Additive Manufacturing/3D Printing Focus Topic
Room: 211B - Session AM+EM+MS+TF-WeM

Materials, Designs, and Applications of Additive Manufacturing
Moderator: Erik B. Svedberg, The National Academies

8:00am **AM+EM+MS+TF-WeM1 An Overview of Additive Manufacturing**, ***Ed Morris***, *R. Gorham*, NCDMM **INVITED**

"An Overview of Additive Manufacturing" - Additive manufacturing, also called 3D printing, has captured worldwide attention. Many believe that it is introducing the next industrial revolution because of its impact on product innovation and its unique manufacturing capabilities. America Makes – National Additive Manufacturing Innovation Institute is the first Manufacturing Innovation Institute established as part of a National Network for Manufacturing Innovation. Mr. Ed Morris, Director of America Makes and Vice President, National Center for Defense Manufacturing and Machining, will give an overview of additive manufacturing, and will discuss America Makes' actions to accelerate the use of additive manufacturing technologies in the United States and increase our nation's global manufacturing competitiveness.

8:40am **AM+EM+MS+TF-WeM3 Material Considerations and Opportunities for Laser Powder Bed Additive Manufacturing**, ***Michael W. Peretti***, *D.H. Abbott*, General Electric Aviation **INVITED**

Additive Manufacturing (AM) has the potential to be a significant supply chain disruptor over traditional means for manufacturing a broad range of components for aerospace and other demanding applications. The ability to unlock complex, high-performance designs while reducing part count and number of manufacturing steps is beginning to revolutionize the way we think about making things. One of the key areas of development to further expansion of opportunities for AM is the production and supply of high-quality raw materials. This presentation discusses the critical issues for AM input raw materials, with particular emphasis on metal powder input stock for laser powder bed AM processes. Some background and experience from GE Aviation's development of the LEAP fuel nozzle will be shared, along with comments on the direction that the AM industry could take and the role of and potential for AM-specific metal powder alloys.

9:20am **AM+EM+MS+TF-WeM5 High Quality and High Speed EBM 3D Printing by the Integration of High Performance Electron Sources**, ***Colin Ribton***, TWI Ltd., UK, *S. del Pozo*, TWI Ltd. and Brunel University, UK

Production of high integrity components must use smart manufacturing methods to be efficient in use of scarce materials and other resources, and must ensure its environmental impact is minimized. Advanced manufacturing techniques, such as metal powder bed 3D printing , can be carried out by selective laser melting (SLM) or electron beam melting (EBM). In both cases the component is built layer by layer, with a beam as an intense energy source drawing each layer by melting powder. EBM is significantly faster than SLM and has been used to create metal parts in large quantities over the past 5 years. EBM machines have produced many tens of thousands of orthopedic implants. There are a number of key benefits in employing this manufacturing technology – including 'complexity for free', efficient use of material and flexibility of design. Increasingly, the aerospace industry is investigating the use of EBM for the manufacture of aircraft components and aero engine parts. However, the size of many of these components presents challenges to the EBM process in production rate and quality consistency over long build times (i.e. 150 hours).

The aim of this work is to overcome key obstacles concerning future requirements for EBM 3D printing for production of aerospace parts through the integration of two enabling technologies. The work will develop and integrate a novel plasma cathode electron source with an EBM machine focusing on realizing the enhanced capabilities of low maintenance, consistent manufacturing performance and higher productivity. Also, development and integration of an array probe device will provide quantified quality assurance of machine manufacturing readiness. The key research challenges will be the design of the electron source and optics and the development of new build procedures making best use of the new source.

The equipment will enable the wider adoption of EBM leading to efficient use of materials – particularly strategic titanium alloys and nickel based super alloys at first.

9:40am **AM+EM+MS+TF-WeM6 Laser Induced Forward Transfer of High-Viscosity, Polymer-Based VO_2 Inks**, ***Eric Breckenfeld***, *H. Kim, T. Sutto, N. Charipar*, *A. Piqué*, Naval Research Laboratory

Additive manufacturing direct-write processes such as direct-write assembly, micropen, inkjet, and laser-induced forward transfer (LIFT) have become increasingly popular as interest in printable electronics and maskless patterning has grown. Compared to conventional lithography, these additive manufacturing processes are inexpensive, environmentally friendly, and well suited for rapid prototyping and large-area applications. At the same time, researchers have pursued various chemical solution deposition processes for combining additive manufacturing technology with functional electronic materials. Among a multitude of transition-metal oxides, vanadium dioxide (VO_2) has emerged as a material of particular interest due to its sharp semiconductor-to-metal phase transition near room temperature. A set of distinct optical and electronic properties which arise as a result of this transition have made VO_2 popular for thermochromic coatings, resistive switching, optical storage, light modulators, and other applications. Here, we demonstrate the development of a polymer-based solution for the deposition of VO_2 thin films. By exploring a variety of sintering and annealing conditions as well as exploring different polar solvents, we have optimized the growth of these films on glass and crystalline substrates. We go on to explore printing of VO_2 devices via the LIFT technique, which is notable for its ability to print high-viscosity inks and pastes. Finally, we will discuss our efforts toward the development of low temperature laser sintering in order to realize VO_2 films on substrates incompatible with high furnace temperatures.

11:40am **AM+EM+MS+TF-WeM12 Printing Multi-Functionality using Additive Manufacturing**, ***Ryan Wicker***, University of Texas at El Paso **INVITED**

Since the commercial introduction of Additive Manufacturing (AM) technologies more than two decades ago, considerable advancements in processing speed, accuracy, resolution and capacity have been achieved and the available AM materials have expanded considerably, enabling customized end-use products to be directly manufactured for a wide range of applications. Many AM technologies have been released that use different processes for fabricating the individual layers from a variety of liquid, solid, and powder-based materials ranging from photoreactive polymers to metals. In 2000, the University of Texas at El Paso identified AM as an emerging technology and invested strategically in establishing the W.M. Keck Center for 3D Innovation (Keck Center). The Keck Center has grown to occupy over 13,000 sq. feet with more than 50 commercial and experimental AM machines, representing 10 system manufacturers, nine distinct layer processing methods, and several custom AM-based patented and patent-pending systems. One particular focus of Keck Center research is on developing the methods and systems required to have automated control over material placement and structure creation, leading to, for example, the realization of complex 3D devices that integrate electronics and thus intelligence within mechanical structures as well as 3D spatially complex bioactive, implantable, tissue engineered constructs. There are myriad issues associated with combining multiple materials to create functional products – from the deposition and processing of different materials to the combined performance of the materials in the resulting product. Despite these issues, the opportunities for AM in aerospace, defense, biomedical, energy and enumerable other applications continue to expand as the achievable length scales in AM decrease, the number of materials available for use in AM increases, the performance of these materials are characterized and controlled in the final product, and new strategies for integrating AM with other manufacturing technologies are successfully demonstrated.

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