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Tensile electromechanical properties of carbon nanotube/poly (lactic acid) – polyhydroxyalkanoate filaments and additive manufactured coupons

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INTRODUCTION & AIM

Recent advances in additive manufacturing have enabled the fabrication of electrically conductive components via fused deposition modeling (FDM). A common approach for this is by incorporating carbon nanotubes (CNTs) as fillers for polymer matrices [1], as polylactic acid (PLA) and its blend with polyhydroxyalkanoates (PLA-PHA). These developments have expanded the functionality of printed materials, allowing the production of actuators and sensors based on piezoresistive mechanism [2]. Nevertheless, the literature on the electrical and piezoresistive behavior of nanocomposite filaments is very limited. This study therefore investigates the mechanical, electrical, and piezoresistive properties of CNT-based conductive filaments designed for FDM processing.

METHODS

CNT – polymer blending

Filament extrusion

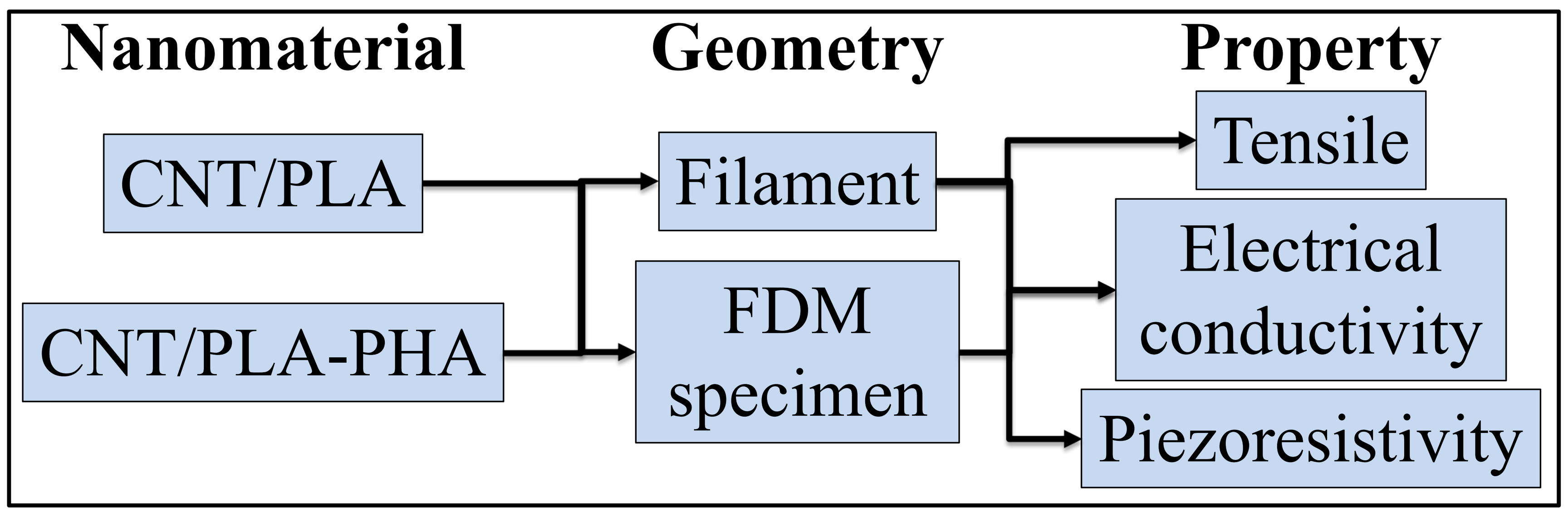

Fig 1. Filament fabrication and experimental framework.

RESULTS

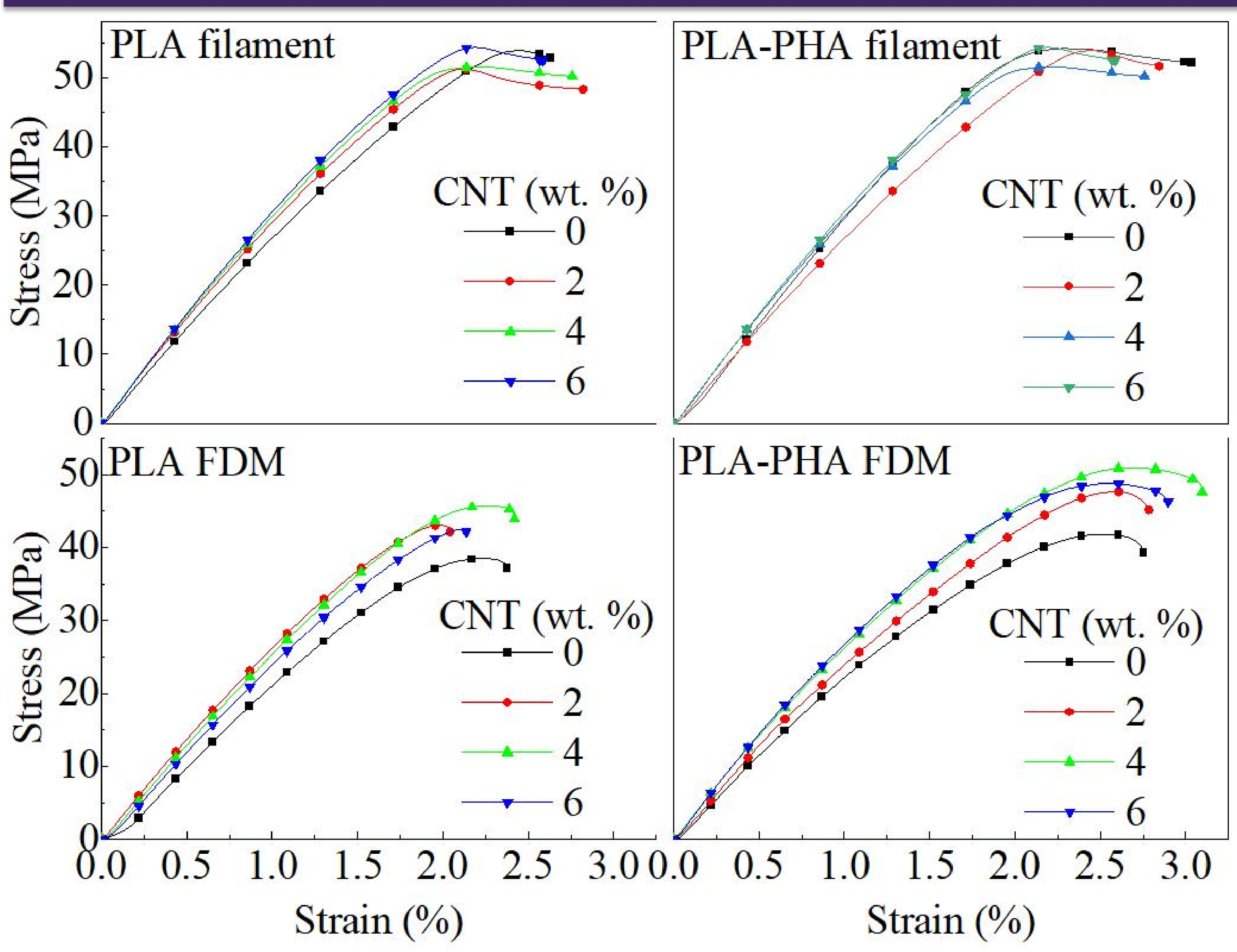

Fig 2. Response to axial loading of polymer and nanocomposite filaments and FDM specimens.

A reduction in mechanical properties from filaments to FDM-manufactured parts, highlighting the inherent anisotropy and process-induced weaknesses.

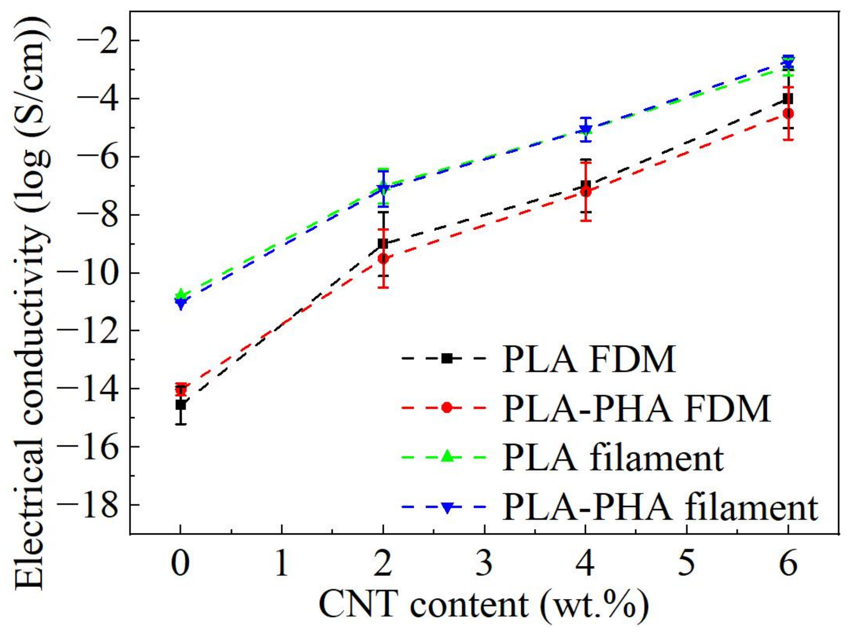

Fig 3. Electrical conductivity of polymer and nanocomposite filaments and FDM specimens.

Conductivity values in the FDM sheets are lower than the filaments due to printing-induced porosity and reduced connectivity. The gauge factor (GF) values are strongly depended on geometry, FDM parameters, and CNT network morphology, particularly the presence of agglomerates in the amorphous regions of the matrix.

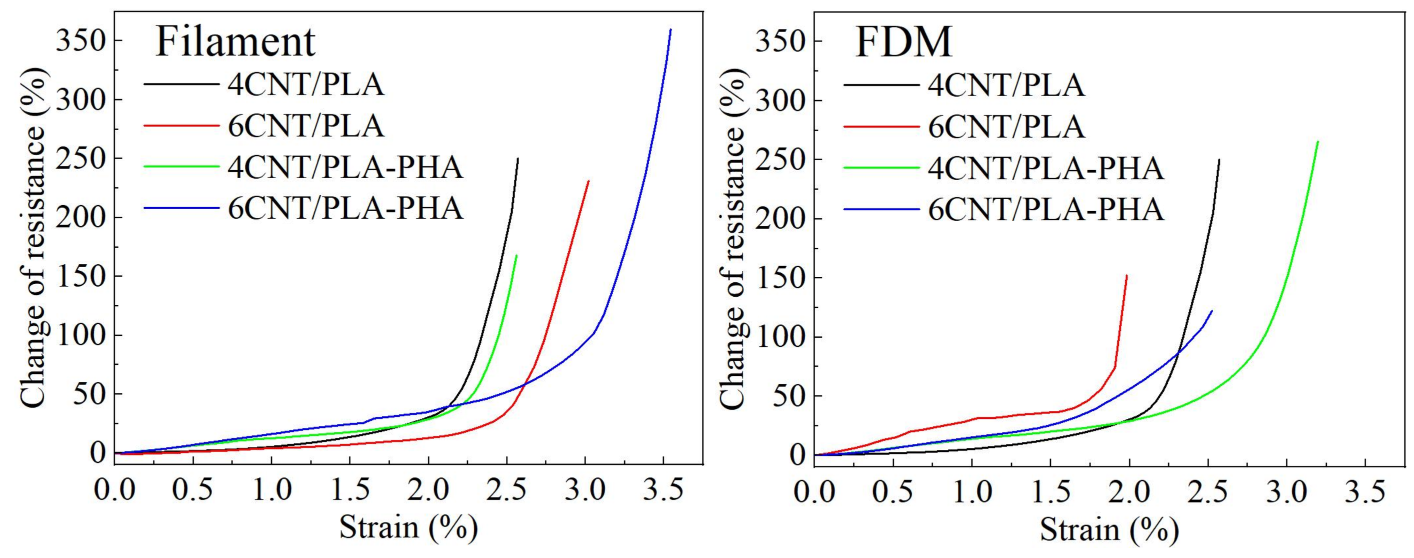

Fig 4. Electromechanical response of nanocomposite filaments and FDM specimens.

Table 1. GF of polymer and nanocomposite filaments and FDM specimens.

Composite	GF (0.2 % < ε < 1.2 %)	
	Filament	FDM
4CNT/PLA	7.41 ± 2.14	3.92 ± 0.97
6CNT/PLA	1.78 ± 0.55	26.4 ± 5.46
4CNT/PLA-PHA	9.91 ± 3.06	14.5 ± 2.96
6CNT/PLA-PHA	8.67 ± 2.74	17.0 ± 3.5

CONCLUSIONS

The highest tensile properties were obtained for PLA-PHA nanocomposites containing 4 wt.% or 6 wt.% CNTs. A general increase in mechanical properties was observed with higher CNT loadings; however, at the highest concentrations some formulations showed a slight decrease, attributed to non-uniform CNT dispersion and restricted polymer chain mobility. Electrical conductivities ranged from 10^{-4} to 10^{-2} S/cm in extruded filaments and from 10^{-8} to 10^{-4} S/cm in FDM-printed sheets (2–6 wt.% CNT), due to a structural effect of the architecture of the FDM sheets. In PLA nanocomposites, the gage factor (GF) depends strongly on the CNT content, with FDM sheets of 6 wt.% CNT being the most sensitive (GF ~26). In contrast, PLA-PHA composites showed a systematic increase in the GF after printing, consistent with the higher matrix flexibility which facilitates deformation of the CNT network.

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