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Birefringence control of oriented polymeric films by anisotropic structure

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Optical anisotropy of polymeric films has been studied intensively in order to produce various types of optical films. In particular, wavelength dispersion of the optical retardation which is given by a product of birefringence and thickness is desired to be controlled correctly as a technical trend. In case of a quarter-wave plate, the retardation has to be a quarter of wavelength. It means that the birefringence of a quarter-wave plate has to increase with wavelength. Although this extraordinary wavelength dispersion is necessary for advanced displays, the orientation birefringence of general polymers decreases with wavelength. In this study, I focus on optical anisotropy of uniaxial-stretched films composed of conventional polymers. Moreover, form birefringence originated from structural anisotropy in a film was investigated to control the wavelength dispersion of the films.

Effect of uniaxial strain on optical anisotropy for a cellulose triacetate (CTA) film is investigated by simultaneous measurements of stress and birefringence. Strain rates at hot-stretching process hardly affect orientation birefringence of CTA, although stress level increases with increasing the strain rate. Furthermore, birefringence is found to decrease slightly after the cessation of the hot-stretching, i.e., stress relaxation process, beyond its glass transition temperature. Wide-angle X-ray diffraction patterns reveal that the orientation of crystals in the stretched film is not relaxed during the stress relaxation process. These results indicate that the orientation birefringence of CTA is mainly determined by the orientation of crystals.

The form birefringence originated from porous structure is investigated to produce a film showing extraordinary wavelength dispersion. A hot-stretched CTA film containing diisodecyl adipate (DIDA) shows negative orientation birefringence with ordinary wavelength dispersion, as similar to that of a pure CTA film; the absolute value of the birefringence decreases with wavelength. However, after extracting DIDA from the stretched film by immersion into an organic solvent, the birefringence of the film dramatically changes from negative to positive with extraordinary wavelength dispersion. SEM observation reveals that the film contains numerous ellipsoidal pores elongated to the stretching direction. Moreover, light transmittance of the porous film increases by decreasing the heating time and increasing the strain rate at hot-stretching process. The results indicate that the ellipsoidal pores provide the form birefringence as a positive value. The combination of form birefringence and orientation birefringence provides extraordinary wavelength dispersion. Moreover, the formation of dispersed phase, and thus the form birefringence as well as light transmittance can be controlled by conditions at hot-stretching process.

As another conventional polymer, polyethylene is employed. It is found that pure polyethylene films produced by the tubular-blowing method show positive birefringence with extraordinary wavelength dispersion. Wide-angle X-ray diffraction patterns reveal that chain axis of crystalline lamellae in the film is oriented to the flow direction. Moreover, stacked lamellae grown perpendicular to the flow direction appear, leading to the periodical change of the refractive indices in the flow direction. This structure provides the form birefringence. Furthermore, the wavelength dispersion of the refractive index of crystal region is significantly different from that of amorphous regions, which is responsible for the strong wavelength dispersion of the form birefringence. The sum of negative form birefringence originated from crystalline structure with strong wavelength dispersion and positive orientation birefringence can give extraordinary wavelength dispersion for the films.

Keywords: Optical film, Orientation birefringence, Form birefringence, Porous structure