Multiscale Process-Structure Simulations for Additive Manufacturing in Metals

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Additive manufacturing (AM) brings advantages for the fabrication of metal parts compared with traditional techniques, including the ability to create complex geometries with reduced production lead time and less material waste.
However, the intricacy of the additive process and the extreme thermal environments involved can lead to material defects, heterogeneous microstructures, and wide variation in properties, leading to unpredictable and sometimes inferior performance of AM-built parts. Computational simulation can be used to understand and predict the effects of various process parameters on the resulting material, and to suggest strategies to optimize ultimate part performance. In this talk, I present modeling approaches at several length scales that are important in predicting material structure in AM. These include the part scale, where geometry and build strategy affect the thermal history throughout the material; the melt pool scale, where fluid flow and phase change dictate the heat transfer in the solidifying material; and the material microscale, where repeated re-melting and the competition between grain growth and nucleation can lead to unusual grain structures. Novel computational methods and tools are used at each scale, and to couple across scales. Finally, I discuss ideas for developing reduced order models to more efficiently material structure for a given set of process parameters.