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Assessment of recycled PLA-based filament for 3D printing

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INTRODUCTION

Plastics are extremely useful for a wide range of applications due to their mechanical and chemical properties, as well as their ease of manipulation [1]. Yet, not being biodegradable, plastic materials pose a serious environmental problem due to the accumulation of products in nature [2]. This aspect has become particularly relevant in the sustainable development of industrial production [3]. Nonetheless, additive manufacturing (AM), well-known as 3D printing, is emerging as a crucial industrial technology for rapid prototyping, to convert a numerical model into material deposition and 3D printed parts [4]. During this cycle, a huge amount of waste products has been developed [5]. In order to reduce plastic waste [5] and limit the environmental impact of AM process [6], bio based and recycled polymers have been considered as alternative perspective to conventional raw materials. In this framework, this study was focused on improving the sustainability aspects of the AM technology by verifying the thermal and mechanical characteristics of recycled polymers, coming from waste products, in comparison with virgin matrices, for developing 3D printed parts.

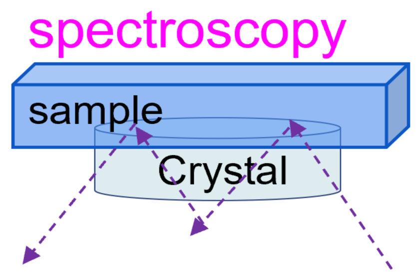
MATERIALS AND METHODS

Supplier : Eumakers (Italy)

Virgin PLA

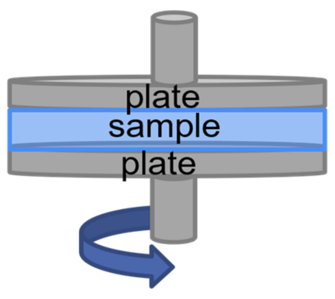
Recycled PLA obtained from the production waste of the virgin PLA

ATR spectroscopy



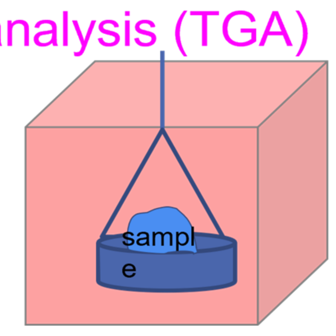
Range of wavenumbers=400–4000 cm-1, Scan=16, Resolution= 4 cm-1. Baseline correction and advanced correction related to specific diamond crystal. Normalized peak at 1455 cm-1.

Rotational rheology



Parallel plates, 25 mm in diameter, and gap of 1 mm. Frequency of 1 rad/s and a strain amplitude of 1% more than 900 s at 210 °C in nitrogen atmosphere on non-dried and dried materials in an oven under vacuum at 80 °C for 10 hours.

Thermogravimetric analysis (TGA)

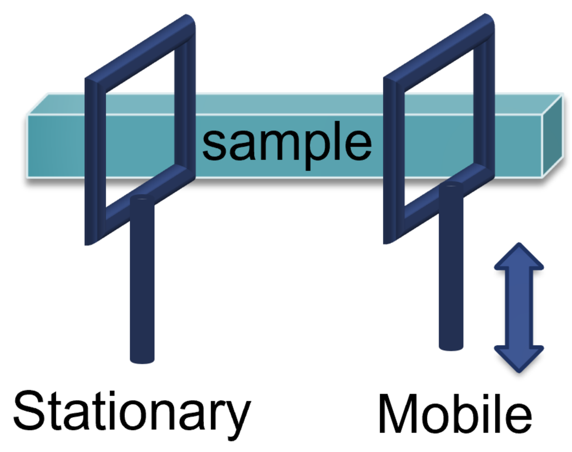


Heating approximately 10 mg of the materials from room temperature to 600 C in an inert nitrogen atmosphere at a ramp rate of 10 C/min

3D printing process

Temperature= 210 °C; Infill density 70%; Layer thickness 0.19 mm; Linear patter

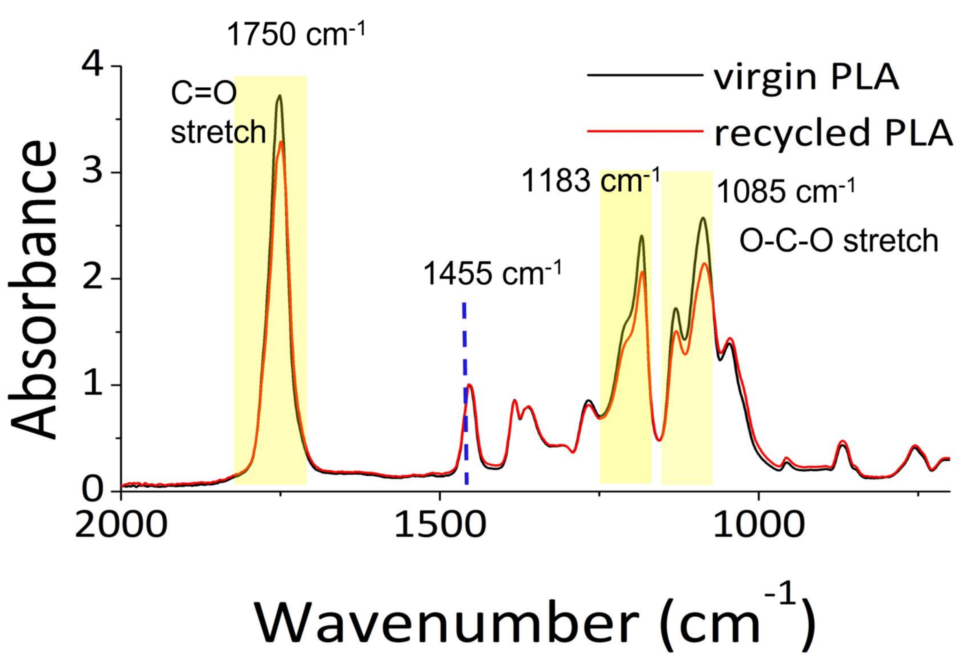
Dynamic Mechanical Analysis (DMA)



Single Cantilever; Temperature range from 30°C to 70°C, Heating rate 2°C/min, Frequency 1 Hz

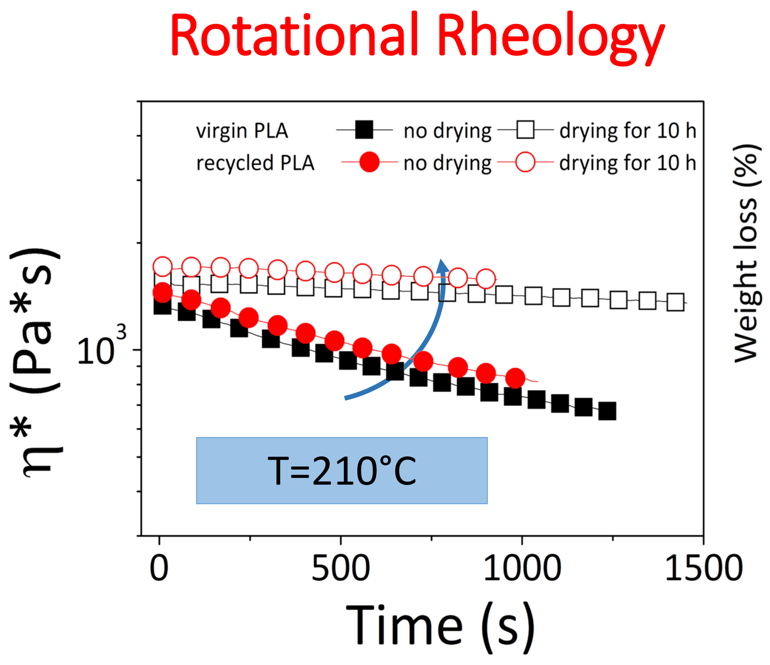
EXPERIMENTAL RESULTS

Infrared Spectroscopy



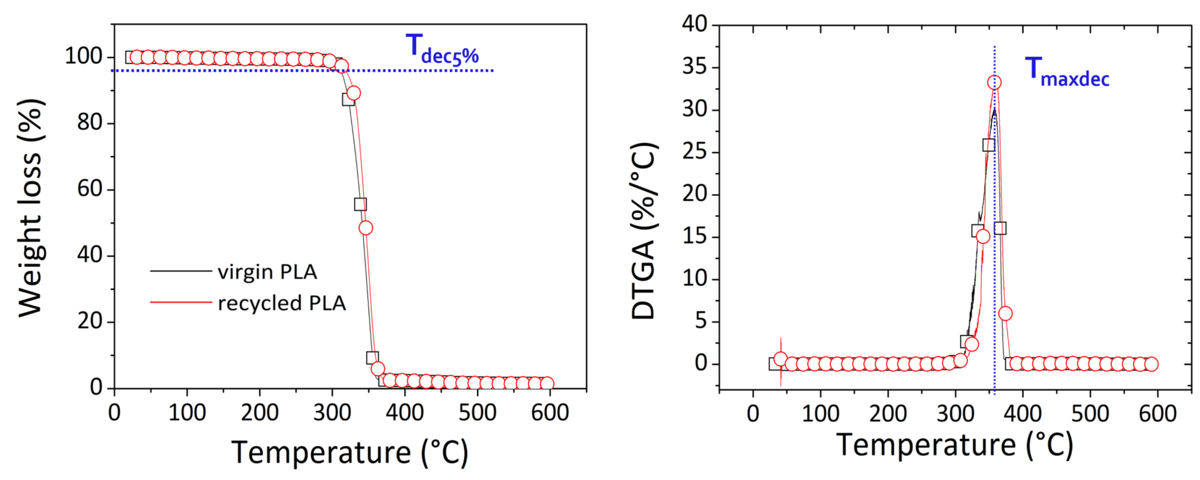
A small reduction of the intensity in correspondence of typical absorption bands of PLA polymer in the case of recycled material compared to virgin one could possible be due to thermal degradation.

Rotational Rheology



The stabilization of the complex viscosity over time at temperature of 210°C for over than 900 s was obtained through sample drying.

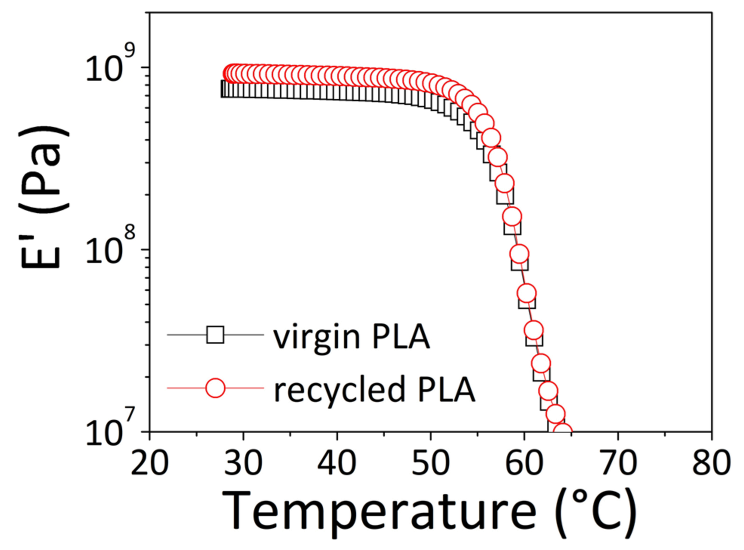
Thermogravimetric analysis



	Tdec5%	Tmax dec	Residue
Virgin PLA	315°C	357°C	1.5%
Recycled PLA	319°C	360°C	1.4%

One step of PLA degradation was shown in both samples, attributed to the loss of ester group that started at about 310 °C

Dinamic Mechanical Analysis



The two curves corresponding to virgin (black square points) and recycled samples (red circle points) roughly overlapped with almost comparable values across the entire temperature range

CONCLUSION *No substantial differences could be highlighted in terms of thermal degradation, rheological behavior and thermo-mechanical properties. In fact, for both materials, the initial degradation temperature was measured around 310°C , the stability of complex viscosity over time was achieved through sample pre-drying, and the storage modulus of 3D printed parts made from recycled matrices was very comparable with that of the virgin ones.*

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