Optical plastic refractive index measurements for NIR region

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ABSTRACT

Optical plastic materials are widely used in VIS and NIR spectral regions. Plastic components are applied in different devices and especially for NV goggles. A number of plastics have been analyzed as PMMA, PS, PC, and CTE. The refractive indices are computed and measured for these optical plastics. The results obtained are presented and discussed.

1. INTRODUCTION

The index of refraction of transparent organic plastic materials can be determined using the standard test method [1]. The principal optical plastics are polymethyl-methacrylate (PMMA), polystyrene (PS), polycarbonate (PC), and methyl-methacrylate styrene copolymer (NAS). The optical properties of plastics are rather good for different designing configurations [2]. The most important spectral regions of the plastic optical systems are VIS and NIR ranges at wavelength from 450nm to 1100nm. Using some new optical materials one can improve the performance and balance the production expenses [3]. Success in the application of optical plastics (OP) depends on knowledge of their optical transmission, refraction, homogeneity, and birefringence [2]. The measurement principles and procedures for OP properties determination are quite different. The well-known test instrument is an Abbe refractometer [1]. It operates with a source of white light and Amici prisms as color compensators. The value of the index of refraction for the sodium D lines can be read directly from the instrument. The Abbe refractometer is convenient when measuring small OP specimens but the accuracy is not acceptable for the modern optical design projects. One can obtain the indices of refraction to three significant figures and the Abbe refractometer method does not meet our requirements.

The Pulfrich-Refractometer PR 2 operates with three spectral lamps: mercury source for green e line 546.0740nm and blue g line 435.8343nm, helium source for yellow d line 587.5618nm and red r line 706.5188nm, and hydrogen source for blue F line 486.1327nm and red C line 656.2725nm. The PR 2 measuring prism requires the test OP specimens with satisfactorily polished surfaces to observe the sharpness of the dividing line between the light and dark field as seen in the eyepiece of the instrument. The second edge surface of the OP specimen must be perpendicular to the first contact one. We need to have rather large OP samples to be measured on the PR 2 device. The end of the OP specimen must be prepared with a fair polish to obtain an entire internal reflection from the PR 2 prism. One of the most popular contacting liquid is Alfa-bromonaphthalene with 1.66 but it attacks the surface of the plastic sample. We used a saturated aqueous solution of zinc chloride for PMMA and a solution of potassium mercuric iodide for PS and PC recommended in [1]. The water contacting solutions are temperature influenced and the OP samples have an coefficient of thermal expansion about 10 times higher than that of glass. The ordinary PR 2 prism is not convenient for OP index measurements with a good accuracy up to 0.001. Avoiding the difficulties we were determined to apply a V-shaped prism having 1.7401 for OP index tests. The OP samples are positioned into the V-prism and the temperature variations reflect minimal changes on the optical block. The used Vo F3 prism is firm when measuring on PR 2 instrument and it is very convenient in operations with an one arc second precise goniometer.We found a silicon oil with a refractive index of 1.56011 for the D-line as a matching immersion applicable for OP measurements. The K-Hg-iodide solution has 1.7301 for the e-line.

2. THEORETICAL AND EXPERIMENTAL INDICES OF REFRACTION

The main problem of OP design is the small number of optical materials available. The optical properties of plastics are not so well studied in comparison with glasses. A program was made in order to calculate a number of refractive indices for our design package. The index is computed using Cauchy's dispersive formula for a given wavelength [4], Table 1.

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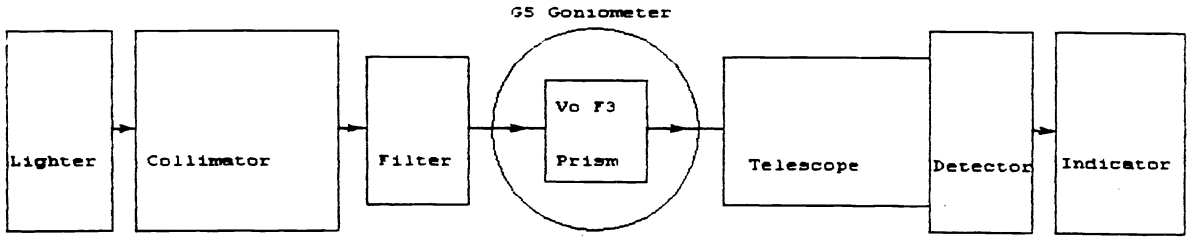
Table 1. Computed indices of refraction based on the Cauchy's formula

OP/WL(nm)	500	545	590	600	655	700	710	750	800	825	850	900
PMMA	1.4966	1.4938	1.4916	1.4912	1.4892	1.4880	1.4877	1.4868	1.4859	1.4855	1.4851	1.4844
PS	1.6015	1.5949	1.5901	1.5892	1.5850	1.5823	1.5818	1.5799	1.5780	1.5771	1.5764	1.5750
PC	1.5971	1.5903	1.5852	1.5842	1.5801	1.5774	1 .5769	1.5746	1.5713	1.5693	1.5670	1.5614

The computed indices are given in Table 1 for the spectral region from 500nm to 900nm. The experimental results are obtained using a goniometer with a Vo F3 prism. The setup is illustrated in the Figure. The collimated white light beam from the Collimator goes to the fixed Filter and the Vo F3 prism is illuminated monochromatically. The angle of deviation is measured on the G 5 goniometer which is formed by the OP sample located into the V-shaped prism. We used metal interference filters made by C. Zeiss having a half-width of 7-9nm. The test set is pointed out in Table 2. The filters have been controlled using a Varian Cary 5 UV-VIS-NIR spectrophotometer. The Lighter is a precise multi-mirror stabilized BAB lamp with a peak at 732nm (Q20MR16 USA 52 source) or at 812nm (Q20MR16C USA 13). A 250W halogen lamp is applied over the VIS-NIR region with filters for 589, 656 and 875nm.

Table2.Optical plastic refractive index data for VIS and NIR regions

Plastic/ WL(nm)	436	546	588	600	700	750	800	825	1025
PMMA	1.500	1.4938	1.4916	1.4913	1.4876	1.4858	1.4852	1.4847	1.4821
PS	1.612	1.59 52	1.5901	1.5896	1.5818	1.5781	1.5765	1.5756	1.5709
PC	1.609	1.5874	1.5829	1.5820	1.5759	1.5731	1.5707	1.5704	1.5651
CTE	1.601	1.5832	1.5785	1. 5777	1.5710	1.5688	1.5676	1.5671	1.5625



3. CONCLUSIONS

Using Cauchy's and Sellmeier's dispersive formulae a theoretical examination was made for OP index computer modeling. An experimental verification was fulfilled applying PR 2 instrument and G 5 goniometer in the VIS region. The results coincide but some nonlinear effects appear during the OP index testing in NIR region. A new more sensitive photo detector head was realized which secures the correct localization of the spectral peaks. The OP index measurements are obtained for some new materials as NAS-23, SAN, COC, and Zeonex. The research project is extending.

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