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INVESTIGATION OF THE IMPACT OF CHEMICAL AGENTS AND SUBSTRATES ON THE STABILITY OF THERMOCHROMIC PRINTING INKS

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Introduction

Thermochromic inks have two primary applications: functional and promotional. In the functional application, thermochromic inks display the current temperature, while in the promotional application, a specific hidden message becomes visible or shelf presence is enhanced at the activation temperature.
Printed thermochromic inks can last for years while undergoing colour changes; however, excessive exposure to UV radiation will negatively impact the longevity of the printed ink. UV sensitivity is one of the main reasons why thermochromic inks are not used in advertising posters or the automotive industry.
Additionally, as with other inks, aggressive solvents and extremely high temperatures of 120°C or more negatively affect the durability of thermochromic inks.
A chemically stable print is one in which no significant change in the print occurs when exposed to certain chemical substances.
Chemical changes can manifest as changes in colour, fading, reduction in the mechanical properties of the ink and substrate, and other factors. The international standard ISO 2836:2021 in graphic technology specifies methods for evaluating the resistance of printed materials to liquids, solids, solvents, varnishes, and acids (ISO 2836, 2021).

Problem Description

This research aims to analyze the chemical stability of prints with thermochromic inks to determine which substances affect the thermochromic effect, which is a crucial factor when such inks are used as indicators on packaging. The goal is to identify which type of paper is preferable and, considering the different chemical compositions of dyes, to determine which are more chemically stable. It is expected that some substances used for chemical stability will have a lesser impact, while others will have a greater effect on the thermochromic effect. Additionally, it is hypothesized that UV inks might be more chemically stable.

Methods

The study selected two printing surfaces: synthetic and bulky paper. The selected papers differ in their chemical structure and absorbency.
The prints were made with two commercially available thermochromic inks, one intended for offset printing and the other for screen printing technique. An offset thermochromic printing ink based on leuco dyes with an activation temperature of 45°C (CTI45) was used. This ink changes colour from green to yellow above the activation temperature. The other ink used was a thermochromic screen printing ink based on leuco dyes with an activation temperature of 31°C (CTI31). This ink changes colour from purple to pink above the activation temperature.
The samples were exposed to four substances – water, alcohol, oil, and alkali. Each sample was exposed to these substances according to the procedure specified in the international ISO 2836 standard in graphic technology. These substances were chosen for testing chemical stability due to their frequent contact with packaging products in everyday life (ISO 2836, 2021).

Results

Spectral reflectance curves were measured at three different temperatures: 15°C, the activation temperature depending on the sample (31° or 45°C), and 55°C. Reflectance was measured on two printing substrates, synthetic and bulky paper, and on samples exposed to alkali, ethanol, water, and oil, compared to unexposed original samples. Based on the results, the spectral curves were obtained and are shown in Figures 1 and 2.

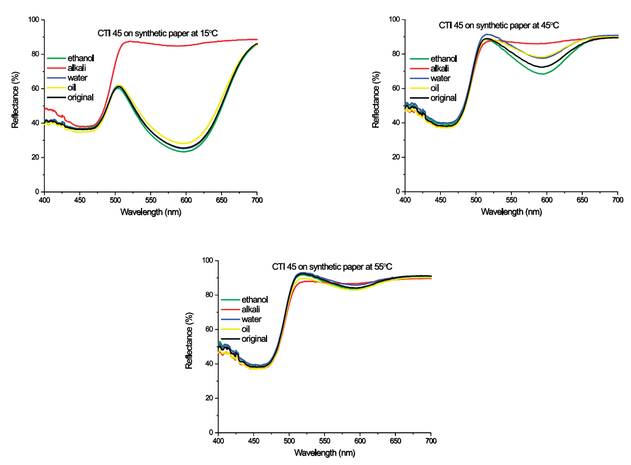

Figure 1. *Spectral reflectance curves of CTI45 measured at three different temperatures on synthetic paper*

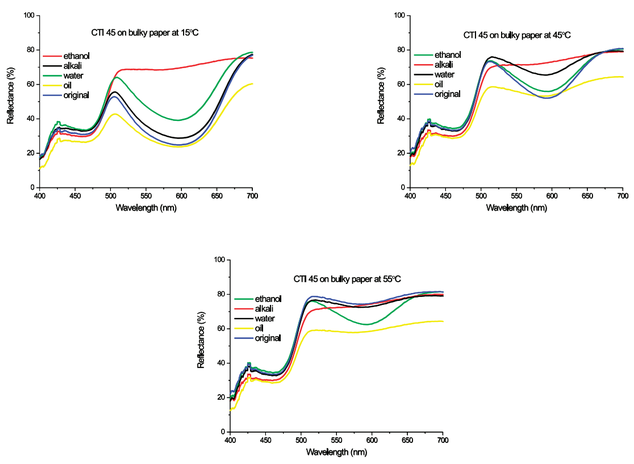

Figure 2. *Spectral reflectance curves of CTI 45 measured at three different temperatures on bulky paper*

The results suggest that the printing substrate affects the stability of the thermochromic ink. Samples printed with screen printing thermochromic ink show greater stability after exposure to certain chemicals than samples printed on bulky paper.

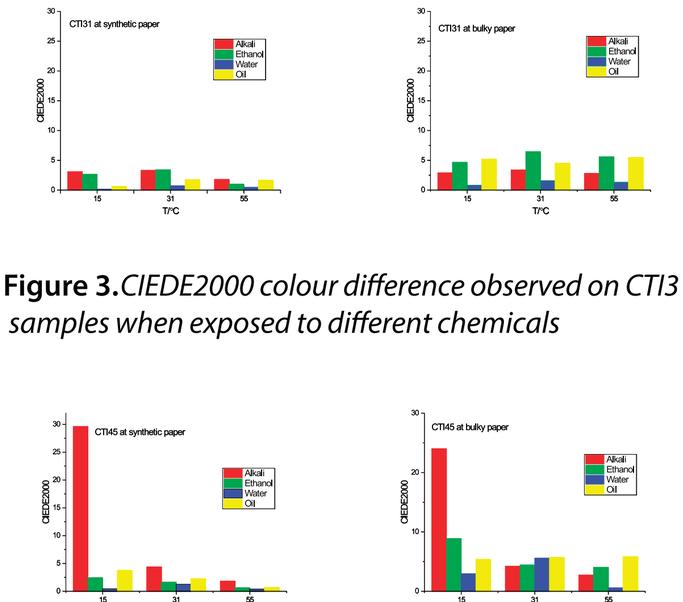

Figure 3. *CIEDE2000 colour difference observed on CTI31 samples when exposed to different chemicals*

Figure 4. *CIEDE2000 colour difference observed on CTI45 samples when exposed to different chemicals*

Discussion / Conclusion

Based on the results, it can be concluded that the printing substrate significantly impacts the stability of thermochromic inks. Samples printed on bulky paper were found to be less stable compared to those printed on synthetic paper. This instability is attributed to the paper's structure, which allows the bulky paper to absorb more of the ink and the chemicals to which it is exposed, leading to faster and easier degradation of the thermochromic ink.
The greatest impact on the thermochromic ink was observed in samples exposed to alkali and printed with offset thermochromic ink, while a slightly smaller impact was noted in samples printed with screen printing thermochromic ink and exposed to oil and ethanol. This is likely due to the drying method of the thermochromic ink. UV-cured inks showed better stability against the exposed substances compared to inks dried by oxy polymerization, as the microcapsules are protected by a polymeric binder.
UV thermochromic inks require specific drying conditions and units, while thermochromic inks that dry by oxy polymerization demand less air supply and fewer conditions, making them more cost-effective.
All these parameters ultimately define the cost of the product and the efficiency of the printing process.
The results of this investigation suggest that the type and purpose of the product must be considered when selecting the appropriate thermochromic ink and substrate for printing.

REFERENCES

Bamfield, P., 2010. Chromic Phenomena, Springer. Royal Society of Chemistry, Cambridge. https://doi.org/10.1039/9781849731034

Friškovec, Mojca ; Kulčar, Rahela ; Klanjšek Gunde, Marta; Light fastness and high temperature stability of reversible thermochromic printing inks // Coloration technology, 129 (2013), 3; 214-222. doi: 10.1111/cote.12020

Homola, T.J. Color-Changing Inks; AccessScience; McGraw-Hill Education: New York, NY, USA, 2008.

ISO 2836, 2021. Graphic technology - Prints and printing inks - Assessment of resistance of prints to various agents. International Organization for Standardization, Geneva.

Jamnicki Hanzer, S., Kulčar, R., Vukoje, M., Marošević Dolovski, A.; (2023). Assessment of Thermochromic

Packaging Prints' Resistance to UV Radiation and Various Chemical Agents. Polymers (Basel). 15, 1208. https://doi.org/10.3390/polym15051208

Kulčar, Rahela ; Maretić, Dorotea ; Vukoje, Marina ; Malenica, Ivan; Dynamics of the thermochromic color change of pressure sensitive labels facestock made from environmentally friendly materials // Proceedings, 11th International Symposium on Graphic Engineering and Design, GRID 2022. Novi Sad, 2022. str. 761-768. doi: 10.24867/GRID-2022-p

Kulčar, Rahela ; Krajnović, Ivana ; Vukoje, Marina ; Ivanković, Kristijan ; Petković, Gorana; UV stability of reversible thermochromic inks with different characteristics on paper with certain percentage of recycled fibres // Book of Abstracts - 23rd International conference on printing, design and graphic communications Blaž Baromić 2019.

Rožić, Mirela ; Vukoje, Marina ; Kulčar, Rahela ; Žužić, Ana
Colorimetric properties of reversible thermochromic ink on different papers // Proceedings of 8th international symposium on graphic engineering and design. Novi Sad, 2016. str. 217-223

Thamrin, E.S.; Warsiki, E.; Bindar, Y.; Kartika, I.A. Thermochromic Ink as a Smart Indicator on Cold Product Packaging—Review. IOP Conf. Ser. Earth Environ. Sci. 2022, 1063, 012021.

Vukoje, Marina ; Huzjak, Juraj ; Kulčar, Rahela; Influence of temperature on the stability of thermochromic prints // Conference Proceedings of the 22th International Conference on Materials, Tribology & Recycling MATRIB 2022.

WRAP. Thermochromic Inks And Reducing Household Food Waste. Available from: https://www.wrap.ngo/ [Accessed 13th August 2024]

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