INFRARED LASER IRRADIATION ON SURFACE OF COTTON FABRIC

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Abstract: This paper is focused on the laser infrared application. In this case is it discussed the influence of IR laser irradiatio on cotton textile fabrics. Accent is focused on quality changes on macroscopic and microscopic characteristics. Topic of this work is estimation of changes in textiles at gradual escalation radiance. Measured was IR spectra after infrared laser radiation, light remission of coloured textile materials and electron microscopy. By the help of different kind of objective and subjective gauge are analyzed future applications.

1. Introduction

This work consider only narrow particular problem from lengthy application laser systems in technical department all over the world. We would demonstrate change in natural and synthetic polymerics after laser irradiation. Such as much good affinity dyes at the surface textile material or more effectively printing process or else change demoting properties. Last but not least this work could be of service to production and modification smart textiles into technical industry [1].

2. Experiment - Application IR laser

For application infrared laser's radiation were selected one type of textile materials. In this case discusses 100% cotton textile fabrics with linen structure. Experiment was created by the help of machinery Flexi Marcatec Carbon Dioxide Laser System operative with wavelength 10,6 μm and peak power 400 Watts (Fig. 1).

Figure 1. Dioxide Laser System Machinery

Samples were irradiated by different power intensity (25%, 50%, 75%). In the case of 100% power intensity is incoming total destruction for testing materials – flash or melting.

For objective understanding executed modification on tested samples was used electron microscope which is located on the Department of Textile Materials (TUL). Samples of 100% cotton fabric with linen structure with and without power intensity are shown in *Figures 2, 3, 4*.

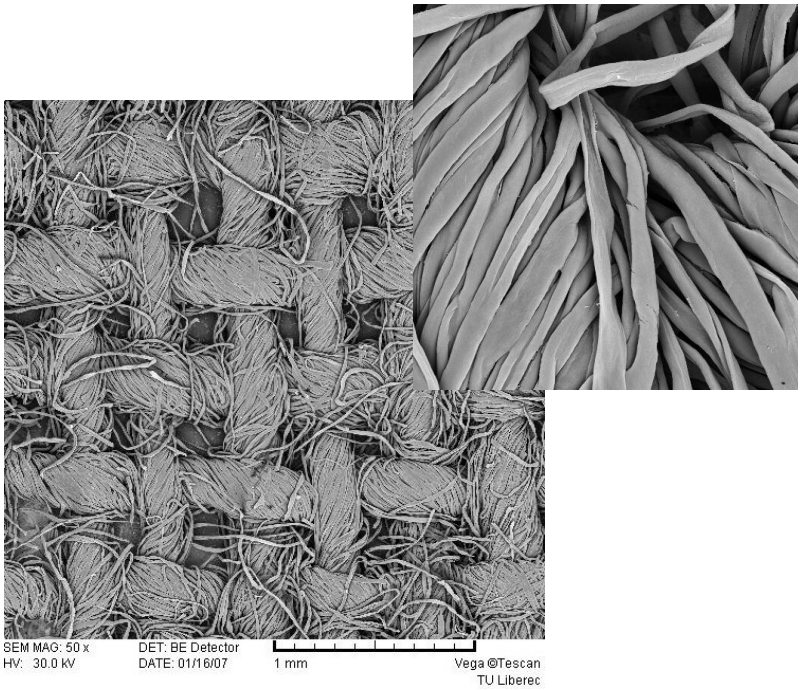

Figure 2. – Cotton fabrics from electron microscope - non-irradiated intensity

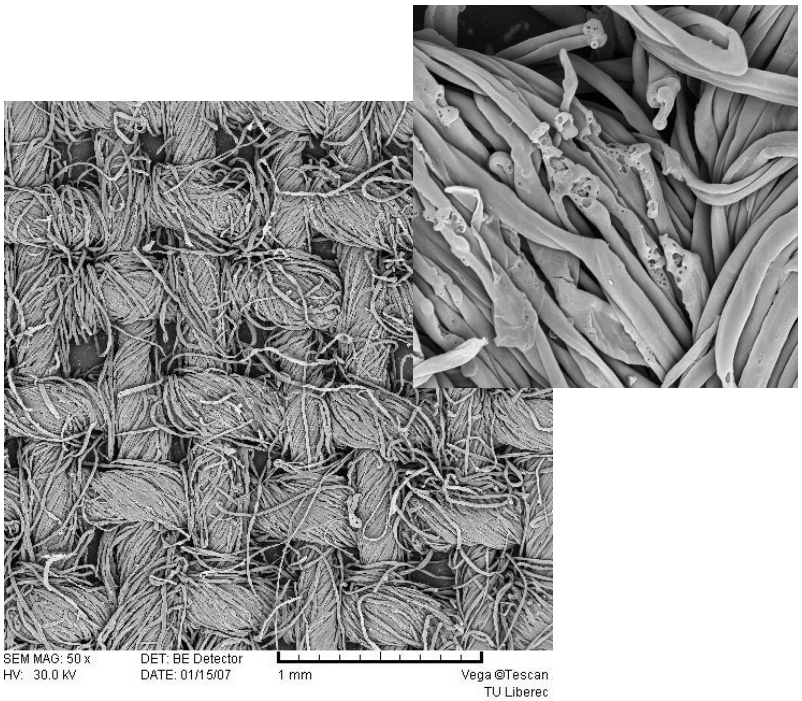

Figure 3. – Cotton fabric from electron microscope - 50% intensity

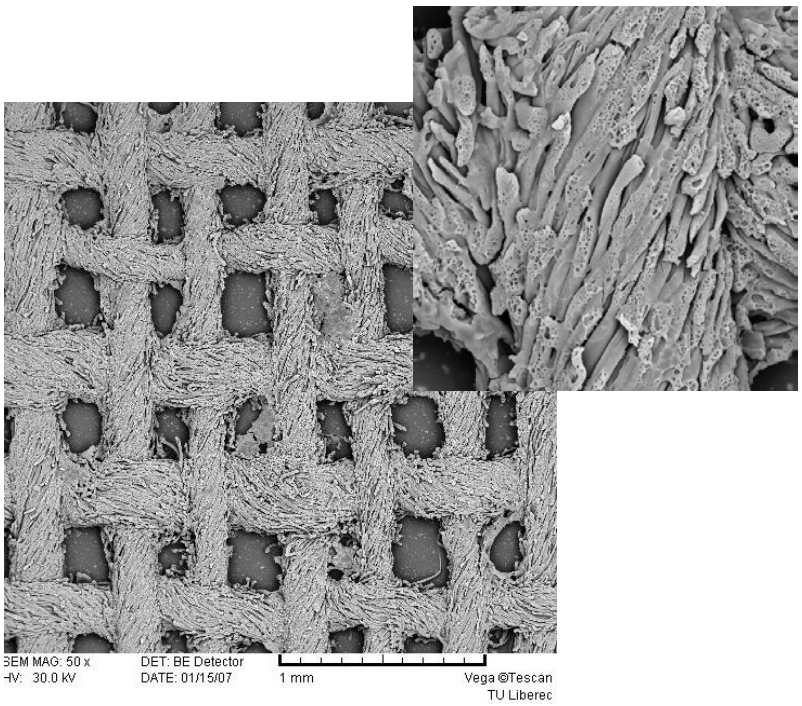

Figure 4. – Cotton fabric from electron microscope - 75% intensity

Next objective understanding executed modification on tested samples was used infrared spectrometry. By the way was research in experimentation whether not coming to macromolecules changes on testing samples Figure 5.
Infrared spectra of testing samples was measuring on the machinery FTIR – Spectrum One fy Perkin-Elmer. Was used reflective equipment with ZnSe crystal. This infrared spectra was standardized and revised on the baselin.

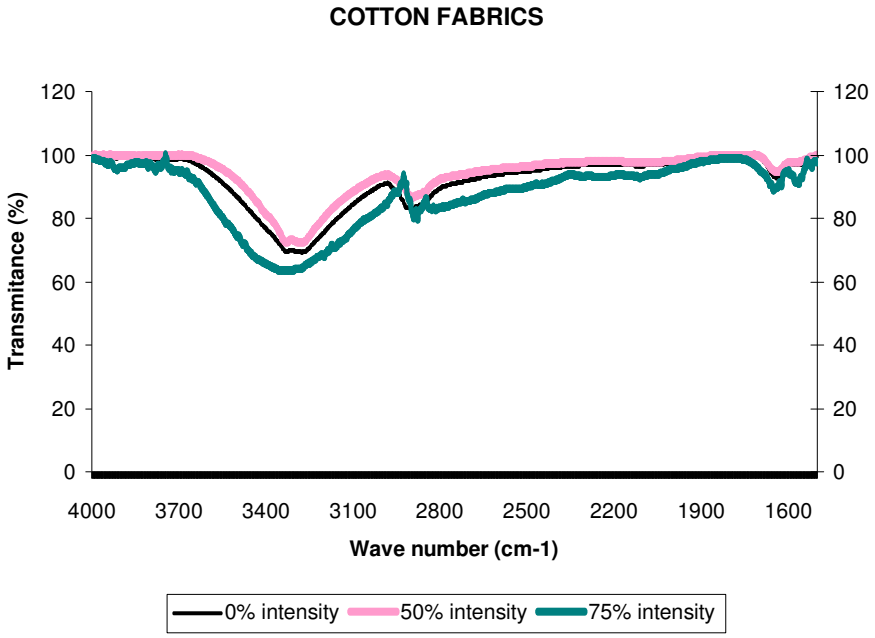

Figure 5. – IR spektra cotton fabric

Description IR spectra from cotton fabric:

c. 3330 cm^{-1}: stretching vibration of structure O-H
c. 2900 cm^{-1}: stretching vibration of structure C-H from group $–CH_3$ and $–CH_2$-
c. 1648 cm^{-1}: stretching vibration of structure C-O and deformation vibration of structure O-H
c. 1564 cm^{-1}: deformation vibration of structure C-H
Bellow the mark 1500 cm^{-1} it is impossible allocated particular structures into molecule because in the case is concerned so-called sceletary vibration - molecular vibration as a komplex.

3. Experiment - Measuring of remission

For objective understanding executed modification on tested samples was used measuring of dying cotton fabric depending on the intensity IR radiance. By the help of Kubelka – Munk theory was provided K/S schedule [3]. This schedule is directly proportional concentration pigment on the fiber.

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \qquad [3]$$

Where K is absorption coefficient, S is scattering coefficient and R is grade of remission.

4. Experiment – coloured fabrics

Next part of experiment was monitored to change of behaviour and to analyze Kubelka – Munk theory after application infrared radiation on coloured cotton fabrics.

Has been chosen two variant type of dyes and three colours. C.I.Vat Yellow 2, C.I.Vat Red 13 and C.I.Vat Blue 6 and other type C.I.Direct dyes orange 39, C.I.Direct red 80 and C.I.Direct Blue 106. Tested samples has coloured with 0,1 % and 4 % intensity of pigmentation. Tested samples has coloured with different intensity of pigmentation 2 g/l it equals 0,1 % pigmenation and 40 g/l it equals 4 % pigmentation

K/S values depending on intensity IR radiance for every one cotton samples are displayed in maximum wavelength peak. In *table 1*. are shown K/S values without $K/S_{non\text{-}coloured}$ values of C.I.Vat dyes cotton samples. In *table 2*. are shown K/S values without $K/S_{non\text{-}coloured}$ values of C.I.Direct dyes cotton samples.

Intensity	K/S – $K/S_{non\text{-}coloured}$ - C.I.Vat dyes					
	Yellow 2 0,1% λ_{max} 440 nm	Yellow 2 4 % λ_{max} 440 nm	Red 13 0,1% λ_{max} 540 nm	Red 13 4 % λ_{max} 540 nm	Blue 6 0,1% λ_{max} 640 nm	Blue 6 4 % λ_{max} 640 nm
0%	1,272	5,692	0,701	15,787	0,696	11,836
25%	0,529	2,394	0,485	8,581	0,598	5,748
50%	0,357	1,557	0,373	5,215	0,464	4,084
75%	0,146	1,207	0,269	5,086	0,324	3,888

Table 1. – K/S values without $K/S_{non\text{-}coloured}$ values of C.I.Vat dyes cotton samples

Intensity	K/S – $K/S_{non\text{-}coloured}$ - C.I.Direct dyes					
	Orange 39 0,1% λ_{max} 440 nm	Orange 39 4 % λ_{max} 440 nm	Red 80 0,1% λ_{max} 540 nm	Red 80 4 % λ_{max} 540 nm	Blue 106 0,1% λ_{max} 640 nm	Blue 106 4 % λ_{max} 640 nm
0%	6,415	12,575	5,209	14,041	2,836	8,616
25%	2,938	7,138	2,535	5,625	1,848	4,218
50%	1,679	5,799	1,517	2,947	1,064	3,294
75%	1,295	5,315	0,943	2,493	1,114	3,2614

Table 2. – K/S values without $K/S_{non\text{-}coloured}$ values of C.I.Direct dyes cotton samples

For example is shown in *Figure 6*. K/S function depending on intensity for samples C.I.Vat Yellow 2 with irradiance wavelength 440 nm. Next *Figure 7*. is shown C.I.Direct Orange 39 L7G with the same irradiance wavelength 440 nm.

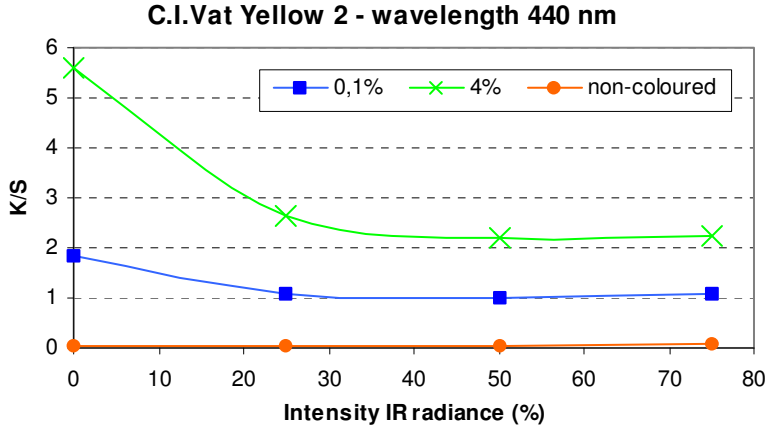

Figure 6. – C.I.Vat Yellow 2

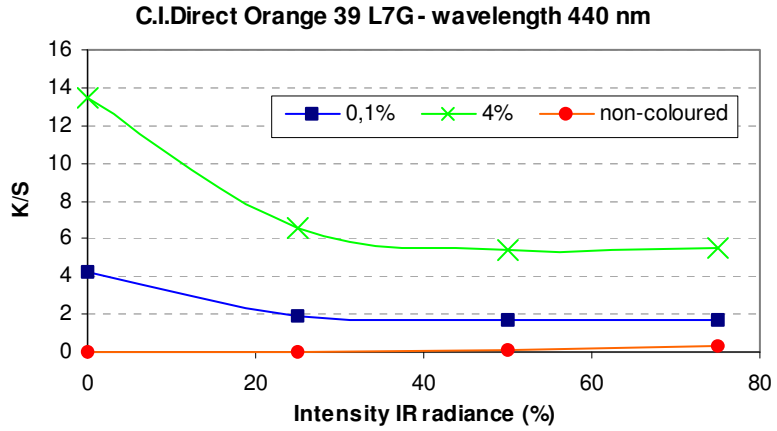

Figure 7. – C.I. Direct Orange 39 L7G

4. Results and conclusions

Measurer changes in K/S values before and after infrared laser irradiation were depend on initial K/S value and intensity of irradiation. For our experimental data was in this study proposed a new empirical model as shown on *Figure 8*.[2]. Comparation of experimental K/S ("exp.") and calculated K/S ("calc.") values we can see on following *Figure 8*. Proposed model is useful for prediction of influence if IR laser irradiation on cotton fabric dyed by direct and vat dyes.

$$K/S = K/S_0 \cdot \left[1 - 0,7. \left(1 - e^{-I.\frac{0,04}{\left(K/S_0\right)^4}} \right) \right]$$

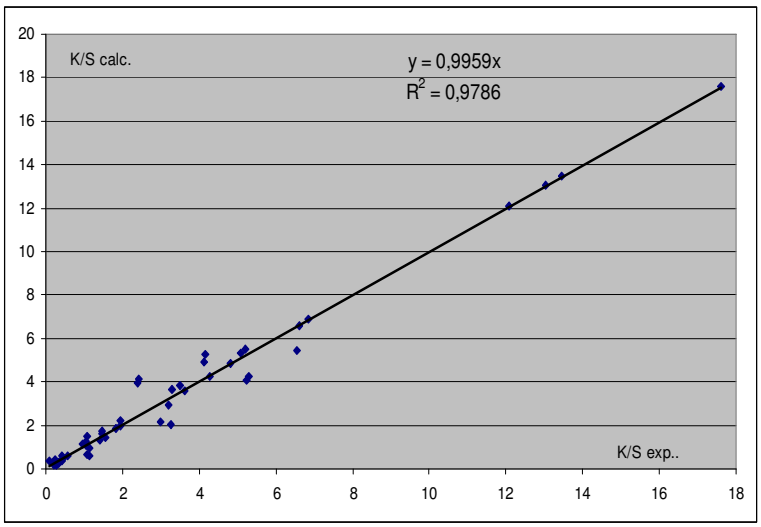

Figure 8: Empirical model and Comparation of experimental K/S ("exp.") and calculated K/S ("calc.") values of cotton fabric dyed with direct and vat dyes

References:
[1] ENGST P., HORÁK M. : Populární přednášky o fyzice – *Application laser systems* Sv. 34. 1991.
[2] READY John F., *Industrial Applications of Lasers*, San Diego – Academic press 1997
[3] VIK M. : *Doplňky k měření barevnosti a vzhledu*, Skriptum TUL 1995.