Optical Temperature Detection, Utilizing Screen-Printed Thermochromic Inks

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Printed electronics is a rapidly growing field, that has recently attracted great interest from both research and industry, as it offers the possibility of manufacturing cost-effective innovative devices on flexible substrates [1]. Thermochromic inks (TCs), belong to the category of chromogenics and exhibit reversible or irreversible alterations in colour, when exposed to temperature variations [2]. In this work, the thermal and optical behaviour of two TC screen-print samples, printed on PET (Polyethylene Terephthalate/PET, thickness 125μm, Goodfellow) and Polyimide (PI) (Kapton® HN Film, thickness 125μm, Goodfellow) substrates, is studied. The inks employed in this study, are the Thermochromic Screen Printing Ink Black 47°C by SFXC and the water based HPR-059 Carbon Black (Carbon content 10 wt%), serving as the heater for the temperature control of the TC element. The samples were fabricated via the semi-automatic screen-printing machine (Ever-bright, S-200HFC) and subsequently cured via the Heating & Dry Heat Sterilization Oven (NUVE FN400). The element's dimensions are 32x3mm and 17.5x13mm for carbon and TC, respectively. (Fig. 1a, Fig. 1b).

The main objective of this study is to establish a correlation between the thermal and optical fields of the TC samples. For this purpose, two distinct scenarios were applied; a wide temperature range (50 – 70 ^{o}C), and a narrow temperature range close to the critical temperature (40 – 52 ^{o}C). To conduct the analysis, controlled heating was applied through the carbon element of each sample, via the probe station. The correlation between the thermal and optical field was established through a High precision Thermal IR Camera - FLIR SC655 and a high-resolution camera, respectively. Thermal data processing was conducted via FLIR SC655 software, which correlates the temperature with the pixels in the selected area of interest in each TC sample. The ImageJ software was employed to extract the grayscale data from the images captured by a high-resolution camera, focusing on the same area of interest on each TC sample. In the resulting graphs, the temperature distribution across the selected width area of the Thermochromic (TC) element, derived from both the IR camera and the high-resolution camera, is presented as a function of distance.

In the thermal-optical correlation graphs of the 1st scenario, the amplitude between the two spikes is attributed to the transparency of the TC element, when exposed to temperatures significantly above its 47 °C critical temperature (Fig. 2). This feature, along with the transparent PET substrate, reveals everything that lies beyond the area of the underlying black carbon material. In the 2nd scenario, further heating of the TC element beyond 52 °C, causes its area of transparency to surpass that of the carbon material beneath it, similarly to the 1st scenario. In this scenario, all graphs exhibited a similar pattern (Fig. 3). This study facilitates the implementation of a surface's thermal mapping, allowing for the identification of the areas that are warmer or cooler than normal. A thorough discussion and analysis of the experimental results will be presented in the related paper.

References

[1] Cruz, S. M. F., Rocha, L. A., & Viana, J. C. (2018). Printing technologies on flexible substrates for printed electronics. In InTech eBooks. https://doi.org/10.5772/intechopen.76161

[2] Liu, R., He, L., Cao, M., Sun, Z., Zhu, R., & Li, Y. (2021). Flexible temperature sensors. *Frontiers in Chemistry, 9*. https://doi.org/10.3389/fchem.2021.539678

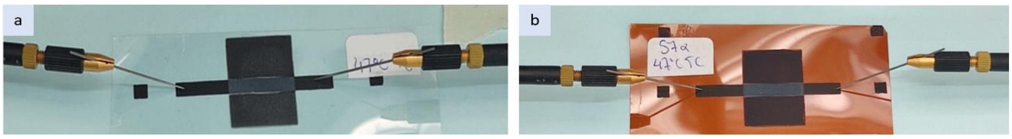

Figure 1: Internal Heating at 60 °C of the Black TC samples with 47 °C critical temperature on **a)** PET substrate, **b)** Polyimide substrate.

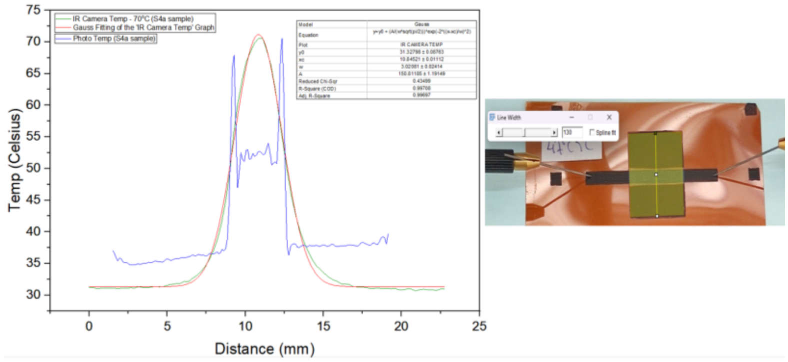

Figure 2: 1st Scenario: Thermal & Optical Field Correlation Graph of the TC sample on Kapton substrate with Gaussian Fittings, for 70 °C heater temperature.

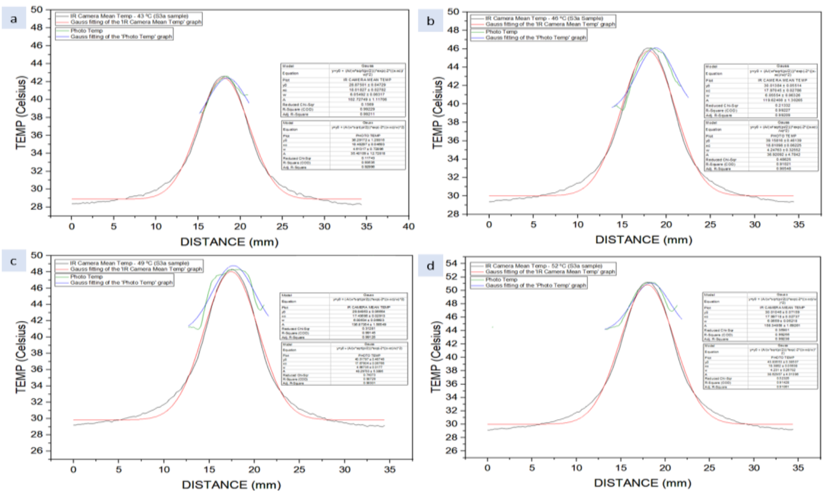

Figure 3: 2nd Scenario: Thermal & Optical Field Correlation Graph of the TC sample on PET substrate with Gaussian Fittings, for **a)** 43 °C, **b)** 46 °C, **c)** 49 °C, **d)** 52 °C heater temperatures.