IMPROVEMENT OF BIREFRINGENT FILTERS

I: *Reduction of Scatter in Polaroid Materials*

(Research Note)

ALAN M. TITLE

Lockheed Solar Observatory, LMSC, Palo Alto, Calif., U.S.A.

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1. Introduction

This is the first in a series of papers which shall deal with improvement of birefringent filters. Increase in transmission, suppression of secondary maximum, reduction of extraneous light and extension of the range of tunability will be the principal concerns of the series. Some of the papers, like this one, will be concerned with filter components such as polarizers, waveplates, crystal elements, and pre-filters, while others will be concerned with characteristics of various types of birefringent filter systems.

In the paragraphs below the cause of scatter in plastic Polaroid material will be discussed. A technique for reduction of the scatter will be described, and the performance of birefringent filters using the improved materials commented upon. It should be noted at the on-set that glass mounted polarizing materials exist commercially that are of the same quality as can be made using the techniques described here. However, to the best of my knowledge glass mounted plastic waveplates are not available.

2. Polaroids

The Polaroid Corporation manufactures a series of materials for polarizing light in the visible called HN followed by the percent of total transmission. Currently available are HN-55, 42, 38, and 22. As the total transmission drops, the ratio of transmission in the pass direction to that in the suppress direction increases from 10 for HN-55 to 4.4×10^4 for HN-22.

The HN-series polarizers are constructed essentially in the same manner. They all consist of a layer of stretched polyvinyl alcohol (PVA) which has deposited on one side a layer of aligned dichroic molecules, sandwiched between two layers of cellulose acetate butyrate (CAB). The amount of dichroic molecules deposited determines the polarizing characteristics of the Polaroid material. The thin (0.001 in.) PVA provides an alignment matrix, while the CAB protects the fragile hygroscopic PVA.

When ordinary Polaroid material is obliquely illuminated by a strong light, a good deal of scatter light can be observed. Almost all of the scatter comes from the interface regions between the PVA and the CAB. When the CAB is removed almost all the scatter disappears.

3. Waveplates

In addition to their polarizing materials, Polaroid Corporation also manufactures a quarter and half waveplate sheet. These materials differ in construction from the Polaroid material only in that the dichroic molecules are not deposited on the PVA. Hence, scattered light in Polaroid waveplates can be significantly reduced by removal of the CAB protective layers.

It should be noted at this point that since stretched PVA is birefringent, there is a phase delay introduced between the passed and suppressed light transmitted by HN-series Polaroids. For HN-55 and HN-42 this is a matter of some concern when designing filters. Typically, the PVA introduces a quarter wave retardation at 5200 Å.

Circular Polaroids are merely a bonded pair of Polaroid and quarter wave material.

4. Experimental Technique

Fortunately, CAB dissolves readily in a number of readily available solvents while PVA resists most common solvents. However, PVA is hygroscopic and dissolves in water.

The CAB readily dissolves in methyl ethyl ketone (MEK). The MEK will remove the CAB in less than 12 h. When the CAB dissolves, the PVA will have a tendency to curl. If the material does not curl, all the CAB has not dissolved. If curling has not occurred after 12 h, use fresh MEK for a longer period.

After removal of the CAB, the PVA should be washed in a clean bath of MEK. To prevent crazing, a final bath of ethylene glycol monomethyl ether should be used. The purpose of the monomethyl ether is to provide a solvent that does not quickly evaporate in air. If the solvent does evaporate quickly, the PVA will craze, producing a milky white appearance. Should crazing occur, it may not be necessary to start again. Good results have been obtained by gently rubbing the monomethyl ether into the PVA before blotting dry with a lint free cloth.

Since PVA is hygroscopic, drying should be done in a low humidity environment, and the PVA material laminated between sheets of glass as quickly as possible. As PVA has an index of 1.49, it can be bonded between ordinary borosilicate glass with a number of optical cements. The Polaroids and waveplates we have processed have been bonded with lens bond between sheets of BK-7.

5. Usage

At Lockheed Solar Observatory, we have constructed a number of low scatter Polaroids and waveplates in the manner described above. These have been incorporated in several birefringent filters which are currently in use on a solar telescope. The filters so constructed deliver excellent image quality with marked lowering of scattered light as compared with undissolved Polaroid material. The filters have been operational for a number of months and no problems with either the polarizers or the waveplates has been observed.

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