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Optimizing Light Illumination: Fabrication and Analysis of Lighting Materials for LED Reflectors

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Abstract. Lighting a room may work successfully or break the room illumination. May frequently feel undesirable when the selected lights don't suit the area or the purpose of the room. The aim of this article focusing on optimization the light illumination and fabricating lightening material from different polymer such as polystyrene and polycarbonate that work as perfect reflector for LED. Optical properties of the luminaire efficiency were studied for different lighting glasses and lighting parameters of LED lamps (SB), (SBPT), (SBS), (SE) and (SEP) were calculated after test. Also, the magnitude of absorption, transmission and reflection were calculated for each lighting polymer glasses that fabricated, and the resultant lighting glass showed an excellent reflection property for UV visible test. The mechanical properties of impact strength were calculated and showed good resistivity to fracture better than raw materials. Based on the results and as a conclusion indicates that, if the corrugated edge of lighting polymer glass is directed into the luminaire body, then the efficiency is insignificant, but still increases and for the spectral transmittance depends not only on the composition of the lighting glass, but also on the geometry of the surface on which the light falls.

Keywords. Lighting polymer glasses, LED, polystyrene, polycarbonate

1. Introduction

There are several lighting glasses available today with a wide range of mechanical and physical characteristics. Wide glasses are frequently employed in lighting technology to refract, reflect, scatter, or alter the spectrum nature of incident light. They are used in the production of lamps for both indoor and outdoor illumination, long-range signaling instruments, ceiling lamps, and caps of all different sizes and forms [1]. Developers of luminaires must decide what glass to employ and how it will affect the consumer attributes of produced goods in light of the wide range of glass nomenclature provided. Therefore, it is vital to research the properties of lighting glasses and make suggestions for their application in the production of lamps for office illumination [1,2].

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Thus, the aim of the work is to optimization the light illumination recommendations for the use of the "microprism" lighting sheet in the design of lamps for office lighting [3]. To accomplish this, the following steps must be completed: study the regulation sheets governing the mechanical and physical characteristics of lighting glasses; determining lighting glass samples' transmissive, reflecting, and absorbing properties, also calculate the impact strength of lighting glass; to evaluate office luminaires with various arrangements of glass (corrugated edge inside and outside the body) with knowing the scattering he scattering indicatrix of lighting glass samples [4]. Lighting materials are used to produce light-converting devices that alter the polarization and spectrum structure of radiation, transfer flux in space, and reduce source brightness [5]. Various instruments that switch, stabilize, and feed electric current to a source are produced with electrical materials [6,7]. Materials that reflect the luminous flux in a direction are called mirror materials (various polished metals). Often, to protect the surface of metals from oxidation and corrosion, protective coatings are used in the form of silicate and organic transparent glasses (glass mirror materials) and films [8-10]. The main lighting characteristic of such materials is their reflection coefficient ρ. Materials with directional light transmission, also characterized by the constancy of the solid angle in the incident and transmitted light, are various kinds of flat silicate and organic glasses, transparent plastics. The redistribution of the light flux is carried out using lenses and various refractive elements (prismatic, cylindrical, spherical). Diffusers are sized according to the maximum power of the light source that can be used in the luminaire. The surface temperature of the diffuser made of silicate glass should be no more than 80–100 °C, and that of organic glass should be no more than 40–60 °C [11]. In contrast to luminaires with specular and diffuse reflectors, for luminaires with closed diffusers the concept of gain does not make sense, since for them it is usually less than unity. The efficiency of a luminaire with smoky and frosted glass diffusers is always slightly higher than the efficiency of luminaires with diffuse diffusers [12]. To illuminate administrative and public buildings, schools, theaters, industrial premises with light ceilings and walls, lamps with diffusers made of muted silicate and organic, as well as frosted and corrugated glasses, are widely used. Architectural lamps (chandeliers, ceiling lamps, floor lamps) have diffusers of various shapes as luminous elements [13]. Therefore, the calculation of such lamps is important for obtaining diffusers that are not only successful in shape, but rational in terms of lighting technology. The mechanical properties determine the materials from each other when a force is applied to the material, usually related to the elastic and plastic behavior for the composite material [14-16].

2. Materials and Methods

Lighting technical organic sheet glass is intended for the manufacture of lamp diffusers with fluorescent lamps, incandescent lamps and LED strips. Light technical organic sheet glass is a polymer of methacrylic acid methyl ester with the addition of polystyrene or polyvinyl chloride (to give the polymer a different degree of light scattering), obtained by block polymerization in silicate glass molds or by extrusion of low molecular weight polymethyl methacrylate. Lighting organic sheet glass is produced in the following grades [17]:

- SB - block;
- SBPT - block with increased heat resistance;

- SBS - block fire-retardant (flammable);
- SE - extrusion;
- SEP - extrusion transparent.

Glass grades SB, SBPT, SBS and SE are produced cloudy, grades SEP are transparent. Glass grades SB and SBPT can be produced colored. Glass grades SE and SEP are produced smooth and corrugated.

- Lighting technical organic block glass should be produced in the form of rectangular sheets with cut edges of the linear dimensions indicated in table 1. Rounded corners are allowed, the length of the rounding chord is not more than 100mm. non-straightness of the sides is allowed within the limits of tolerances for linear dimensions.

Table 1. Dimensions of lighting technical block glasses (dimensions in mm)

Brand glass	Thickness		Length	Width	Previous off in length and width
	Rated	Previous off			
SBPT	2.00	±0.35	1730	1400	+ 20
	3.00 4.00	+0.50	from 500 to 1360	from 400 to 1190	+10
	3.00 4.00	±0.70	from 1360 to 1750	from 1190 to 1550	
SBS	2.00	±0.35	from 500 to 1300	from 400 to 1150	+50
	3.00	+0.50			
	3.00		from 1300 to 1650	from 1150 to 1450	

Lighting organic extrusion glass should be produced in the form of rectangular sheets with linear dimensions indicated in table 2.

Table 2. Dimensions of lighting extrusion glasses (in mm).

Rated thickness	Previous off for smooth plexiglass	Length	Previous off	Width	Previous off
3.00; 3.50; 4.00	±0.50	1400 1500 1670 1700 1830 1900	±10	1200 1200 1140 1200 1200 1200	-60 -60 -40 -60 -40 -60

In terms of lighting performance, lighting engineering smooth unpainted organic glass must comply with the standards specified in table 3. Lighting indicators for corrugated and painted glass are not standardized.

Table 3. Requirements for lighting technical smooth glass according to lighting indicators.

Appearance	Lighting technology nic groups	Norms		
		Scattering degree ν	Coefficient transmission, τ	Coefficient acquisitions, α, no more
1. Transparent	-	-	Not less than 0.88	-
2. Cloudy	I	0.02–0.15	0.75–0.90	0.10
	II	0.16–0.40	0.66–0.85	0.10

	III	0.41–0.60	0.55–0.75	0.10
	IV	0.61–0.80	0.40–0.65	0.10
	V	0.65–0.80	0.20–0.39	0.10

2.1. Lighting Glass Testing Methods

Consider the basic requirements and rules for testing lighting glass. Test specimens are taken from a strip cut from one side of the sheet. It is allowed to take samples from the corners of the sheet. Thickness, appearance, physical-mechanical and lighting parameters are determined at a distance not less than 40mm from the edge of the sheet [18]. The appearance of glass is checked with the naked eye at a distance of 250-400 mm from the surface of the sheet in natural light or fluorescent light. Silicate glass leaching marks are determined by applying a stencil made from a sheet of thick paper or cardboard. Foreign inclusions are measured with any measuring tool that provides a measurement error of no more than 0,1mm. Block glass haze inhomogeneity , craters, and extrusion glass bleed are determined by comparison with a duly approved control [15,18]. The length and width of glass sheets are measured with any measuring tool - that provides a measurement error of not more than 1 мм. The thickness is measured with a micrometer according to GOST 6507-78 or a dial indicator according to GOST 577-68, along the perimeter at four points (in the middle of each side) with an error of no more than 0,01 мм. The softening temperature is determined according to GOST 15088–83 at a test load of (50 ± 1) N at a temperature rise rate of 120°C/h. Impact strength is determined according to GOST 4647–80 on five type 3 samples without notch and thickness equal to the glass thickness, with a pendulum velocity of 2.9 m/s at the moment of impact. The impact strength of extruded glass is determined across the direction of extrusion. Test specimens are kept at a temperature of (23 ± 2) °C for at least 3 hours. Tests are carried out at the same temperature. Combustibility is determined according to GOST 12.1.044–84 by the oxygen index method. The transmission coefficients (τ) and reflection coefficients (ρ), as well as the degree of scattering (ν), are determined on a spherical universal photometer of the FSHU type (VNISI setup) according to the instructions attached to it. In this case, the transmission and reflection coefficients are measured when the light beam is incident at an angle of 4° to the normal to the sample surface [13,19].

The degree of scattering (ν) is calculated by the formula:

$$\nu = \frac{I_{40}}{I_0} \tag{1}$$

Where I_{40} and I_0 are the light intensity from the light spot on the surface of the - measured sample in transmitted light at angles of 40° and 0° to the normal when the light beam is incident perpendicular to the sample surface. The absorption coefficient (a) is calculated by the formula:

$$\alpha = 1 - (\tau + \rho) \tag{2}$$

where τ is the transmittance; ρ is the reflection coefficient. Lighting indicators are determined on three samples with a size of at least 60-60 ×mm and a thickness corresponding to the thickness of the glass. The test result is taken as the arithmetic mean of the results of three parallel determinations, rounded to the second decimal place [20]. The polymer was applied using a hand lay-up molding process technique for the composite material. The process is done by preparing a dimensional mold 20 x 20 cm, then a careful cleaning process is carried out to avoid scratches and to avoid deformation of the sample surfaces and following with curing dry the mold [20]. Then the mold is covered with a layer of transparent insulation from the adhesive fablon on the surrounding walls in order for the resin model not to stick to the casting mold after its hardening, and for the castings to be extracted from it after the completion of the process sclerosis, after the casting process is completed, the second metal plate is placed over the mold with weights placed on it to pressurize it the mold to ensure that all bubbles come out of it, then it is left for 24 hours to solidify, after which the mold is placed in an oven for three hours until it is completely solidified for the purpose of completing the curing process, which is drying at a temperature of 55-60 C^{o} necessary stage to get the best tangle. Figure (1) shows the samples produced after hand lay-up molding process technique [18].

Figure 1. Samples prepared after hand lay-up molding process technique. (A)-Acrylic 4mm WOP 35%, (B)-Monolithic polycarbonate 1.5mm diff 60%, (C)-Monolithic polycarbonate 2mm diff 80%, (D)-Monolithic polycarbonate 1.5mm diff 90%, (E)-Polystyrene gpps with 2mm “chipped ice” embossing (light falls on the corrugated edge), (F)-Polystyrene gpps with 2mm “chipped ice” embossing (light falls on a smooth edge).

3. Results and Discussion

Transmitting, reflecting and absorbing abilities of lighting glass samples were obtained on an OL 700-31 spectrophotometer operating in a two-beam scheme. Table (4) shows the integral transmission, reflection and absorption coefficients of the samples, figures 2-7 shows the spectral coefficients.

Table 4. Integral transmission, reflection and absorption coefficients of lighting glass samples (τ - integral transmission coefficient, ρ - integral reflection coefficient, α - integral absorption coefficient).

Glass brand	τ, %	ρ, %	α, %
Acrylic 4 ммWOP 35%	35.75	55.60	8.65
Monolithic polycarbonate 1.5mm diff 60%	51.78	36.90	11.32
Monolithic polycarbonate 2mm diff 80%	71.28	13.58	15.15
Monolithic polycarbonate 1.5mm diff 90%	70.71	16.43	12.86
Polystyrene gpps with 2mm “chipped ice” embossing (light falls on the corrugated edge)	88.28	7.62	4.10
Polystyrene gpps with 2mm “chipped ice” embossing (light falls on a smooth edge)	85.19	8.03	6.78

Analysing the data in table (4), we can conclude that out of 6 samples, on which the manufacturer indicated the transmittance, only one corresponded to the indicated information, namely "Acrylic 4 ммWOP 35%". In other cases, the measured reflection coefficient turned out to be lower than indicated. For other glasses an increase in transmission capacity is observed if light falls on an uneven edge. This is due to a decrease in Fresnel losses and also an increase in reflective and absorbing abilities is observed if the light falls on a flat edge [21].

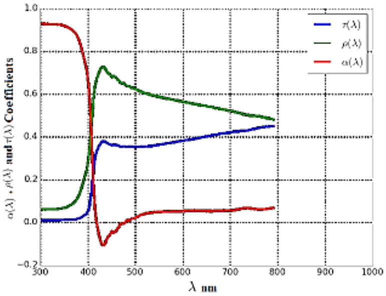

Figure 2. Spectral transmission, reflection and absorption coefficients of the sample "Acrylic 4mm WOP 35%"

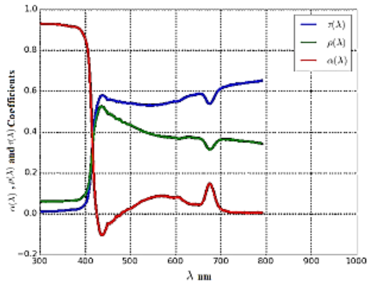

Figure 3. Spectral transmission, reflection and absorption coefficients of the sample "Monolithic polycarbonate 1.5mm diff 60%"

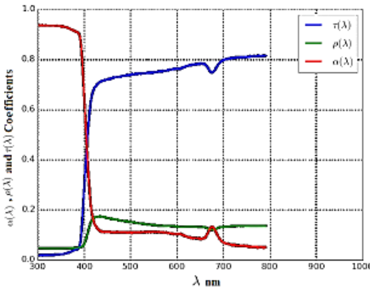

Figure 4. Spectral transmission, reflection and absorption coefficients of the sample "Monolithic polycarbonate 2mm diff 80%"

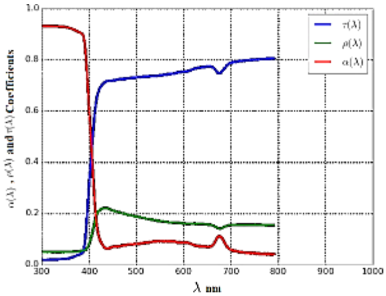

Figure 5. Spectral transmission, reflection and absorption coefficients of the sample "Monolithic polycarbonate 1.5mm diff 90%"

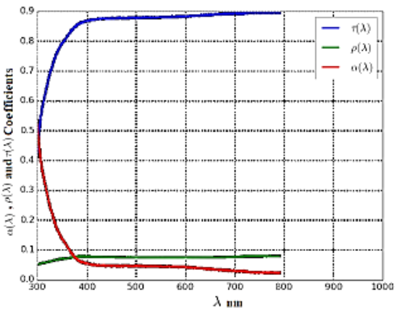

Figure 6. Spectral transmittance, reflection and absorption coefficients of the sample "Gpps polystyrene with 2mm crushed ice embossing" (light falls on the corrugated edge).

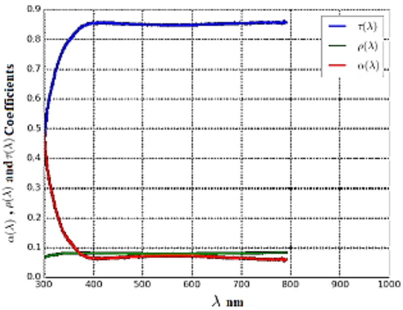

Figure 7. Spectral transmittance, reflection and absorption coefficients of the sample "Gpps polystyrene with 2mm crushed ice embossing" (light falls on a smooth edge).

Analysing samples "Acrylic 4mm WOP 35%" and "Monolithic polycarbonate 1.5mm diff 60%" in the absorption spectrum in the region of 420-480 nm, negative branches are observed, which indicates the luminescence of these samples, as shown in figures 2-7. For samples made of acrylic and polycarbonate, with increasing wavelength, the reflectivity decreases, and the transmission increases. For polystyrene samples, with increasing wavelength, the reflection coefficient practically does not change, and the reflection coefficient does not change, or changes slightly. For polystyrene samples in the visible wavelength range in the region of 660-690 nm, a peak in the absorbing capacity is observed. Note that this effect is observed for samples whose thickness does not exceed 3mm. For a sample whose thickness was 4mm, this peak was not present.

4. Impact Results

In terms of physical and mechanical parameters, lighting engineering smooth unpainted organic glass must comply with the standards specified in figure (8). Physical and mechanical parameters for corrugated and colored glass are not standardized.

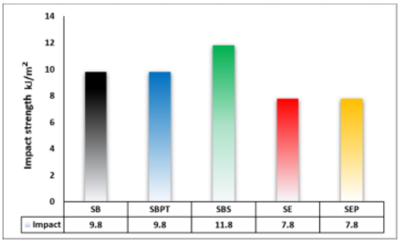

Figure 8. Mechanical properties of impact strength for lighting materials.

The impact test was made by charby method. 5 primary impact test specimens were prepared, which are (SB), (SBPT), (SBS), (SE) and (SEP) in order to know the best impact strength value for each sample. The results showed that the best impact strength in laboratory conditions was specimens of (SBS) materials after adding PC and PVC to PMMA because the reinforced used in the research contain binders mainly to increase the illumination and impact against fracture and scratches [18,21].

5. Conclusion

The methods of obtaining and physical and mechanical characteristics of organic glass used in the lighting industry were studied, the spatial distribution of radiation transmitted through glass and the influence of the location of the glass on the lighting parameters of the lamp was studied. As a result of the work carried out, relationships were established between the spectral and spatial distribution of the transmitted radiation and the composition, as well as the thickness of the lighting glass. A number of glass samples showed the presence of weak luminescence. And based on the results, the following main conclusions can be drawn:

a) If the corrugated edge is directed into the luminaire body, then the efficiency is insignificant, but still increases. In this case, the light distribution changes in such a way that the unevenness of illumination over the illuminated surface increases.
b) The spectral transmittance depends not only on the composition of the lighting glass, but also on the geometry of the surface on which the light falls. If light falls on a corrugated face, then this parameter practically does not change after 400 nm.
c) For some samples of lighting glasses, weak luminescence is observed.
d) With a decrease in the size of the prisms, in the case when the light falls on a smooth face, the luminaire's CSS becomes narrower.

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