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Leuco Dye-Based Thermochromic Systems for Application in Temperature Sensing

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Abstract : Leuco dye-based thermochromic systems are classified as intelligent materials because they exhibit thermally induced color changes. Thanks to this feature, they are mainly used as temperature sensors in many industrial sectors. For example, placing a thermochromic material on a chemical reactor may warn about exceeding the maximum permitted temperature for a chemical process. Usually two components, a color former and a developer are needed to produce a system with irreversible color change. The color former is an electron donating (proton accepting) compound such as fluoran leuco dye. The developer is an electron accepting (proton donating) compound such as organic carboxylic acid. When the developer melts, the color former - developer complex is created and the termochromic system becomes colored. Typically, the melting point of the applied developer determines the temperature at which the color change occurs. When the lactone ring of the color former is closed, then the dye is in its colorless state. The ring opening, induced by the addition of a proton, causes the dye to turn into its colored state. Since the color former and the developer are often solid, they can be incorporated into polymer films to facilitate their practical use in industry. 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. For this purpose, benzofluoran leuco dye (as color former) and phenoxyacetic acid (as developer with a melting point of 100°C) were introduced into the polymer films during the drop casting process. The film preparation process was optimized in order to obtain thin films with appropriate properties such as transparency, flexibility and homogeneity. Among the optimized factors were the concentration of benzofluoran leuco dye and phenoxyacetic acid, the type, average molecular weight and concentration of the polymer, and the type and concentration of the surfactant. The selected films, containing benzofluoran leuco dye and phenoxyacetic acid, were combined by mild heat treatment. Structural characterization of single and combined films was carried out by FTIR spectroscopy, morphological analysis was performed by optical microscopy and SEM, phase transitions were examined by DSC, color changes were investigated by digital photography and UV-Vis spectroscopy, while emission changes were studied by photoluminescence spectroscopy. The resulting thermochromic system is colorless at room temperature, but after reaching 100°C the developer melts and it turns irreversibly pink. Therefore, it could be used as an additional sensor to warn against boiling of water in power plants using water cooling. Currently used electronic temperature indicators are prone to faults and unwanted third-party actions. The sensor constructed in this work is transparent, thanks to which it can be unnoticed by an outsider and constitute a reliable reference for the person responsible for the apparatus.

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