DETERMINING THE POLARIZATION STATE OF THE RADIATION CROSSING THROUGH AN ANISOTROPIC POLY (VINYL ALCOHOL) FILM

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The birefringence of polymers derives from the asymmetry of their chemical structures. A polymer material may become birefringent when the polymer foils are stretched. Knowing the birefringence dependence on the stretching degree of the polymer film at a given thickness, we determine the value of the stretching degree on which the film can be used as a compensating blade.

Key words: polyvinyl alcohol, birefringence, stretching degree, compensating blade.

1. INTRODUCTION

The polyvinyl alcohol is a thermoplastic polymer with many applications. The anisotropy properties of the polyvinyl alcohol are due to the asymmetric placement of the molecules [1]. This condition is obtained by subjecting the film to some external requests so that the molecules arrangement, which is disordered in the isotropic substance, be disturbed and display an order which depends on direction.

We analyze the possibility of using polyvinyl alcohol films to obtain compensatory blades. The aim of this paper is to establish the change of polarization state of the monochromatic radiation after passing through an anisotropic polymer layer. The propagation of light in anisotropic media depends heavily on its polarization. Polarization state is conventionally described by the electric field intensity vector. Let be a plane monochromatic wave [2], [3] which propagates the *z* axis. The electric field vector is in the *xy* plane. The electric field intensity vector is decomposed in two components E_x and E_y. The general equations for E_x and E_y are written as:

$$E_x = E_{0x}\cos(\omega t - kz + \delta_x) \quad (1)$$

$$E_y = E_{0y}\cos(\omega t - kz + \delta_y) \quad (2)$$

The two components satisfy the equation:

$$\left(\frac{E_x}{E_{0x}}\right)^2 - 2\frac{E_x}{E_{0x}}\frac{E_y}{E_{0y}}\cos\delta + \left(\frac{E_y}{E_{0y}}\right)^2 = \sin^2\delta \tag{3}$$

The equation (3) describes an ellipse, so the general polarization state corresponds to the general state of the elliptical polarized light. The ellipse shape depends on the phase difference between the two components and on the size of the two amplitudes.

The light is linearly polarized if the displacement of vector peak $\vec{E}$ is rectilinear. This occurs if:

$$\delta = \delta_y - \delta_x = m\pi, \quad m = 0, 1, ... \tag{4}$$

If peak $\vec{E}$ describes a circle, it is an indication of circularly polarized light.

This state of polarization is achieved when:

$$\delta = \delta_y - \delta_x = \pm\pi/2 = \pm\,\pi/2 \text{ and } E_{0y} = E_{0x} \tag{5}$$

If the general elliptical polarization state is obtained, the peak $\vec{E}$ describes an ellipse. If $\delta \in (0, \pi)$, there is elliptical right polarization; If $\delta \in (\pi, 2\pi)$, there is elliptical left polarization. If $\delta = \pm\,\pi / 2$ the ellipse axes coincide with the Ox and Oy axes.

2. THE EXPERIMENTAL PART

A system of two polarizing filters was used. Between the polarizers there is a polymeric film, perpendicularly oriented to the propagation direction of a beam of parallel, monochromatic light rays, with propagation direction Oz (Fig. 1).

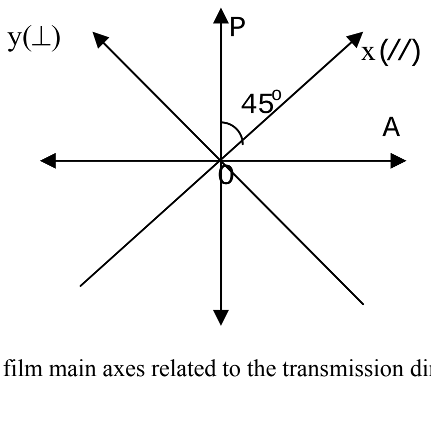

Fig. 1 – Orientation of the film main axes related to the transmission directions of the polarizers.

The main directions of anisotropy are the stretching film direction (Ox) respectively the perpendicular one to it (Oy). These neutral lines are rotated 45 degrees from the transmission directions of the polarizers which are mutually perpendicular. When entering the anisotropic blade, the electric field intensity vector is decomposed into two components linearly polarized in the directions parallel to the film main axes. The two components propagate in the anisotropic medium with different velocities whose values are determined by the main refractive indices n_{II} and $n_{\perp}$.

n_{II} is the refractive index of the film for radiation having the electric field direction parallel to the stretching direction, and $n_{\perp}$ is the refractive index of the film for radiation that has the electric field direction perpendicular to the stretching direction.

$\Delta n = (n_{II} - n_{\perp})$ is the polymer film birefringence [4]. A phase angle appears between the components that oscillate on the two directions:

$$\delta = \frac{2\pi}{\lambda}\Delta nd \tag{6}$$

This makes the polarization state of the radiation be amended after passing through the anisotropic blade. The flux density of the emerging beam [5] can be calculated using the relationship:

$$\varphi_A = \varphi_P \left(\sin^2 \delta / 2\right) \tag{7}$$

We thus express the system transmittance factor:

$$T(\lambda_0) = \varphi_A / \varphi_P = \left[\sin^2 \frac{\delta}{2}\right] \tag{8}$$

The anisotropic polymer films were prepared from polyvinyl alcohol (PVA) using the method presented in [6]. The film anisotropy was obtained by stretching under heating. The degree of stretching γ, (γ = a / b) was expressed as the ratio of the semi axes of an ellipse in which a circle drawn on the PVA foil degenerated by stretching.

According to [6], the induced birefringence depends on the stretching degree of the PVA films for different thicknesses. The birefringence tends to decrease according with the increasing film thickness. For a given thickness, the birefringence tends to increase linearly (Fig. 2) for a stretching degree smaller than 2,5. For more than 2,5 degrees, slope of the line is smaller, proving saturation in the alignment of the polymer chains for the high degree of stretching. For thicknesses greater than 2 mm, the internal alignment process of the polymer chains is more complex and the dependence on the stretching degree is not linear any more.

3. RESULTS AND DISCUSSIONS

For a 1.3 mm thick polymer film whose the stretching degree varies between 1.00 and 4.00, the birefringence *versus* stretching degree is shown in Fig. 2.

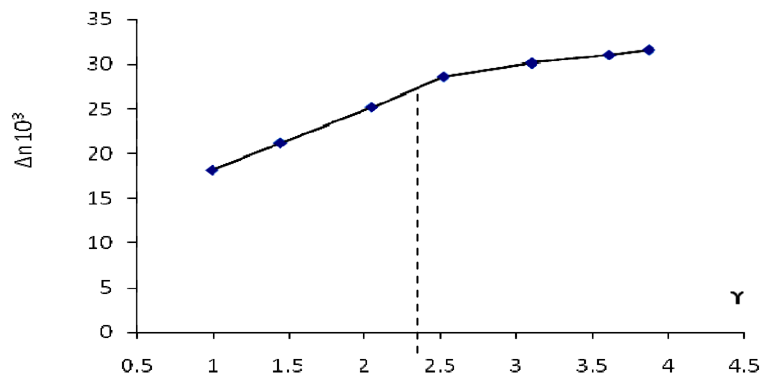

Fig. 2 – The birefringence Δn(λ) *versus* stretching degree of a film with a given thickness.

We consider the curve as being composed of two linear sections. Where there are the expressions (9), (10)

$$\Delta n = 0{,}0070\cdot\ \gamma + 0{,}0110;\quad \gamma = 1{,}00 \div 2{,}50 \tag{9}$$

$$\Delta n = 0{,}0023\cdot\ \gamma + 0{,}0227;\quad \gamma = 2{,}50 \div 4{,}00 \tag{10}$$

The change of polarization state of the monochromatic radiation with the wavelength of 589,3 nm will be analyzed. The polarization state of the emerging radiation was estimated for various degree of stretching. Once the stretching degree is modified, we have a change in the birefringence and the phase shift δ. Due to the regularity of the harmonic functions involved in the relationships used, the phase shift values were reduced to the range 0-2π. The accuracy of determining the degree of stretching allows us to find a good approximation of the phase shift values corresponding to cases of polarization states, close to the ideal case.

Table 1

The polarization state of radiation depending on the stretching degree

Nr. crt.	γ	Δn	δ (grad)	T	Polarization state
1.	2,46	0,0282	91,27	0,5111	right circular
2.	2,67	0,0288	224,44	0,8570	left elliptical
3.	3,04	0,0297	180,27	1,0000	linearly with changed azimuth
4.	3,36	0,0304	44,78	0,1451	right elliptical
5.	3,73	0,0313	0,61	0,0000	linear

4. CONCLUSIONS

If after going through the anisotropy film, the radiation remains linearly polarized, with the same azimuth, the foil acts as a wavelength blade (γ = 3,73). In this situation, the flux density and the transmittance after analyzer are minimal.

When the radiation is linearly polarized with the changed azimuth, the foil acts as a semi wavelength blade (γ = 3,04) so thus case the flux density and the transmittance are maximum. The oscillating direction of electric field intensity of the emerging radiation is parallel to the transmission direction of the analyzer.

For a phase shift (2m +1) π / 2, the foil acts as a quarter wavelength blade (γ = 2,46).

REFERENCES

1. www.physics.pub.ro/Cursuri/Gabriela_Cone_-_Optica.../Optica3.pdf.
2. Kužel P., *Electromagnétisme des milieux continus— OPTIQUE —Licence de Physique, Institut Galilée, Université Paris-Nord* 2000 / 2001, pp. 31–38.
3. Moisil D., Moisil G., *Teoria si practica elipsometriei*, Ed.Tehnica Bucuresti, 1973, pag 20.
4. Pop V., Dorohoi D.O., Cringeanu E., *A new method for determining birefringence dispersion,* J. Macromol. Sci., Physics, B33, Iss. ¾, 1994, p.373.
5. Delibas M., Dorohoi D.O., *Indrumar de Optica*, Litografia Univ. Al.I.Cuza, Iasi, 1999.
6. Nechifor C.D., Angheluta E., Dorohoi D.-O., *Birefringence of Etired Poly (Vinyl Alcohol) (PVA) Foils*, Materiale Plastice, 47, Nr.2, 2010, pag.164.