Control of Variability in the Performance of Selective Laser Melting (SLM) Parts through Microstructure Control and Design

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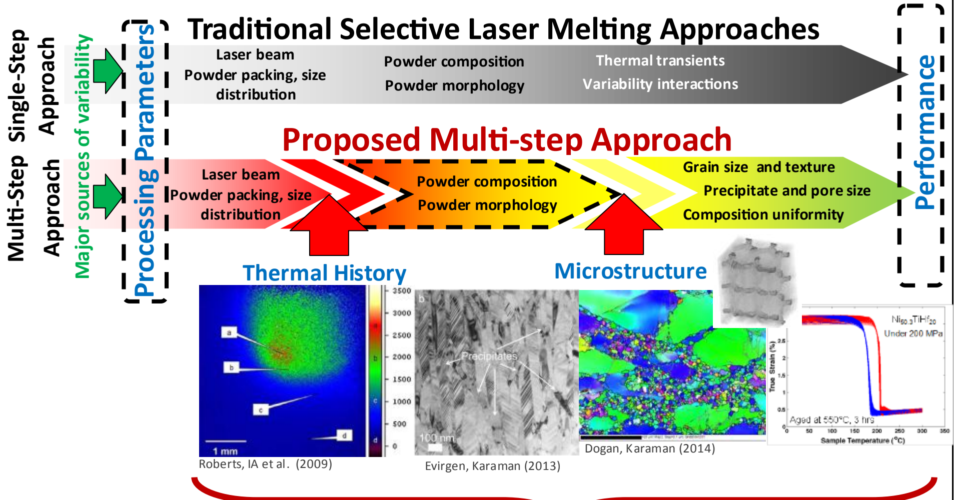
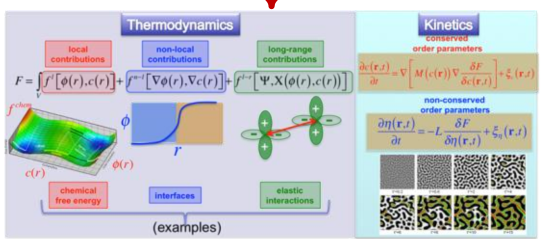


Missing link

Processing—Microstructure Modeling



Research Objectives

- Develop a novel Phase Field Modeling framework for characterizing microstructure evolution of parts produced using Selective Laser Melting (SLM).
- Conduct systematically designed experiments to identify process parameters and higher order interactions that contribute to the variability in the predicted microstructures. A Response Surface model (RS) will then be constructed to optimize the identified process parameters.
- Validate the proposed methodology using Ni-rich Shape Memory Alloy (SMAs) as a model material, properties of which are very sensitive to changes in the microstructure. This will help amplify the variability and help identify the sources of variability.
- The key contribution lies in bridging a major gap in the existing efforts on modeling SLM processes. Current models have rarely considered the actual microstructure evolution of the solidifying liquid as well as the evolution of the microstructure of the already solidified material subject to re-heating through subsequent passes of the energy source (the laser beam)
- Phase Field Modeling of microstructure evolution in the Selective Laser Melting of SMAs is currently missing in the literature (TRL 1)
- Integrating the Phase Field Modeling with Response Surface models and experimentally validating the proposed framework using in SMAs will lead a functional laboratory demonstration (TRL 3)

Approach

- The temperature history of the part will be modeled as a time-based stochastic process to characterize the influence of processing parameters on this history.
- The temperature history will then be experimentally determined using a custom integrated monitoring setup on a ProX 100 Selective Laser Melting system.
- The estimated thermal history will be used as 'boundary conditions' with associated uncertainties for the microstructure evolution of the solidifying and solidified material through the use of phase-field models.
- The properties and performance of the part made from high performance Shape Memory Alloys will be characterized. Fractional factorial experiments will be used to identify the parameters and higher order interactions that significantly contribute to the property of the part.

Potential Impact

- The proposed framework will present a significant contribution to the qualification and certification processes of parts and materials in Selective Laser Melting (SLM) for space and aerospace applications.
- The proposed framework linking processing and thermal history to microstructural evolution and then microstructural evolution to performance are applicable to other material systems
- A clear insight on the specific process parameters that need to be monitored *in situ* will be provided by identifying key sources of variability.
- SLM fabricated SMA parts will enable high energy density solid state actuators for space and aerospace applications for aeroelastic tailoring, active noise, thermal, or flow control and multifunctional deployable structures in space.
- Similar impact on non-aerospace applications.