WK10: Applications of Synchrotron X-ray Techniques for Studying Metal Additive Manufacturing

Organizers: Tao Sun, Andrew Chuang, Xianghui Xiao, Ruqing Xu, Yang Ren, and Kamel Fezzaa (Advanced Photon Source, Argonne National Laboratory)

Location: Bldg. 446, Advanced Protein Characterization Facility Conference Room

Additive manufacturing (AM, a.k.a. 3D printing) refers to a suite of transformative technologies that build three-dimensional objects by adding materials layer by layer based on digital design. In particular, metal AM has found many applications in the fields of biomedical, aerospace, automobile, and defense. Compared with conventional metal manufacturing techniques, AM exhibits many unique advantages, including short design-to-market, short supply chain, on-site and on-demand spares and tools manufacturing, less consumption of energy, and less generation of material waste. More importantly, AM largely eliminates tooling constraints, and gives us the freedom to design and build parts with complex geometries and improved performance. Metal AM has developed rapidly in the last three decades, thanks to substantial investments in the technology from both public and private groups worldwide. Numerous 3D printer manufacturers have emerged, and the technique maturation was seemingly reached. However, a precise control of microstructures and properties of additively manufactured products remains challenging, and the metallic materials we can use for AM are still very limited. Therefore, solving the fundamental material problems holds the key to unleash AM's full potential to revolutionize the way we build metal parts.

There are a few AM techniques for printing metallic materials. Except binder jetting, all other metal AM techniques involve depositing thermal energy to the sample with laser or electron sources. In a typical build process, the laser or electron beam heats up the sample locally to temperatures higher than the melting or even boiling temperatures of metals. In the meanwhile, the heating and cooling rates are in the order 106 K/s and above, and the local thermal gradient can easily reach 103 K/mm. Such extreme thermal conditions allow us to fabricate materials with very unique and favorable microstructures that we could never achieve before; but on the other hand, a variety of defects exist in AM materials, including porosity, cracks, residual stress, undesired grain structures and non-equilibrium phases.

Synchrotron x-ray techniques are among the most versatile and effective techniques for characterizing materials microstructures and their evolution in various processes and conditions. The APS has seen more and more users from the AM community in the recent years, who take the advantages of the superior hard x-ray source and sophisticated beamline instruments the APS affords. With state-of-the-art high-energy x-ray diffraction, Laue microscopy, computed tomography, high-speed imaging techniques, scientists start to address many critical material issues in AM associated with the feed stocks, build processes, and end products. This workshop aims to bring together AM experts from industry, government labs, and academia for a full-day discussion. It will serve as a venue for the AM user community to present their observations and theoretical advances from synchrotron experiments, identify the major challenges associated with AM materials, and propose desired beamline instruments and capabilities for future study.

Program (Session Shair: Tao Sun)

8:30—8:40	Tao Sun (Argonne National Laboratory) *Welcome and Introduction*

8:40—9:00	Aaron Greco (Argonne National Laboratory) *Argonne Additive Manufacturing Initiative*

High-speed Imaging (Session Chair: Kamel Fezzaa)

9:00—9:30	John Barnes (The Barnes Group Advisors) *Additive Manufacturing is Making Our Future*
9:30—10:00	Lianyi Chen (Missouri University of Science and Technology) *Characterizing the Dynamics of Laser Powder Bed Fusion Additive Manufacturing Processes by High-speed X-ray Imaging/Diffraction*
10:00—10:30	Break

Tomography (Session Chair: Xianghui Xiao)

10:30—11:00	Jian Cao (Northwestern University) In Situ *Characterization of Directed Energy Deposition Process*
11:00—11:30	Christopher Tassone (SLAC National Accelerator Laboratory) *Tracking the Evolution of Phase, Microstructure and Meso-structure Using High Speed* In Situ *X-ray Diffraction, and X-ray Imaging of Metallic Alloys during Selective Laser Melting Additive Manufacturing*
11:30—12:00	Hahn Choo (University of Tennessee) *The Effect of Volumetric Energy Density on Defect Characteristics in a 3-D Printed Stainless Steel Alloy*
12:00—1:30	Lunch

Diffraction (Session Chair: Ruqing Xu)

1:30—2:00	Uta Ruett (Argonne National Laboratory) *Perspectives for Insight to AM with High-energy X-rays at Sector 11*
2:00—2:30	Lyle Levine (National Institute of Standards and Technology) *Synchrotron X-ray and Neutron Based Benchmark Measurements for Additive Manufacturing*
2:30—3:00	Xin Sun (Oak Ridge National Laboratory) *High Energy X-ray in Qualifying Additive Manufacturing Parts for Energy Applications*
3:00—3:30	Break

Diffraction and Microscopy (Session Chair: Andrew Chuang)

3:30 – 4:00	Don Brown (Los Alamos National Laboratory) *Using Neutron and High Energy X-ray Diffraction to Probe Additively Manufactured Materials over a Range of Length and Time Scales*
4:00 – 4:30	Paul Shade (Air Force Research Laboratory) *Materials Informed Data Driven Design of Additive Structures*
4:30 – 5:00	General discussion