SOLUTION COMPOSITION INFLUENCE ON THE OPTICAL CHARACTERISTICS OF LIQUID-CONTAINING COMPOSITE MATERIALS

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ABSTRACT

The spectral characterization of the material impregnated with the aqueous solution of alkaline-earth metal salt covered with a crystalline hydrophilic polymer showed that the modification of the material surface ensures spectral brightness decrease as a result of reflected light polarization ensured by nanosized inclusions of liquid of the sample surface. A specific polyhidride compound of the metal salt aqueous solution and polymer within the capillars is formed possessing specific optical properties.

Keywords: spectral brightness coefficient, composite materials.

1. INTRODUCTION

The optical properties of the materials depend on the color of the material, their pigment composition, and surface microstructure. Studying the optical properties of the materials and their difference makes it possible to detect, emphasize, or disguise the material texture, shape, object structure or man's figure. Scattering of the electromagnetic waves on the surface irregularities of the material ensures the spectral filtration of the electromagnetic radiation in the visible and near-infrared wavebands. In order to assess the light scattering characteristics the spectral brightness coefficient is commonly used in optics.

The optical properties of white fabrics which have a developed surface studied previously possess an increased spectral brightness coefficient values (up to 0.9…1.0) in the waveband of 540…940 nm, and the visible light reflected off the fabric is not polarized thus indicating that the material is highly visible in the optical band [1].

The work is aimed at fabric surface modification in order to vary its optical characteristics in the waveband of 540 … 940 nm.

2. METHODOLOGY

In order to obtain information about the object we analyze the brightness and the spectral distribution of the reflected light. The reflectivity of an object depends on the light wavelength and spectral characteristics of the object surface. When the light wavelength increases the reflectivity of many of the natural backgrounds and biological objects rises by times, but in the case of the artificial objects it almost doesn't change. Knowing the optical characteristics of different backgrounds (Table) is very important when synthetic materials for natural objects imitation are developed [2].

In order to reduce the electromagnetic waves intensity in the optical band various composite structures based on hydrophilic porous, fiber knitted and non-knitted materials can be applied [3].

Table 1. Spectral brightness coefficient of natural objects

№	Objects	Spectral brightness coefficient (r_λ)- λ(nm)					
		400	500	600	700	800	900
1	Black and sandy-loam soils	0.02	0.021	0.03	0.04	0.055	0.1
2	Podsol and loam soils	0.07	0.08	0.095	0.155	0.24	0.28
3	Sand	0.115	0.198	0.27	0.298	0.32	0.35
4	Limestone	0.35	0.55	0.66	0.72	0.75	0.755
5	Coniferous forest in winter	0.01	0.025	0.03	0.05	0.17	0.21
6	Coniferous forest in summer; dry meadow	0.025	0.05	0.07	0.14	0.28	0.32
7	Broad-leaved forest in summer, thick grass cover	0.05	0.07	0.1	0.18	0.52	0.55
8	Broad-leaved forest in autumn, ripe field crops	0.05	0.08	0.19	0.31	0.53	0.57
9	Newly fallen snow	0.825	0.81	0.77	0.72	0.66	0.59
10	Ice-crusted snow	0.71	0.735	0.75	0.76	0.76	0.76
11	Water reservoirs	0.14	0.075	0.035	0.02	0.01	0.01

Machine-knitted fabrics impregnated with water possess smaller spectral brightness coefficient values about 0.6…0.9 because of refraction index of the initial material changing and scattering of the reflected light ensured by the local nanosized water particles. The reflected light is slightly polarized (polarization degree < 0.1). Synthesis of aqueous solutions (incl. NaCl, C_3H_5OH) for impregnation didn't change the obtained optical characteristics as compared with water [4]. In addition the liquid content of the described materials is non-stable because of the liquid evaporation process and it affects their properties.

Some salts of alkaline-earth metals possess high sorption properties and the dissociating salt ions form strong chemical bonds with liquid molecules affecting the molecular structure of the liquid. Water molecules are kept within the pores of the fabric at a certain content level, which depends on the metal salt concentration in the solution as well as temperature and humidity of the ambient air (for the experiment t°=20-25ºC; φ=70-80%).

Spectral polarization properties of porous fiber fabrics impregnated with the synthesized solution were studied in the waveband of 540…940 nm on the goniometer set-up with the spectropolarimeter "Gemma MC-09" furnished with a polarizer, which registers the spectral radiance distribution of samples and the linear polarization of the light reflected by the samples with different polarizer axis positions [2].

The halogen bulb KGM-250 was used as the light source with the maximum of the radiance spectral distribution at the wavelength of 1 μm. The power supply of the bulb was stabilized to ensure the constant light brightness. The collimated light beam is incident on the studied object at the angles (γ) of 45, 50, 55°. The observation angles (β) were fixed equal to: 0, 30, 50 and 70°. The observation and incidence angles were referred to an object surface normal. Three polarizer axis positions - 0, 45 and 90° with the accuracy of 0,5° were set with reference to the vertical plane in order to obtain the linear polarization characteristics of the reflected light.

Stokes parameters were calculated to describe the reflected light. The spectral characteristics of the material under study were registered at three different positions of the polarizing filter axis (0, 45 and 90^0) with reference to the vertical thus obtaining the primary parameters I_0, I_{45}, I_{90} of the spectral radiance distribution.

The Stokes parameters {L, Q, U, V=0} [5] were calculated as:

$$L = I_0 + I_{90} \quad (1)$$

$$Q = I_{90} - I_0 \quad (2)$$

$$U = I_0 + I_{90} - 2I_{45} \quad (3)$$

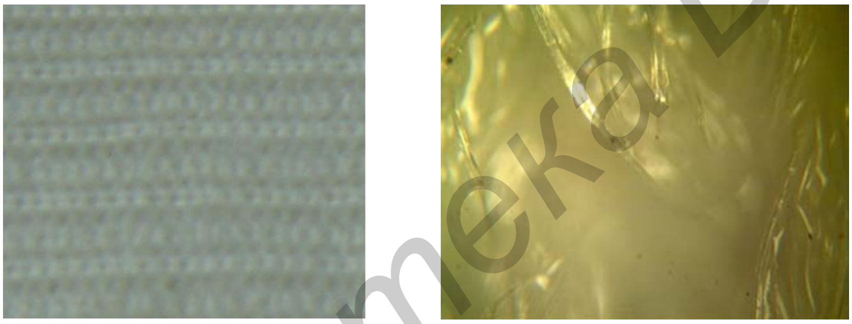
Through the Stokes parameters the polarization degree P was calculated as:

$$P = \frac{\sqrt{Q^2 + U^2}}{L} \quad (4)$$

The results were used to calculate the spectral brightness coefficient and the linear polarization degree of the reflected light. The spectral brightness coefficient was calculated as a ratio between the spectral radiance distribution of the sample under study and the spectral radiance distribution of the standard material with the even scattering indicatrix.

3. DATA

The knitted fabrics used for impregnation possess a high surface density of 1313 g/m^2 to form a highly porous regular structure with microsized pores (Fig. 1 a). The impregnation solution is well-wetting to the synthetic fibers of the fabric, is non-freezing in a wide temperature range and possess high sorption properties.



a b

Fig. 1 - Porous fiber knitted fabric impregnated with aqueous solution: a – surface appearance; b – microphotography of the surface

In order to conserve the solution within the fabric volume we additionally applied a layer of the hydrophilic crystalline polymer. The polymer also forms the nano-structured surface as a result of polyhydride compounds between the alkaline metal salt and the polymer forming. As the result a composite liquid-containing material was developed with a developed micro- and nanostructured surface (Fig. 1 b).

4. RESULTS

The spectral characteristics of the surface of the developed material are given in Fig. 2 which indicate a decrease of the spectral brightness coefficient by 0.15…0.22 of the fabric surface modified with the solution in comparison to the water-impregnated fabric due to a specific solution nanosized structure on the fabric surface. The spectral brightness coefficients are close to the snow brightness values given in Table.

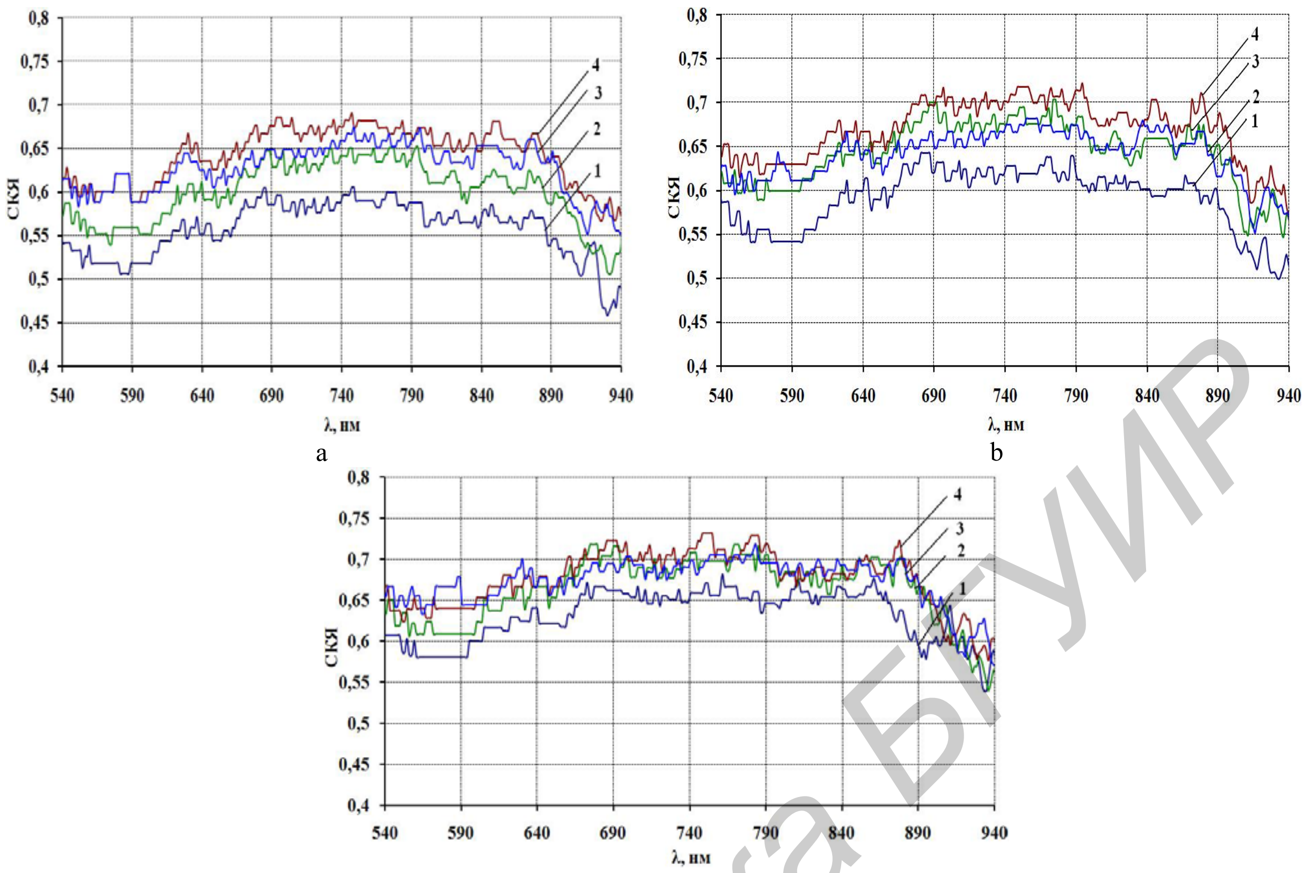


Fig.2 – Typical spectral brightness coefficient characteristics for the composite liquid-containing material for various angles of light incidence: a - 45º, b - 50°, c - 55º and observation angles: 1 — β=0°, 2 — β=30°, 3 — β=50°, 4 — β=70°

The polarization characteristics (Fig. 3) of the developed material with modified surface are at a very low level and is ensured by a non-uniform shape of the fabric surface.

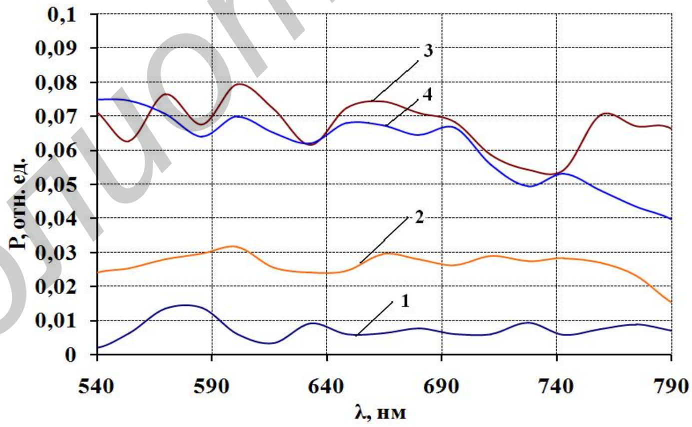


Fig.3 – Polarization characteristics for the composite liquid-containing material for three polarizing filter axis positions (0, 45 and 90^0) with reference to the vertical and for the following observation angles: 1 - β=0°, 2 - β=20°, 3 - β=60°, 4 - β=90° the incidence angle was 50º

It is explained by a high level of adhesion of the applied crystalline polymer to the fabric material and the optical properties of the polyhydride compounds formed as a result of interaction between the polymer molecules and metal salt solution formations at the surface layer. The optical characteristics of the white machine-knitted fabrics with modified surface allow suggesting them to decrease the intensity and for depolarization of the light reflected from the surface as well as to apply the developed materials to disguise the contrast objects against the background in winter.

5. CONCLUSIONS

The obtained results show that impregnating the machine-knitted fabric with the aqueous solution of alkaline-earth metal salts and applying the layer of hydrophilic crystalline polymer on the surface of the fabric results in spectral brightness decrease and depolarization of the reflected light in the waveband of 540…940 nm ensured by the complex nanosized liquid-containing structure. The spectral brightness coefficient characteristics in the range of 0.5…0.69 are close to the snow brightness values for various observation angles and is the reason to use the developed materials to decrease the intensity and for depolarization of the light reflected from the surface as well as to apply the developed materials to disguise the contrast objects against the background in winter.

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