Multi-scale and multi-physics modeling for process-structure-property relationships of laser powder-based additive manufacturing

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A laser powder bed fusion (LPBF) process has emerged as a promising manufacturing technology for various industries such as medical, automotive, aerospace, and offshore. However, the technology is still facing a great challenge due to the processing complexity. The process contains more than 100 adjustable parameters. As a result, the comprehensive experiments that can reveal the process-structure-property relationship are practically unachievable. For this reason, computational modeling becomes essential for attaining a fundamental understanding of the process. However, developing high-fidelity modeling is not an easy task owing to the multi-scale nature of the LPBF system. For an instance, the melting and solidification can occur within a fraction of milliseconds while the total build time could take up to several hours. Linking multiple physics at multiple spatial and temporal scales has been a target of this community. Therefore, I aim to provide an overview of the modeling works for the LPBF process from laser-material interaction, defect formation, microstructural development, mechanical properties, and damage initiation. Integration between different numerical strategies to gain a better understanding of a complex phenomenon and achieve a printed component with high build quality will be presented. I will also demonstrate how we can utilize different process strategies to modulate desirable mechanical properties through processing-mediated mesostructured. Finally, this talk hopes to describe the challenges, opportunities, and future research direction of the LPBF additive manufacturing process.