The importance of melting in 3D printing

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Introduction

3D printing is gaining attention for its ability to create complex objects layer by layer [1,2]. PLA (polylactic acid) is widely used due to its biodegradability and printability [3]. Crystallization plays a crucial role in determining the quality of adhesion during the process. If crystallization occurs early during deposition, it limits the molecular diffusion at the interface, with consequent poor adhesion [4]. In this study, a PLA filament has been obtained by extrusion and annealed to achieve desired crystallization degree. The annealed filament has been used in 3D printing with different conditions to obtain the parts. The crystallinity degree may affect the melting inside the liquefier: high crystallinity in the fed filament could lead to incomplete melting. The consequence of an uncomplete melting is a weaker part.

Methodology

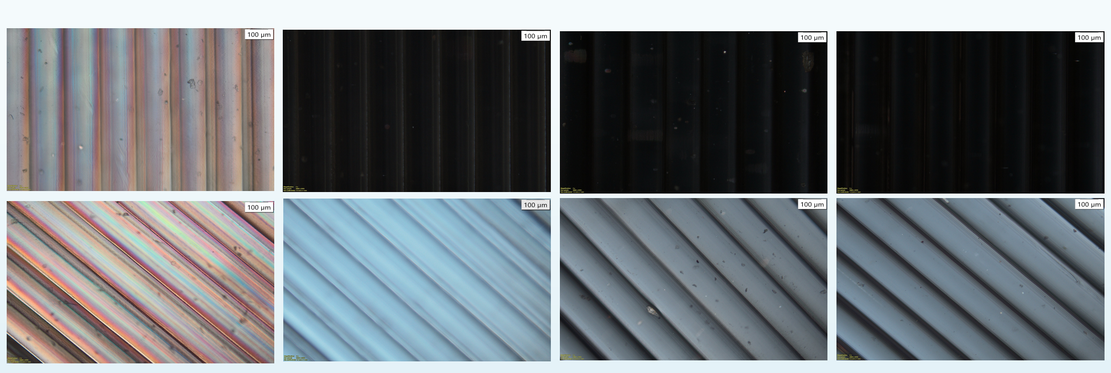
1. PLA Filament was annealed at 105°C for 40 minutes and achieved 40% crystallinity degree.
2. Optical analysis
3. Differential Scanning Calorimetry (DSC)
4. Dynamic mechanical analyses (DMA)
5. Simulation of melting inside the liquefier

Results and discussion

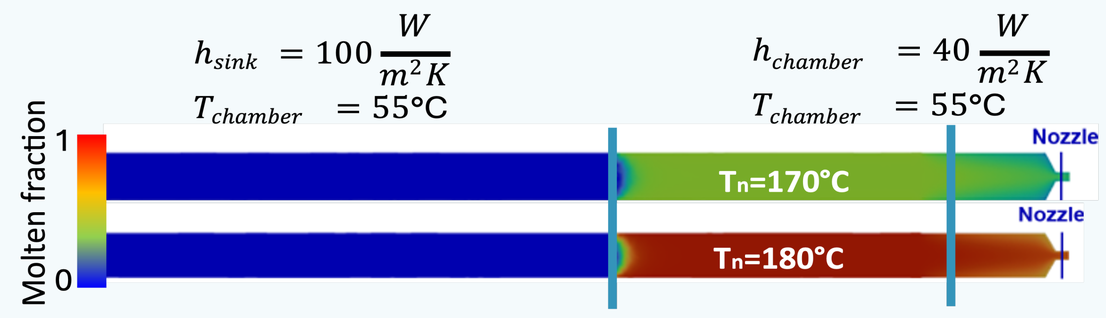
Effect of annealing on crystallinity of the **filament**

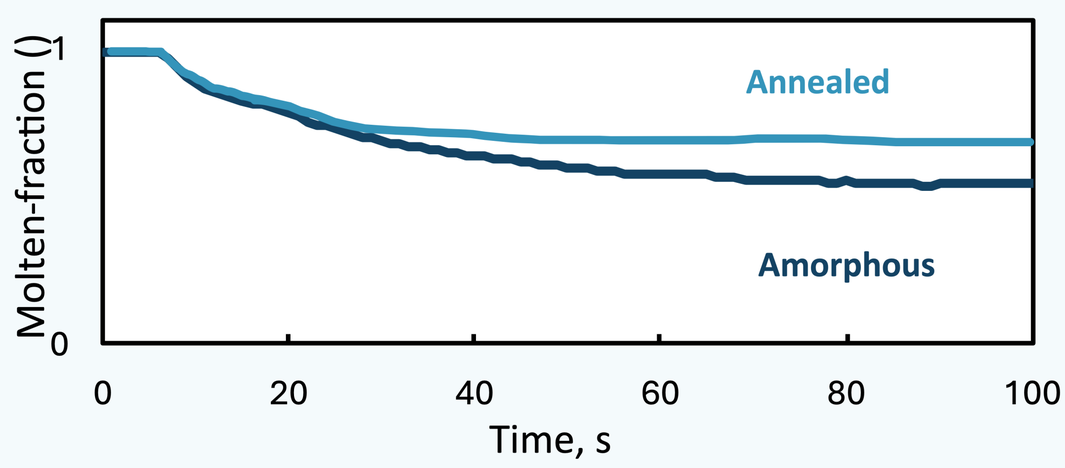
CRY=annealed filament, AM=amorphous filament
T_n=nozzle temperature, ER= extrusion ratio

CRY	AM	CRY	AM
ER=140%	ER=140%	ER=80%	ER=80%
T_n=170°C	T_n=170°C	T_n=170°C	T_n=170°C

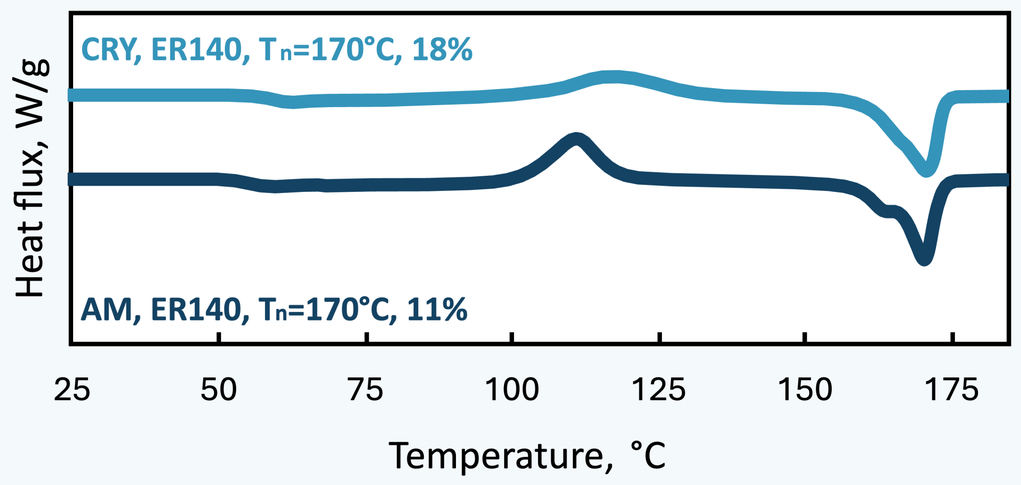


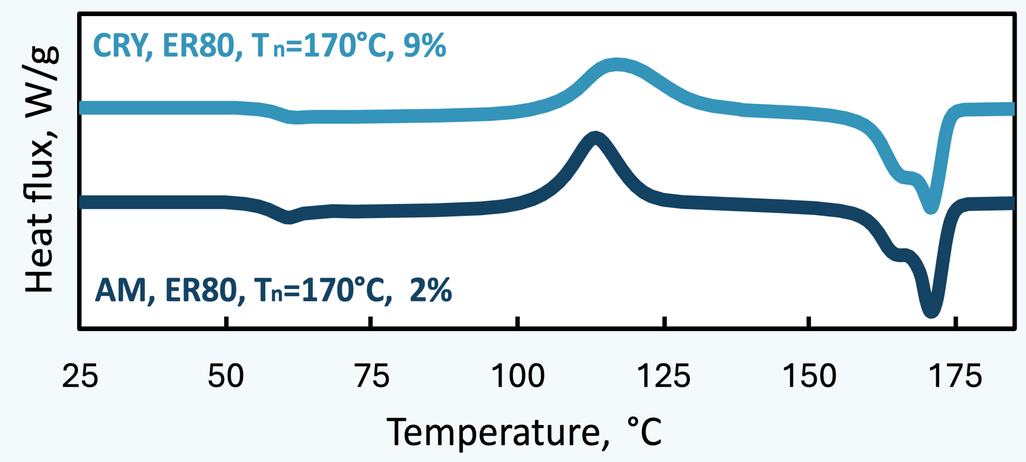
In the simulation we consider a high heat transfer coefficient (h) for the region of heat sink in order to model the heat dissipation. But at the end of nozzle which enters to the chamber the h has a lower value.

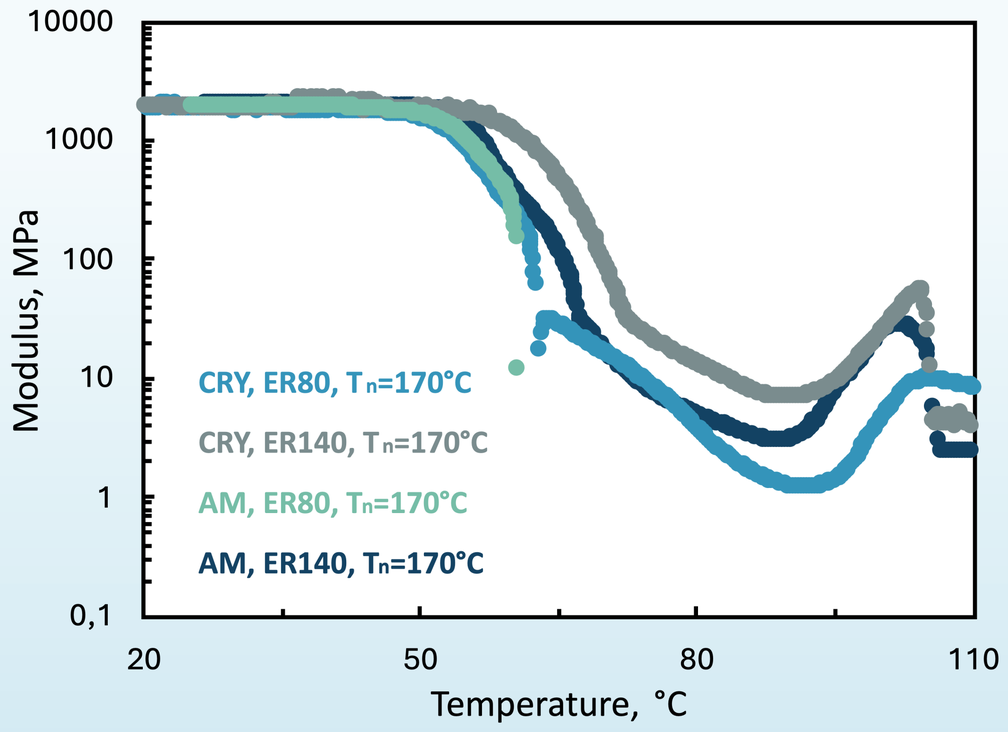




There is an interplay with the cooling rate, diffusion and crystallization. In case of slow cooling (higher extrusion ratio) although the crystallization is not too high but the diffusion at the interface induce the mechanical performance of the parts.







Conclusion

The study demonstrates that the behavior of PLA parts is influenced by both pre-processing of the filament and processing conditions. Parts obtained from annealed filament show modulus with higher deflection temperature. A higher flow rate allows to achieve better mechanical performances due to the slower cooling that improvs the adhesion. The simulations are consistent with this finding. Controlling crystallization timing is critical for enhancing bead adhesion and overall part quality in polymer 3D printing.

References

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