Sustainability driven additive manufacturing: Repetitive mechanical recycling response evaluation to valorize Polycarbonate scrap

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Abstract

Polycarbonate (PC) is a widely used thermoplastic. Therefore, the amount of waste produced is notable. The exploitation of such waste is of great interest nowadays in the industry and academic society, due to its contribution to environmental pollution and other negative consequences. Herein, the possibility of using PC scrap as raw material in 3D printing (material extrusion - MEX) is reported. The efficacy of the PC polymer after six thermomechanical courses was evaluated. The effect on the rheology, the

mechanical performance, and thermal behavior is reported. The morphological characteristics were also assessed through scanning electron microscopy, while two quality metrics, i.e., geometrical accuracy and 3D printing structure porosity of the parts were investigated through micro-computed tomography. The findings were correlated to report the impact of the thermomechanical processing on the PC polymer properties. A 9% tensile strength increase compared to the virgin polymer is reported (third round), while the flexural strength was improved by 14% (second round). Then the strength declined. It was lower than the virgin material on the sixth thermomechanical repetition. The findings showed that the life of PC can be extended through thermomechanical recycling for 3D printing applications.

S1. Filament quality control and testing

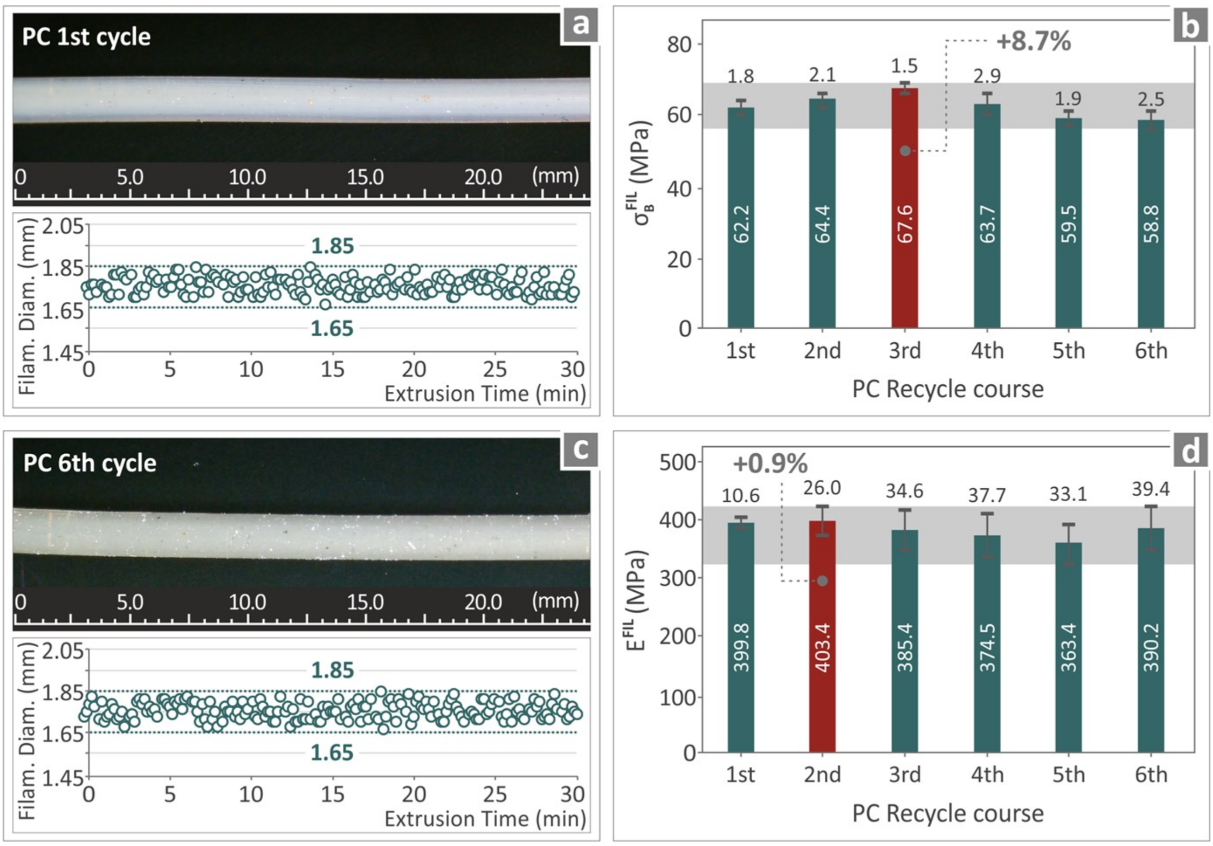

Figure S1. Filament quality control and testing.

S1. Raman Spectra

A LabRAM HR Raman Spectrometer (HORIBA Scientific, Kyoto, Japan) was used to acquire Raman spectra. A 532 nm solid-state laser module was selected for excitation with a maximum output power of 90 mW. The Raman spectral resolution was approximately 2 cm^{-1} achieved using a grating with 600 grooves. An Olympus objective lens (LMPlanFL N) with a numerical aperture of 0.5 delivered light onto the sample while also collecting the Raman signals. The 50× magnification objective lens operated at a 10.6 mm working distance. A Neutral Density filter with 10% transmittance limited the laser power, which was measured to be 4 mW for the sample. The measurement volume was measured to be 1.7 µm laterally and 2 µm axially. Raman spectra were collected between 40 and 2000 cm^{-1}, which was achieved in three optical windows. Each measurement point had an exposure time of 3 s, with five accumulations. The irradiated areas were then visually inspected to ensure that no discoloration or degradation was observed owing to laser irradiation.

Raw Raman data were processed using LabSpec software (HORIBA, Kyoto, Japan). Each spectrum acquired was processed using the same methodology: a) data were cropped in the spectral range between 250 and 2000 cm^{-1}; b) cosmic rays were removed; c) signal denoise with 5 points kernel; d) background removal using a 6th-grade polynomial; e) spectra were normalized by the maximum peak intensity. To highlight these differences, the spectrum from the first recycle sample was subtracted from all recycling cycle samples.