Challenges in 3D Printing of Semi-Crystalline Polymers

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Additive manufacturing, namely 3D printing, is attracting increasing interest in the industrial field since it allows obtaining parts with complex shape that are challenging to obtain with conventional processes. Fused Filament Fabrication (FFF) is the additive manufacturing technique mainly used for polymers. It consists of filament feeding to a liquefier where it melts, the injection through a suitable nozzle, and the deposition layer by layer to obtain the final part. Despite the potential of such a process, when it comes to semi-crystalline polymers with fast crystallization rate, notable challenges arise. Indeed, the material fast deforms up to induce the detachment from the deposition plate. Issues such as shrinkage, warpage, and inadequate interlayer adhesion frequently occur because of the complex thermal history and crystallization kinetics involved in the process. Interlayer adhesion depends on a complex interplay between rearrangement of molecules once they come in contact at the interface during deposition and crystallization. If crystallization occurs faster than the rearrangement, also referred to as diffusion, the adhesion will be poor, and the final part will show poor mechanical performances. Therefore, crystallization is crucial in determining the mechanical properties and dimensional stability of the printed parts. Furthermore, the crystallization degree achievable by the material determine the maximum volume reduction, i.e. the shrinkage, upon deposition. In summary, if the crystallization not properly managed, it can result in internal stresses, geometric distortions, and weak layer bonding. The interaction between melting within the extruder, the rate of crystallization, molecular diffusion at bead interfaces, and cooling conditions will be explored in this work. Furthermore, the effect of filament crystallinity on the final crystallinity degree and performance of the printed part will be analyzed for Polylactic acid (PLA). To achieve the desired degree of crystallization of PLA, annealing of the filament was conducted with different temperatures and times. After that, the filament was used in FFF in different conditions at the liquefier, namely temperature and flow rate. The findings underscore the influence of extrusion parameters on crystallinity, molecular orientation, and interfacial bonding, providing insights into how processing strategies can be adjusted to better address crystallization and melting-related challenges in the additive manufacturing of semi-crystalline polymers.

Keywords: *3D printing; Fused filament fabrication; Polylactic acid; Polymer crystallization; Deformation*