Modeling for particle filled 3D printing

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Predicting residual stress and deformation through a multi-physical and multi-scale numerical framework

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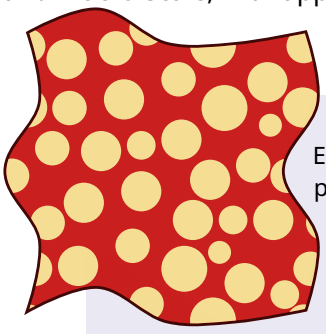
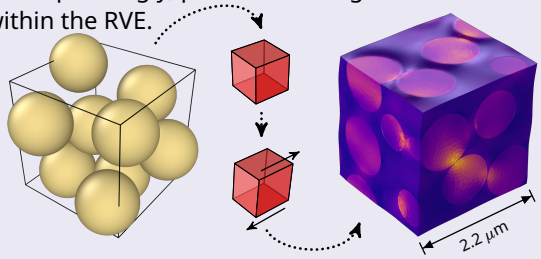
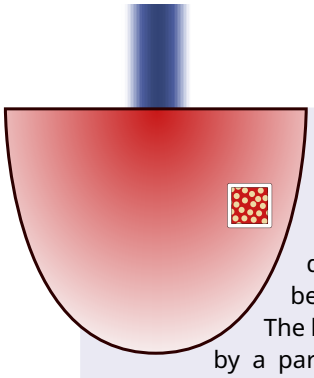
Vat photopolymerization or stereolithography is a versatile Additive Manufacturing (AM) technique broadly used for functional high quality polymer products. This technique can be used to produce composites or ceramic parts, by adding ceramic particles to the polymer. As the inclusion of the powder filler results in a more complex irradiation and thermo-mechanical behavior of the material, multi-physical and multi-scale numerical models are generated to further the understanding of the print process. From small to large, these length scales are referred to as the micro-, meso- and macro-scale, with application to an alumina filler.



Micro-scale

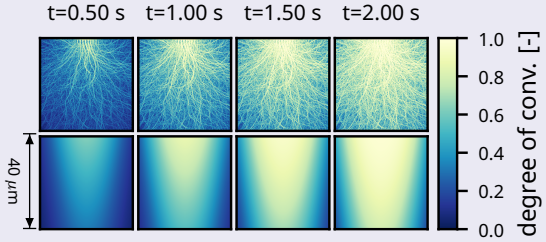
Effective thermo-mechanical properties are obtained from a homogenization approach on micro-structural representative volume element (RVE) realizations. The large scale separation with the macro-scale allows for a homogeneous intensity assumption and, correspondingly, provides homogeneous conversion within the RVE.

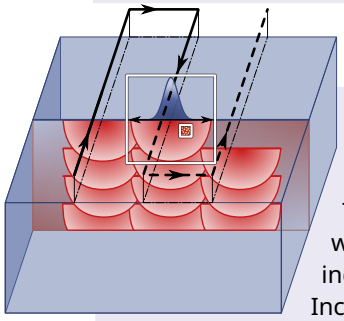




Meso-scale

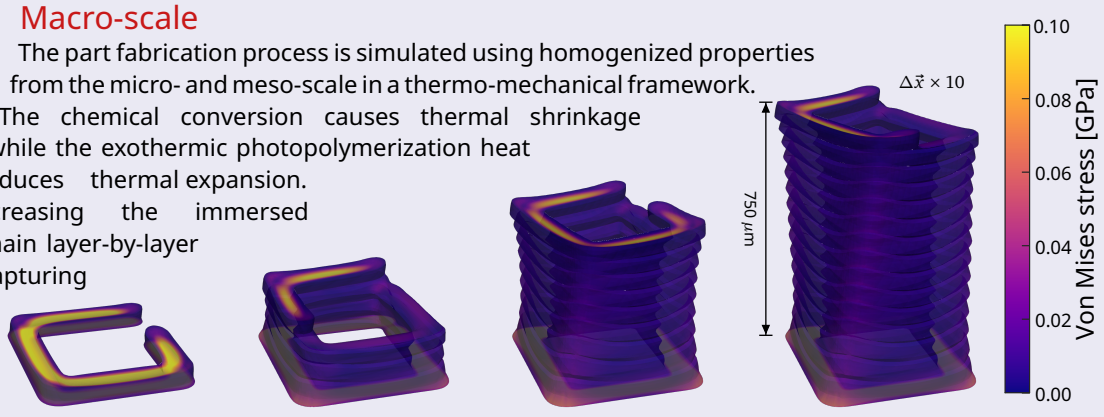
An intermediate length scale is introduced to capture the light scattering caused by the difference in refractive index between powder inclusion and resin. The broadened cure profile is captured by a parameterized law which conserves input laser energy and effective conversion inside the domain.





Macro-scale

The part fabrication process is simulated using homogenized properties from the micro- and meso-scale in a thermo-mechanical framework. The chemical conversion causes thermal shrinkage while the exothermic photopolymerization heat induces thermal expansion. Increasing the immersed computational domain layer-by-layer ensures correct capturing of the cumulative shrinkage effect in AM.



Using the developed multi-scale framework, the multi-physical nature of the filled vat photopolymerization process can be studied. The combination of the different length scales provides insight in the influence of the particulate inclusions on the required material and process conditions. In the end, this will further assist to obtain the intended final product first-time-right.

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