Influence of lignin, SCG and Ox-SCG on FDM 3D-printability and electronic applications of PLA/MWCNT composites

Lage-Rivera, Silvia; Ares-Pernas, Ana; Dopico-García, M. Sonia; Costa, Carlos; Macedo Silva, Nelson; Lanceros-Méndez, Senentxu; Abad, María-José

Universidade da Coruña, Campus de Industrial de Ferrol, CITENI-Grupo de Polímeros, Campus de Ferrol 15403-Ferrol, Spain

Introduction

The rapid development of additive manufacturing (AM) technologies requires advanced functional materials tailored for specific applications, including those with electrical properties. At the same time, the transition toward sustainable alternatives emphasizes the use of bio-based polymers and composites. In this work, electrically conductive composites suitable for FDM 3D printing were developed using a PLA matrix and multi-walled carbon nanotubes (MWCNT). Additional bio-based fillers such as lignin, spent coffee grounds (SCG), and oil-extracted SCG (Ox-SCG) were incorporated to modify physical properties.

Experimental


PLA

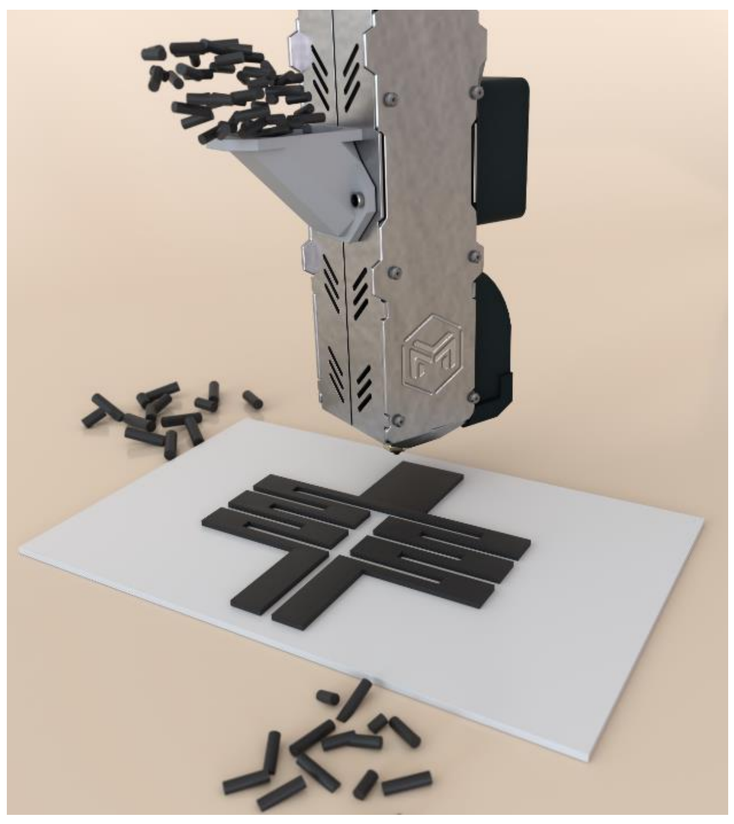

MWCNT


Lignin

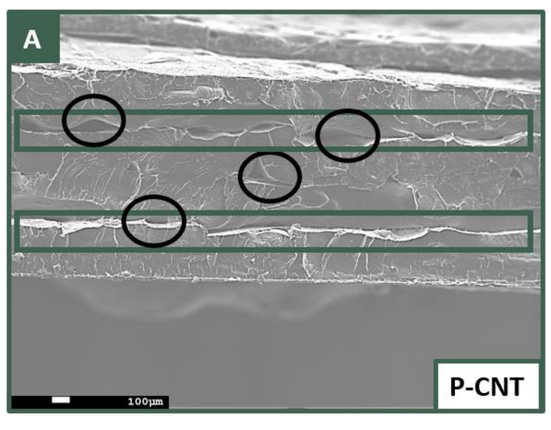

SCG


Ox-SCG

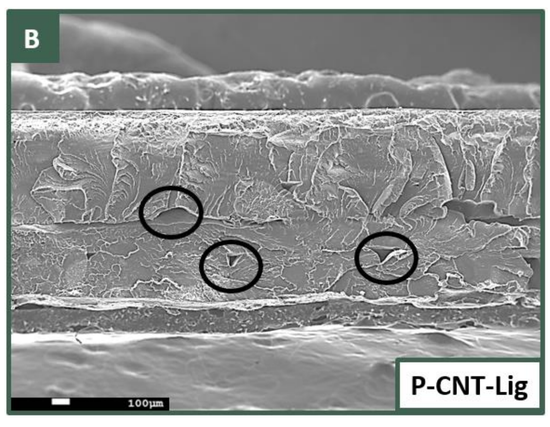
- Obtaining method: combination solvent-casting and melt mixing (DCM/acetone 4:1). Electrical threshold PLA/MWCNT 5 wt.%
- PLA/MWCNT/bio-additive (lignin, SCG, Ox-SCG) (92/5/3)
- Formulations (200ºC): P-CNT, P-CNT-Lig (210ºC), P-CNT-SCG, P-CNT-Ox
- Measurement and comparison of: micro-structure (SEM), viscoelasticity, electrical conductivity
- The best formulation was selected for a proof of concept accelerometer



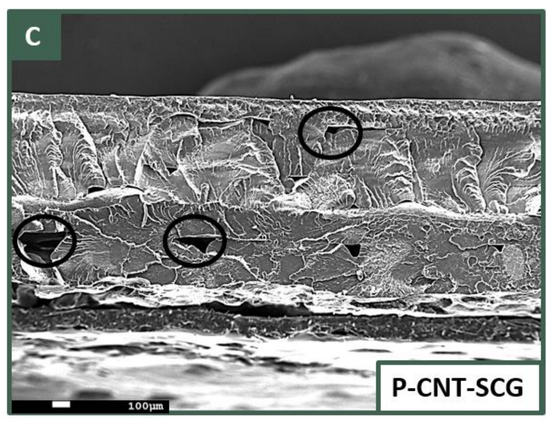
Results

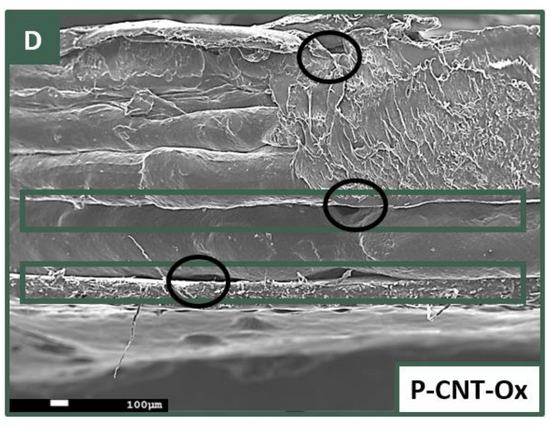


Bad inter-layer adhesion
Voids between filaments

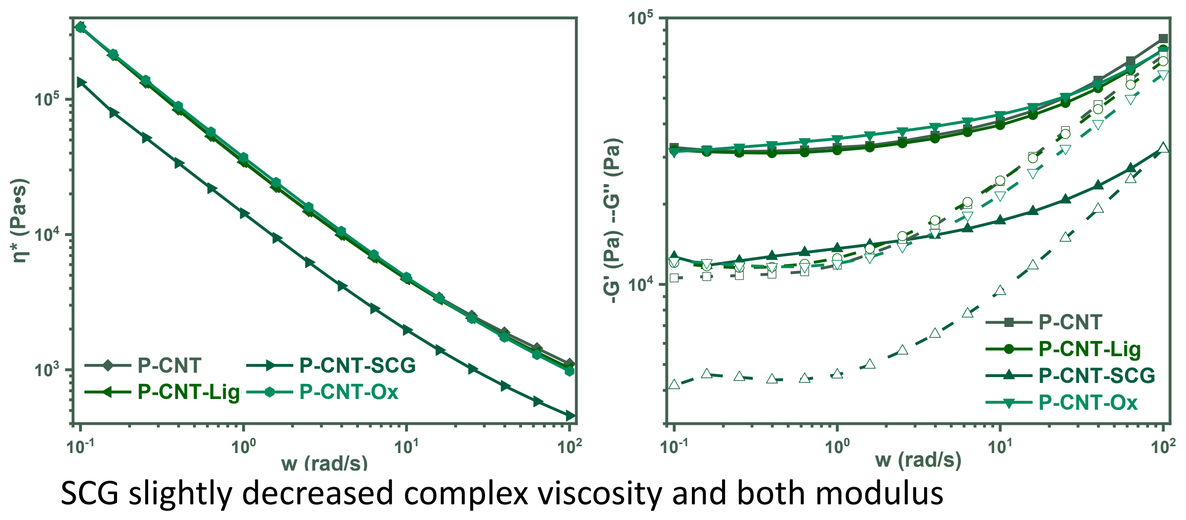


Lignin and SCG enhanced inter-layer adhesion
Voids still visible

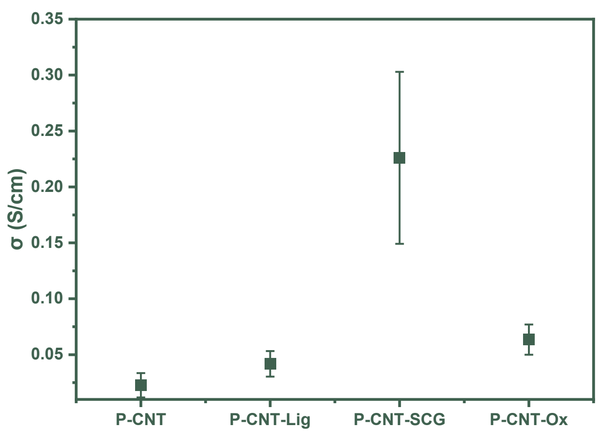


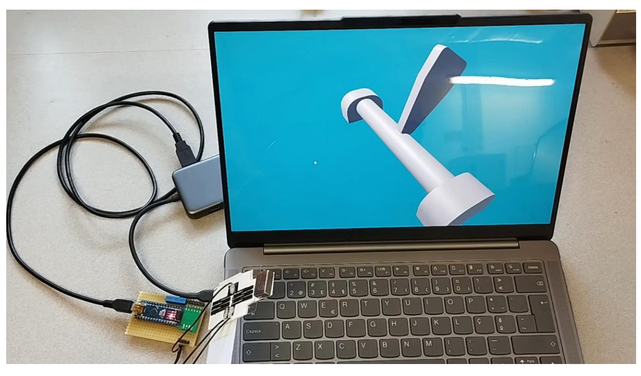


Bad inter-layer adhesion
Voids between filaments

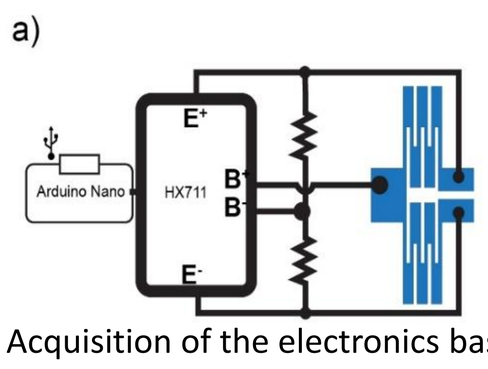


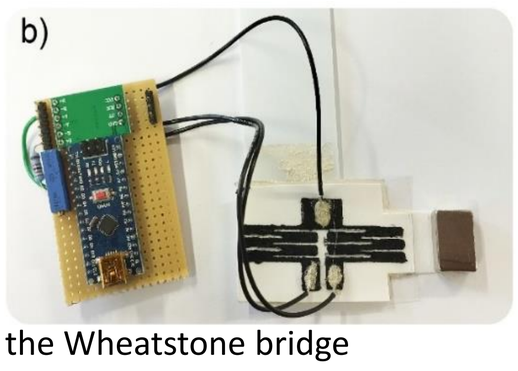
SCG slightly decreased complex viscosity and both modulus





P-CNT-SCG selected material for 3D-printing sensors





Acquisition of the electronics based on the Wheatstone bridge

Rotation counterclockwise, idle state, rotation clockwise

Conclusions

- PLA/MWCNT/bio-additive (lignin, SCG, Ox-SCG) by solvent-casting/melt mixing for material extrusion 3D printing were obtained and successfully tested
- SCG enhanced PLA/MWCNT electrical conductivity (from $(0.2\pm0.1)\cdot10^{-1}$ to $(2.6\pm1.3)\cdot10^{-1}$ S/cm and interlayer adhesion in printed samples
- Since no significant differences in viscoelastic properties were made, electrical conductivity was the design parameter
- With the previous results, sensors were 3D-printed using PLA-CNT-SCG

References

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