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Nanoporous Anodic Alumina Membrane as Passive Light Amplifier

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Abstract: Anisotropic optical properties of free nanoporous anodic alumina films transparent in the visible spectrum for the restricted range of pore diameters and pore intervals are discussed. The basic experimental procedure is presented for the production of these films. The results obtained show that the nanoporous structure of anodic alumina films can be purposefullyused in LCD to control a light propagation.

Keywords: Anodic alumina, Membrane, Light scattering, Light propagation.

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1. Introduction

Important elements that increase the optical characteristics of the LCDs are diffuse-scattering films. These films are designed to create a uniform illumination of the LCD backlight, to eliminate glare and reduce the reflection coefficient, to increase the brightness of screens and change the viewing angle.

One of the most promising directions in the technology of creating films with diffuse scattering is the development of holographic forming structures with a given angle of the maximum intensity of light scattering [1]. Diffuse such films possess an optical transmittance in the region 365 – 1600 nm. Depending on the angle of light distribution, the transmittance reaches values of 85 – 92 %. These films are anti-reflective and reduce Fresnel losses.

The search for new technologies and materials for diffuse-scattering films continues. In this regard, films made of nanoporous anodic aluminum oxide are very promising among the new poorly studied materials. Nanoporous anodic alumina was originally considered as insulating component of semiconductor silicon microchips with metal aluminum conductors. It can be developed by electrochemical anodizing of aluminum to get free membranes with thickness up to 1 mm. Depending on the anodization regimes, pore size can be made from a few nanometers to hundreds of micrometres. Though structural properties and basic electrochemical routes are subject of extensive research during last five decades, only in the recent years unique optical properties of nanoporous anodic alumina have been discovered: a high transmission along pores with simultaneous high reflection from cut-edges [2], an optical birefringence [3], etc. So, nanoporous anodic alumina films are promising to control a light propagation in liquid crystal display devices [4].

2. Experimental

The 100 mm thick aluminum foils were used as initial substrates. The back side of the samples was protected with a masking layer. The two-stage porous anodization was made from the front side of the sample. The pore diameter and spacing are dictated by parameters of the anodization process, specifically by the electrolyte composition and the anodization voltage. High-ordered anodic alumina pore array with controllable parameters can be formed [5-8]. Structural properties of anodic alumina (porosity, pore size and shape) and therefore oxide parameters (electrophysical, optical, thermal, etc.) as well as thicknesses of porous layers are controlled by the anodization parameters. The masking layer was removed from the back side and the rest of aluminum foil was etched to get free-standing films of porous alumina. Fig. 1 illustrates the technological stages of the formation of nanoporous alumina membranes.

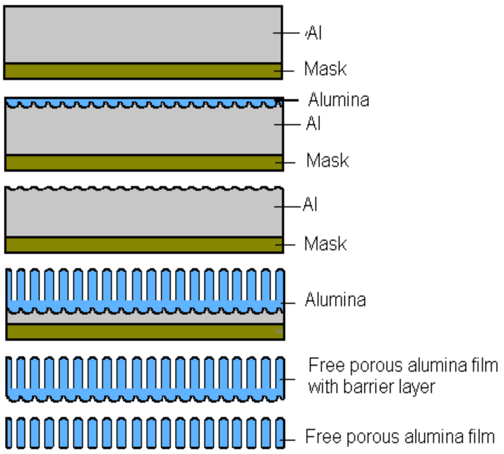

Fig. 1. Technological stages for the formation of optically homogeneous and transparent alumina films.

Then the light transmission through porous anodic alumina membranes was studied. For comparison, a commercial Kimoto PF-90S M/M (K) holographic scattering film was used.

The spectra of light transmission by porous anodic alumina films were studied using an experimental test desk, the scheme of which is shown in Fig. 2.

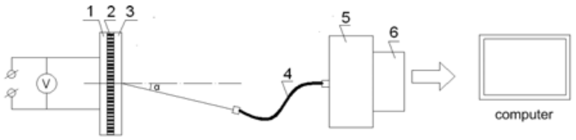

Fig. 2. Test desk scheme for the study of the light transmission spectra: 1 – LED backlight, 2 – porous anodic alumina film, 3 – LCD indicator, 4 – waveguide, 5 – spectrograph Solar TII S-3801, 6 – CCD matrix LN/CCD-1152-E.

The detector consists of a highly sensitive spectrometer and a waveguide that transports light from the point of space under study to the spectrometer. As a power source, a voltage source was used, the value of which can be continuously adjusted. The ability to change the detection angle α is realized in this scheme (in our experiments the registration was carried out along the normal to the surface of the samples, i.e., α = 0 °).

For the research, three types of porous anodic alumina membranes were prepared under various anodizing conditions as shown in Table 1. For comparison, a commercial holographic Kimoto PF-90S M / M (K) holographic scattering film was used.

Table 1. Anodizing conditions and output parameters of anodic alumina membranes.

No.	Electrolyte	U_a, (V)	T_a, (ºC)	Sample color	Thickness, µm
1.	5 % $H_2C_2O_4$	60	2	yellow	230
2.	10 % H_2SO_4	25	2	colorless	100
3.	12 % H_3PO_4	160	9,5	white	50

3. Results and Discussion

Fig. 3 shows the intensity of light scattering along the pores of alumina membranes for different angles of incidence.

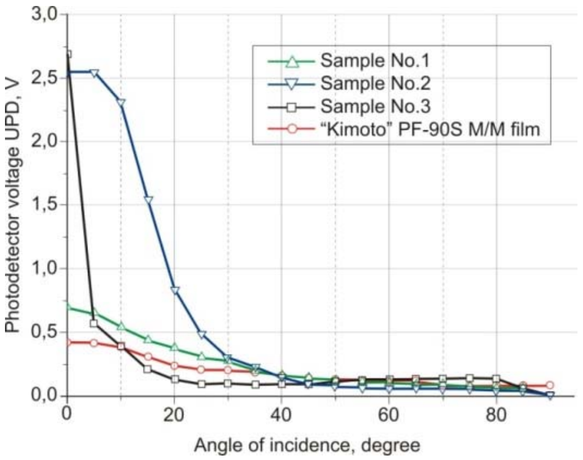

Fig. 3. The intensity of light scattering along the normal to the surface at different angles of incidence.

It can be seen that varying the membrane formation conditions makes it possible to obtain both the samples that are similar in characteristics to a commercial holographic scattering film as well as the samples with a pronounced predominance of scattering along pores. The latter property characterizes the possibility of using aluminum oxide films as passive brightness amplifiers for illuminating liquid crystal indicators and displays.

Fig. 4 demonstrates the emission spectra of the LCD backlight LED system with a nanoporous alumina membrane (red line) and without the membrane (black line) as well as differential spectrum.

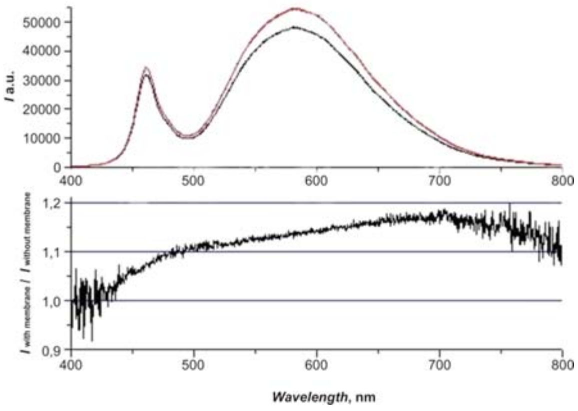

Fig. 4. The emission spectra of the LCD backlight system with a nanoporous alumina membrane (red line) and without the membrane (black line) (upper panel) and differential spectrum (lower panel).

As can be seen from Fig. 4, when the porous alumina membrane is applied, the radiation intensity of the LED illumination system increases in the entire spectral range studied (from 400 to 800 nm). The signal amplification at the detector in the visible range was obtained by an average of 11 % (the maximum gain reaches 18 %).

Fig. 5 shows the differential emission spectra of the LCD backlight system for three samples of nanoporous anodic aluminum oxide.

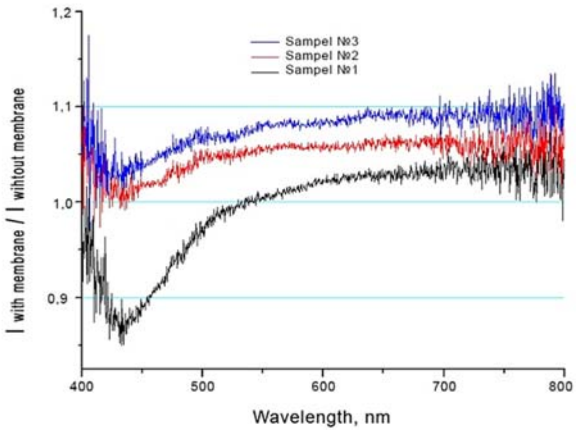

Fig. 5. Differential emission spectra of the LCD backlight system for three samples of nanoporous anodic aluminum oxide.

As can be seen from Fig. 5, the LED backlight system in combination with porous anodic alumina membranes provides higher radiation intensity than the LED backlight system without a membrane in the entire wavelength range studied.

4. Conclusions

The results obtained show that nanoporous structure of electrochemical anodic alumina films can be purposefully used to control light propagation, namely, to perform anisotropic light scattering in LCD backlight systems as well as the luminance enhancement.

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