Overview Chart

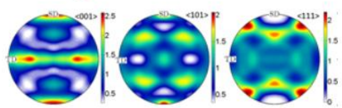
Prediction of Microstructure Evolution in DMLM Processed Inconel 718 with Part Scale Simulation

PI: Prof. Albert To, Mechanical Engineering, University of Pittsburgh
Co-PI: Prof. Wei Xiong, Materials Science, University of Pittsburgh
Co-I: David Conover, Chief Technologist for Mechanical Products at ANSYS

Prof. Albert To: Mechanical scientist in mechanical property simulation, additive manufacturing, finite element simulation, and numerical modeling development.

Prof. Wei Xiong: Physical metallurgist in materials thermodynamics and kinetics (CALPHAD), phase transformation model development, and materials characterization.

Mr. David Conover: Expert in the development of elements, nonlinear material models, distributed memory parallelism, solution strategies and solvers in mechanical CAE software development.



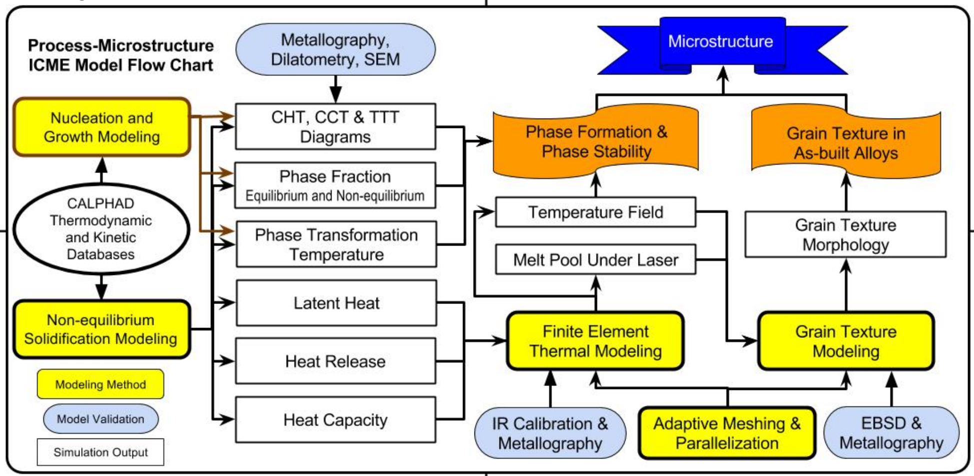
Research Objectives

<u>Accomplish</u>: An integrated AM design model for process-microstructure simulation.

<u>Innovations</u>: (1) incorporating alloy thermodynamics into thermal modeling for cyclic superheating and supercooling processes; (2) developing a new integrated phase transformation and grain texture model to predict microstructure evolution under cyclic laser process with high fidelity; (3) explore simultaneous time scale parallelization and adaptive meshing to accelerate thermal modeling for part-scale process simulation.

<u>Compare to SOA</u>: Unlike the state-of-the-art AM process-microstructure simulations, quantitative rather than qualitative prediction of the microstructure and its stability through an integrated theoretical and experimental approach.

<u>Start and end TRLs</u>: Start TRL is 1, since simulation models need to be constructed and integrated. Existing models are lack of accuracy in both thermal modeling and microstructure simulation due to missing physical basis. The end TRL is 4, since an robust ICME materials microstructure simulation code is the final deliverable.



Research Approach

- CALPHAD-informed thermal modeling for cyclic thermal history.
- Modified phase transformation modeling considering both superheating and supercooling effects and their impact on microstructure evolution.
- Grain texture modeling based on solidification in melt-pool.
- Adaptive meshing and Parallelization.
- Key experiments for model calibration/verification: metallography, EBSD, dilatometry

ICME Process-Microstructure Modeling Approach
CALPHAD + Finite element modeling +
Phase transformation modeling + Grain texture model +
Adaptive meshing + Parallelization

Potential Impacts

- Maximize freedom to design materials microstructure based on created reliable model.
- The proposed process-microstructure modeling demonstrates the way to perform an efficient design-level simulation providing the method to evaluate in-situ phase stability.
- Leading a direct approach to optimize laser process parameter to improve mechanical properties through designable as fabricated microstructure.
- Paving the way for the future development of a simultaneous microstructure-topology optimization framework for the designing of AM structural metal components.
- The proposed model can be directly adopted in design route for AM components leading a significant shortened design-cycle, and will assist in certifying an AM part for space mission.