INDUSTRIAL GRAPHENE STRIPS AS TEMPERATURE SENSORS

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In recent years, graphene-based materials have attracted significant interest due to their outstanding mechanical, thermal, and electrical properties, enabling a wide range of applications from electronics to environmental monitoring. With many proof-of-concept devices already demonstrated, current research has shifted toward industrial scalability. Industrial-grade graphene, particularly in the form of graphene nanoplatelets (GNPs), shown in Figure 1, offers a cost-effective alternative to high-quality monolayer graphene, balancing performance and production feasibility.

(a) **(b)**

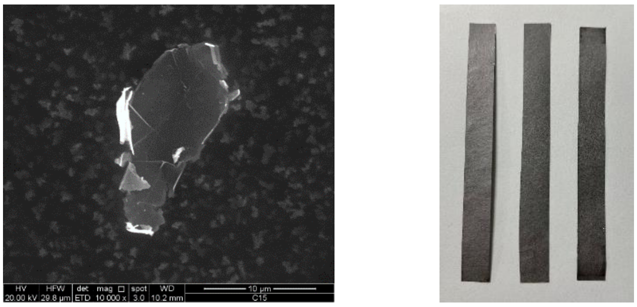

Figure 1. Scanning Electron Microscope characterization of a single graphene nanoplatelet (**a**), macroscopic strips (**b**).

In our work it's explored the use of commercially available GNP-based composite coatings—originally designed for thermal management or electromagnetic shielding—as low-cost, distributed temperature sensors, without requiring changes to the material or its manufacturing process. GNPs can be produced efficiently through scalable methods like wet-jet milling or liquid exfoliation.

Previous studies have shown that graphene-based materials can be used to build highly sensitive and fast-response temperature sensors, though many are not commercially viable due to the high cost and complexity of fabrication. Nonetheless, the multifunctional nature of graphene allows for integration into broader sensing systems.

Building on this, our work [1] investigates whether an industrial GNP-polymer composite coating in the shape of a strip (Fig. 1), developed by Nanesa srl (Italy), can be repurposed as a temperature sensor. Rather than aiming for peak performance, the focus is on demonstrating feasibility and functionality. The sensor's working principle is based on temperature-dependent electrical resistance.

To verify this, electrical measurements were performed on the GNP-strip. First, a V-I characterization was performed in order to verify the linearity between the applied current and the voltage drops and to detect any possible non-linear issues during subsequent thermal-electric tests. Subsequently, the resistance of the GNP strips was measured in a climatic chamber, varying the temperature (range from -40°C to 60°C) and humidity (range from 10% to 90%), highlighting an NTC behavior, typical of the semiconductors (Figure 2).

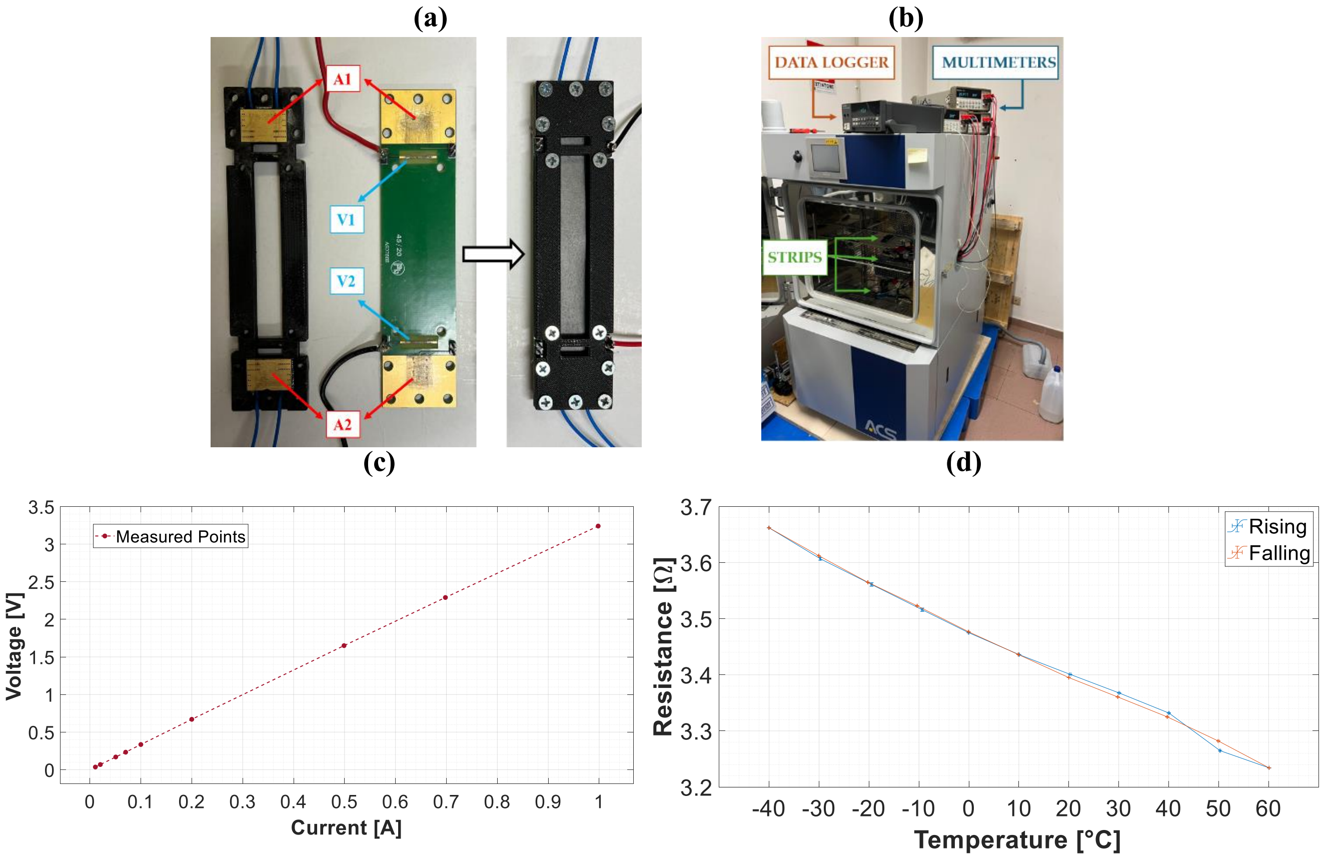

Figure 2. Test fixture with references for amperometric (A1, A2) and voltmetric (V1, V2) contacts (**a**), climatic chamber (**b**), V-I characteristics (**c**), R-T characteristics (**d**).

Furthermore, a model was built to justify the behavior of the electrical resistance of these GNP-strip at varying temperature and therefore their aptitude for temperature sensing as an additional function, and it was successfully validated by the experimental tests (Figure 3).

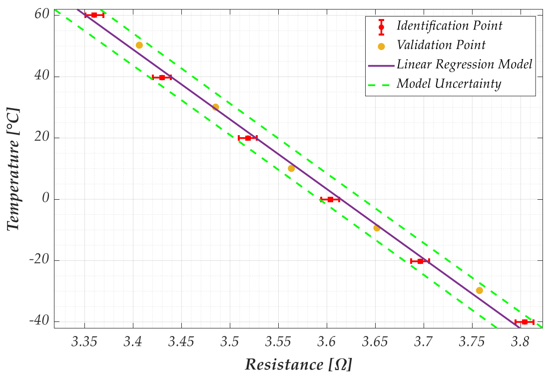

Figure 3. Plots of the temperature versus the electrical resistance according to the linear model: red dots for the values adopted to identify the model, yellow dots for the values used to validate it. The red bars for the uncertainty on the measurements, and the dashed green lines for the estimated model uncertainty.

ACKNOWLEDGEMENT

This work was supported by the "Ecosistema dell'innovazione – Rome Technopole" financed by EU in NextGenerationEU plan through MUR Decree n.1051 23.06.2022 - CUP H33C22000420001.

REFERENCES

[1] Siconolfi, F.; Cavaliere, G.; Sibilia, S.; Cristiano, F.; Giovinco, G.; Maffucci, A., Industrial-grade Graphene Films as Distributed Temperature Sensors, *MDPI Sensors* **2025** (under review).