Phase-field simulation on process-microstructure-property relation in power bed fusion additive manufactured metals

Bai-Xiang Xu*, Yi Min, and Yangyiwei Yang

Institute of Materials Science, Technische Universität Darmstadt, Germany
e-mail: xu@mfm.tu-darmstadt.de, web page: http:// www.mawi.tu-darmstadt.de/mfm

ABSTRACT

There exists large potential for the mechanical and functional property of the additively manufactured part to be optimized with respect to the process and material parameters. Compared with the expensive trial-and-error principle, physical models and numerical simulations are much more efficient in terms of both cost and time. They allow massive parameter studies which can provide large database for statistical analysis such as machine learning to extract the process-microstructure-property relation. One needs hence a reliable physical model, which can recapture the processing and the microstructure development. In this work we present a thermodynamically consistent phase-field model and the finite element simulations of microstructure evolution (pore and grain structure) during powder bed fusion additive manufacturing of metallic materials. Preliminary work has been done on the particle level [1-2] and the mesoscopic level [3]. Furthermore, we study both the selective laser sintering (SLS) [1] and selective laser melting (SLM) (Fig. 1). The model includes simultaneously complex underlying physics, such as extreme heat diffusion, melting, solidification and grain coalescence. The models are parameterized using measured thermodynamic and kinetic data. For the process simulation, we overcome the numerical challenges on powder bed deposition, power injection and strategies to reduce the computation cost by a novel algorithm analogy to minimum coloring problem and grain tracking approach. Simulation results will be shown for e.g. stainless steel 316L and Fe-alloys. We reveal the influences of process parameters e.g. the laser power and scan speed on the microstructure features, such as porosity, surface morphology, geometric variation of grains and densification. The simulation results will be discussed in comparison with the experimental data available in the literature. Moreover, through micromechanics tools, the effective mechanical properties of the simulated microstructure will be evaluated.

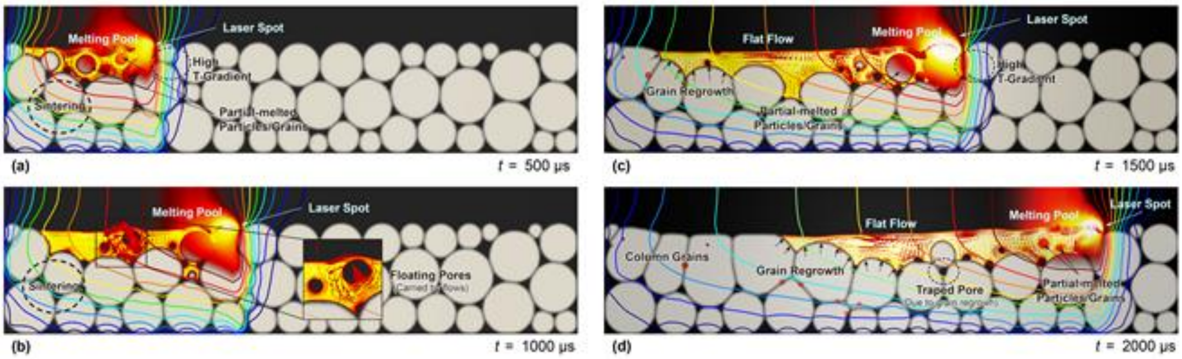

Fig. 1 Preliminary FE phase-field simulation of selective laser melting.

REFERENCES

[1] Y. Yang, O. Ragnvaldsen, Y. Bai, M. Yi, B.-X. Xu, "Three-dimensional non-isothermal phase-field modeling of microstructure evolution during selective laser sintering", arXiv preprint arXiv:1902.04519, (2019).
[2] Y. Yang, M. Yi, B.-X. Xu, L.-Q. Chen, "Phase-field modeling of non-isothermal grain coalescence in the unconventional sintering techniques", arXiv preprint arXiv:1806.02799, (2018)
[3] M. Yi, B.-X. Xu, O. Gutfleisch, "Computational study on microstructure evolution and magnetic property of laser additively manufactured magnetic materials", Computational Mechanics. https://doi.org/10.1007/s00466-019-01687-2 (2019)