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Electro-thermal characterization of 3D printed CNT-based samples for active de-icing applications

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Introduction

The advantageous mechanical, thermal, and electrical properties of carbon nanotubes (CNTs) have increased the interest for the development of CNT-based nanocomposites as materials for the 3D printing of functional elements. Such composites have demonstrated potential for use in electronic and sensing applications due to their unique electrical properties induced by the inherent anisotropy and charge transport dependent by the arrangement of percolation networks within multiscale formulations [1]. Magnitude and character of electrical resistivity of such composites is strongly influenced by both external and residual mechanical stresses applied to the specimens and by the thermal loads [2] [3] then, a deeper understanding of the response of electrical resistance to thermo-mechanical stimuli needs to be gained to assess the applicability of printed polymeric heaters.

Purpose of this work

In the aim to enable the fabrication of Joule-Heaters to be employed in anti-icing surfaces, polymer matrix nanocomposites containing CNTs have been experimented by processing the Filoalfa wire (supplied from Alfaohm) by Fused Filament Fabrication (FFF). Their electrical properties have been studied in a climate chamber under cyclic thermal loading. The purpose of this work is to characterize the resistance vs. temperature (R-vs.-T) behavior and the stability of 3D-printed heaters under controlled environmental conditions.

Materials and methods

Starting material

FILOALFA®

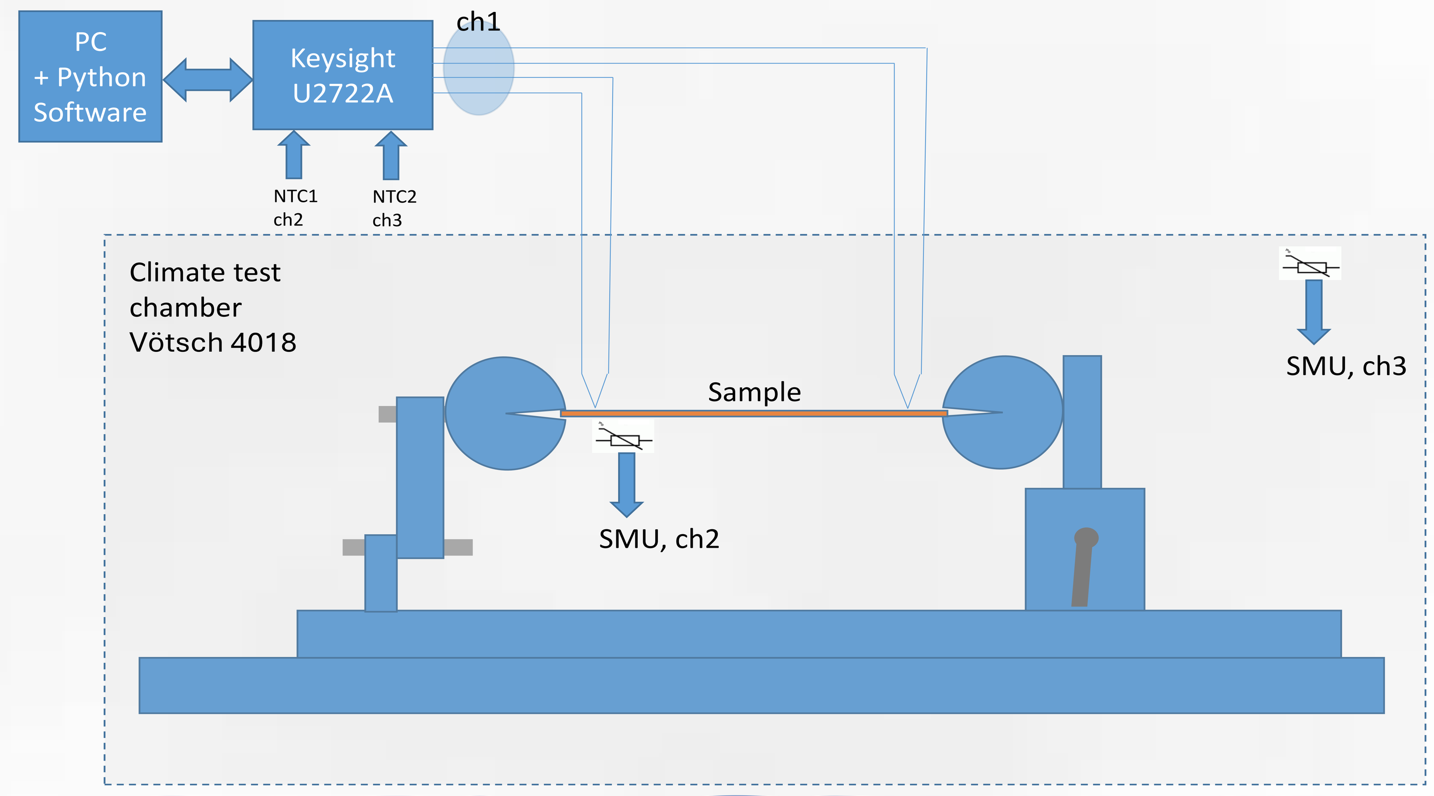
Resistivity:

- Parallel to print dir.: 15Ω*cm
- Perpendicular to print dir.: 20Ω*cm

Sample preparation:

FFF by Prusa i3 MK3S

Test Setup



3D-Printed Filoalfa conductor stacked on a printed TPU surface

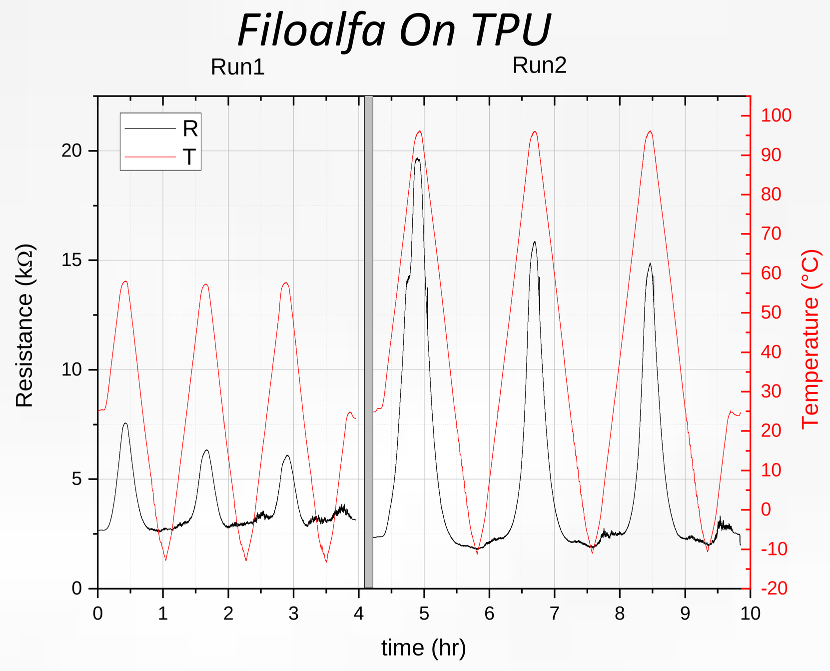
Resistivity (top surface): 14.2 +/-5.8 Ω*cm

Results.

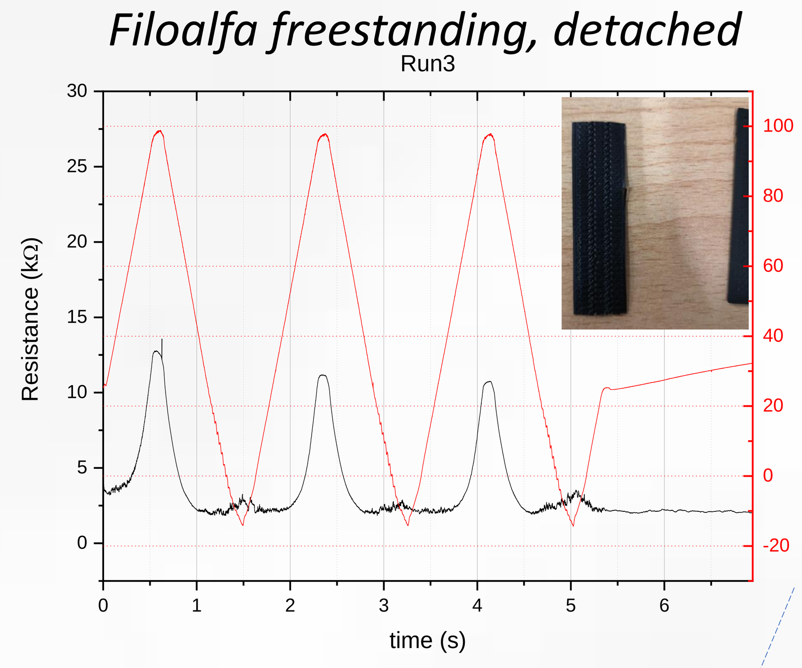
The temperature coefficient of the electrical resistance has been estimated, from which the temperature coefficient of resistivity (TCR) has been derived, which, in turn, can be used to detect structural modifications, phase transitions, as well as geometric deformations of electrically conductive samples [4]. Thermal cycling has revealed instabilities in the low-temperature regime.

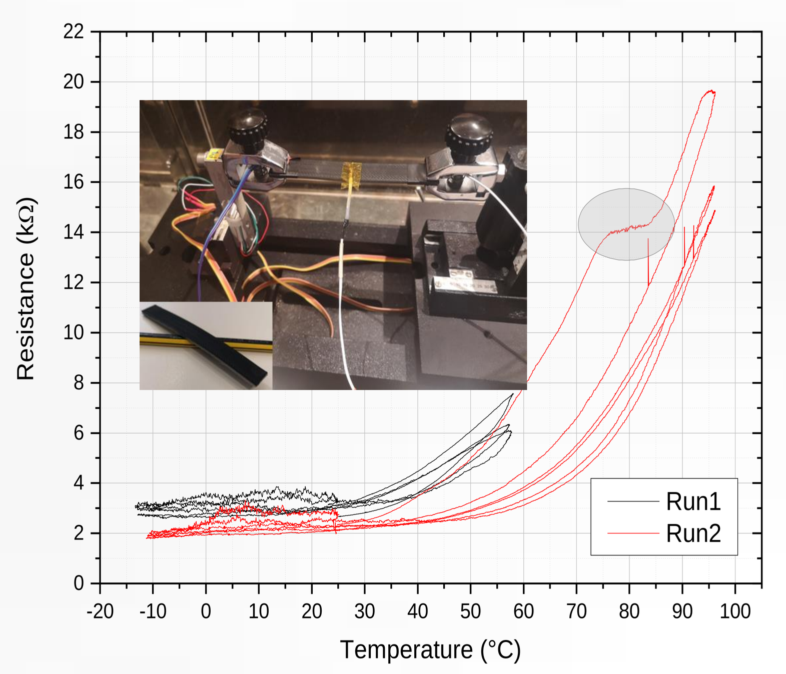
Effects of the substrate and first heating

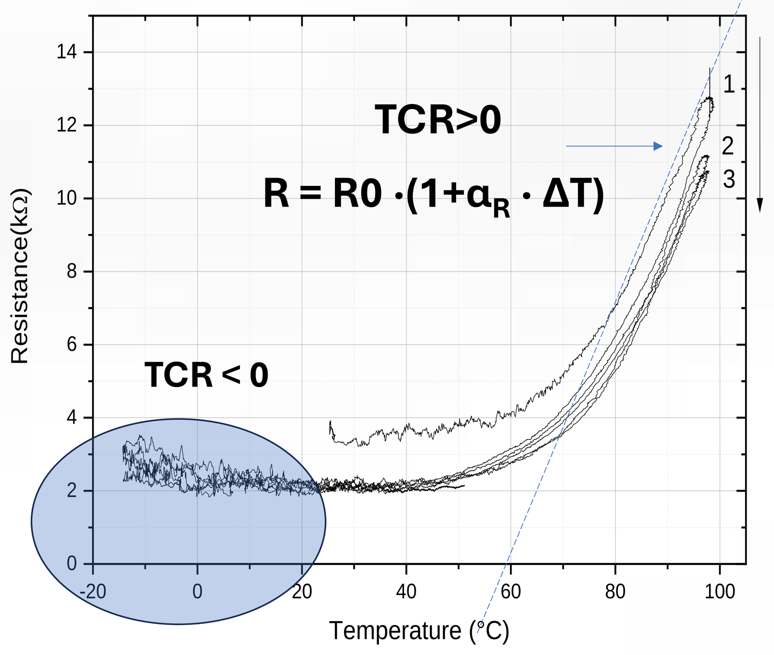
Filoalfa On TPU



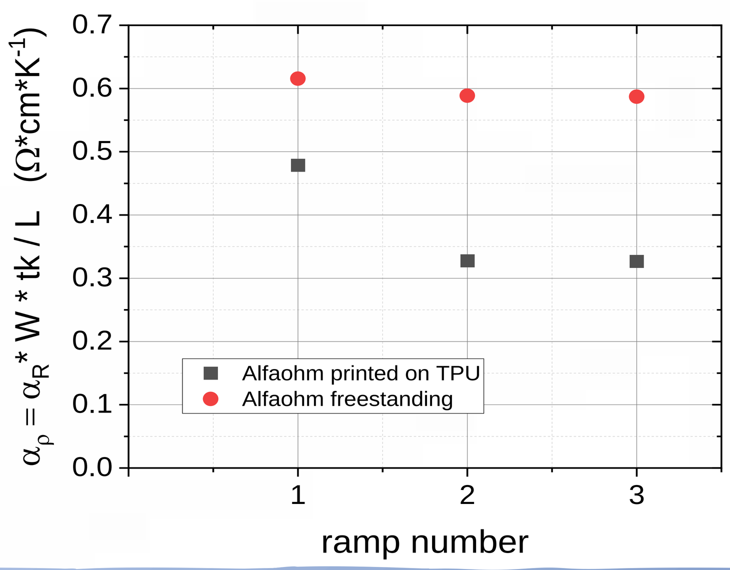
Filoalfa freestanding, detached



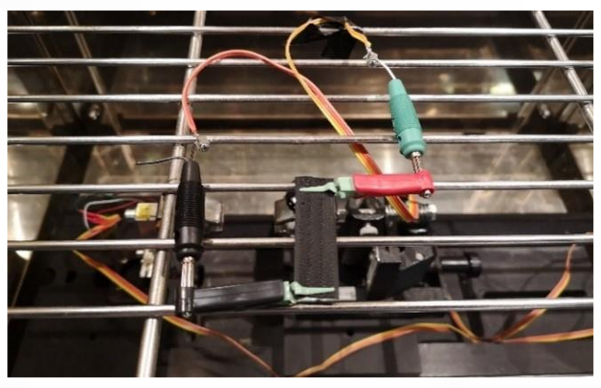


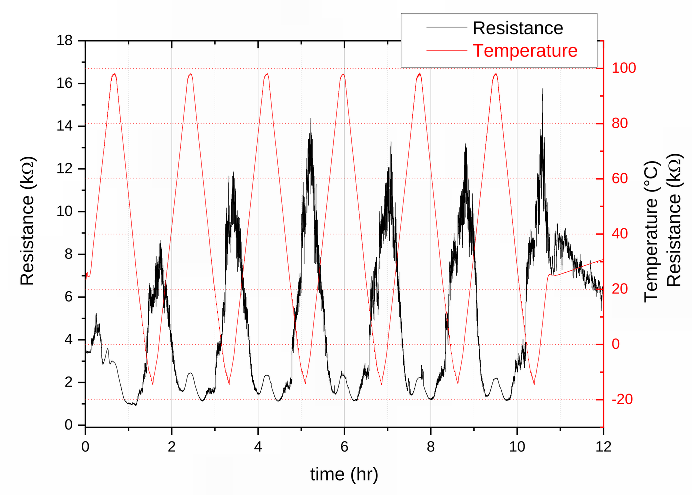


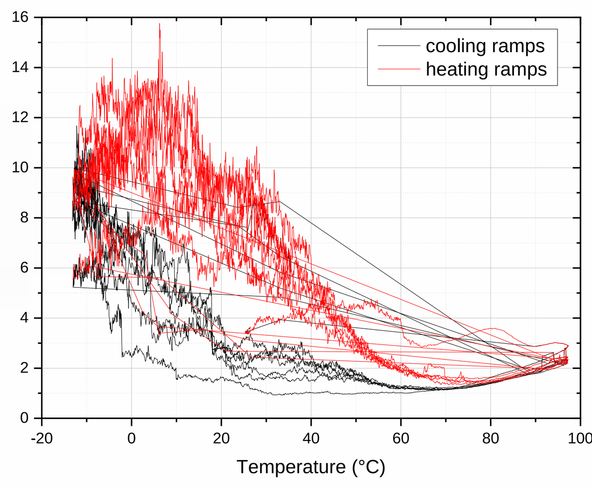
$\alpha_\rho = \alpha_R \frac{W*tk}{L}$ In 60°C-100°C range	Filoalfa (tk=35μm) on TPU	Filoalfa (tk=35μm) free-standing
	α_ρ (Ω/K)	α_ρ (Ω/K)
ramp 1	0.479	0.616
ramp 2	0.328	0.589
ramp 3	0.327	0.587

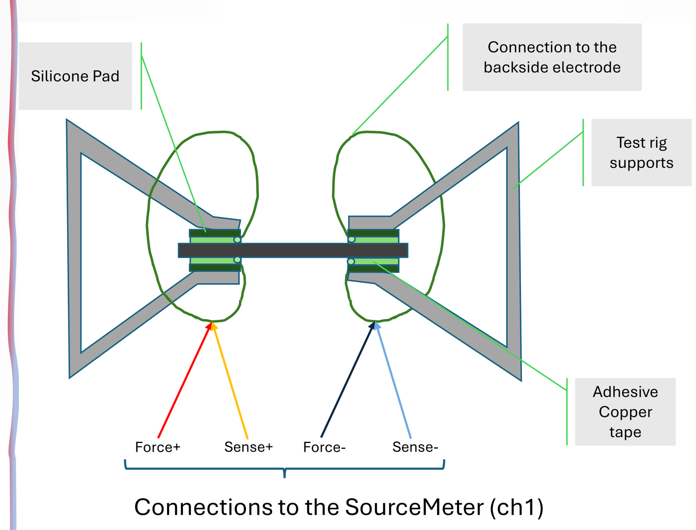


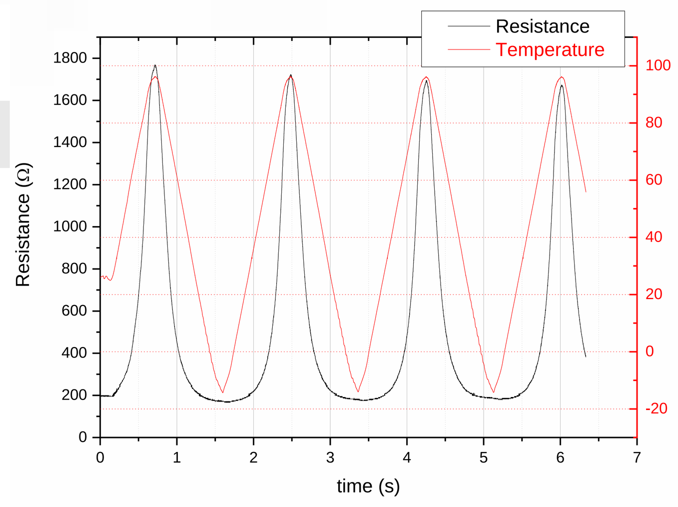
Effects of electrical connections (freestanding samples)

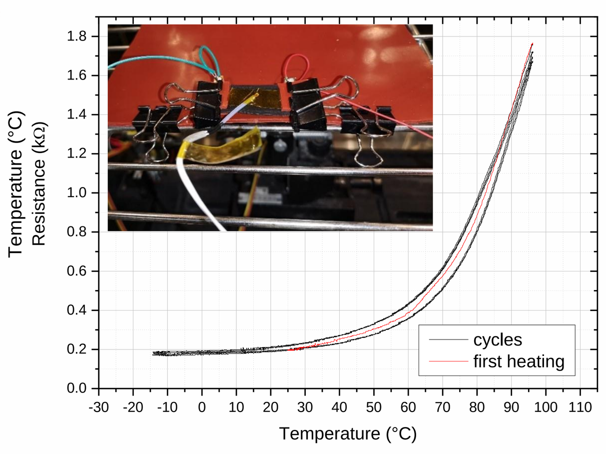




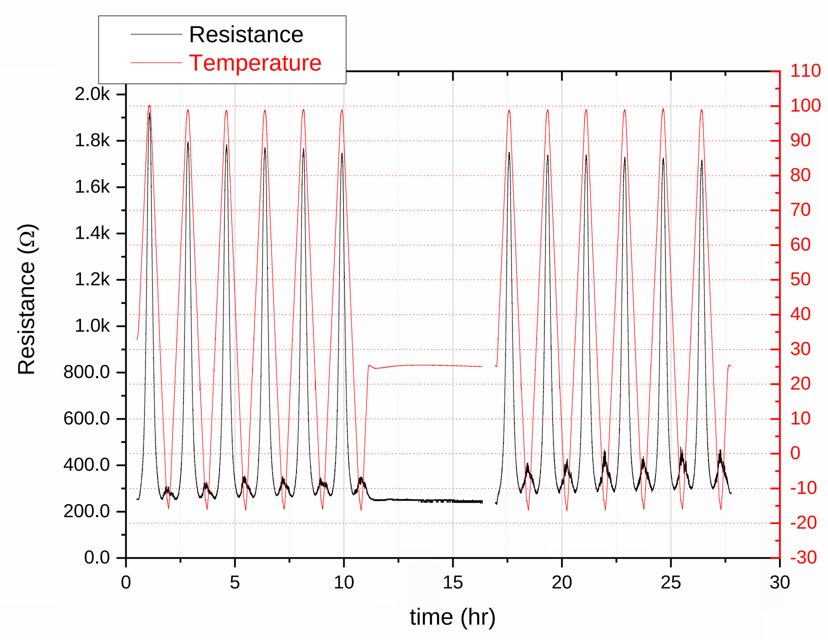


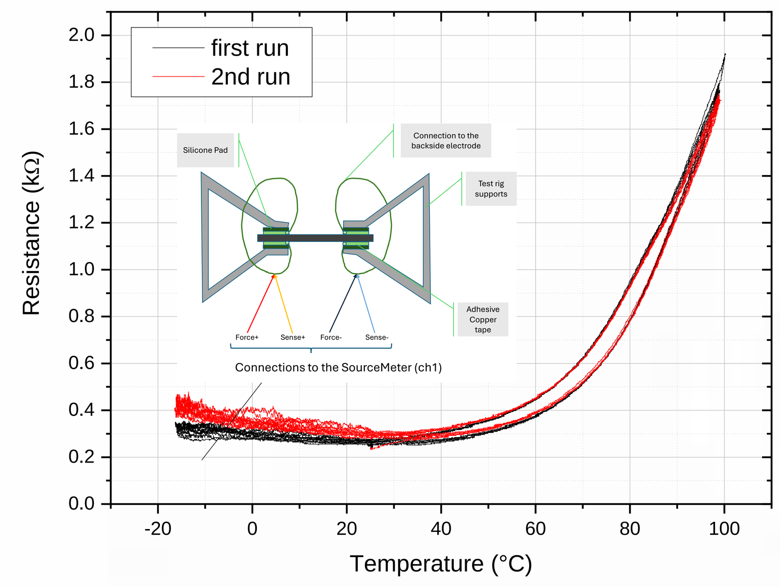






Thermal loading effects (freestanding samples)





Analysis and conclusions

- strong dependence of the electrical resistance on the temperature
- positive temperature coefficients above ambient temperature and stabilization drifts (R decreases)
- mayor drifts appear in 1st heating during first heating above 60°C (in the glass transition region of PLA).
- TCR depends upon the presence of the underlying substrate
- Mechanical stresses e.g., due to contact clips can induce strong modification in R-T curves in the low-temperature trait
- Thermal cycling decreases and stabilizes the TCR
- after several thermal stress cycles, negative temperature coefficient traits appear.

Credits

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