ADVANCING METAL ADDITIVE MANUFACTURING MODELS THROUGH OPERANDO SYNCHROTRON X-RAY EXPERIMENTS

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ABSTRACT

Predictive modeling is essential for elucidating metal additive manufacturing (AM) mechanisms and developing digital twins that support process optimization, product qualification, and certification. However, the fidelity of a model is often limited by material properties, kinetic parameters, and process conditions that are unavailable in databases or inaccessible to conventional measurements, particularly under extreme thermal conditions. Operando synchrotron X-ray imaging and diffraction experiments offer powerful tools to fill these gaps by characterizing transient phenomena in AM with high spatial and temporal resolution, and providing quantitative measurement data to inform, calibrate, and validate models.

This symposium will bring together experimentalists and modelers to advance the integration of operando synchrotron measurements with predictive simulations of metal AM. Contributions are invited on thermal models, reduced-order models, multiphysics models, CALPHAD-based thermodynamic and kinetic descriptions, or phase-field models. Topics include using X-ray imaging and diffraction to determine effective material and process parameters, constrain heat transfer and melt pool dynamics; identify phase transformations and solidification pathways; and quantify microstructural evolution and defect formation.

The session aims to establish practical strategies for experiment-informed model improvement, including inverse identification, uncertainty quantification, sensitivity analysis, and the design of experiments that discriminate between competing physical mechanisms. Discussions will address measurement limitations, parameter identifiability, model discrepancy, and the transferability of calibrated descriptions across materials, geometries, and processing conditions. By connecting high-fidelity multiphysics and microstructure simulations with efficient reduced-order representations, the symposium will explore pathways toward experimentally grounded digital twins. The intended outcome is a shared framework for assessing predictive capability and identifying the additional measurements needed to strengthen mechanistic understanding and generate credible modeling evidence for qualification and certification.