Revolutionizing Biomedical Advances: Unleashing the Potential of 3D Printed PLA

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Introduction

PLA is a biodegradable material widely applied in several industries, such as automotive and engineering. In addition, this material stands out as a possibility for the biomedical area due to its safe use inside the human body. However, **PLA** has limitations related to **high brittleness** and **poor adhesion** between **3D printed layers**, which affects its performance in the vertical printing direction.

Then, a 4-year research is ongoing to develop a **tough 3D printed PLA** parts with a **strong interface between the layers**. For this, plasticizers and polymers are tested to **reduce PLA brittleness** while the **stereocomplexation reinforces** the connection between the 3D printed PLA **layers**.

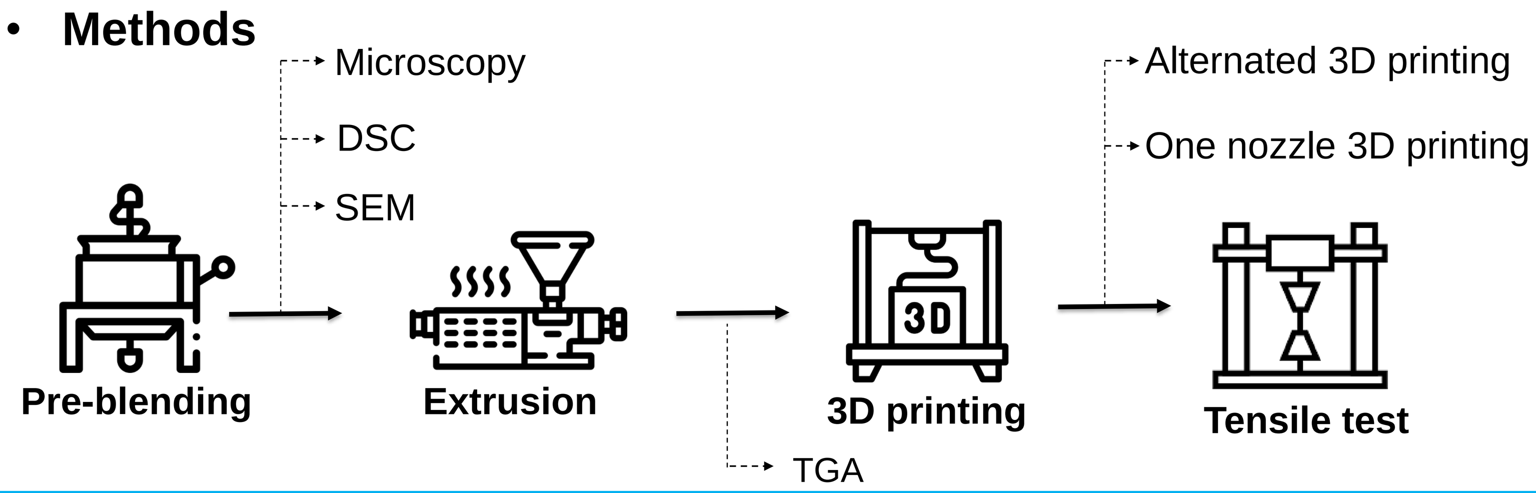
Materials & Methods

- **Materials**

Material		Molecular Weight (kg/mol)
PLA	PLLA	220
	PDLA	140
Plasticizers	TEC	0.28
	PEG	1
Polymers	PBS	131.2
	PBAT	128.8

- Blends with approximate ratio PLA vs plasticizer/polymer 80/20 wt%

- **Methods**



Results & Discussion

1°Test Route: Stereocomplexation to reinforce the connection of 3D printed layers

- **Polarized light microscopy with hot stage**

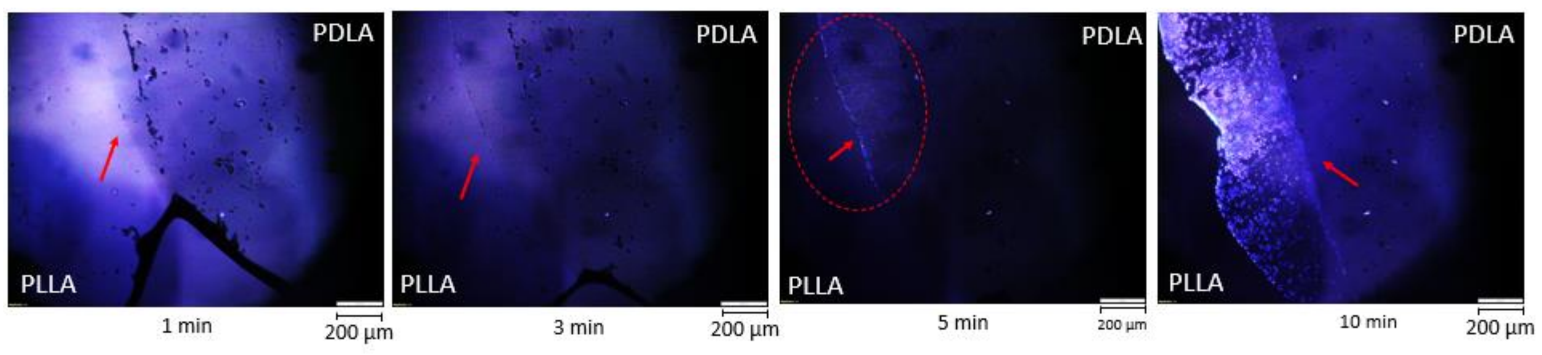


Figure 1. PLLA-PDLA behavior under polarized light microscope upon heating the sample at 200 °C for 10 minutes

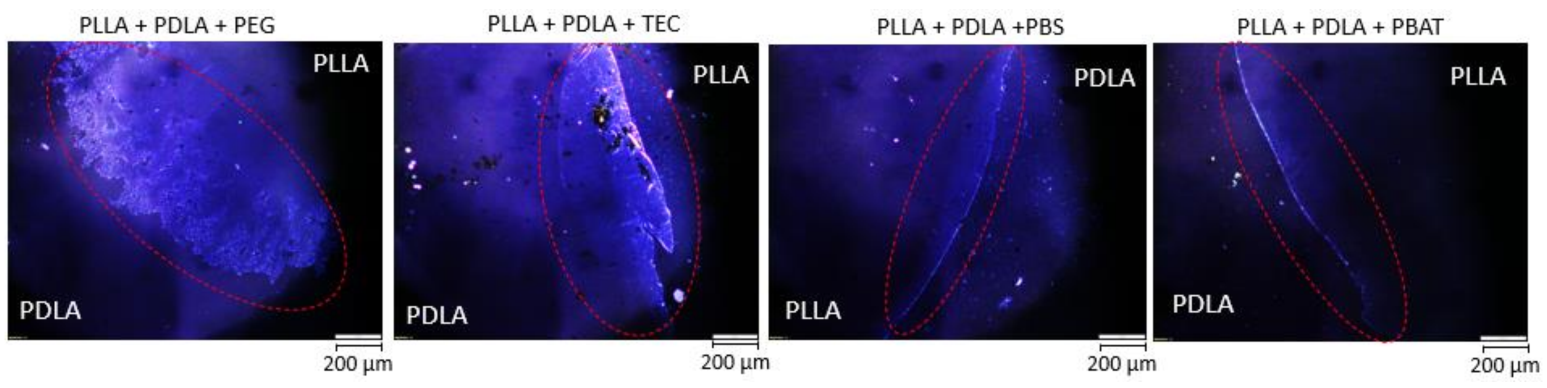


Figure 2. Effect of each plasticizer/polymer on the stereocomplexation of PLLA and PDLA after 10 min of contact in the polarized light microscope with hot stage

- **DSC**

Table 1. Characteristics of the stereocrystals formed during isothermal crystallization for 60 min at 215°C

Material	Stereocomplexation	
	Melting temperature (°C)	Enthalpy (J/g)
PLLA + PDLA (Pure)	231.7	2.7
PLLA + PDLA + PBS	223.9	1.8
PLLA + PDLA + PBAT	227.7	1.2
PLLA + PDLA + TEC	228.6	3.8
PLLA + PDLA + PEG	229.8	5.4

- PEG and TEC stimulate the occurrence of stereocomplexation due increase of mobility of the system by the dissolution of low mol weight components.
- The presence of PBS and PBAT in PLLA and PDLA culminates in the presence of two phases when blending these materials, which increases the diffusion path and thus hinders stereocomplexation.

Results and Discussion

- **SEM**

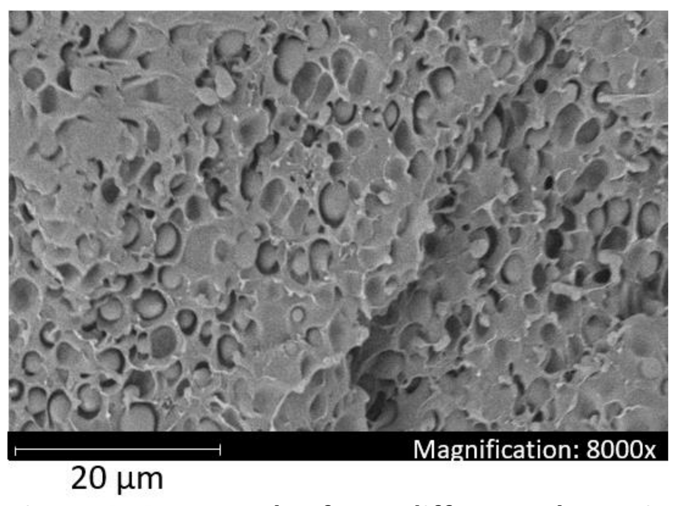


Figure 3. SEM result of two different phases in blend of PDLA + PBAT

- Figure 3 shows the presence of two different phases when blending PDLA and PBAT. This same behavior is observed for all samples with PBAT or PBS.

2°Test Route: Reduce the PLA brittleness by adding plasticizers or polymers

- **Tensile test**

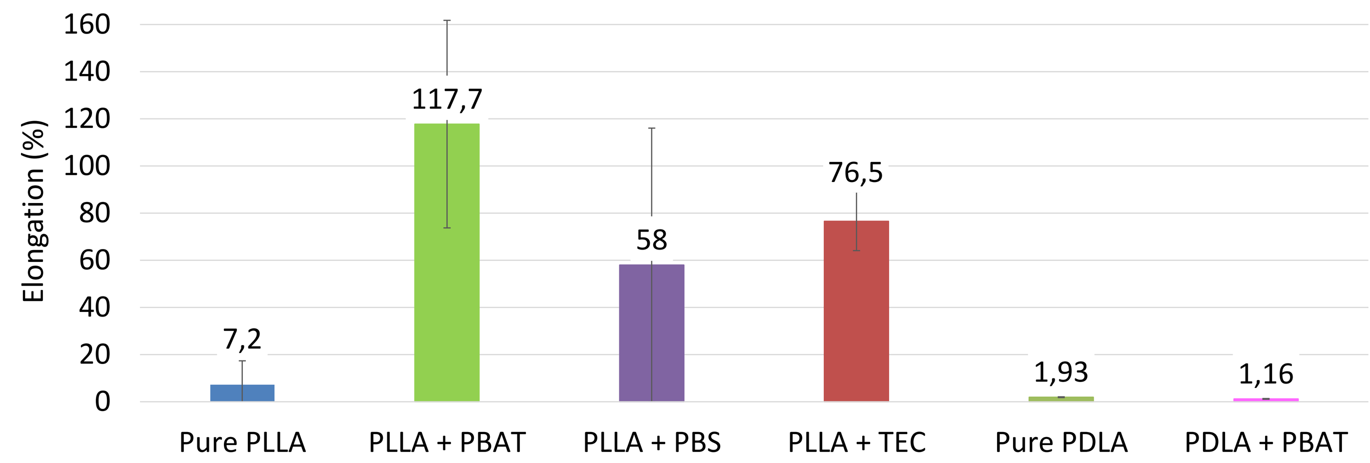


Figure 4. Elongation at break of horizontally cut samples from a single wall 3D printed object.

- Figure 4 shows a considerable increase in the elongation of the PLLA samples with TEC, PBS and PBAT.
- PDLA + PBAT shows a lower elongation than pure PDLA, which may also be related to the instability of printing just a single wall in the tensile bar.

3°Test Route: Combining Stereocomplexation and higher ductility

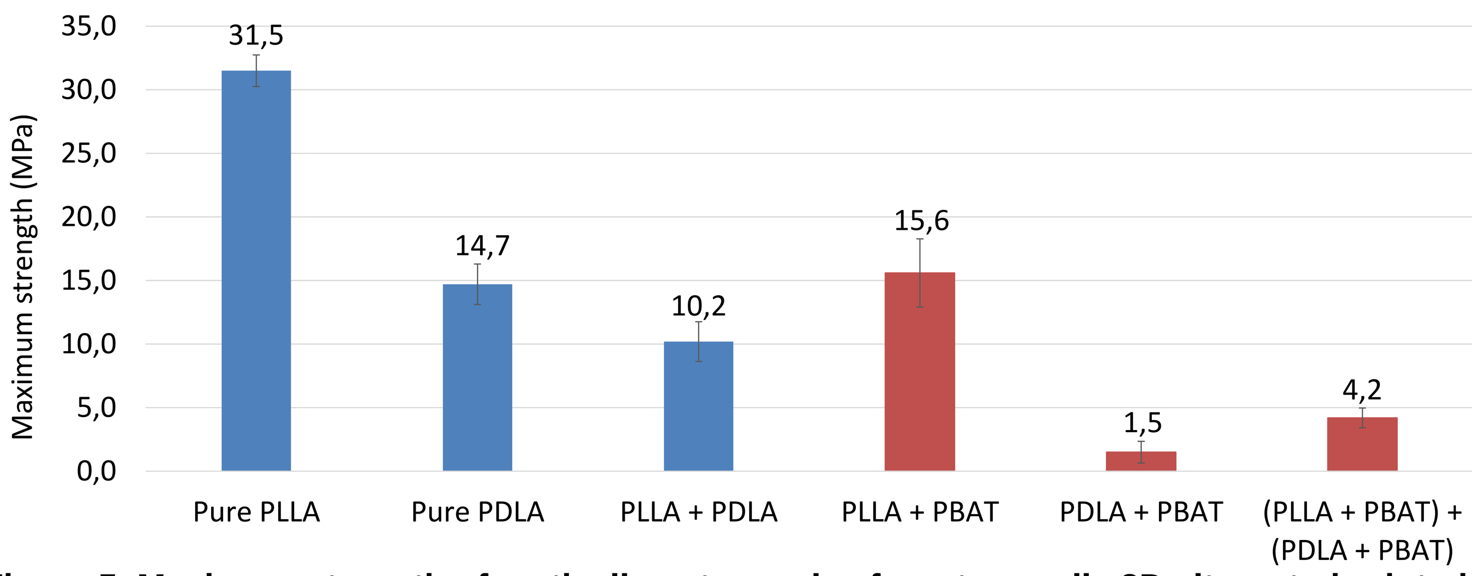


Figure 5. Maximum strength of vertically cut samples from two walls 3D alternated printed. Samples of pure PLLA or PDLA and PLA/PBAT has been studied.

- Higher Elasticity Modulus and maximum strength caused by the stereocomplexation were not found for alternated 3D printing between samples with PLLA and PDLA probably due o the use of only two printing walls, which may not be promoting the necessary heating time.
- The figure 5 shows a lower maximum strength in samples with PBAT, which is probably related to the presence of two phases in the blends of PBAT with PLLA and PDLA, especially at the border between two layers.

Conclusions

- The plasticizers TEC and PEG have a positive effect on the stereocomplexation between PLLA and PDLA, while the polymers PBS and PBAT hinder it.
- The PBS, PBAT and TEC increase the ductility of the PLLA samples. PDLA samples are affected by the low thickness of the tensile bars cut from printed single wall.
- Alternating 3D printing between PLLA and PDLA presents low Elasticity Modulus and maximum strength probably due the use of only two printing walls, which may not be enough to promote the necessary heating time.
- Alternating 3D printing in the presence of PBAT causes a reduction in Modulus and Elasticity and maximum strength of the samples due to the presence of two immiscible phases in the blends.
- **Overall Conclusion**

It has been possible to verify that some materials stimulated the stereocomolexation and other increase the ductility of PLA. However, so far it has not been possible to combine the two characteristics and create a system with improved layer adhesion in combination with tough behavior.

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