"Additive Manufacturing: From Nonequilibrium Interfaces to Strange Grains"

Professor Peter W. Voorhees
Northwestern University, USA

Additive manufacturing (AM) has emerged as a promising technique for the fabrication of complex metallic parts. Under AM processing conditions the resulting microstructures can be very complex due to a combination of factors such as the alloy powder being processed, the AM technique, the heat source power and speed and the resulting shape of the melt pool, and the scan strategy employed by the build, to name a few examples. The microstructures and the resulting properties of the part can differ significantly from those observed through traditional solidification processes due to fast solidification rates (10^{-3} - 1 m/s) and large thermal gradients (10^5-10^7 K/m). Simulation plays a critical role in understanding the link between the processing conditions and the resulting microstructure. A phase field model for the development of grain structure during powder bed AM will be discussed. Using the parameters from molecular dynamics simulations, these three-dimensional phase field simulations of the morphological development of grains illustrate the complicated interaction between interfacial mobility anisotropy, weld pool shape, laser scan strategy and multiple powder layers on the resulting grain morphology. The large solidification velocities of AM require a phase field model with the flexibility to incorporate a wide range of models for nonequilibrium solid-liquid interfaces. A phase-field model in which non-equilibrium effects such as solute trapping, solute drag, and interface kinetics can be introduced in a controlled manner while at the same time using interface widths that permit calculations at experimentally accessible length scales will be discussed.