Stock Sheets of Polycarbonate as Inexpensive Low-order Optical Wave Plates

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Abstract

The optical properties, specifically the linear retardance magnitude, of two thicknesses of McMaster-Carr polycarbonate sheets were characterized using a Xenon light source and an Axometrics Polarimeter. Retardance values were measured for multiple wavelengths and sheet orientations in order to determine the effectiveness of polycarbonate as an inexpensive zero order quarter- or half-wave plate. Results indicate that sheets with 0.118” and 0.0625” thicknesses behave as low (zeroth and first) order retarders. Further results show that quarter- and half-wave retardances are achieved across the visible spectrum by rotation around the fast or slow axis of 40 degrees or less.

Introduction

Low order wave-plates are commonly used in commercial and laboratory optical settings. In response to the high cost of these wave-plates, inexpensive alternatives such as overhead transparencies have been studied,[1] with results indicating that the transparencies behave as multi-order wave-plates. The multi-order characteristic of the transparency, along with its structural weakness, make it a less than perfect substitute for low order wave-plates. Thicker polymeric sheets offer much greater structural strength and exhibit linear retardance characteristics.[2] In this study, the linear retardance characteristics of 0.0625 inch and 0.118 inch McMaster-Carr polycarbonates are examined using Mueller matrix decomposition.

Methods and Materials

All measurements were taken using an Axometrics AxoScan™ Mueller Matrix Polarimeter and a Newport Oriel Apex Illuminator Xenon Arc Lamp as seen in Fig. 1. The polycarbonate was placed in a rotating stand between the polarization state analyzer and polarization state generator. Temperature measurements were taken using a ThorLabs TC200 Temperature Controller and SM1L10H Heated Lens Tube, with a section of polycarbonate placed within the lens tube and the temperature changed incrementally over a 24 hour period to allow thermal equilibrium to be reached.

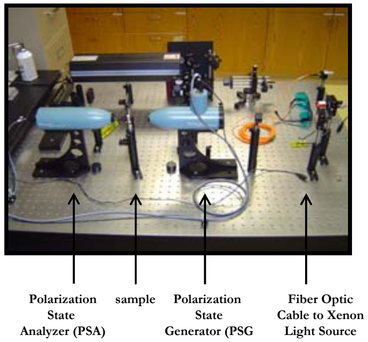

Fig. 1. Axometrics AxoScan™ Mueller Matrix Polarimeter

- fast, high-precision measurements of Mueller matrices for entire visible spectrum
- sophisticated data reduction algorithms for extracting detailed information from matrices

Results and Discussion

The results represented in Fig. 2 and Fig. 3 indicate that both the 0.118 inch and 0.0625 inch polycarbonates behave as low-order linear retarders. The small temperature dependence shown in Fig. 2 (a,b) is characteristic of low-order[1] linear retarders, with the 0.0625 inch being of slightly lower order. The exact order value is determined by analyzing the data in Fig. 3. At wavelengths far from absorption bands, the linear retardance as measured in nanometers is assumed to be a constant value.[1] The degree values of linear retardance for the entire visible spectrum are then applied to Eq. 1 to measure the ellipticity of light emerging from the polycarbonates. This data set forms a quasi-periodic triangle wave, as seen in Fig. 3 (a,b). By taking the wavelength values of two consecutive zero-degree ellipticity crossing points and applying them to Eq. 2, the order of the shorter wavelength is given as one-half the value of n. Using this method, it was determined that the 0.0625 inch poly-carbonate exhibits zeroth-order characteristics for wavelengths longer than 520 nm, and the 0.118 inch polycarbonate exhibits first order characteristics within the range of 500-780 nm.

Measurements were then taken to find at what wavelengths and incident angles quarter- and half-wave retardance could be achieved. Fig. 4 (a,b) shows the linear retardance values for the 0.0625 inch and 0.118 inch polycarbonates when rotated about the Slow and Fast Axis up to forty degrees. At normal incidence, quarter-wave values were achieved near 450 nm for the 0.0625 inch poly-carbonate and 750 nm for the 0.118 inch polycarbonate, as seen in Fig. 5 (a,b).

Eq. 1 $\chi = \frac{1}{2}\arcsin[\sin\delta]$ Eq. 2 $n = \frac{\lambda_2}{\lambda_2 - \lambda_1}$

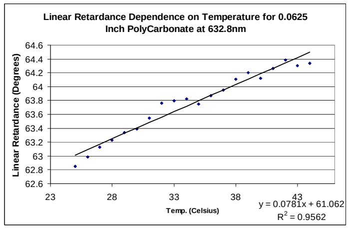

Fig. 2a Linear retardance increases by 0.078 degrees for every degree Celsius increase in temperature for the 0.0625 inch polycarbonate.

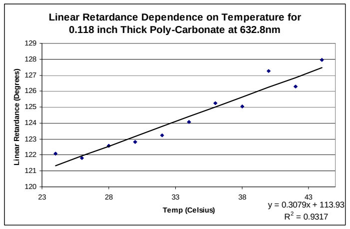

Fig. 2b Linear retardance increases by 0.31 degrees for every degree Celsius increase in temperature for the 0.118 inch polycarbonate.

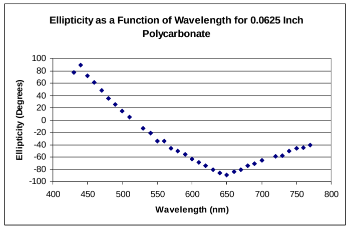

Fig. 3a Using the wavelength values at the peaks of the triangle wave, the order was calculated to be zeroth order for wavelengths longer than 520 nm for the 0.0625 inch polycarbonate.

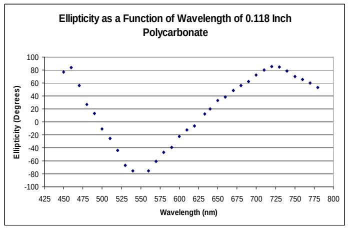

Fig. 3b Using the wavelength values at the zero ellipticity crossings, the 0.118 inch polycarbonate was calculated to be first order in the range of 500-770 nm.

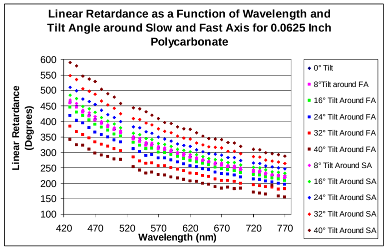

Fig. 4a The range of linear retardances that can be attained at each wavelength by tilting the 0.0625 inch linear retarder up to 40 degrees about the Fast or Slow Axis.

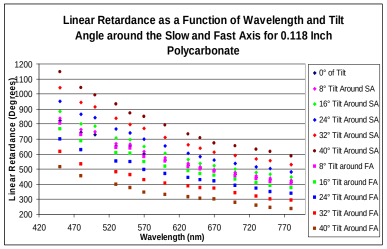

Fig. 4b The range of linear retardances that can be attained at each wavelength by tilting the 0.118 inch linear retarder up to 40 degrees about the Fast or Slow Axis.

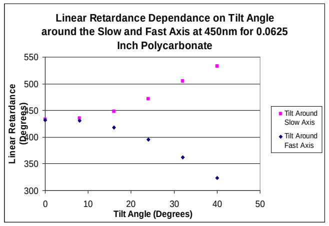

Fig. 5a The range of linear retardances attained at 450nm for the 0.0625 inch linear retarder, including nearly quarter waver at normal incidence.

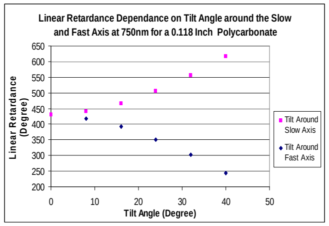

Fig. 5a The range of linear retardances attained at 750nm for the 0.118 inch linear retarder, including nearly a quarter wave at normal incidence.

References

1. I. Savukov, D. Budker. Wave-plate retarders based on overhead transparencies.
Applied Optics. 46 (22) 5129 (2007)
2. N.N. Nagib, S.A. Khodier, H.M. Sidki, A.A. Abd El Megeed. Polymeric sheets as phase retardation elements. *Measurement Science and Technology.* 12, 1714 (2001).

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