

## Selected problems of measurement of photochromic colorants

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### ABSTRACT

In our study we prepare new view on the relationship between intensity and time of exposition, time of relaxation respectively. In our research we follow the develop simple textile based sensor sensitive to UV light and kinetic study of behaviour and main attention was given to possibility use the technology of textile printing by stencil printing. This experiment was completed the study of influence of UV absorbers and ability of properties modulation of sensors. Also was studied dependence of Colour change intensity on concentration of photochromic pigment. Above mentioned studies was necessary complete by study of fatigue resistance in dependence on Intensity of source and time of exposition including also classic tests of light fastness on Xenon test and dry staining fastness, which are the same as for normal classic pigment use in textile finishing. During study of dynamic properties of photo chromic textile sensors we found, that relation between colour hysteresis area  $H_p$  is linear related to the intensity of illumination  $E$ . Bi-exponential functions, which are used in  $H_p$  calculation, well described the kinetics of colour change intensity of photochromic pigments. They give good fits to the growth curves as well as to the relaxation one's.

### 1. INTRODUCTION

In present time become worse living conditions and increase harmful pollutants in environment, which can non-reversible damage our health and jeopardize full quality our life. Big attention is given in research area respectively in development and perfection of protective clothes specially their barrier features. Protective barriers we understand how the clothes or textiles protect wearer against above mentioned dangerous conditions and if the protection is only partial or the protection is time limited by ambient conditions. Most of protective clothes are not developed for long time wearing. During development of these barrier structures we have to keep in our mind full comfort of acting persons without limitation. Some of protective clothes are equipped by electronics, respectively other sensors or devices, which monitoring and quantify dangerous substances in environment. In present time is big attention given to miniaturization of electronics and also flexibility their connection with computing units<sup>1</sup>.

Above mentioned describe concept of protective clothes we call as intelligent structure. Disadvantage of this intelligent structure is no adequate response on the external stimulus, there is only monitoring of external dangerous conditions. This structure we call as passive intelligent textile structure.

Sensors and textile structures, which react adequate response and they are able modulate protective degree in accordance on the external stimulus (change of intensity UV, temperature, press, electrical field etc.) is called as SMART textile. As example of passive intelligent textiles are optical fibres, which leading the not only signal, but they are also sensitive on the deformation, concentration of substances, press, electric power etc. As example of active intelligent textiles could be textiles which react by change own colour in dependence on external stimulus (light, temperature) and called as a chameleonic textiles or heat containing textiles, which are able to store or slack energy according external temperature. Moreover textile based sensors and active protective textiles has advantages that textile structure is easy customizable by sewing, thermal bonding or gluing. Also there are advantages of easy maintaining (washing, chemical drying) and low specific weight with good strength, tensibility and elasticity. Good features are also workability without change of technology of production and extremely large specific surface. Big advantages are possible integration these types of sensors into system of protective clothes and also their price availability. From this reason is this

article directed to research of textile-based sensors with photo chromic behaviour, respectively to study of dynamic behaviour and modulation of sensitivity photo chromic sensors.

In this work is described new definition of colour reversible hysteresis, which is described by hysteresis of colour change curve. This colour hysteresis curve is described by kinetic model, which defines the speed of colour change initiated by external stimulus – UV light. Kinetic model verification is done for textile sensors with photo chromic pigment applied by textile printing, fibre mass dyeing.

## 2. METHOD

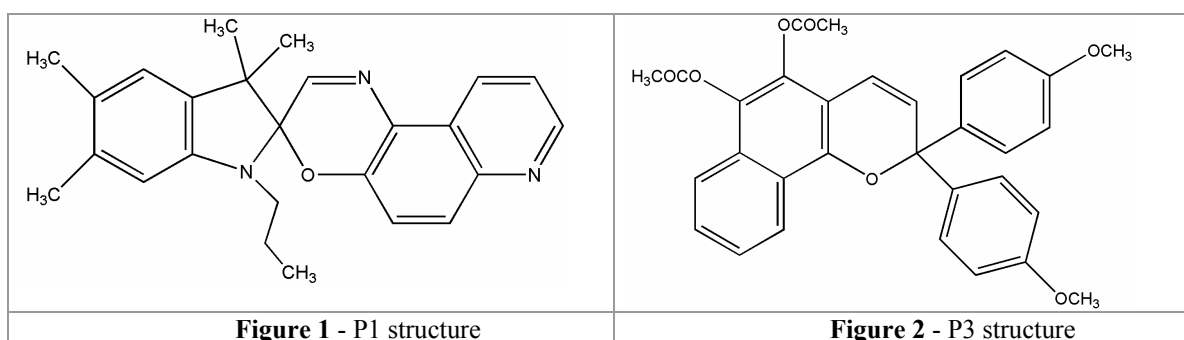
Our experiment was divided to 3 parts and every part is directed to special form of application of photochromic pigments and study of photochromic behaviour from point of kinetics and dynamics in different mediums:

- Application of photochromic pigments by textile printing - PTP
- Application of photochromic pigments by mass dyeing - NWT
- Study of photochromic pigments behaviour in solution - PPS

In our research we follow the develop simple textile based sensor sensitive to UV light and kinetic study of behaviour and main attention was given to possibility use the technology of textile printing by stencil printing. This experiment was completed the study of influence of UV absorbers and ability of properties modulation of sensors. Also was studied dependence of Colour change intensity on concentration of photochromic pigment. Above mentioned studies was necessary complete by study of fatigue resistance in dependence on Intensity of source and time of exposition including also classic tests of light fastness on Xenon test and dry staining fastness, which are the same as for normal classic pigment use in textile finishing and these tests are also limitation of application offered sensors.

In second part of our experiment was studied change of photochromic behaviour tested pigments in non-woven textiles produced by technology Melt Blown (mass dyeing) and in third part was checked the photochromic behaviour used pigments in solution via measurement of transmission characteristics as complete study how is changed the photochromic response via kind application. For experiment was used commercial photochromic pigments PPG-Photosol 33672 (P1), PPG-Photosol 7106 (P2), PPG-Photosol 749 (P3), PPG-Photosol 0265 (P4) and PPG-Photosol 5-3 (P5). Chemical structure illustration is shown on FIG. 1 and FIG. 2<sup>2</sup>.

As was mentioned in our experiments were prepared two kinds of solid media – textile substrate with photochromic pigments.



Besides measurements of prints and NWT via classical spectrophotometer Spectraflash 300UV was used arrangement of AVANTES S2000 spectrometer due to short time, continuous measurement respectively. S2000 arrangement makes possible using different light sources for tested samples illumination. Same possibility was obtained via modification of CS-5 spectrophotometer for measurement of photochromic solutions.

Because is relationships between remission and concentration of colorant agent non-linear, in colour measurement is obviously used relation between Kubelka-Munk function (K/S) and concentration, colour change intensity I respectively. Colour change intensity, I that we used, is defined as following equations:

$$I = \int_{400}^{700} K / S_{\lambda} d\lambda \quad (1)$$

For description of kinetic behaviour of our UV sensors we used first class kinetic model as is shown in following equations<sup>3</sup>:

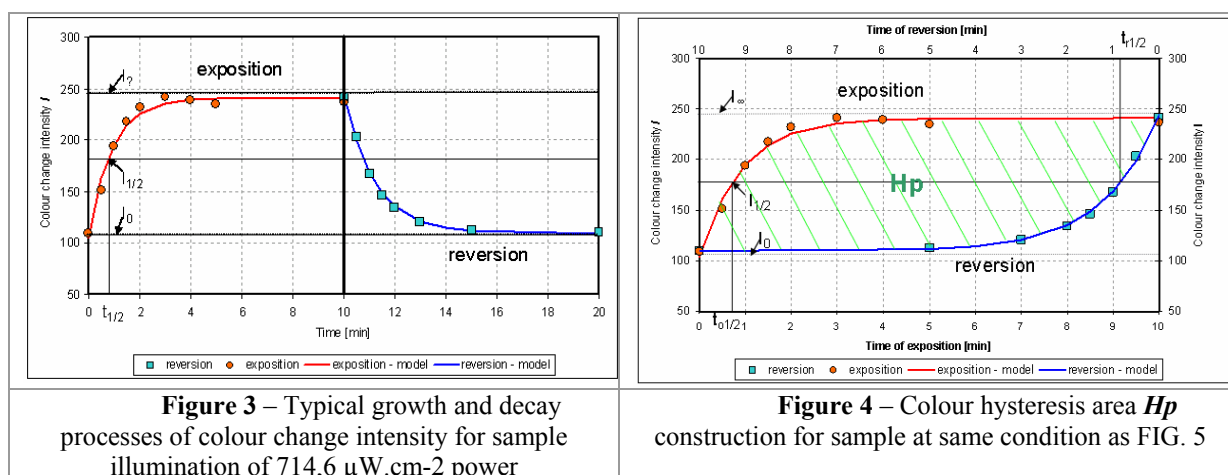
$$\text{Exposition: } I = I_{\infty} + (I_0 - I_{\infty}) \cdot e^{(-kt)} \quad \text{Relaxation: } I = I_0 + (I_{\infty} - I_0) \cdot e^{(-kt)} \quad (2, 3)$$

From these equations is possible to calculate halftime of colour change  $t_{1/2}$ <sup>4</sup> and colour hysteresis area  $H_p$ :

$$t_{1/2} = \frac{\ln 2}{k} \cdot 60 \quad (4)$$

$$H_p = \int I_{\infty} + (I_0 - I_{\infty}) e^{-kt} dt - \int I_0 + (I_{\infty} - I_0) e^{-kt} dt \quad (5)$$

As is from equation (5) evident that colour hysteresis area  $H_p$  arises by time reverse of reversion data as is shown on the FIG. 4.

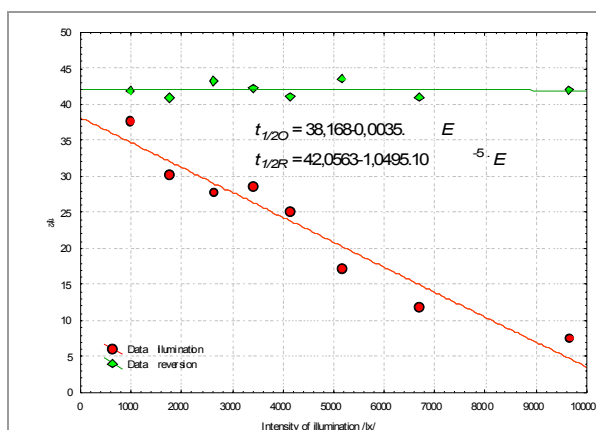


### 3. RESULTS

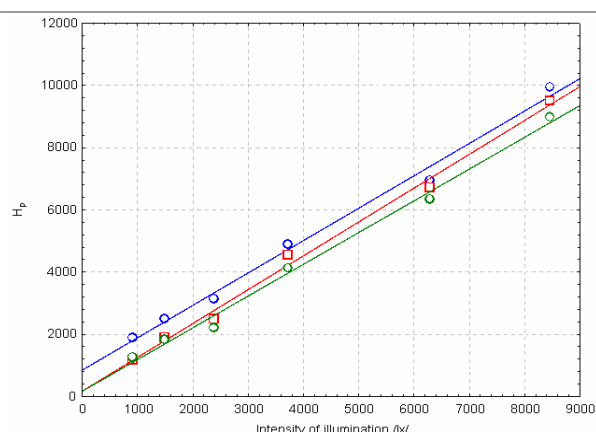
Data on both figures 3 and 4 were obtained for lowest intensity of illumination  $E$  (979.3 lx). On the FIG. 4, we can see that already for this  $E$  in the colour change speed is higher during of exposition than reversion phase. In our study we prepare new view on the relationship between intensity and time of exposition, time of relaxation respectively. Name of this new kind of graphs is colour hysteresis area  $H_p$ . When we will test relationship between halftime of colour change  $t_{1/2}$  and intensity of illumination  $E$ , we obtain decreasing linear relation - FIG.5. That means time of colour change is shorter during intensity of illumination increasing.

Linear relation we obtain also via dependency of hysteresis area on intensity of illumination  $E$ . On the FIG. 6, is shown dependences hysteresis area relation to UV absorber dose. It is evident, that increasing of UV absorber dose gives decreasing of  $H_p$ .

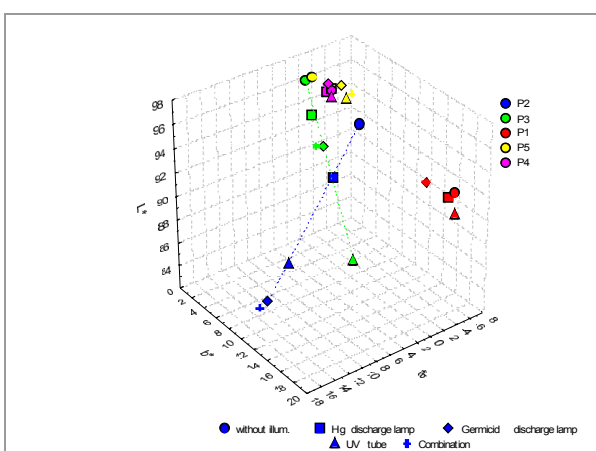
As was mentioned used measuring units were prepared for measuring colour change of tested samples under different light sources. On FIG. 7 and FIG. 8 are shown results for photochromic pigments solutions PPS and prints PTP.



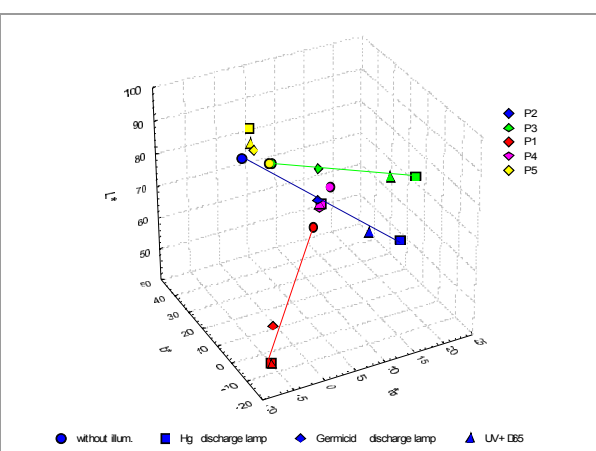
**Figure 5** – Halftime of colour change  $t_{1/2}$  relation on intensity of illumination



**Figure 6** – Colour hysteresis area  $H_p$  relation on intensity of illumination



**Figure 7** – Change of PPS colour position dependent on different light source



**Figure 8** – Change of PTP colour position dependent on different light source

#### 4. CONCLUSIONS

In our study we prepare new view on the relationship between intensity and time of exposition, time of relaxation respectively. That means colour hysteresis area  $H_p$  is linear related to the intensity of illumination  $E$ . Via this relation we demonstrate the possibility of flexible textile-based sensors construction in area identification of radiation intensity. Beside of this one, we demonstrate differences between photochromic pigments behaviour in solution and prints on textiles: differences between spectral power distributions of light source sensitivity of this one's. Bi-exponential functions, which are used in  $H_p$  calculation, well described the kinetics of colour change intensity of photochromic pigments. They give good fits to the growth curves as well as to the relaxation one's.

#### References

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