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Leuco dye-based thermochromic systems for application in temperature sensing

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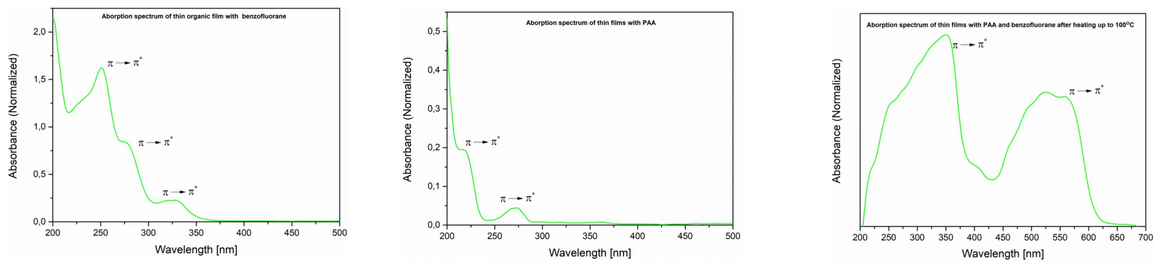
MOTIVATION AND OBJECTIVE

Currently, temperature sensors are becoming more and more popular in many areas of life. For example, they could allow us to control the temperature of chemical processes in water cooling systems. Currently, electronic control systems are used for this purpose, which are susceptible to unwanted third-party action and numerous faults.
The major category of materials used to impart colors that change with temperature, involves organic dyes. A leuco dye can be defined as a structure, usually organic, that is designed to be made to react with a developer in order to impart color to that leuco dye. In the case of thermochromic organic dye mixtures, at least two chemical components are required in order to achieve colors that change with temperature.

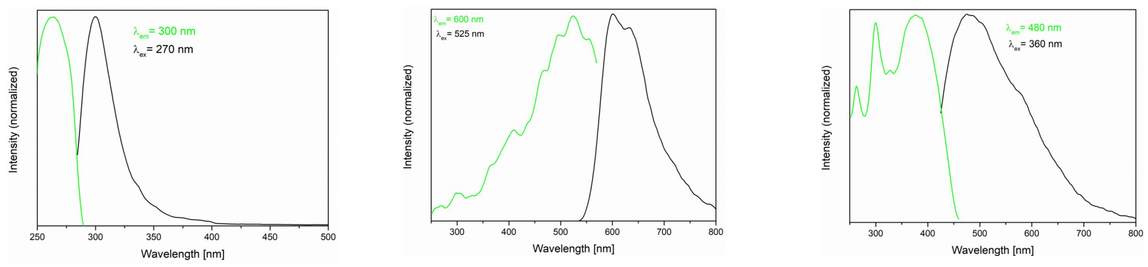
The objective of this research was to fabricate a leuco dye-based termochromic system that will irreversibly change color after reaching the temperature of 100°C.

https://chillerserwis.com/wp-content/uploads/2020/11/Chillery-Systemy-chlodzenia-oparte-o-wode-lodowa.jpeg

RESEARCH RESULTS (electron spectroscopy)



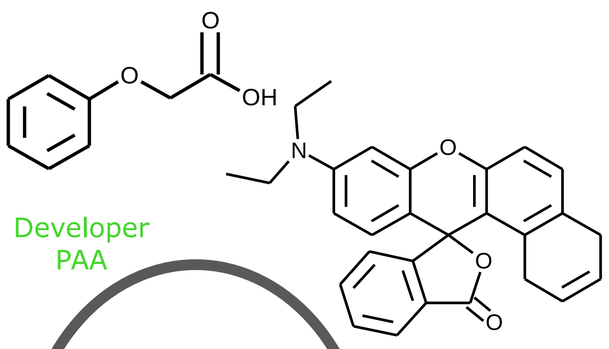
The bands observed on the absorption spectra are the result of the π → π * transitions in the aromatic PAA and benzofluoran groups. The presence of the second band in the last spectrum is associated with the change of the benzofluoran color to dark pink and is the result of opening the lactone ring. It can be attributed to the transition π → π *.



Due to fluorescence spectroscopy, a change in the emission of electromagnetic radiation after developing benzofluoran by PAA was observed. The observed in emission spectra bands are the result of the transition π * → π in the PAA and benzofluoran aromatic group, before and after lactone ring opening

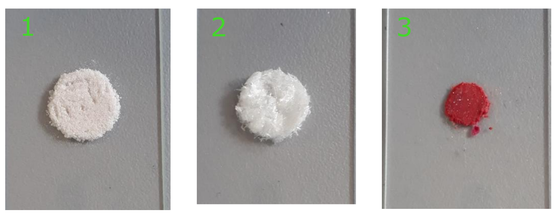
SELECTION OF ACTIVE COMPOUNDS

The research began with the selection of an appropriate compound having an acidic pH and its melting point temperature oscillates around 100°C in order to develop a color change of the leuco dye after heating to the assumed temperature. It was decided to choose PAA (phenoxyacetic acid) as a developer. Chosen organic dye was 6'-(diethylamino)-1'2'-benzofluoran.



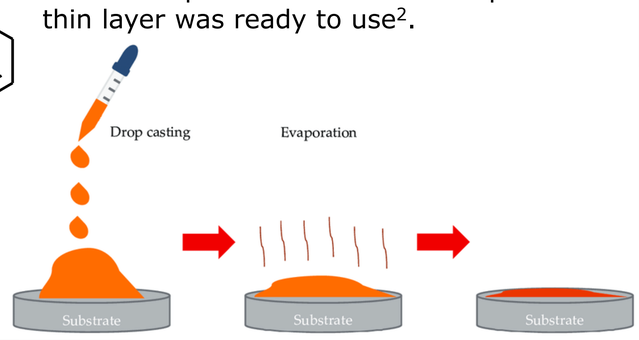
Developer
PAA

Color former
benzofluoran



1 – Color former
2 – Developer
3 – Color former-developer complex after heating up to 100°C

In order to create thin polymer film drop casting method was used. Petri dish was coated by liquid polymer solution with active compounds. After slow evaporation thin layer was ready to use[2].



CONCLUSIONS

TO SUM UP:

- Firstly, selection of active compounds (color former and developer) was made,
- Next, polymer matrices were selected so that they were compatible with active ingredients,
- Optimization process was performed to obtain homogeneous mixtures,
- By drop casting method transparent thin layers with PAA and benzofluoran were prepared,
- The resulting films were combined together by welding at elevated temperature (30-40°C),
- New materials were characterized by TGA, DSC, SEM, FT-IR ATR, electron spectroscopy methods,
- Transparent material characterized by irreversible color change to dark pink after heating to 100°C was obtained and could be used to warning about the failure of the cooling system of industrial equipment.

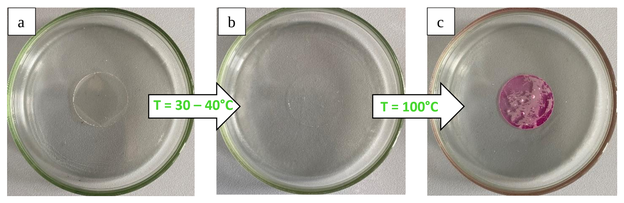
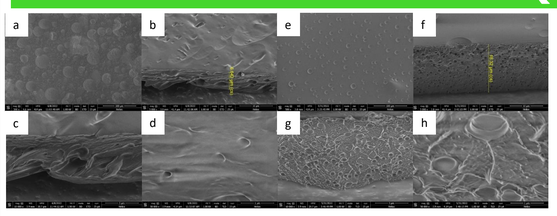


Image a – Organic film was applied on the top of water film
Image b – both layers were combine with each other by heating up to 40 °C
Image c – Temperature sensor after heating up to 100 °C

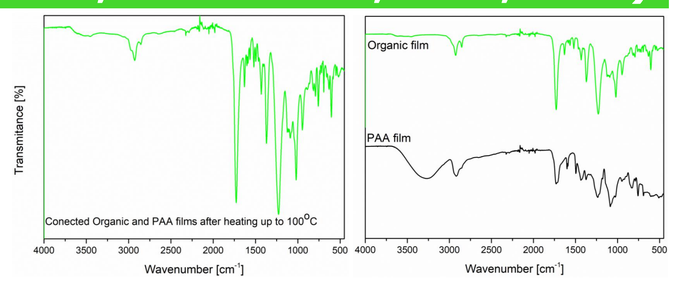
RESEARCH RESULTS (SEM, FT-IR ATR, DSC, TGA)



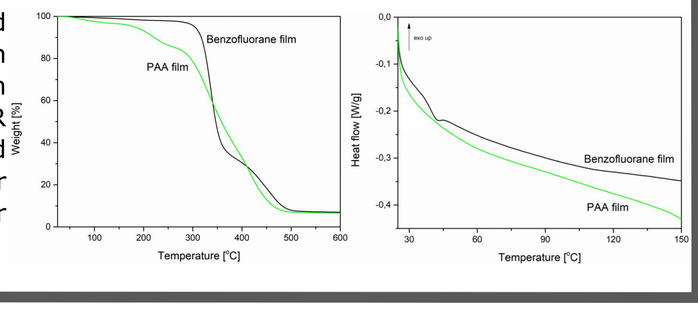
WATER FILM (a-d) ORGANIC FILM (e-h)

SEM microscopy method was used in order to determinate of material thickness and confirm the homogeneity of thin films. Both of them were characterized by high homogeneity.

Structural analysis was investigated by FT-IR ATR method for both organic and water films before and after heating up to 100°C. Characteristic bands have been assigned to prove opening of the lactone ring in benzofluoran after developing organic film by water film. First image shows FT-IR spectra of water and organic films. Second FT-IR spectrum was investigated for combine organic and water films after heating and developing color change.



The TGA method was used to test the thermal stability of the resulting films and the simultaneous confirmation of their possible use in the range of 25-100°C. DSC method complemented TGA method and allowed for a comprehensive assessment behavior of polymer films in relation to temperature change by examining the presence of a glass transition in tested materials.



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