ACTUAL POLARIZERS AND METHODS OF LIGHT MICROSCOPY

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Abstract
The paper presents results of the experimental determination of the residual transmission of polarizing filters versus the incidence angle of the polarized light. Features of the optical schemes arrangement for the microscopic polarizing technique are discussed.

Keywords: polarizing filter, polarization methods of microscopy

New microscopic techniques, such as differential and interferential contrast (DIC), DIC with circular polarization, PlasDIC and luminescence, TIRF 3 (fluorescent microscopy with total internal reflection) have been actively developing recently [1]. The modern microscopy allows to receive not only high-quality images, but also to make high accuracy quantitative estimates [2] of the images of specimens. These developments were possible only on the basis of the novel kit of optical elements.

The paper aims at the experimental study of the characteristics of thin-film polaroids and at the analysis of opportunities of their application in polarization techniques of light microscopy.

The polarizing prisms used in microscopy of, for example, Nicole from the Iceland spar, are now being replaced by polarizing films. A limited term of service of such polaroids does present a problem, though.

The following are known to be basic characteristics of polaroids: the main transmission coefficient (amplitude- and energy-related); the main transmission coefficients ratio; degree of the radiation polarization; the main transmission optical densities; the dichroic ratio; the polarizing defect. These characteristics are good enough for crystal polarizing materials, but the producers nowadays offer polarizing films with the degree of polarization almost as good as that of crystals. The films have quite a number of advantages versus other polarizers, specifically, the fact that using polarizing film it is possible to obtain polarized light beam of bigger diameter; small thickness of a polar-
oid allows to set it up in any place of an optical system; the light passing through the polaroids has a greater range of wavelengths. Therefore, this makes the implementation of new optical schemes in the polarization microscopy possible.

Features of the optical schemes arrangement for the polarization techniques in microscopy

We have conducted a study of samples of polarizing light filters and offered a new observation approach in the polarization light microscopy. The distinctions of two ways of observations in the polarized light are illustrated by the schemes in Fig.1.

![Diagram](image)

**Fig.1 – Schemes for observations in the polarized light.**

The left part of the drawing typifies an observation scheme I. The light from source coming through the light color filter and linear polarizer (it is assumed that its ability to completely pass one linear polarization and completely absorb polarization, orthogonal to it, is ideal), then passes through a micro objective. Then the light passes the analyzer (it is assumed to be ideal, too), with the image of object being built in the intermediate image plane. The surface of each lens of micro objective depolarizes the light. After passing the micro objective, orthogonal component \( E_\perp \) will be present, apart from \( E_\parallel \) component.

Scheme II (Fig. 1b), in the right part of the drawing, is similar to scheme I (Fig. 1a) except for the analyzer location. The analyzer is installed in front of the micro objective. It means that depolarization brought about by the surface of each lens of micro objective does not affect the process of the object image building.

The image is built in the intermediate image plane. The image built by micro objective according to scheme I (Fig.1a) due to the presence of polarizing component \( E_\perp \), passed through the analyzer, will have a smaller contrast, than the image built according to scheme II (Fig.1b). Scheme II rules out the production of polarizing component \( E_\perp \), since \( E_\parallel \) component will be absorbed by the analyzer, therefore, preventing it from passing through the micro objective, whereas the micro objective will not introduce a depolarized component in the image.
Thus, we exclude the depolarizing effect of the microlens from the image. The contrast in the image obtained will tend to increase.

**Experimental studies of polaroids**

The following characteristics of polarizing light filters were tested: their uniformity and residual transmission of specimens depending on the incidence angle of the light onto specimen. The characteristics uniformity of the films was tested on monochromatic zero-ellipsometer LEF-3M, and variations of residual transmission were measured on the chosen portion of the film surface. The results for different samples are given at Fig.2. Sample 9 is Nicole prism.

Based on the results of measurements for determining the angle of extinction of the analyzer versus the light incidence angle onto the polarizing film, there have been built curves for the spread of the analyzer angles. The data on the extinction angles spread of the analyzer make it possible to determine the uniformity of films. The less is the spread, the higher quality is the specimen.

![Graph](image)

**Fig. 2 – Polaroids quality estimates.**

**Measurements of angular dependences of residual transmission of specimens.** The schematic optical diagram of measurement of angular dependences of residual transmission of specimens (Fig. 3) consists (along the ray travel path) of the laser, quarter-wave plate, polarizer, diaphragm, the analyzer and the photo-sensor element.

![Diagram](image)

**Fig. 3 - Scheme for measurements of dependences of residual transmission of samples versus incidence angle of the light beam falling onto them.** L - He-Ne laser; λ/4 – quarter-wave plate; P - polarizer in the frame; diaphragm with 0.8 mm diameter; f - tested polarizer sample; A - analyzer; Ph - photodiode FD-24K operating in the linear mode.

While measurements proceeded the polarizer and the analyzer were positioned criss-cross with the specimen laid perpendicular to the light beam falling on the turntable. The photocurrent was measured by voltmeter. The turntable with the specimen rotated round the vertical axis at 2°
steps as long as it was possible for it to make turns. Further, based on the results of the measurements we built residual transmission curves versus the angle of light incidence onto the sample. The plots for samples 4 and 5 are given at Fig. 4.

![Graphs showing transmission (Voltage) versus rotation angle of specimen No. 4, 5 for two mutually perpendicular planes.](image)

*Fig. 4 – Transmission (Voltage) versus rotation angle of specimen No. 4, 5 for two mutually perpendicular planes.*

The specimen is investigated in two mutually perpendicular planes, for which the polarizer is turned by 90° from its original position, with the specimen exposed to minimum intensity. The technique runs repeatedly. According to the results obtained from the measurements we built the residual transmission curves versus the angle of light incidence onto the polaroid.

**Experiment with test objects**

We used the following as test objects: line pattern with target spacing; specimen of chalcocogenide film on the glass underlying layer with latent images; liquid crystal screen (black-and-white), having clear outlines (fringe) along the perimeter.

The screen photometry data are given in Fig. 5. Two micro objectives magnifying by 20 and 10 times were used, data are given for the micro objectives of 10 times.
Fig. 3 – Photometry of images

Conclusions

Based on the results and findings of the experimental works some practical approaches for studying polarizing films were developed and improved. Dependence of residual transmission versus film turning angle both at vertical and horizontal position of polarizer axis are usually not controlled by the manufacturers, however, this has proven a key factor for the technique developed. We conducted the experimental study of the light passing through polarizing films made by different producers who utilized different technologies, and the comparison of their characteristics was carried out.

Measurements have shown that mean square deviation from average value of transmission differ strongly (from 5 to 95 %) for specimens from different producers. It was found out that polarizing films with improved characteristics on residual transmission have been developed by the S.I.Vavilov NPK GOI, Federal State Unitary Enterprise (specimen No. 3). They possess high transmission values in visible area of the range, close to transmission coefficients within the range of 400-800 nanometers, given t high polarization degree (P > 99 %) and uniformity of polarization plane position on the film cross-section.

The results of testing of the new polarizing technique attests to the efficiency of use of polarizing glass layers. The new scheme for polaroids arrangement in comparison with the standard layout, has shown an increase in image contrast by 5.8 % for micro objective of 10× and by 4.4 % – for micro objectives of 20×.

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References