Institute for Materials Science

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IMS Distinguished Lecture Series

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Advanced Characterization of Additively Manufactured Materials, including Synchrotron–based 3D X-rays

Wednesday, August 3, 2016
2:00 - 3:00pm
MSL Auditorium (TA-03 - Bldg 1698 - Room A103)

ABSTRACT: A brief review is given of metals additive manufacturing, emphasizing the most common technology, viz. powder bed. The most critical feature is the melt pool size, which is, to first order, determined by a trade-off between absorbed power and travel speed. The melt pool size must in turn be controlled in relation to the depth of the powder layer that is spread in each pass. The cooling rates are high, ~ 106/s, which means that rapidly solidified metals is available in bulk form. In effect, on can apply the analysis of laser or electron beam welding in heat conduction mode.

It is important to understand the microstructure and, in particular, porosity in additively manufactured metallic parts. Absent manufacturing defects, pores are the primary origin of fatigue failures under cyclic loading, for example. The morphology and location of these pores can help indicate their cause; lack of fusion pores with irregular shapes can usually be linked to incorrect processing parameters, while spherical pores suggest trapped gas. Synchrotron-based 3D X-ray microtomography was performed at the APS on additively manufactured samples of Ti-6Al-4V using electron beam powder bed and Al-10Si-1Mg using laser powder bed. The spatial and size distributions of the porosity over a range of processing conditions were determined. Marked variations in the type and amount of porosity were observed as a function of the melt pool area. Outside of incomplete melting and keyholing, porosity appears to be inherited from pores or bubbles in the powder.

Beyond measurements of porosity, 3-D printed parts are known to have residual stress as a consequence of the shrinkage that occurs on solidification as well thermal contraction. Thanks to recent advances in high-energy (synchrotron) x-ray methods, a combination of near-field and far-field high energy diffraction microscopy (HEDM) enables the mapping of both 3-D grain structure and the lattice strains. Preliminary measurement results are presented for printed Ti-6Al-4V. Remarkably enough, both the majority hexagonal phase and the minority bcc phase can be reconstructed. Moreover, parent bcc orientations inferred from the product hcp material agree well with the HEDM reconstructions of the bcc grains. Once such data are available, the impact of microstructure on properties can then be evaluated. The application of image-based spectral methods for calculating the micro-mechanical response is described, where the measured image is used as direct input.

Bio: Professor Rollet received his M.A. in Metallurgy & Materials Science at Cambridge University, UK and his Ph.D. in Materials Engineering, Drexel University, 1987. He was at Los Alamos National Laboratory from 1979 to 1995, starting as a technical staff member. In 1995 he left his position of Deputy Deputy Division Director of Materials Science & Technology Division for a professorship and Department Head position at Carnegie Mellon University.

His many honors include: Bain Award - ASM International Pittsburgh chapter, 2016; *Membre d'Honneur* - French Society of Materials & Metallurgy - SF2M, 2015; *Cyril Stanley Smith Award*, TMS, 2014; *Chercheur d'Excellence* - University of Lorraine, Metz, France, 2012; *Brahm Prakash Professor* - Indian Institute of Science (Bangalore), 2011; *Fellow of TMS*, 2011; *Fellow of the Institute of Physics* (UK), 2005; H*owe Medal for Best Paper in Metallurgical Transactions A*, 2004; *Fellow of ASM-International*, 1996; *Award for Technology Transfer* - Federal Laboratories Consortium, 1989.

* *Jon Almer, Edward Cao, Ross Cunningham, Peter Kenesei, David Menasche, Tugce Ozturk, Suraj Rao, Hemant Sha, Samikshya Subedi, Chasen Ranger, Paul Chao, Jack Beuth, Elizabeth Holm, Fred Higgs, Robert Suter, and Xianghui Xiao are thanked for their contributions. NSF (DMREF), DOE, APS (ANL), the Commonwealth of Pennsylvania, and America Makes supported this work.*

Hosted by Alexander Balatsky * Director of the Institute for Materials Science

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