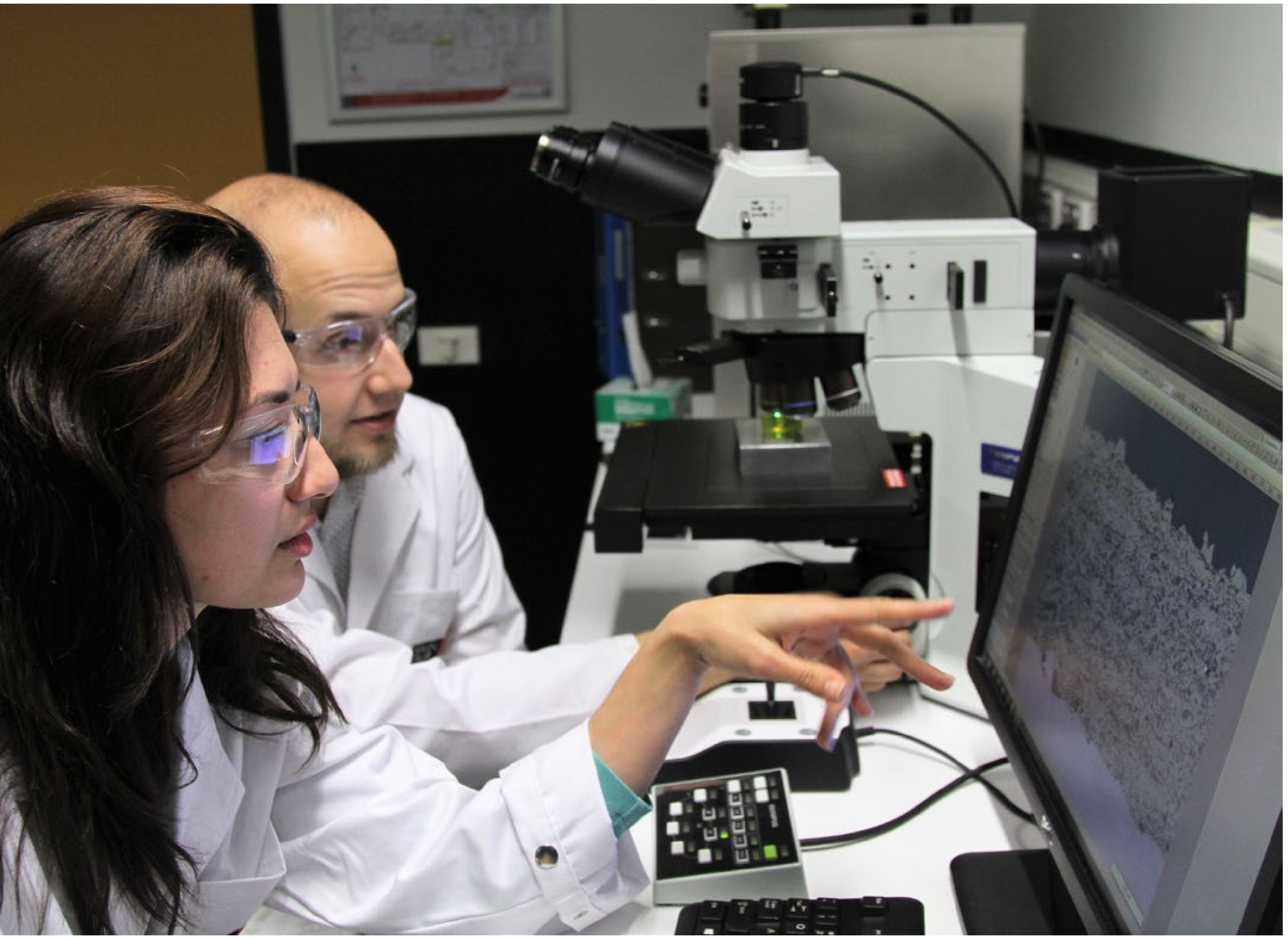
The start-up of SEAM has occurred at a dazzling pace; i.e., 'warp speed' in planning, recruitment of ECRs, strategizing the future, collaborations initiated, and a host of activities that respond to the objectives of the Industrial Transformation Training Centre (ITTC) large project scheme of the ARC. SEAM leads the way in featuring quality research events (page 42-52) and our researchers are publishing in high impact journals.

SEAM is a collaborative and integrated body of engineers, scientists and support personnel: all of whom have contributed to our incubation, execution and delivery of ITTC outcomes. There is no doubt that the first operational year of SEAM has been a dizzying blur of exhilaration with a reputation that is now global.

SEAM is a world-leading Centre for the study of Surface Engineering in Advanced Materials. The years ahead will continue our momentum and be just as exhilarating as the first year as we push the boundaries of innovative industrial research. These outcomes have arisen from a strong team and established SEAM as a world class industrial training and research centre.

Remember: 'SEAM Covers it ALL'.

Chris C Berndt
Distinguished University Professor
Director, ARC Training Centre in Surface Engineering for Advanced Materials



SEAM Early Career Researchers:
Samuel Pinches and Azadeh Mirabedini
Swinburne University of Technology

ABOUT SEAM

The Australian Research Council (ARC) Industrial Transformation Training Centre in Surface Engineering for Advanced Materials (SEAM) is Australia's premier manufacturing Research and Development centre that focuses on applied research with tangible outcomes to nurture and cultivate the industrial innovation leaders of tomorrow.

The Centre aspires to provide an excellent environment for carrying out research, explore projects with industry, government and other organisation. SEAM will target the training of early career researchers in an industrial context and build an international research collaborative network to pursue ambitious outcomes that are reflected as industry-fit researchers providing a commercial benefit for industry.

The outcomes of the applied research and Intellectual Property creation will promote new commercial ventures for Australian and international entrepreneurs.

Three surface engineering themes form the technological foundation of SEAM, and promote interactions between and among these technologies, these are: thin films, thick coatings and additive manufacturing.

SEAM currently comprises of thirteen projects, all aligned with key industry partners, chief and partner investigators and a team of early career researchers, trained to be the next generation of industry experts in surface engineering and advanced materials.

RESEARCH PROJECTS

REFURBISHMENT AND ENHANCEMENT OF MINING EQUIPMENT

Industry Partner: D&T Hydraulics Pty Ltd

Project 1

D&T Hydraulics' core business involves the refurbishment of hydraulic shafts, cylinders and associated components, primarily for the mining and manufacturing industries. In 2018 the business invested in the installation of a high-speed laser cladding facility. This technology is state-of-the-art, and offers a range of new capabilities that in turn have the potential to both deliver existing refurbishment services at a higher rate and quality, as well as extending in-house capabilities further and enabling applications in new markets to be tapped.

By partnering with Swinburne under a SEAM project, D&T benefits from additional resources to assist with accelerating the development and refinement of laser cladding capabilities at D&T. Samples prepared via laser cladding have been provided to Swinburne for microstructural analysis, with results used to optimise processing conditions. In turn, Swinburne benefits from the opportunity to be at the forefront of research around this cutting-edge advanced surface engineering process, and supporting the training of new surface engineering researchers. To date, under this collaboration a broad range of cladding materials have been tested and studied using high-speed laser cladding, with the capability demonstrated to be clad alloys from different metal alloy classes. Specific alloys have been identified for targeted commercial applications, and further work is now underway to validate the performance of the cladding through accelerated environmental and wear testing. Further research continues in parallel, working to optimise process control in order to ensure consistent and reliable cladding, as well as studies underway to investigate interactions between different cladding and substrate materials to ensure reliability under different environmental conditions.

L-R: Christiane Schulz, Christopher C Berndt, Samuel Pinches, Warren Smith, Colin Hall, Sean Graham, Jamie Graham.

THIN FILMS FOR INFECTION CONTROL

Industry Partner: Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Project 2

With an increase in demand for orthopaedic surgeries, a growing number of implant related infections has become great concern of all modern orthopaedic surgical procedures. Bacterial adhesion to various biomaterials and the formation of biofilm on implant surfaces are key steps in the development of most infectious condition, which starts from bacteria adhere to implant surface, followed by proliferation and the multi-layer accumulation of extracellular matrix, which often leads to severely implant failure and repeated surgery procedures for chronic wounds.

Nevertheless, surface engineering has been helping biomedical science with better understanding and control of implant related infections. For example, surface modification of implant surface enables to interfere with bacterial adhesion as well as delay the initial stage of infection happening within implant–tissue interfaces. As biological systems are inherently complicated and hierarchically structured, we believe a better preventative approach can be achieved particularly by combining multiple antimicrobial strategies in the same device or coating. Here, we are aiming to develop new antimicrobial coatings with multifunctionalities providing a broad range of antimicrobial spectrum and multiple layers of defence. Thermal spray methods will be mainly used to deposit new antimicrobial coatings in the form of mixture or multiple layers of coatings with bioactive species including polymers, metals, and nanoparticles, molecules that could interfere with microbial signalling. The coatings will be characterized using XPS, IR, AFM, SEM, Raman, XRD, contact angles, profilometer, and their antimicrobial properties and biocompatibilities will be tested using a range of medically relevant microbes and different cell lines.

L-R: Peter Kingshott, Elena Ivanova.

RESEARCH PROJECTS

LAYER-BY-LAYER DEPOSITION OF NANOMETER THIN FILMS ON ARBITRARY 3D STRUCTURES

Industry Partner: GrapheneX Pty Ltd

Project 3

Conformal coatings over a complex 3D structure are needed to achieve additional functionalities and prevent corrosion. However, the complete covering the complex 3D surface is extremely challenging for conventional coating techniques, especially when the parts are intricate and of small dimensions with intricate gaps or channels involved. The incomplete covering on 3D structures with conventional coating techniques will introduce defects, thus compromise the functionalities and, in particular, the anti-corrosion performance. Therefore, it is required to develop a new conformal coating technique with the capability of the complete coating of 3D structures. In this project, the Team will develop a scalable and low-cost layer-by-layer conformal coating technique based on a patent pending wetchemical coating method SUT researchers have developed. The research will focus on the attachment of the coating to different substrates. The strength and longevity of the coating will also be investigated according to the industry requirements. The anti-corrosion performance under a number of harsh conditions will be understood versus the coating parameters, including the compactness, coating thickness and structure complexity to meet the industry standards. SEAM Project Team will be trained in advanced nanotechnology coating techniques. They will master the coating process and the coating properties to be suitable for the industry demands.

L-R: Peter Kingshott, Stephen Wee , Baohua Jia, Xiaodong Huang, Rosalie Hocking.

COATING AND REPAIR OF ADDITIVE MANUFACTURED COMPONENTS

Industry Partner: LaserBond Ltd

Project 4

Laser Cladding can be used for Laser Metal Deposition (LMD) as an Additive Manufacturing (AM) method to repair or add structures to structural components. These components can find uses in mining, agriculture, aerospace and automotive industries. Anywhere, in which complex structures, normally made via substrative processes, need to survive tough environments. Through LaserBond, partnering with Unisa, this project will address the need to understand the possibilities and limitations of added and/or repaired LMD structures. It will develop quality control techniques for these structures, so as to give end-users confidence in the expected performance.

In addition, the role of advanced feedback systems in controlling the critical parameters in LMD structure manufacture will be investigated. This will enable LaserBond to offer an advanced AM process and capitalise on the inherent advantages of AM, that is low wastage (cf – subtractive processes) leading to a more economical and ecological production process. Finally, coating protocols will be investigated, this can include graded coatings, duplex systems and the investigation of the effect of the deposition pattern on the AM part. This will cumulate in prototype fabrication and testing.

L-R: Thomas Schlaefer, Colin Hall, Gregory Hooper, Christiane Schulz, Jeremy Rao.

RESEARCH PROJECTS

HIGH PRECISION COATING WITH A GRAPHENE LAYER

Industry Partner: Innofocus Photonics Technology Pty Ltd

Project 5

Optics industries rely on thin film coating technologies to manipulate light reflection, transmission, and absorption within specified wavelength ranges. However, the coatings are fabricated at a high cost using complicated vacuum coating machine, greatly limiting their effectiveness and accessibility. These processes are also of low efficiency and require an experienced workforce. Therefore, it is necessary to develop a low-cost, simple and large-scale coating method that is able to precisely control the coating properties and thicknesses with nanometer accuracy.

The SEAM project team aims at achieving two important milestones through this project: The first one is to demonstrate nanometer precision coating on a flat substrate to achieve simple functionalities. The second one is to use a laser to pattern the film to achieve more complicated functionalities. The Team will first focus on the development of the multilayer deposition technique of graphene materials to target the nanometer film thickness and large-scale uniformity requirements placed by the optical coating industry. Then through employing and developing advance nanofabrication technology by ultrafast lasers, nanopatterning of the thin film can be achieved, enabling sophisticated tenability of light in the nanometer scale. Advanced device architectures can be developed in collaboration with industry partners, thriving the photonics industry in Australia. The SEAM team will be trained in the area of precision optical coating and optical design. In particular, advanced computer modelling skills will be developed in combination with nanotechnology fabrication.

L-R: Nouman Tariq, Baohua Jia, Rosalie Hocking.

OPTIMINIZATION OF SURFACE PROPERTIES OF ADDITIVE COMPONENTS USING AN ADDITIVE/SUBTRACTIVE MACHINE

Industry Partner: Romar Engineering Pty Ltd

Project 6

Metal additive manufacturing has many advantages including the ability to reproduce from CAD designs and develop intricate structures as well as significant energy and material savings compared to traditional manufacture. However there are however some areas where improvements can be made: additive manufacturing is relatively slow, it can induce residual stresses in parts , surface finish may be rough requiring post processing and it needs high quality and expensive powders. This project will assess whether the use of a hybrid machine in which both additive and subtractive manufacturing is possible can reduce these issues.

The project will use a the DMG Mori Lasertec 3D 5axis have several interesting functionalities including faster deposition rates (10 times faster than other additive machines) plus the ability to undertake laser deposition welding and milling in the one machine. The project will assess if the use of subtractive manufacturing (ie milling) interspersed with additive can reduce residual stress and also control the surface finish. The effect of powder shape and chemistry will also be investigated to determine if lower cost powders can be used. In addition to training post-doctoral fellow and PhD students the project aims to produce higher quality parts that require either less or no post processing in a faster and more economical way. The technology will be used in aerospace, defence and biomedical applications.

L-R: Ivan Cole, Christopher C Berndt

RESEARCH PROJECTS

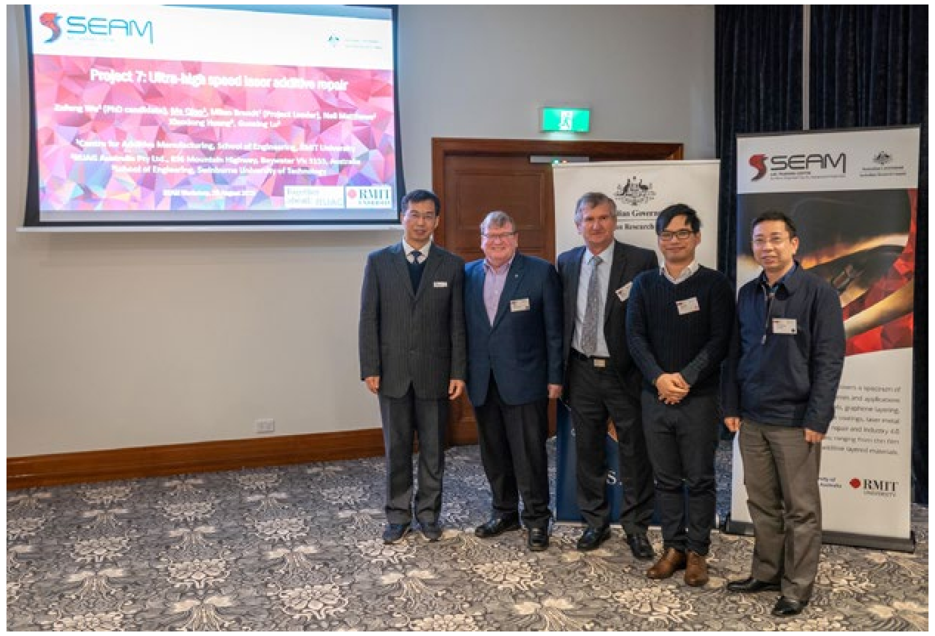
ADDITIVE METAL MANUFACTURING FOR AEROSPACE APPLICATIONS – HIGH SPEED LASER DEPOSITION OF THIN METAL COATINGS

Industry Partner: RUAG Australia Pty Ltd

Project 7

Laser metal deposition (LMD) is a surfacing technology used for obtaining high quality wear and corrosion resistant coatings on a range of substrates. The technology is now well established as an industrial process and complements other coating technologies such as thermal spraying. The current research efforts in LMD in the context of surface repair focus on processing and microstructural optimisation, novel coating alloy design and knowledge transfer from traditional fabrication technologies. However, the process operates at a relatively low laser scanning speed (typically ~2 m/min) which makes it less attractive in relation to large surface area repair.

A new process which has been reported in the literature and which is attracting increasing attention from industrial perspective is Ultra High Speed LMD (UHSLMD). The UHSLMD process has a capability to deposit metal alloys at speeds of 100 m/min or 500 cm2/min. As an emerging rapid repair technology, the potential of UHSLMD to efficiently produce competitive clad layers with various materials on large surface areas has not been investigated in depth. This project has identified a need for the development of thin film coatings (< 100 micron thick) for wear and corrosion protection based on UHSLMD technology for a range of aerospace components. The technology to be investigated and developed will examine the process parameters for depositing high quality coatings and characterise their microstructure and wear and corrosion performance. The project has the potential to deliver new laser coating technology for repair of large surface areas of aerospace components more economically and environmentally friendly.



L-R: Ma Qian, Neil Matthews, Milan Brandt, Zefeng Wu, Xiaodong Huang.

ADDRESSING ASH-RELATED CHALLENGES FROM BIOMASS COMBUSTION USING CERAMIC AND COMPOSITE COATINGS

Industry Partner: SCG Chemicals Co Ltd

Project 8

Although the use of biomass as an energy source has been growing, some challenges related to biomass combustion are inevitable and they can negatively affect the efficiency and performance of the boiler. The degradation of the boiler is a result from high temperature corrosion from corrosive compounds released from biomass combustion and erosive wear due to impingement of solid particles.

The new desired coatings to address the challenges must be capable of reducing slagging deposition and corrosion attack from biomass combustion, contain both tough and hard phases to resist erosion as well as be compatible to the existing substrate in a practical working environment.

According to previous studies, metal-based Ni-Cr coating has shown excellent corrosion and erosion resistance in a practical boiler environment. In addition, it is evident that adding appropriate content of ceramic phase to the coatings as a reinforcing hard material can enhance erosion resistance of the coatings. The research team aims to implement these finding to create a new generation of composite coatings that positively modify surface properties such as resistance to corrosion, wear and oxidation to prolong the life span of the boiler component and improve its performance.

L-R: Andrew Ang, Noppakun Sanpo, Christopher C Berndt, Peter Kingshott.

RESEARCH PROJECTS

EDGE PREPARATION, SURFACE FINISH, AND THEIR EFFECTS ON MODERN PRECISION CUTTING TOOL PERFORMANCE

Industry Partner: Sutton Tools Pty Ltd

Project 9

Edge preparation and surface finish are vital considerations in the manufacture of modern precision cutting tools, as they may significantly impact tool efficacy and life. Existing methods of preparing tool surfaces are principally based on honing operations through abrasive mechanisms such as drag finishing, micro-blasting, and diamond polishing. While cost-effective, these methods are limited in their application to many tool materials due to the high hardness of tool materials, and/or limited dimensional control. Although other methods of tool preparation, based on thermal or (electro)chemical processes have been developed, there is limited understanding of these edge preparation techniques and the relationships between process parameters and the resulting cutting tool geometries.

In this project, a comparative evaluation of various existing edge-preparation processes will be performed, and the key characteristics associated with satisfactory edge preparation will be identified. Next, a novel electro-polishing edge-honing process will be developed, and the impact of the various associated process parameters on the resultant edge preparation will be investigated; this will be used to develop protocols to achieve the optimum surface quality of the cutting edge. In addition, various wear resistant thin films will be deposited onto cutting tools with different geometries and sizes using physical vapour deposition technique. The coated thin films and the cutting tools will be evaluated in terms of their chemistry, microstructure, crystal structure, micro hardness, wear properties and tool life.

L-R: Derry Doyle, Guy Stephens, James Wang.

CREATING THE TITOMIC KINETIC FUSION® SMART FACTORY

Industry Partners: Titomic Ltd and Australia's Nuclear Science and Technology Organisation (ANSTO)

Project 10

Titomic (ASX:TTT) is an Australian public company specialising industrial scale metal additive manufacturing using its patented Titomic Kinetic Fusion® (TKF) technology. The TKF technology provides unique capabilities for producing commercially viable additively manufactured metal products, competing directly with traditional manufacturing methods. Titomic provides OEM production and R&D services from its TKF Smart Production Bureaus to the global Aerospace, Defence, Shipbuilding, Oil & Gas, Mining and Automotive industries. Titomic also provides an extensive range of metal powders for 3D Printing, especially titanium and super alloys, and provides sales and support services for their TKF production systems.

SEAM and Titomic have outlined several specific areas of need for research going forward. These goals including further optimisation of the Kinetic Fusion process, the exploration and development of operations with mixed-materials, and the development of advanced predictive models to validate part manufacture and ensure ongoing part reliability. The use of advanced sensors and process control feedback enables auxiliary data sources to be used and compared to the results obtained from traditional destructive and non-destructive sample analysis techniques. Foundational process development will be supported by analysis of prepared samples at Swinburne to verify cladding quality, with active involvement ramping up in early 2020 with a PhD student joining the project in Q1. Planning is presently underway into the design of advanced process monitoring systems that are expected to form key inputs into both research studies, as well as providing data that will be used to develop models for predictive process quality control monitoring.

L-R: Azadeh Mirabedini, Jason Miller, Andrew Ang, Samuel Pinches, Xiaodong Huang.

RESEARCH PROJECTS

DEVELOPING TECHNOLOGIES FOR THERMAL SPRAYING COMPOSITE SUBSTRATES

Industry Partners: Defence Materials Technology Centre (DMTC) Limited, MacTaggart Scott Australia (MTSA) United Surface Technologies (UST) Pty Ltd

Project 11

Thermal spray coatings have shown the ability to improve the properties of a variety of structures/components in relation to their wear, corrosion, conductivity and/or thermal protection performance. These coatings have traditionally been applied to standard metallic substrates. For many applications, however, industry has been increasingly looking at the use of different substrate materials/designs to manufacture their products and also to develop coatings that can allow structures/components to be used in harsh environments. For example, there is an increasing demand for the reduction of the weight of components and structures, while maintaining required performance/operational characteristics. This project will investigate the development of the thermal spray coating processes that are used to functionalise composite material structures. To achieve this the research team, comprising of industry and research experts, will look at the coating process from a holistic perspective in terms of the coating materials, coating application parameters and the substrate properties. Test components as specified by industry partners will be developed as prototypes, which will then be trialled in the field to determine the performance in relevant operational environments.

L-R: Matthew Leigh, Andrew Ang, Phillip Duncan, Miles Kenyon.

MAINTENANCE AND REPAIR OF AGEING INFRASTRUCTURE IN REMOTE AUSTRALIAN LOCATIONS

Industry Partner: Santos Limited

Project 12

Like many companies in the oil and gas sector, SANTOS have an extensive gas and oil pipeline network made from steel. Some of these pipelines suffer accelerated corrosion inside the pipes due to the activity of microbes, and this is referred to as microbially induced corrosion (MIC). This project aims to look at several aspects of MIC in gas pipelines. Firstly, anti-microbial coatings on the inside of large diameter pipes will be studied, with a view to improving the pipelines that may be built in the future. External pipeline repair using laser cladding will also be examined, as this has many advantages over existing repair technology such as longevity and resistance to the harsh Australian environment, in particular, the expose to ultra-violet radiation from sunlight. Lastly, a dedicated surface study will be carried out to investigate how the implementation of new chemicals such as foaming agents and newly developed anti-microbial additives effect the corrosion behaviour inside the pipeline.

L-R: Christiane Schulz, Colin Hall, Nikki Stanford, Steven Benn, Jeremy Rao.

RESEARCH PROJECTS

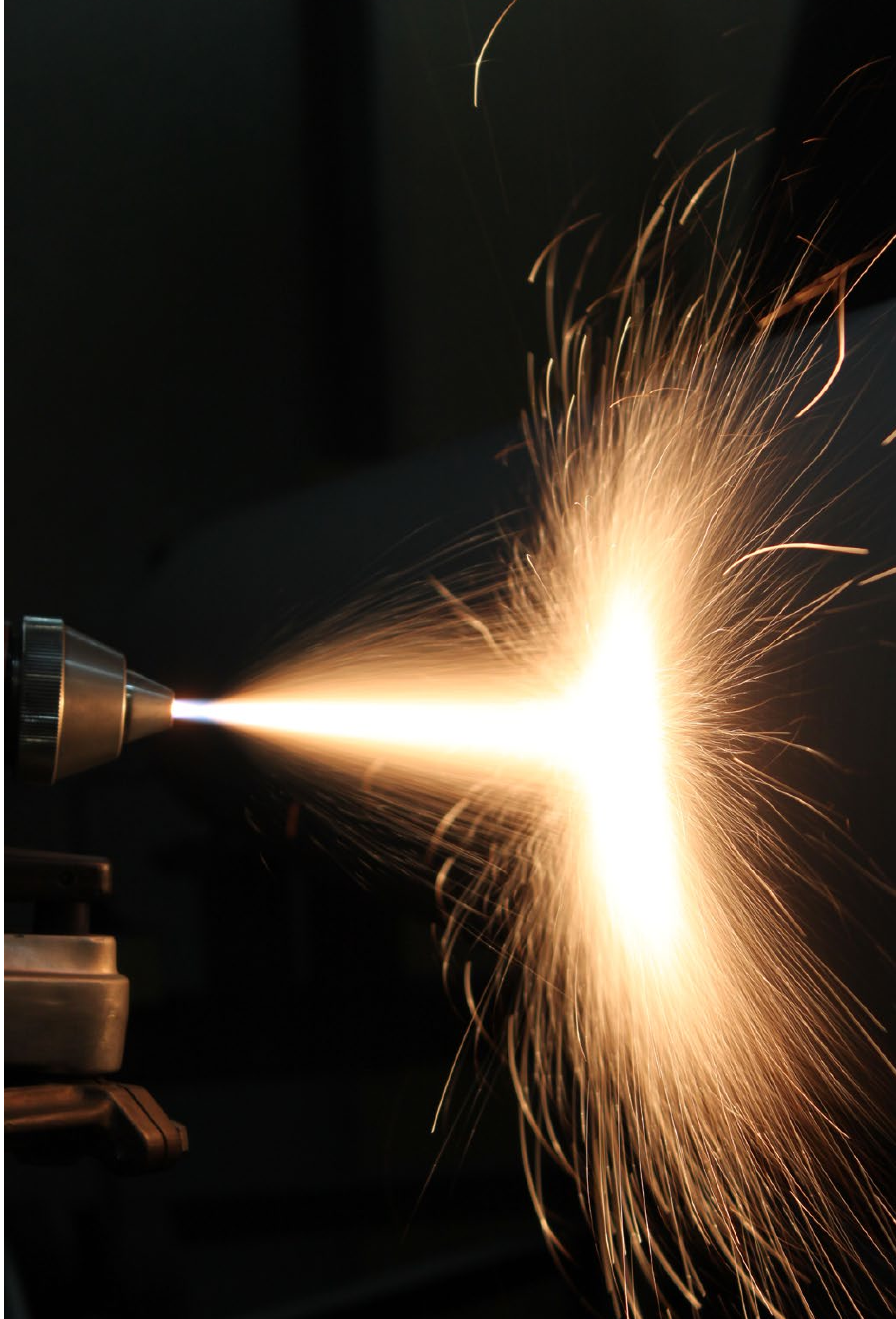
FUNCTIONAL COATING MATERIALS FOR INDUSTRIAL APPLICATIONS

Industry Partner: GrapheneX Pty Ltd

Project 13

Multifunctional coatings with the advancement of nanotechnology and nanomaterials have emerged as a fascinating field with the potential to have significant impacts on industry and society. Superhydrophobic, easy-to-clean coatings for sensors; self-cleaning, hydrophobic/hydrophilic coatings for aerospace and automotive industries, anti-fingerprint and anti-glare coatings for touch-screen displays are few examples of smart coating applications. Owing to the stimuli-response behaviour of the smart materials towards various intrinsic or extrinsic events in the form of altered temperature, electric current, pressure, sound, pH etc., key challenges such as the enhanced coating lifetimes, effective performances under real-world conditions, conversion of laboratory smart coating concepts to practical coating systems need to be addressed. Poor mechanical strength, slow response and undesirable environmental instability of conventional smart materials leads to the introduction of advanced materials such as polymer nanocomposites, nanoparticles and nanostructured materials such as CNTs, graphene etc. that can enhance the properties of existing coatings and thereby fulfil the modern industry needs. This project will develop an innovative and cost-effective pathway to create advanced coating materials and improved methodologies for the synthesis of functional coatings for industrial applications.

L-R: Nishar Hameed, Andrew Ang.



RESEARCH THEMES

SEAM aims to solve crucial surface engineering problems, such as the design, fabrication, testing, analysis, and pathways towards value-added applications, all of which enable the Australian manufacturing industry to be more efficient and profitable in the global marketplace.

To spearhead enrichment of Australia's manufacturing industry, SEAM research will draw upon a global surface engineering expert network that covers Australasia, Asia, Europe, and North and South America.

SEAM has four goals aligned with its initiative toward the industrialisation of academic outcomes. Implementing industry/academic projects that tackle specific surface engineering issues of critical consequence for partner organisations. For example, wear and corrosion resistance within the mining sector, or antibacterial films for medical implants. Solutions will evolve from applied research based on a foundation of scientific understanding rather than the current trial and error methods that lead to quick but highly risky and costly short-term fixes. Creating a strong and pervasive training team where industry will work closely with academia to maximise their return by leveraging members of the SEAM team. Additional joint projects will be nurtured within SEAM so that industry can maximise growth and achieve its potential. Establishing a pragmatic mindset where SEAM research feeds into the economic and productivity needs of industry aimed at enhancing economic growth and competitiveness.

Three surface engineering themes form the technological foundation of SEAM, which promotes interaction between and among these technologies.

THEME 1

Nanoscale surface modifications and thin films such as PVD and CVD are used in applications ranging from films for bacterial and infection control, to microelectronics, to hard coatings for the machining industries.

THEME 2

Thick coatings are manufactured by laser and thermal spray technologies. These overlays are used in heavy industries, mining, and in commercial transportation for repair and remanufacturing of components.

THEME 3

Additive manufacturing (AM) is a layer-by-layer deposition process that creates a new surface. The two prime AM technologies explored include laser technology and cold spray. These are considered the most challenging because they involve fabricating near-net artefacts from difficult to process metals such as titanium alloys.

Christiane Schulz, SEAM Chief Investigator
University of South Australia

The SEAM TEAM

THE SEAM Team

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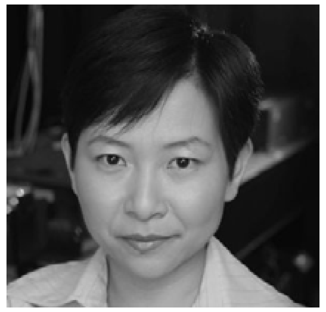

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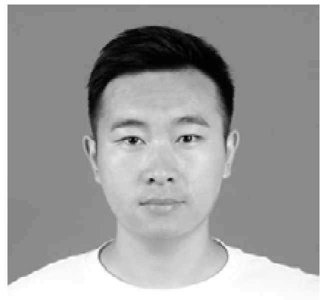

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- Mr Stephen Wee - GrapheneX Pty Ltd
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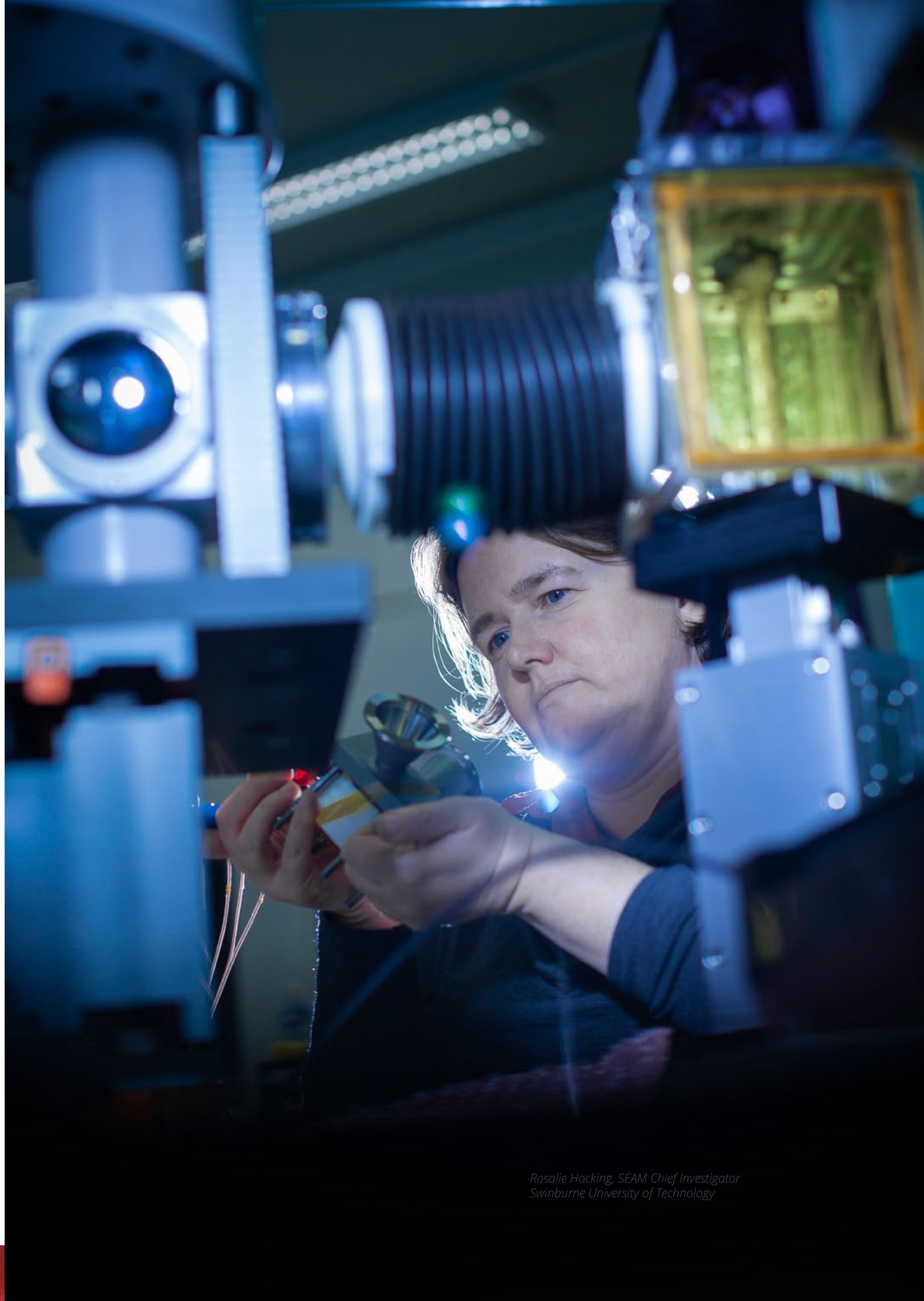
- ASB Industries, Inc.
- The Australasian Corrosion Association Inc.
- Flame Spray
- GTV
- IIT Madras – Indian Institute of Technology Madras
- IPP – Institute of Plasma Physics of the Czech Academy of Sciences
- Inovati
- 暨南大學 Jinan University
- Materials Australia
- Nanyang Technological University Singapore
- Oerlikon Metco
- Stony Brook University
- Victoria University of Wellington – Te Herenga Waka
- Weld Australia



Rosalie Hocking, SEAM Chief Investigator
Swinburne University of Technology

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SEAM Outreach at the 2019 Avalon Airshow, Australia

ENGAGEMENT AND OUTREACH

28 AUGUST 2019
SEAM LAUNCH

L-R: Professor Peter Kingshott, Professor Aleksandar Subic, Professor Sue Thomas, Distinguished Professor Christopher C Berndt.

The Australian Research Council Industrial Transformation Training Centre in Surface Engineering for Advanced Materials (SEAM) was formally launched on 28 August 2019 by the Australian Research Council Chief Executive Officer Professor Sue Thomas at an impressive event with 150 distinguished guests in attendance.

Professor Derry Doyle, Sutton Tools Professorial Chair in Materials and Surface Engineering, hosted the event, with a special introduction by Deputy Vice-Chancellor (Research and Development) Swinburne, Professor Aleksandar Subic. SEAM Director, Distinguished Professor Christopher C Berndt wowed the audience with an uplifting speech and highlighted “SEAM trains industry-fit professionals. Our staff are trained to be ‘plug-&-play’ and to provide immediate economic outcomes that can evolve from industrial transformations. In short ‘SEAM covers it all’”, he said.

Professor Sue Thomas and Professor Therese Jefferson (ARC) enjoyed the exhibition and showcase viewing sample elements from our selected industry partners, and enjoyed meeting Early Career Researchers, SEAM’s future graduates.

The SEAM Launch was a wonderful celebration, both for all who had worked so hard to get SEAM off the ground and for those who will work tirelessly as they embark on this wonderful journey of discovery and exploration. We were proud to launch SEAM in a grand celebration together with our researchers, industry representatives, staff, students as well as our international guests. Delighted to have hosted our colleagues from Oerlikon Metco, Singapore, from Polycontrols Technologies Inc., Canada, and SCG Chemicals, Thailand.

In a Media Release, Minister for Education The Hon Dan Tehan, MP, noted that SEAM’s placement of early career researchers into key industry partners would result in job creation and a high quality workforce in manufacturing. “This centre will be an innovator for the manufacturing of biomaterials, graphene layering, high temperature coatings and laser metal deposition for materials repair,” Mr Tehan said.

Above - L-R: Professor Peter Kingshott, Professor Milan Brandt, Distinguished Professor Christopher C Berndt, Professor Sue Thomas, Professor Therese Jefferson, Associate Professor Colin Hall.

Below - L-R: Distinguished Professor Christopher C Berndt, Professor Elena Ivanova, Professor Saulius Juodkazis, Professor Sue Thomas.

27-28 AUGUST 2019

ANNUAL PLANNING AND STRATEGY WORKSHOP

Dr Jeremy Rao, SEAM Postdoctoral Fellow (UniSA)

The SEAM Annual Planning and Strategy Day held on 27-28 August 2019 was an important event for SEAM as it was the first time it brought together its Chief Investigators (CIs), Early Career Researchers (ECRs), Partner Investigators (PIs), and Affiliated Researchers and distinguished visitors. The event was attended by about 60 Australian and international researchers to discuss how SEAM will generate a significant level of benefit to industry, to education and to the fundamental understanding of advanced materials and surface engineering – core to developing new advanced manufacturing products.

Professor Steven Langford, Dean, Research & Development, Faculty of Science, Engineering and Technology, Swinburne, opened the event, and set the theme noting the importance for research in advanced manufacturing, followed by brief introductions from all in attendance.

SEAM Director, Christopher C Berndt was excited to reiterate the SEAM vision: to train the next generation of engineers and technologists; to solve crucial problems in surface engineering and manufacturing; and to implement new technologies. The audience were privileged to have international guests Luc Pouliot and Sylvain Desaulniers from Polycontrols Technologies Inc. present on the research innovation and direction of Canadian technologies.

Swinburne's Professor Emad Gad, Dean of School of Engineering, and Professor Hung Nguyen AM, Pro Vice-Chancellor, Faculty of Science, Engineering and Technology, Swinburne, both highlighted research priorities and were pleased to see SEAM's impressive plethora of researchers.

Above: Day 2 of SEAMs Annual Planning and Strategy Workshop, pictured Mr Kevin Thomson (SEAM Executive Committee member)

Above: Dr Danielle Martin (ANSTO)

Above: Distinguished Professor Christopher C Berndt

Below: Professor Hung Nguyen, Pro Vice-Chancellor (Faculty of Science, Engineering and Technology, Swinburne)

Below: Day 1 of SEAMs Annual Planning and Strategy Workshop

EVENTS

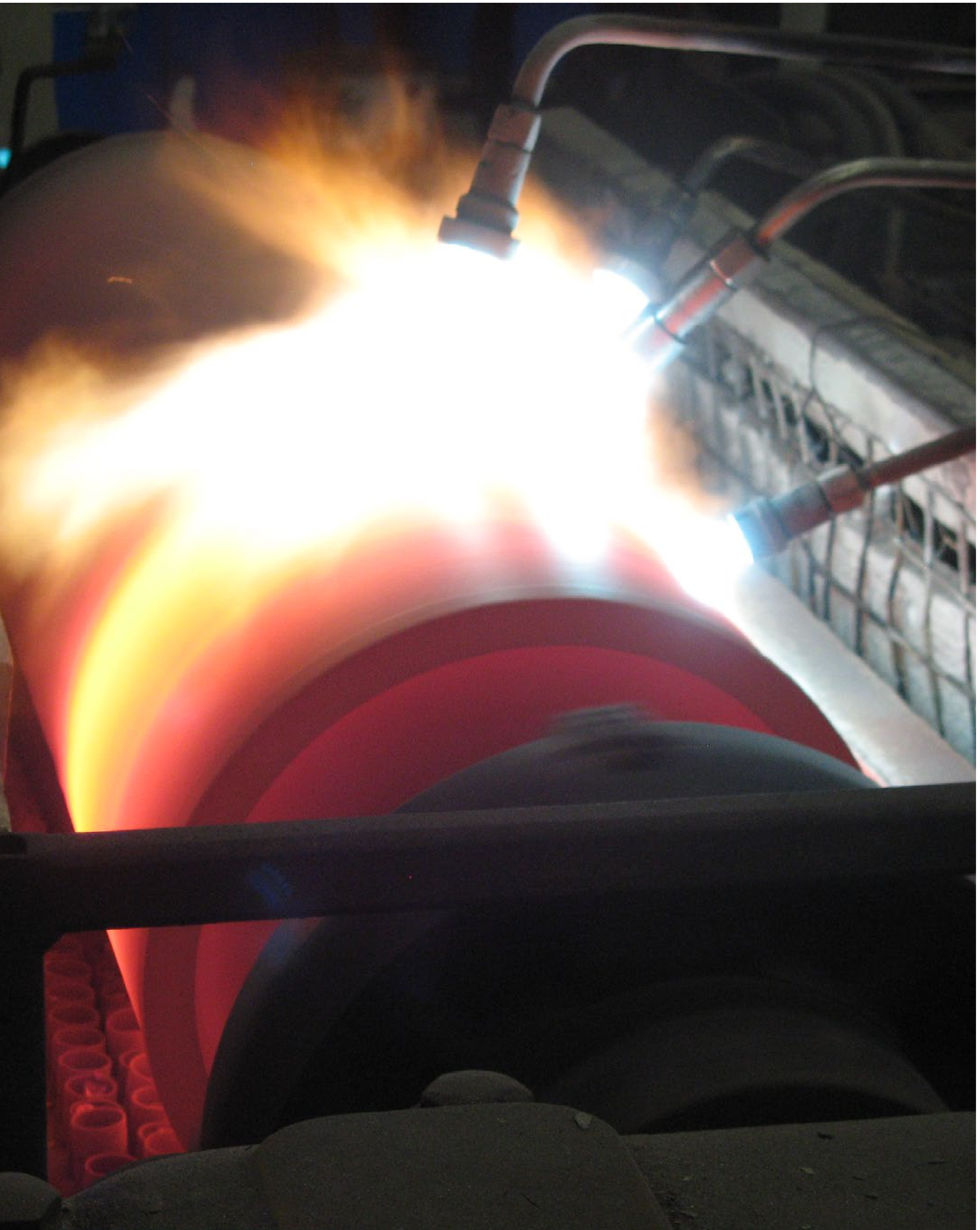
21 MAY 2019 SEAM SEMINAR HELIUM ION MICROSCOPY: THE DIFFERENCE 7,362 MAKES

by Dr Anders Barlow (Melbourne)

In this SEAM Seminar Dr Anders Barlow (Melbourne) introduced and discussed the technique, of Zeiss ORION NanoFab HIM, one of only four in Australia, its strengths (and weaknesses) and how it can be applied in materials engineering. The helium Ion microscope (HIM) is a scanned ion probe instrument that is similar in many respects to that of the well-established scanning electron microscope (SEM). Fundamentally, however, the two differ in that the HIM utilises a beam of He+ ions generated from a gas field ion source (GFIS).

This affords beam characteristics superior to that of an electron source; very low chromatic aberration, orders of magnitude higher brightness, greater depth of field, and an ultimate imaging resolution that is not diffraction limited. Unsurprisingly then, the HIM may be destined to become an important imaging tool in the materials and life sciences, where there is an ever-pressing demand to look closer at surfaces and elucidate the finest nanoscale features.

Anders Barlow is an Academic Specialist within MCFP where he manages the helium ion microscopy node of the platform, alongside other synergistic instruments. Dr Barlow was awarded his PhD in 2012 from Flinders University where he studied the surface functionalisation of carbon nanomaterials using plasma, applying surface analysis methods to gain a mechanistic understanding of the surface reactions. Dr Barlow's primary research interest lies in instrument and multi-technique development, leveraging the strengths of multiple techniques against one-another.



EVENTS

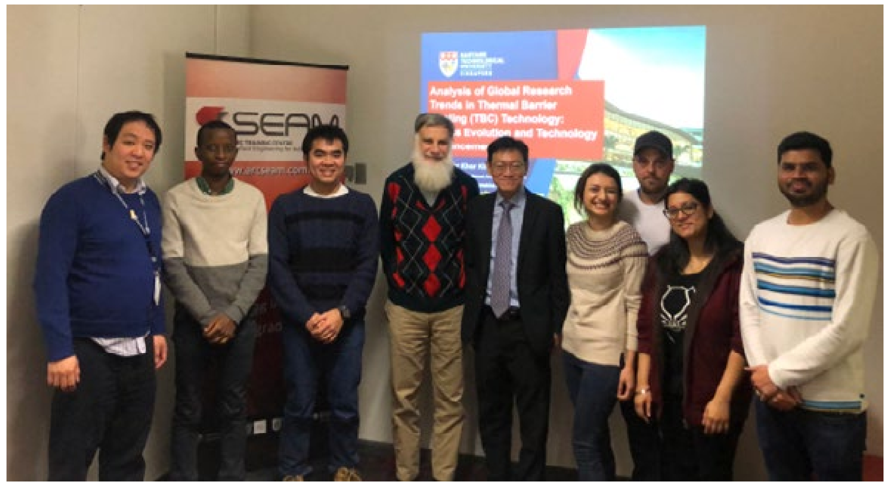
3 JULY 2019 SEAM SEMINAR ANALYSIS OF GLOBAL RESEARCH TRENDS IN THERMAL BARRIER COATING (TBC) TECHNOLOGY: TOPICS EVOLUTION AND TECHNOLOGY ADVANCEMENT

by Professor Michael Khor (Nanyang Technological University, NTU)

Professor Khor in this SEAM seminar presented findings on a study on thermal barrier coating (TBC) systems which reduce the temperature of the metallic substrate of modern gas turbines, resulting in improved component durability and increased efficiency. He explained how the study examined the research publications and patents on TBC in Scopus and USPTO patent database, respectively. Bibliometrics analysis reveal the developments in country and institution contribution to TBC research as well as the trends in topics evolution and technology advancement. He presented results that showed USA, China, Germany, Japan, India and UK as top countries in TBC research, with the Chinese Academy of Science (Beihang), Forschungszentrum Juelich, NASA Glenn Research Center and Deutsches Zentrum fuer Luft- Und Raumfahrt among other leading institutions.

USA dominated TBC publication outputs from 1981-2010, with China taking the lead post 2011, and India took over Germany taking up third spot. The terms of the publications are visually mapped using the VOSviewer to reveal the progress of TBC. It is found that atmospheric plasma spraying (APS) and electron beam physical vapour deposition (EB-PVD) are well-established deposition techniques for TBC coating preparation, and plasma spray physical vapour deposition (PS-PVD) and low-pressure plasma spraying (LPPS) are two new emerging deposition techniques in TBC research. The journal papers cited by patents have high correlation with the highly cited papers in Scopus.

Michael Khor (BSc (Hons), PhD, Monash) is Professor at the School of Mechanical & Aerospace Engineering, and Director, Talent Recruitment and Career Support Office and Bibliometrics Analysis at NTU, Singapore. Professor Khor's research interests are in advanced materials processing; thermal sprayed coatings; spark plasma sintering, nano-bioceramics and nano-composites for artificial cornea implants, orthopaedic and dental implants. He has published over 370 journal articles in a range of journals including Thermal Spray Technology, Thin Solid Films, Surface & Coatings Technology and many others, as well as conference papers, edited several international conference proceedings, has held numerous visiting scholar positions, and received many awards and accolades.



Above - L-R: Andrew Ang, Mark Mogeke, Duy Quang Pham, Christopher C Berndt, Michael Khor, Azadeh Mirabedini, Bruno Kahl, Ameey Anupam.

EVENTS

19 JULY 2019 SEAM MPDE SEMINAR NOVEL CERAMIC BIOMATERIALS FOR IMPLANTS APPLICATIONS: BAGHDADITE COATINGS

by Mr Duy Quang Pham (PhD Candidate, Swinburne)

Baghdadite ceramic (BAG: $Ca_3ZrSi_2O_9$) in its bulk form has the potential of supporting osteoblast cell adhesion and proliferation, while showing enhanced mechanical properties compared to hydroxyapatite (HAp: $Ca_{10}(PO_4)_6(OH)_2$). Mr Pham presented how this work explores the use of Baghdadite powders as feedstock for the atmospheric plasma spray (APS) process to manufacture biomaterials coatings onto Ti-6Al-4V substrates. The paper compares the microstructure and mechanical properties between BAG and HAp coatings. More consistent surface and bulk features are found for the BAG coating. The BAG coating reveals greater Vickers microhardness results compared to HAp coating (BAG: 325.5 ± 55.2 HV300 and HAp: 118.3 ± 21.2 HV300). Although BAG coatings show a lower level of crystallinity compared to the HAp coating; both nanohardness and elastic moduli results for the nanoindentation tests indicate that the BAG coating presents enhanced mechanical properties compared to the HAp coating. The distributions of mechanical properties including hardness and moduli indicate a more homogeneous microstructure for the BAG coating. BAG coating presents better wear resistance than HAp coating with regards to nanoscratch and scanning wear tests. The results indicate that APS of BAG is a candidate coating for orthopedic implants in load bearing applications.

Duy Quang Pham is a PhD candidate with Swinburne. His thesis topic is Bioactive ceramic coatings with antimicrobial properties to increase orthopaedic implant longevity, and is being supervised by Distinguished Professor Chris Berndt (Swinburne) and Dr Andrew Ang (Swinburne). His thesis focuses on the short lifespan of orthopaedic implants as a major clinical problem, where failure often occurs within a few months because of infection, or within 10–15 years due to loosening.

L-R: Duy Quang Pham and James Wang

11 SEPTEMBER 2019 SEAM SEMINAR FROM METAL MATRIX COMPOSITE TO CERAMIC MATRIX COMPOSITE CR3C2-NICR COATING MICROSTRUCTURES THROUGH NOVEL PROCESSING

by Dr Steven Matthews (Auckland University)

In this SEAM Public Seminar Dr Steven Matthews (Auckland) presented a talk on carbide composite thermal spray coatings. He explained how carbide composite thermal spray coatings are widely used to mitigate wear and erosion. The powder feedstock typically consists of agglomerates of carbide particles (primarily WC and Cr_3C_2) bonded with metallic binder particles of Co or NiCr. During spraying the composite powder particles are heated to soften and melt the metallic binder, to allow the particles to spread upon impact with the substrate to form “splats”. The build-up of multiple splats on top of each other results in the formation of the coating.

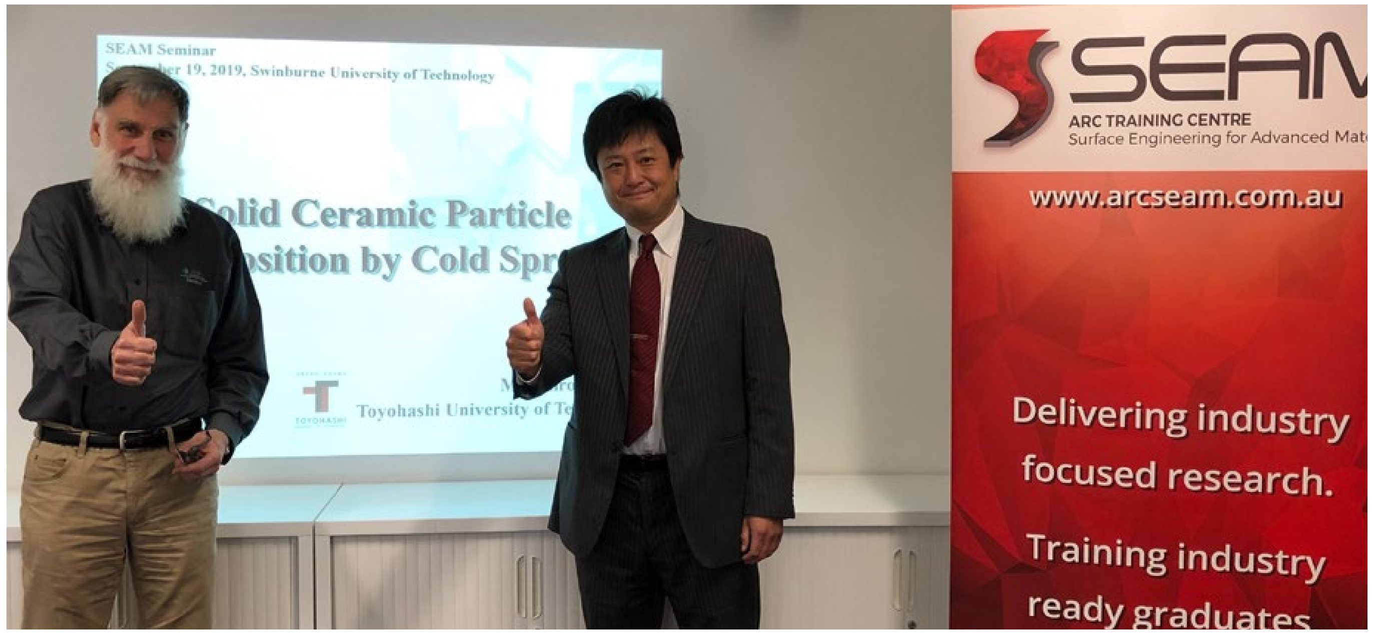
This presentation summarised the research into developing this concept in Cr_3C_2-NiCr thermal spray coatings. Initial trials were performed to optimise the formation of high carbide dissolution coatings using conventional carbide composite feedstock powders. Critical to the concept was generating high degrees of carbide dissolution without the loss of carbon. Dr Matthews explained how this led to the development and optimisation of gas shrouding systems to prevent in-flight oxidation. The development of the carbide microstructure within the highly supersaturated, metastable coatings with heat treatment was studied using DSC to characterise the critical temperatures needed to generate the desired phase transitions and carbide precipitation. This work highlighted the significance of precipitation from the supersaturated metallic matrix, but also the importance of the metastability of the secondary carbide phases formed. Heat treatment trials, ranging from several hours up to 30 days, were used to characterise the development of the carbide microstructure and the steady-state coating compositions that were formed. The range of microstructures, from nano-carbide precipitates through to interconnected carbide networks, are reviewed to illustrate the diversity of carbide composite structures that were formed through this concept.

Dr Steven Matthews (University of Auckland)

Steven Matthews is Senior Lecturer with the Department of Chemical and Materials Engineering, University of Auckland. His PhD researched the area of high temperature erosion resistant Cr_3C_2-based coatings deposited by high velocity thermal spray techniques. While at Bekaert Advanced Coatings in Belgium Dr Matthews focused on the design and manufacture of industrial sputtering targets.

Seminar attendees.

EVENTS



L-R: Christopher C Berndt and Motohiro Yamada (Toyohashi University of Technology, Japan)

19 SEPTEMBER 2019 SEAM SEMINAR SOLID CERAMIC PARTICLE DEPOSITION

by Assistant Professor Motohiro Yamada (Toyohashi University of Technology)

In this SEAM Public Seminar Motohiro Yamada presented how cold spray has been developed as a high-quality coating process. Feedstock particles are accelerated by a supersonic gas stream at a temperature that is lower than the melting point of the material, resulting in a coating formation from particles in a solid state. This process can form metallic coatings without oxidation under an atmospheric ambient. The deposition of solid particle is based on plastic deformation both particle and substrate. It means that the fabrication of ceramic coating through cold spray is considered to be impossible due to the lack of ductility. Motohiro presented about his study, where it was possible to deposit titanium dioxide (TiO2) and some ceramic coatings. Unique microstructures of feedstock particles enabled to deposit thick ceramic coating. He introduced what we know and what we don't know about the ceramic coating deposition by cold spray.

Motohiro Yamada is Assistant Professor from the Department of Mechanical Engineering, from Toyohashi University of Technology, Japan. His specialised field of research is thermal spray processes and ceramic coatings. He completed his PhD from Toyohashi University of Technology, and is a member of a number of societies: including Japan Thermal Spray Society, The Ceramic Society of Japan, Japan Welding Society, The Institute of Electrical Engineers of Japan, and The Japan Society of Mechanical Engineers.

3 OCTOBER 2019 SEAM SEMINAR POLYMER COATINGS FOR DRUG DELIVERY AND BIOACTIVATION OF IMPLANTS

by Professor Henning Menzel (Braunschweig University of Technology)

In this SEAM Seminar, Professor Menzel presented how implants help to restore mobility, functionality and with that the quality of life for the patients. He further spoke about how in most cases, the materials for implants are chosen because of their mechanical or electrical properties, but not that much according to their interaction with the body tissue. Most implant materials e.g. titanium or silicone should be regarded as bio-inert, rather than biocompatible. Ultrathin polymer coatings can be used to control the interface between implant and tissue. In this way, polymer coatings might influence protein adsorption and with that cell attachment, cell differentiation and can make the implants bioactive. We have developed different synthetic strategies for coating various implant materials. One strategy is (co)polymers to coat titanium and other metals as well as ceramics in an easy and scalable way. Using these copolymers signalling proteins can be installed. A further coating strategy relies on drug loaded nanoparticular hydrogels, which are stable in dispersion, but form films upon application to surfaces. These coatings release growth factors. These coatings could be installed not only on metallic surfaces but also on polymeric fibres. The deposition from a dispersion also allowed depositing coatings loaded with different growth factors and realizing a spatiotemporal control of the release. In this way, implants suitable for an in-situ tissue engineering at tendon-bone transition are prepared.

Henning Menzel is a Professor of polymer chemistry at Braunschweig University of Technology, Germany. He received his Habilitation (University of Hanover) for his thesis entitled Rigid rod-like polymers with flexible, mesogenic or photochromic side chains, and has been a Fulbright Fellowship at University of Michigan, where he worked with Dr Christine Evans on self-assembled monolayers of diacetylenes and their polymerization. Professor Menzel has numerous research interests including application-oriented problems in synthetic macromolecular chemistry, with special interest in biomedical and biotechnological applications: ultrathin polymer coatings used to tailor the bio-interfacial interactions with cells and bacteria; polymeric drug delivery systems used to implement biological signalling in biomedical devices.

Professor Henning Menzel (Braunschweig University of Technology, Germany)

EVENTS

18 OCTOBER 2019 SEAM MPDE SEMINAR THERMAL SPRAYED BASED COATINGS FOR EXTREME ENGINEERING ENVIRONMENTS

by Mr Ashok Meghwal (PhD Candidate, Swinburne)

In this seminar Ashok Meghwal presented his research on serviceability of HVOF sprayed coatings from an atomised chromium carbide based feedstock ($Cr_{23}C_6$-40NiCr) compared with those from a conventional Cr_3C_2-25NiCr agglomerated and sintered feedstock powder. Coatings were exposed to 540 °C and 610 °C for 168 hours in both air and steam environments. XRD analysis revealed that $Cr_{23}C_6$ was the major carbide phase present in the $Cr_{23}C_6$-40NiCr powder and coatings. Analysis of the $Cr_{23}C_6$-40NiCr XRD patterns by Rietveld analysis showed a comparable concentration of $Cr_{23}C_6$ in both the powder and coating, implying minimal carbide dissolution. However, the Cr_3C_2 content in the conventional Cr_3C_2-25NiCr coating was markedly reduced, indicating carbide dissolution occurred to a greater extent. Air oxidation led to the formation of a coarse surface oxide, due to the initial formation of Ni-based oxides, before a continuous Cr_2O_3 layer could develop underneath. A notably finer and more uniform oxidised surface composed only of Cr_2O_3 was formed during steam treatment across both coating types. Despite, $Cr_{23}C_6$ being the main carbide phase in the coating and the high binder content (40%NiCr), the microhardness of the $Cr_{23}C_6$-40NiCr coating was comparable to that of the conventional Cr_3C_2-25NiCr coating, both in the as-sprayed and treated states.

Ashok Meghwal is a PhD Candidate in materials engineering with Swinburne. His doctoral research investigates the thermal spray coatings for extreme engineering environments. He holds a master's in metallurgical engineering (RWTH Aachen) and a bachelor's degree in metallurgical and materials engineering (Malaviya National Institute of Technology Jaipur).

L-R: Ashok Meghwal and James Wang

6 NOV 2019 SEAM SEMINAR MICROSTRUCTURAL ANALYSIS OF HVOF SPRAYED IN PARTICLES ON STEEL SUBSTRATE

by Mr Musharaf Abbas (UNSW)

In this SEAM seminar Mr Abbas presented how high-velocity oxy-fuel (HVOF) deposition is a thermal spray process which uses high kinetic energy to produce coatings of high strength and density. Single splat formation is fundamental to define the structural integrity of the entire coating structure. However, limited understanding is available with respect to splat formation behaviour and splat-substrate interface properties of HVOF coatings because of the difficulties involved in the high-resolution characterisation of these features. In the present study, Ni powder was sprayed onto both mild and stainless-steel substrates using HVOF deposition to comparatively analyse the effect of substrate surface properties on splat formation.

A range of microscopy techniques including scanning electron microscopy (SEM), focused ion beam (FIB) microscopy, transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM) and energy dispersive X-ray spectroscopy (EDX) were employed to characterise both splat morphologies including their cross-sectional structure, as well the nature of the splat-substrate interface. It was shown that the majority of the particles reached the substrate surface in a partially melted form owing to the high velocities typical of the HVOF process. Mr Abbas explained that the splats produced on the mild steel substrate displayed comparatively less splashing as compared to the splats formed on the stainless-steel substrate. Ni-Fe interdiffusion profiles, determined by STEM-EDX linescans, revealed significant diffusion at the splat-substrate interface, especially in the case of the stainless-steel substrate. These microstructural observations are correlated with the thermo-mechanical characteristics of the substrates to provide a model for the mechanisms driving splat formation.

Musharaf Abbas is a PhD Candidate with the School of Material Science & Engineering at UNSW with Professor Peter Munroe (UNSW) as his primary supervisor, with main research areas of thermal spray coatings and material characterisations. Musharaf received a Bachelor of Science in metallurgical and materials engineering (University of Engineering and Technology, Lahore) followed by a masters in materials science and engineering (Beijing University of Aeronautics & Astronautics).

L-R: Musharaf Abbas (UNSW) and Christopher C Berndt

EVENTS

Ameey Anupam, partnered PhD program with Swinburne & Indian Institute of Technology Madras

22 NOVEMBER 2019 SEAM MPDE SEMINAR UNDERSTANDING THE MICRO-STRUCTURAL EVOLUTION OF HIGH ENTROPY ALLOY COATINGS MANUFAC-TURED BY ATMOSPHERIC PLASMA SPRAY PROCESSING

by Ms Ameey Anupam (PhD Candidate, Swinburne)

Ameey Anupam presented her current research project on atmospheric plasma spray (APS) of mechanically alloyed equiatomic AlCoCrFeNi high entropy alloy (HEA) results in a complex alloy-oxide coating. All the constituent phases have been identified via extensive microscopy and spectroscopy at various length scales. This microstructural characterization along with the in-flight particle size and temperature measurements and single-pass studies have been used to decode the particle-plasma-atmosphere interaction that resulted in the observed coating microstructure. Particles finer than 5 μm diameter are expected to melt, spheroidize and oxidize completely in-flight when closer to the plasma plume core, whereas those larger than 15 μm only exhibit softening and surface oxidation. Molten particles splat on impact resulting in typical lamellar microstructure, while the unmelted particles either get embedded in the coating or bounce off the substrate. Equiatomic AlCoCrFeNi powder oxidizes differently in plasma in air than the cast alloy during isothermal oxidation, resulting in multiple oxides – alumina, chromia, spinels and residual unoxidized alloy cores. Understanding these phenomena in conjunction with each other enables us to tailor feedstock and spray parameters to get the desired coating properties.

Ameey Anupam is a PhD Candidate as part of the partnered PhD program with Swinburne and the Indian Institute of Technology Madras, India. Her supervisors are Distinguished Professor Christopher Berndt (Swinburne) and Professor Ravi S. Kottada (IIT Madras) and Professor B.S. Murty (IIT Madras). Ameey completed a Bachelor of Technology with Honours in metallurgical and materials engineering from the National Institute of Technology Jamshedpur, India. Her research is focussed on developing thermal sprayed high entropy alloy coatings for high temperature applications and decoding the science governing them.

AWARDS

6 NOV 2019:

Industry Associate Professor Colin Hall wins the UniSA Mid-Career Researcher Award, recognising Mid-Career Researchers who has best demonstrated high-quality research outputs, mentoring and training as well as strong external engagement and collaboration.

Colin Hall (right) receiving the certificate.

27 NOV 2019:

Professor Ivan Cole wins 2019 Corrosion Medal from The Australasian Corrosion Association Inc., bestowed for outstanding scientific or technological work in the field of corrosion in Australasia.

L-R: Christiane Schulz, Ivan Cole, Karen Dacy

Ivan Cole (left) being awarded the Corrosion Medal.

KPI DASHBOARD 2019

"The Australian Research Council has approved the 2019 Key Performance Indicators (KPIs) for SEAM and is pleased to see that over the past twelve months the Training Centre has contributed to the schemes objectives and continues to be on track to deliver on objectives."

	Key Performance Indicators (KPIs)	Outcomes
	Research Training & Professional Education	
1	Early Career Researcher (ECR) enrolled	17
2	Partner Mentoring Programs	25
3	ECR Short Course Attendance	23
4	Partner Professional Short Courses	5
	International Links & Networks	
5	International Visiting Fellows	9
6	International Workshops	2
7	International Laboratory Visits	18
	End-User Links	
8	Government/Industry Briefings	23
9	Industry Visitors	19
10	Public Presentations	41
	Outputs	
11	Research Outputs	118
12	Journal Publication Quality	90.3%
13	Industry Reports	3
14	Invited Talks	17
15	Media & Social Media	148
16	Articles	5
17	Additional Research Income	$1.8M
18	Intellectual Property Disclosures	2

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2	A Training Centre for future engineer and science leaders. ***"Plug Play"***
3	***Embed*** Post Docs, Post Grads and Under Grad Interns into Industry.
4	University resources (***staff and kit***) used to address industry issues.
5	High level ***concept testing*** for surface engineering and additive manufacturing.
6	Time relevance: Industrial R&D that can be transferred in 2-3 year projects; i.e. focused on ***Manufacturing Readiness Level (MRL) of 4 5.***
7	Innovation focused: Use ***a combination of technologies*** to modify surfaces.
8	***Leverage*** the existing technologies among the Team.
9	Apply manufacturing robotics via ***Industry 4.0; i.e., automation.***

Engage and Collaborate with SEAM

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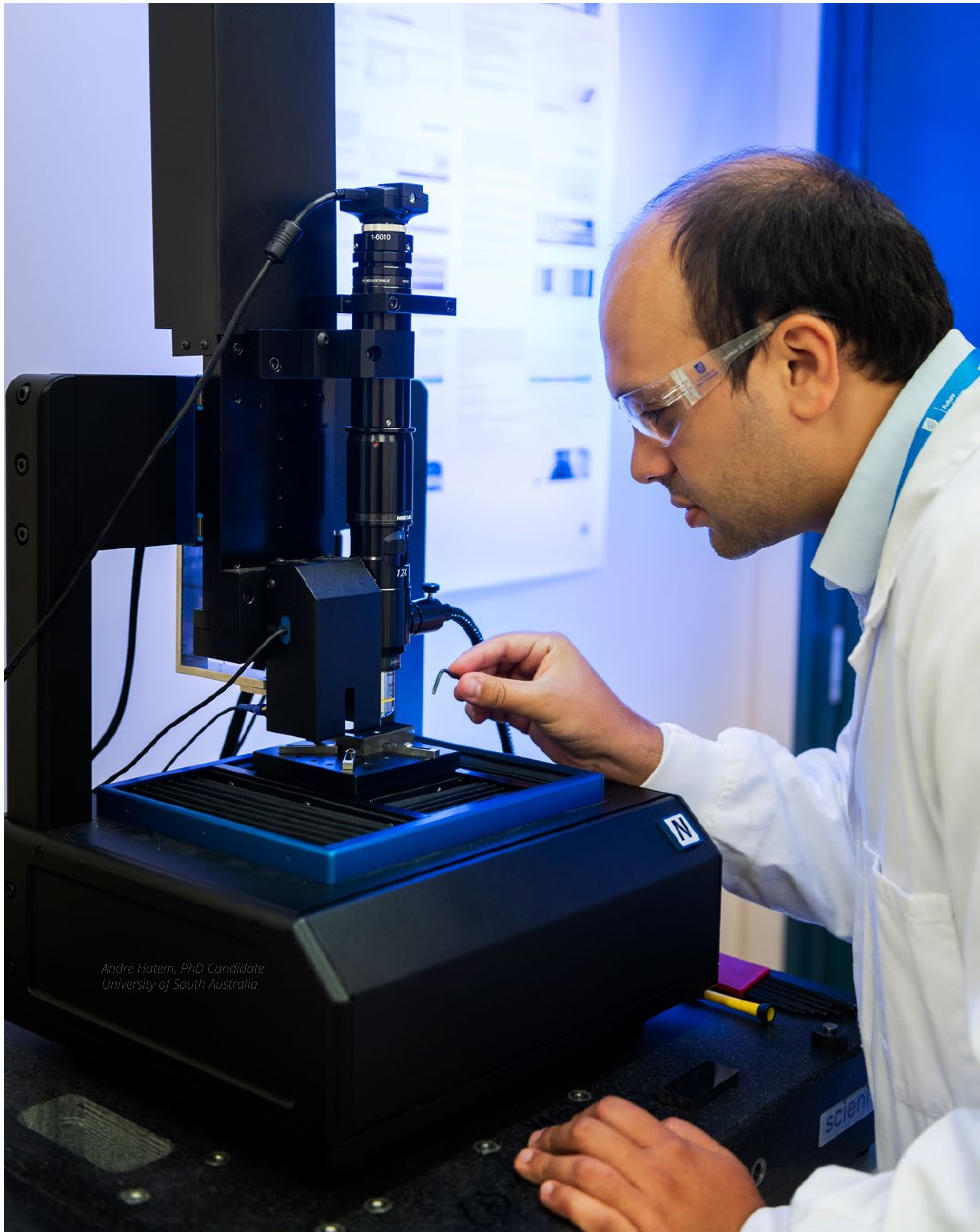

Andre Hatem, PhD Candidate
University of South Australia

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