NASF SURFACE TECHNOLOGY WHITE PAPERS
88 (8), 1-6 (May 2024)

The SUR/FIN 2024 Technical Program: Capturing the Flavor

Compiled by
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Introduction

SUR/FIN is the primary conference and trade show dedicated specifically to the surface technology industry. It is where leading surface technology companies connect, collaborate and contribute. Because it is the only conference and trade show sponsored by the National Association for Surface Finishing (NASF), it attracts noted business leaders and prominent thinkers to a forum where relevant issues are addressed, and cutting-edge technologies are presented. SUR/FIN 2024 will take place in Atlanta next month.

Under the able guidance and direction of Dr. Tim Hall, Chair, and Ms. Kelsey Kind, NASF Education Manager, the Technical Advisory Committee has organized a technical program covering the latest in technology in our industry. This year, the program consists of 65 presentations over 12 sessions, covering the latest in the many segments of the surface finishing field. What follows is a sampling of the presentations in each of the 12 sessions, capturing the flavor of the offerings available at SUR/FIN 2024.

LIGHT METALS (Session 1; Wednesday Morning, June 5)

Novel White Anodizing Process
by Chris Goode, Cirrus Materials Science, Albany, Auckland, New Zealand

The authors present a newly developed eco-friendly technology to create robust, native white anodized surfaces on aluminum alloys, offering new and environmentally friendly options for durable, luxurious surfaces in consumer electronics, aviation, automotive and architectural industries. Currently only paints or powder coats are available to produce white surfaces on aluminum; however, these finishes are neither durable nor provide a luxurious metallic finish. Anodizing, especially hard anodizing is durable and, when combined with organic or mineral dyes, is available in colors other than white. Introducing white pigments, such as titania into porous anodizing can approximate white but typically the translucent alumina structure allows the substrate to remain visible, limiting the degree of lightness available.

Creating a native, undyed white anodizing structure requires a game-changing anodizing process which develops a graded anodizing structure comprising a plethora of light scattering intersections which combine to produce surfaces with an L* of greater than 92 and a* and b* of close to zero. The novel Cirrus Lustre™ process produces a graded structure where the anodizing density, as measured by Vickers hardness on the cross-section, varies continuously from above 800 near the substate to approximately 200 near the surface. The uniformity of the anodizing ensures surfaces show low delta-E color variation which combines the resilience of ceramics with the feel of metals. When combined with a new electrophoretic sealing process which develops boehmite structures within the surface porous layer to enhance the lightness, the new process produces a robust chemical, corrosion and wear resistant surface suitable for multiple applications.

ADVANCES IN MATERIALS (Session 2; Wednesday Morning, June 5)

3D printing Porous Zirconia for Hydrogen Energy Devices
by Moein Khakzad, The University of Texas at Dallas, Richardson, Texas, USA

This work is partially funded by the AESF Foundation research program. Advances in vat photopolymerization 3D printing have the potential to significantly improve the production of ceramic materials for electrochemical energy devices. Solid oxide fuel cells (SOFCs) and solid oxide electrolysis cells (SOECs) necessitate high resolution ceramic manufacturing methods, as well as precisely controlled porosity (~20-40%) for optimal gas transport. Achieving a balance between this porosity and mechanical

integrity, especially under thermal stress, remains a challenge. Here, we demonstrate the successful fabrication of porous Yttria Stabilized Zirconia (YSZ) ceramics using vat photopolymerization 3D printing, achieving porosities ranging from 6% to 40% and corresponding grain sizes of ~80 nm to 550 nm. We found that 3D printed YSZ with ~33% porosity exhibited a Weibull modulus of m = 5.3 and a characteristic strength of over 36 MPa. Our investigation further reveals that these ceramics can withstand thermal shock up to 500°C, retaining over 70% of their flexural strength. This remarkable performance suggests significant potential for 3D printed porous YSZ in SOFCs and SOECs, paving the way for potential improved efficiency, reduced fabrication costs and innovative designs in these next-generation clean energy technologies.

Besides partial debinding, packing density and particle arrangement of ceramic during DLP 3D printing can affect the porosity of the ceramic structure. The packing density is a function of the ratio of the sphere diameters and the fraction of the large (coarse) or small (fine) spheres in the mixture. We investigate a high solid loading zirconia slurry for DLP 3D printing with the combination of large and course particles to study a fully sintered porous ceramic. Moreover, the mechanical properties of the 3D printed components are characterized by flexural and thermal shock tests.

CORROSION PROTECTION AND WEAR RESISTANCE (Session 3; Wednesday Morning, June 5)

21st-Century Tools for Choosing, Developing, Depositing and Repairing Corrosion Control Coatings
by Dr. Keith Legg, Corrdesa LLC, Tyrone, Georgia, USA

This presentation provides information on new tools to improve corrosion control, by predicting corrosion, developing and optimizing coating processes, and repairing corrosion coatings. It includes coating databases, methods for developing and optimizing coatings, software that can be used by engineers for minimizing corrosion, and new non-drip coating equipment that is now becoming used around the world for coating and anodizing repair.

Although the digital world is constantly expanding, corrosion exists in the real world, and it requires real-world tools to control it. However, in order to improve real-world corrosion control, we are increasingly turning to the digital world for help in predicting and reducing corrosion and developing better coatings and coating equipment to control it.

This presentation will provide an update with examples of new tools that use digital methods to improve corrosion control in the real world, optimizing coating processes, and remediating and repairing corrosion coatings. Coatings databases are growing, including a database of coatings and surface treatments that meet ever-expanding environmental and health regulations. Corrosion prediction tools are becoming more reliable and user-friendly, allowing M&P engineers to choose the right coatings by automatically predicting how different coatings, treatments and designs will affect corrosion in entire assemblies and products. This method is now being used in the automotive, aerospace and defense industries. Computational modeling now allows us to design coatings and optimize plating and other electrochemical processes. New, clean, non-drip brush plating tools are now available around the world to repair electroplated and anodized coatings in the field, with larger and more specialized tools and computer-controlled processes.

QUALITY, EFFICIENCY, AND DATA (Session 4; Wednesday Afternoon, June 5)

Optimizing Pretreatment through Data Collection and Utilization
by Amanda Walden, Chemical Methods, Brunswick, Ohio, USA

A discussion on the impact paint pretreatment has on finish quality and how data collection and analysis can lead to fewer rejects, lower chemical usage and reduced man-hours. Pretreatment is often overlooked in Lean Manufacturing and not given the attention it deserves as the piece of the process that sets the stage for success or failure. Data collection is simple, but utilization is another animal. Anyone can install monitoring and metering equipment, but not everyone uses the data to their advantage - leaving tens of thousands on the table. We'll explore several case studies that leverage Data Collection & Utilization that led to data driven decision-making, improved product quality, and increased profitability.

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ADVANCES IN SURFACE FINISHING (Session 5; Wednesday Afternoon, June 5)

Pulsed Electropolishing of Metal AM
Jamie Stull, Los Alamos National Laboratory, Los Alamos, New Mexico, USA

Metal additive manufacturing (AM) is being pursued as a manufacturing technique to shorten development cycles and reduce cost through rapid iteration and agile design. Metal AM allows for designs that were not previously possible, optimizing the balance between mechanical strength and weight. However, rough as-built surfaces do not meet engineering specifications, with roughness measurements between S_a = 5-60. Furthermore, depending on the build angle, the surface roughness varies widely within a single part. These rough surfaces result in different surface morphology and chemistry compared with other manufacturing methods which has a direct impact on the susceptibility to localized corrosion and mechanical performance. Our team is also developing environmentally friendly surface finishing techniques to reduce the surface roughness to meet specifications for metal components. We will show that post-processing surface treatments result in a more homogeneous surface and improve the performance of the material.

ELECTROPLATING AND THE DOD (Department of Defense)(Session 6; Wednesday Afternoon, June 5)

Approach to Trivalent Chromium Processes for Conversion Coatings and Anodize Seal on Aerospace Aluminum Finishing – Techniques for Process Optimization and Maintenance
Dr. Carol F. Glover and Mellyssa E. Greene, The Boeing Company, Auburn, Washington, USA

Requirements around aerospace aluminum finishing have been around for decades and were developed around the capabilities of existing Cr(VI) technologies. Due to the superior corrosion protection and performance of Cr(VI) that contributes to product airworthiness and longevity, there are challenges to reducing Cr(VI) usage and moving over to trivalent chromium process (TCP) alternatives. The supporting chemistries for TCPs have a narrow operating window in terms of pH, temperature and bath composition, relative to the incumbent Cr(VI) technologies. Identifying and maintaining the parameters to optimize performance for TCP alternatives is an on-going challenge. Industry standard tests, such as ASTM B117 salt spray and paint adhesion, are traditionally used for troubleshooting and optimization. While these tests provide a robust system for performance capabilities, they lack key mechanistic information that could facilitate a more efficient path to optimization and characterization. The presentation will focus on how performance data from industry standard tests is used to identify critical TCP parameters, and how *in situ* electrochemical open circuit potential (OCP) monitoring can be utilized to better understand the coating formation process. OCP monitoring captures the evolution of coating formation and, used in combination with targeted surface characterization, specific features can be understood.

METHODS IN EFFICIENCY IMPROVEMENT 1 (Session 7; Thursday Morning, June 6)

Production Planning 4.0 - How Information from Plating can be Used to Realize Comprehensive Scheduling
Andreas Scholz, Aucos AG, Aachen, Germany

This presentation will show how Artificial Intelligence (AI)-based planning systems, working hand in hand with logistics, ERP and the plating control system, enable a new level of performance in production planning. How can reliable planning be established that reacts to changes and unforeseen events in real time? How can such planning adaptively incorporate criteria such as capacity, on-time delivery, and people? How can the system learn on its own and better adapt to the individual production process? And how does all this translate into potential energy savings? Answers to these and other challenges will be provided with this presentation.

The foundation of efficient production is scheduling that takes a comprehensive view of the entire manufacturing facility. The ever-increasing complexity of planning, from individual build-to-order products to energy-optimized production, increases the challenge of scheduling immensely. As an often central component, the plating shop is a critical point in this planning process. A significant amount of information for optimized planning can already be extracted from the data collected by a modern plating control system.

METHODS IN EFFICIENCY IMPROVEMENT 2 (Session 10; Thursday Afternoon, June 6)

Modular Digital Twinning of Electroplating Systems and Dynamic Sustainability Assessment
Mahboubeh Moghadasi, Wayne State University, Detroit, Michigan, USA

This work is partially funded by the AESF Foundation research program. Advanced manufacturing is coming into the digital age. Among top strategic digital technologies, Digital Twins (DTs) technology has received significant attention. DT, a virtual counterpart of physical systems, is characterized by its real-time reflection, interaction, and convergence within physical and virtual spaces, by integration of both historical and real-time data, resulting in self-evolution capability. Recent advancements in DT technology include the introduction of Physics-Informed Neural Networks (PINNs). PINNs, as universal function approximators, embed physical law knowledge directly into the data learning process, enhancing the DT's analytical capabilities. A PINN-based modular DT system should be able to provide accurate real-time information about plant operation, which is critical for conducting dynamic sustainability assessment.

This study introduces an innovative approach to applying DTs in the electroplating industry, leveraging advancements in Physics-Informed Neural Networks (PINN). We focus on the development of plant-wide modular DTs for characterizing electroplating system operation. The modular design is particularly significant as it allows for flexible adaptation to various operational scenarios, promoting scalability and efficiency in process management. We will then use the information generated by the modular DT system to conduct dynamic sustainability performance. Our case studies will show that dynamic sustainability assessment is more effective than conventional static sustainability assessment for plant sustainability performance improvement.

ADVANCES IN COATINGS (Session 8; Thursday Morning, June 6)

Electroless Nickel Composite Coatings Containing PTFE and Boron Nitride – Properties and Performance
Ambrose Schaffer, MacDermid Enthone Industrial Solutions, Waterbury, Connecticut, USA

Electroless nickel deposits offer a multitude of unique properties including corrosion resistance and high hardness. These aspects make electroless nickel a coating of choice for applications where wear and corrosion performance are particularly of interest. The incorporation of hard particles into the electroless nickel matrix enhances some of these properties further. This presentation will focus on two particles in particular, PTFE and hexagonal boron nitride, and serve to illustrate the effects these particles have when introduced into the electroless nickel coating by comparing and contrasting the results of testing of some key mechanical and tribological properties.

Advanced Ternary Alloy High Phosphorus Electroless Nickel
Doug Hughes, MacDermid Enthone Industrial Solutions, Waterbury, Connecticut, USA

High phosphorus electroless nickel is a highly inert barrier coating that has low inherent porosity, low intrinsic stress and high resistance to chemical attack, especially from acidic media. These properties have made High P electroless nickel the coating of choice for highly demanding applications in the oil and gas, aerospace and semi-conductor sectors where high performance coatings are required. A new high phosphorus system has been developed that incorporates an additional element into the alloy which further enhances these properties. This presentation will illustrate these enhancements, particularly in the case of reduced porosity and improved corrosion resistance, through comparative data which was generated from several testing matrices.

WATER TREATMENT AND PFAS (Session 9; Thursday Morning, June 6)

Treatment of Per- and Polyfluoroalkyl Substances in Water by Electrochemical Oxidation with Titanium Suboxide Anode
Qingguo Huang, Yuqing Ji and Yifei Wang, University of Georgia, Griffin, Georgia, USA

This work is partially funded by the AESF Foundation research program. Treatment of per- and polyfluoroalkyl substances (PFAS) in water remains a challenge to date. Our studies indicate effective electrochemical degradation of per- and polyfluoroalkyl substances (PFAS) in aqueous solutions using Magnéli phase titanium suboxide (TSO) anodes, providing a

promising technology to treat PFAS in wastewater. The results delineated the mechanisms of PFAS degradation on TSO anodes and identified factors controlling its performance in terms of reaction rates and energy efficiency, including reactor setups, operation conditions and water qualities. The means to couple EO with a separation technology for treatment of PFAS-containing wastewater were evaluated, in which EO was used to destroy PFAS concentrated in the waste stream generated from the separation technology, such as Ion Exchange Resin (IXR), Foam Fractionation or Nanofiltration. The results indicate great energy-efficiency of such a hybrid separation-destruction strategy for FPAS treatment. The overall results of our studies provide a basis for design and optimization of the TSO-based EO systems as well as a separation-EO treatment train for effective treatment of PFAS-contaminated waters.

MILITARY FINISHING APPLICATIONS (Session 11; Thursday Afternoon, June 6)

Installation and Qualification of a New Zinc-Nickel Plating Line
Alexander Nicoloff, Naval Air Systems Command (NAVAIR), USA

Zinc-nickel electroplating is a widely known replacement for cadmium plating. It has been studied and developed extensively over the past two decades and is now considered a fully mature technology. The DoD is looking towards zinc-nickel as the primary replacement for cadmium plating, and more and more aircraft components containing cadmium are being approved to transition to zinc-nickel over time. Several DoD aircraft depot maintenance sites have zinc-nickel plating capability, and many more electroplating facilities are expected to follow in the coming years.

The laboratory qualification studies, technology demonstration and validation of zinc-nickel coatings have been widely established and reported on, and so this presentation will focus more narrowly on the process of building and starting up the new zinc-nickel plating line at Fleet Readiness Center SW. Establishing full production capability is always a multi-step process that occurs over years of planning, and each construction project brings with it unique lessons and experiences that can be built upon to further enhance future projects. Sharing this knowledge enables subsequent new developments where projects can be completed more smoothly and with fewer hiccups than the projects that came before it. For instance, the piping and equipment designs for these tanks benefited from lessons learned from installing the zinc-nickel plating line at Hill Air Force Base, eliminating failure modes that created a propensity for leaks and spills to occur.

Fleet Readiness Center Southwest (FRCSW) is a leading depot rework site for US Navy and US Marine Corps aircraft, located in San Diego, CA. The depot operates an extensive electroplating and surface finishing facility as part of the Department of Defense (DOD)'s maintenance, repair and overhaul program for critical aviation assets. The facility serves the electroplating and surface finishing needs for F/A-18, E-2, C-2, H-53, H-60, and V-22 aircraft components.

In 2022, FRCSW began the installation of a brand new zinc-nickel electroplating line, a $5 million capital investment that broadens the inorganic coating capabilities of the facility. The installation was completed in early 2023 and builds on the work already done by other DoD maintenance facilities, including at Naval Air Station Jacksonville, Hill Air Force Base, and Warner Robins Air Force Base. Implementation of this plating line furthers the availability of zinc-nickel as a cadmium replacement for DoD aircraft maintenance activities. This presentation will discuss the background of zinc-nickel plating, the unique technology and design used in the new plating line, and observations and lessons learned during implementation and qualification testing.

WASTE TREATMENT (Session 12; Thursday Afternoon, June 6)

Membrane-Based Processes and their Potential for Waste Minimization in Surface Finishing / Plating
James Mitchell, PAVCO, Charlotte, North Carolina, USA

This talk will discuss the technological advances of ion-exchange membranes and their potential applications in surface finishing applications such as membrane anodes in chloride zinc / zinc-alloy plating systems and bipolar membrane electrodialysis for regeneration of pickling acids.

Decades of engineering in ion-exchange membranes have dramatically enhanced their properties such as resistivity and perm-selectivity, enabling a wide range of potential electrochemical applications. While the surface finishing industry has not yet

widely adopted these specialty membranes, it is perfectly poised to take advantage of these technological advancements to enable new waste minimization strategies. In this talk, we will discuss membrane-based processes relevant to the surface finishing industry including membrane anodes and bipolar-membrane electrodialysis (BPMED).

Membrane anodes can be utilized with inert anodes to mitigate metal growth in chloride zinc / zinc-nickel plating baths, and their development could prevent excessive waste generation caused by cutting baths to control metal concentrations. To evaluate these membranes for these applications, the chloride crossover rates, energy consumption and durability must be assessed. Our preliminary membrane exploration and their effectiveness in mitigating metal growth in chloride-zinc plating baths will be discussed. Lastly, BPMED is proposed as a method to regenerate acid / base from salt solutions. This application and how it may be used to regenerate pickling acid will be discussed to highlight another potential application of ion exchange membranes to minimize waste generation in the surface finishing industry.