ECSA-12 2025 Conference
The 12th International Electronic Conference on Sensors and Applications
08–10 December 2025 | Online
MDPI

Development of Paper-Based Thermal Devices Using Graphene and Carbon Black Composite Inks for Flexible Printed Electronics

Dimitris Barmpakos[1], Apostolos Apostolakis[1], Vassiliki Belessi[2,], Vasilios Georgakilas[3], Grigoris Kaltsas[1]
[1] microSENSES Laboratory, Department of Electrical and Electronics Engineering, University of West Attica, Athens, Greece
[2] Department of Graphic Design and Visual Communication, University of West Attica, Athens, Greece
[3] Department of Materials Science, University of Patras, Rio, Greece

INTRODUCTION & AIM

- Growing demand for sustainable electronics leads to paper electronics
- Eco-aware material development for conductive inks
- Hybrid, cost-effective material design[1]

In this study, we developed paper-based sensors and heaters using two custom-formulated water-based conductive inks. The facile coating technique allows for rapid, on-demand fabrication of thermally active printed devices on paper, with comparable performance to traditional similar devices.

METHOD

- Two water-based conductive inks were formulated: (1) reduced graphene oxide (rGO) and (2) a composite of carbon black and reduced graphene oxide ($CB_{70}rGO_{30}$).
- Devices were printed on glossy paper using rod coating, with single-pass (1P) and double-pass (2P) coatings to investigate film thickness impact on electrical performance (Fig. 1a-e)
- Electrical evaluation was performed (four-point I-V), while temperature sensing and heater performance were assessed through TCR determination and power efficiency respectively.

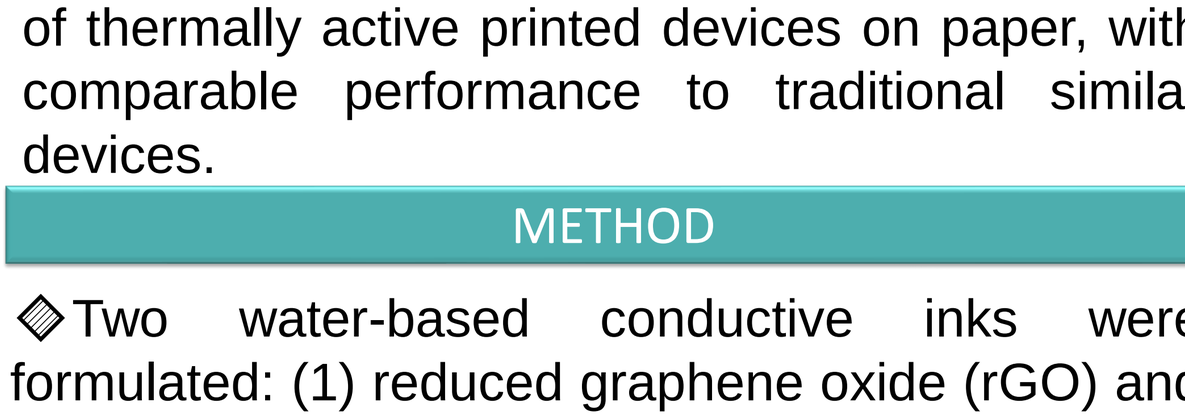

Figure 1. Printed device on glossy paper (a) optical microscopy surface of the samples (b-e).

- Optical microscopy and white light interferometry was employed to characterize surface morphology

RESULTS & DISCUSSION

- TCR values: $–7.37×10^{–3}$ °C$^{–1}$ for rGO-based sensors and $–3.94×10^{–3}$ °C$^{–1}$ for CB/rGO composites

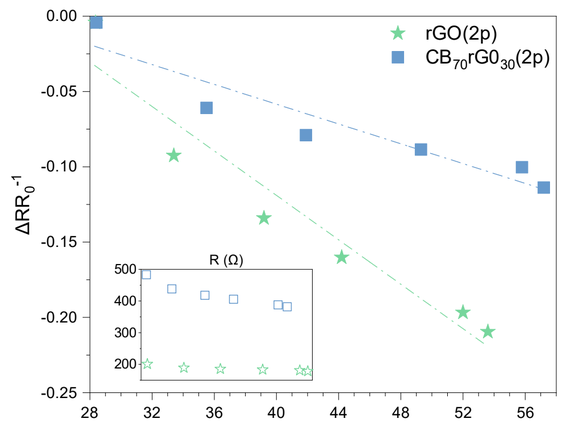

Figure 2. Temperature – normalized resistance relationship

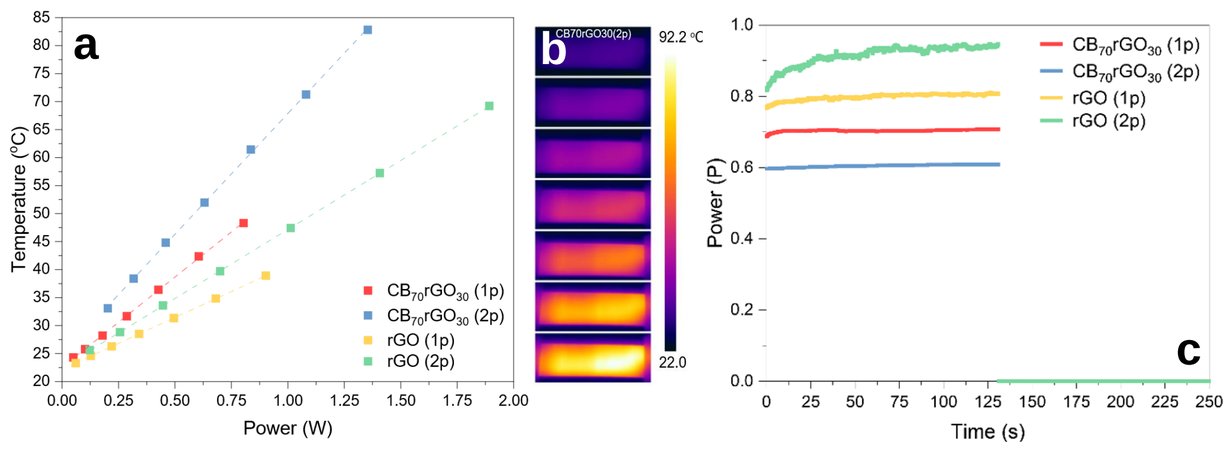

Figure 3. Power – temperature (a), IR profile for one sample (b) and power required to reach 55 °C for each sample

- $CB_{70}rGO_{30}$(2p) sample demonstrates superior electrical-to-thermal power conversion owing to carbon-black particles (improved thermal conductivity, uniform thermal field, Fig. 3a,b).
- The same sample reached 55 °C with 600 mW, validating its superior efficiency (Fig. 3c)

CONCLUSION

- rGO exhibited higher TCR while CB/rGO inks converted power to heat more efficiently
- Combining rGO and carbon-black inks for paper-based sensors and heaters, with paper's insulating nature assisting the printed structures for both efficient sensing and heating

FUTURE WORK / REFERENCES

Sensors (2022) 22:1173, doi:10.3390/s22031173