Manufacturing Science and Technology Group
Room: 5 & 6 - Session MS-ThM

Additive and Other Novel Manufacturing Techniques
Moderator: Vincent Smentkowski, General Electric Global Research Center

8:00am **MS-ThM1 Thermal Spray for Additive Manufacturing**, *A. Agarwal, **Cheng Zhang***, Florida International University **INVITED**

Additive manufacturing is gaining popularity in the commercial domain due to engineering and economic advantages over conventional manufacturing, such as reduced material wastage, lightweight components, and rapid manufacturing to near net shapes. Thermal spray processes are promising for additive manufacturing of metals, ceramics as well as polymers. Thermal spray is a wide range of manufacturing processes in which material in the form of particles/wire is sprayed and deposited at elevated temperatures to form coatings and free-standing 3D structures. These processes include plasma spray, flame spray, detonation gun, high-velocity oxyfuel spray, wire arc spray and cold gas spray. Thermal spray allows rapid processing of near net shape structures at bulk scale with complex shapes, contours, and variable thickness. Thermal spray techniques enable manufacturing of composite materials and functional gradient structures. While thermal sprayed coatings have diverse applications in wear resistance, biomedical implants, thermal barrier, corrosion protection, direct write sensors, fuel cells, etc., free-standing 3D structures fabricated by thermal spray are not as extensively used. This talk will present an overview of the state of the art of additive manufacturing via thermal spray techniques. The challenges and potential solutions will be described. A Novel in situ characterization techniques will be discussed that provide insight into processing-structure-property correlations in bulk 3D components fabricated by thermal spray. This will enable development of bulk components with predictable properties by thermal spray techniques.

8:40am **MS-ThM3 Eliminating Excess Flow during Active Brazing through Surface Preparation with ALD**, ***Ronald Goeke**, C.A. Walker, P. Sarobol, P.T. Vianco*, Sandia National Laboratories

Active brazing is a permanent metallurgical joining method in which highly reactive brazing filler metals are utilized to directly braze metals to nonmetals. Due to limitations of the active brazing filler metal spreading adequately over a nonmetal surface, the filler metal must be preplaced between the two faying surfaces of the brazement. When heated the liquid filler metal is normally contained within the brazement by capillary attraction. Chemical reactions at the brazement faying surfaces often lead to excessive braze filler metal flow, rendering the brazed assembly useless. Conformal coatings nanometers thick, deposited by atomic layer deposition (ALD) onto the metal surfaces, modify the surface chemistry to eliminate excessive filler metal flow. Unlike other means used to prevent excessive filler metal flow, the thin ALD coating does not hinder next assembly processes, does not require post-braze cleaning or alter the base material mechanical properties.

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

9:00am **MS-ThM4 Analysis of Textile Surface Characteristics for Direct Write Printing of Ink-based Textile Electronics**, ***Jesse Jur**, R. Bhakta, H. Shahariar, H. Soewardiman*, North Carolina State University

Direct write printing is studied as a method for producing large-area electronics directly onto flexible textile substrates. This process delivers viscous conductive particle inks in the range of 1 - 20 kilo-cps to a surface via a pressure-backed nozzle, making it a process that has key similarities and differences to traditional screen-printing and ink-jet printing. In this work, key correlations are defined between the print head speed and viscosity on the ability to design electronic device structures on textile substrates. For standard surface printing on the textile, sheet resistance values ranges from 5 - 16 mOhms/sq for Ag and Ag/AgCl inks. In addition, the ability to design devices through the bulk of the textile is explored. Ink penetration is shown to vary between to 100 microns into the textile structure based on the hydrophobic characteristic of the textile substrate, ink viscosity and the delivery pressure of the ink. Such penetration is shown to fabricate multi-layered printed structures on the surface and back of the textile. Device applications range from printed/flexible heaters, antennas, circuit boards, and dry electrodes for biopotential monitoring.

9:20am **MS-ThM5 Three-Dimensional Silicon Mesostructures for Bioelectric Interfaces**, ***Yuanwen Jiang****, *B. Tian*, The University of Chicago

Silicon-based materials exhibit biocompatibility, biodegradability as well as a spectrum of important electrical, optical, thermal and mechanical properties, leading to their potential applications in biophysical or biomedical research. However, existing forms of silicon (Si) materials have been primarily focused on one-dimensional (1D) nanowires and two-dimensional (2D) membranes. Si with three-dimensional (3D) mesoscale features has been an emerging class of materials with potentially unique physical properties. Here, we incorporated new design elements in the traditional chemical vapor deposition (CVD) method to prepare various forms of 3D Si mesostructures and studied their functional biointerfaces with cellular components. In the first example, an anisotropic Si mesostructure, fabricated from atomic gold-enabled 3D lithography, displayed enhanced mesoscale interfacial interactions with extracellular matrix network. This topographically-enabled adhesive biointerface could be exploited for building tight junctions between bioelectronics devices and biological tissues. Another Si mesostructure with multi-scale structural and chemical heterogeneities, was adopted to establish a remotely-controlled lipid-supported bioelectric interface. We further adapted the bioelectric interface into the non-genetic optical modulation of single dorsal root ganglia neuron electrophysiology dynamics. Our results suggest that the dimensional extension of existing forms of Si could open up new opportunities in the research of biomaterials manufacturing and application.

9:40am **MS-ThM6 Microplasma Sputtering for 3D Printing of Metallic Microstructures**, ***Yosef Kornbluth***, Massachusetts Institute of Technology, *R. Matthews, L. Parameswaran, L. Racz*, MIT Lincoln Laboratory, *L. Velásquez-García*, Massachusetts Institute of Technology

Additive manufacturing technologies promise to transform the development and production of agile microsystems, but are limited by the ability to print microelectronics-quality interconnects. State of the art 3D printing techniques for conductors cannot yet deliver the feature resolution and electrical conductivity required for high performance microcircuits, and have materials and substrate constraints and post-processing requirements. We develop a novel microplasma sputtering system that has the potential to provide direct-write capability of quality metal interconnects on non-standard substrates for integrated circuits, with future extensibility to dielectrics and semiconductors. The microplasma is generated at atmospheric pressure, obviating the need for a vacuum. By manipulating the metal at the atomic level, we retain the resistivity of bulk metal, and by sputtering the metal, we eliminate the need for post-processing or lithographic patterning.

We have modeled and constructed a first-generation system that incorporates continuous material feed and focusing with electrostatic fields. The microplasma head has a grounded central target wire, surrounded by two pairs of electrodes evenly distributed around the target: two opposing electrodes biased at a positive voltage to form the plasma, and two biased at a negative voltage to focus the plasma. Electrostatic fields guide the ionized fraction of the working gas towards a localized spot on the substrate. The directed ions collide with other gas atoms and, crucially, with sputtered metal atoms from the target. The net force of these collisions drags the metal atoms towards the substrate. This indirect electrostatic focusing mitigates the inherent spread of the sputtered material caused by collisions at atmospheric pressure, and enables fine feature definition. By focusing the sputtered material, we achieve imprints significantly narrower than the cathode, avoiding the need to machine target electrodes as small as the desired feature size.

Multi-physics COMSOL simulations predict that features orders of magnitude narrower than the target-wire cross section can be printed if the electric fields are set appropriately. We present findings from our COMSOL simulations and experimental confirmation of key findings.

DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

This material is based upon work supported under Air Force Contract No. FA8721-05-C-0002 and/or FA8702-15-D-0001. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the U.S. Air Force.

* **National Student Award Finalist**

Authors Index
Bold page numbers indicate the presenter