

G. BRODSKY.
POLARIZING PRISM.
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1,358,413.

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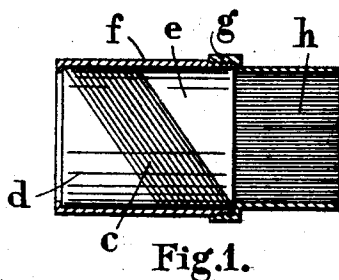


Fig. 1.

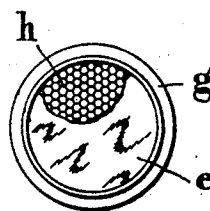


Fig. 2.

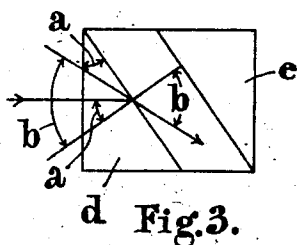


Fig. 3.

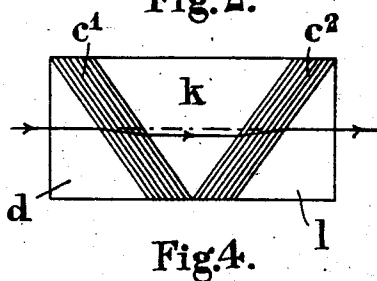


Fig. 4.

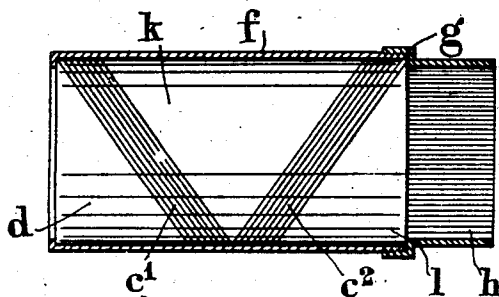


Fig. 5.

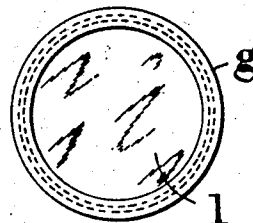


Fig. 6.

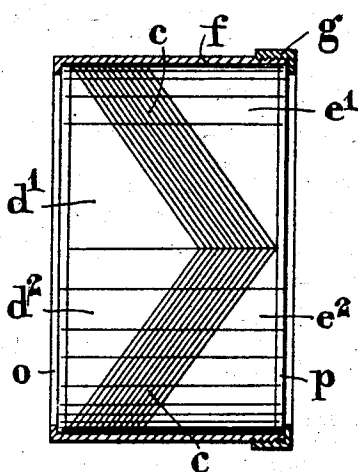
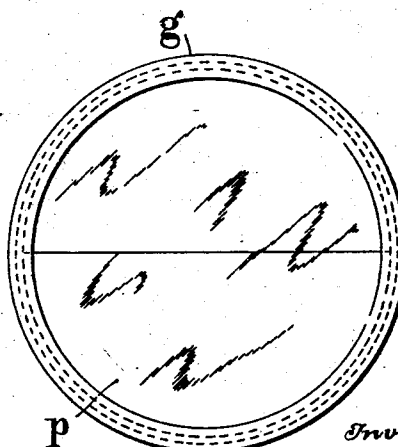


Fig. 7.



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POLARIZING-PRISM.

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To all whom it may concern:

Be it known that I, GREGORY BRODSKY, a subject of the King of Great Britain, and residing at 3 Glazbury road, London, W. 14., England, have invented certain new and useful Improvements in Polarizing-Prisms, of which the following is a specification.

This invention relates to polarizing prisms. It is the object of the invention to provide an improved form of polarizer which can be manufactured in any required quantities and sizes and at no great expense, so that it can be used as a substitute for crystals of Iceland spar. There are in fact a great many uses for polarizers which have not been developed in practice because of the difficulty of making suitable polarizing devices on a substantial scale.

According to the present invention, the desired result is attained by combining with a pile of plates, a pair of prisms, one in front and one behind the pile, of a suitable angle such that when the faces of the prisms are applied to opposite sides of the pile of plates, the proper conditions for polarizing the light passing through the combination, are secured with the plates at a larger and much more convenient angle to the light. The increased angle reduces the depth of the combination and therefore the weight and bulk. At the same time, difficulty due to reflected light, displacement of the beam, and chromatic aberration is largely diminished. The device can be reduced in depth and weight still further by arranging it in sections with plane surfaces between them, the edges of the piles of glass plates between the prisms terminating at these surfaces. Any difficulty due to lateral displacement of the beam of light, or to chromatic aberration, is avoided when necessary by dividing the system into two sections, in one of which the plates are inclined in the opposite direction to the other, the light passing through both sections successively. These and other features of the invention are hereinafter set forth with reference to the accompanying drawings, wherein:—

Figure 1 shows in longitudinal section, and

Fig. 2 shows in front elevation with parts broken away, one form of the polarizer according to the invention.

Figs. 3 and 4 are diagrams explanatory of the optical principles involved in the invention.

Fig. 5 shows in longitudinal section, and Fig. 6 shows in front elevation a form of the polarizer constructed on the lines of Fig. 4.

Fig. 7 shows in longitudinal section, and Fig. 8 shows in front elevation, another form of the polarizer, built up in sections.

In Fig. 1, *c* is the pile of glass plates, say ten plates or more, each preferably of about one millimeter or less in thickness, while *d* and *e* are the two prisms placed at the front and back respectively of the combination. The prisms *d* and *e* are of a form which would be obtained by cleavage on a diagonal line of a cylinder of glass. The plates *c* are placed close together, or separated by a very thin film such as is produced by laying rings of very thin metal foil between each plate and the next adjacent to their circumference. The prisms and plates are fitted together in a cylindrical mount *f* with a flanged ring *g* closing the rear thereof and leaving a suitable aperture. The prisms are secured together with the plates around their edges by a suitable optical cement such as Canada balsam, so as to build up a complete composite cylinder with plane front and rear faces, and with a large number of internal cleavage faces in the pile of plates *c*.

The angle at which the plates *c* stand may be determined as indicated in Fig. 3. If a prism *d* of glass with an apex angle *a* is chosen, a beam of light entering the prism axially strikes the inclined face at an angle *a* to the normal, and is refracted to an angle *b* to the normal where it leaves this face. The angle *b* represents the angle at which the whole of the light strikes the face of the first plate in the pile *c*. The angle to the normal at which the light must strike the pile of plates when formed of any given glass, in order to secure the maximum polarizing effect is about 65°, although this angle is best determined by experiment. Applicant finds 67° to be satisfactory though Wood (*Physical Optics*) has referred to angles of about 60°–65°. Without the prisms *d* and *e* therefore, it would be necessary for the pile of plates *c* to be inclined at an angle of 67° to the vertical plane through the axis, and with such a large angle the depth of the combination would be large and awkward to deal with. When the prisms *d* and *e* are used, the effect is to reduce the angle of the pile of plates to the vertical from *b* to *a* in Fig. 3, and

thus substantially to reduce the depth or thickness of the combination. If m is the refractive index of the glass used for the prisms, then

$$m = \frac{\sin b}{\sin a}$$

If b has to be 67° for the maximum polarizing effect with the pile of plates used, and if the refractive index for the prisms d and e is $m=1.604$, then from the above equation the angle a is found to be approximately 35° . This is the angle, therefore, of the pile of plates to the vertical plane in the examples of construction illustrated. The larger the refractive index of course, the smaller the angle a will become, but it will be found to be in the neighborhood of 35° for most suitable types of glass.

In Fig. 3 the pile of plates c is omitted, so that the light leaving the prism is shown passing through air, but if the plates were inserted the light striking the first plate in the pile situated after an air gap would be refracted back again toward the horizontal, would leave the farther face of the first plate again at an angle of approximately b° to the axis, would be refracted toward the horizontal again in the next plate, and so on. The result would be a little lateral displacement of the ray of light in passing through the set of plates, represented by the arrow in Fig. 4, in which d is the first prism as before, and c^1 is a pile of plates. In order to determine this lateral displacement (assuming the refractive index m to be the same for both prisms and plates) we may use the formula:

$$\text{displacement } x = \frac{y \sin (b-a) (n+1)}{\cos b}$$

where y is the air gap between the plates and n is the number of plates used, while the refractive index is assumed to be the same for the prisms and the plates of the pile. With an air gap y of about one-tenth of a millimeter, and with the angles as above stated, the axial displacement x will be about two millimeters for a pile of twelve plates.

The displacement can not be exactly computed of course, owing to the difficulty of measuring the almost infinitesimal air gaps accurately, but it is found in practice to be of the order stated above. This axial displacement is different of course for rays of light of different colors, and thus some chromatic aberration is set up. This is not detected in a simple beam of light except around the edges, and if the flange of the ring g cuts off the borders of the beam of light for about two millimeters, the beam which emerges will appear practically as white light. The construction of Fig. 1 therefore is sufficient for many purposes,

and the polarizing effect may be rendered more complete without much loss of light by combining with the prism a cellular structure such as that indicated at h comprising a large number of tubes of hexagonal form for example, through which the light passes, the walls of the tubes being blackened internally to absorb any divergent rays. A certain amount of light may pass through the optical combination without complete polarization, and such rays at an angle to the axis are largely cut off by the tubular structure or grid h . Such a structure may be built up readily from thin metal plates stamped out with projecting ridges, which, when suitably placed together, form a honeycomb structure as is well known. A certain amount of light is lost of course apart from the cutting off of rays at an angle, by the thickness of the walls of the tubular structure, and the device h is only used, therefore, where the strength of the beam of light can be sacrificed to considerations of complete polarizing with the exclusion of all divergent rays.

Difficulties due to displacement of the beam and chromatic aberration can be disposed of in various ways, for example by using plates for the pile c of a different refractive index from that of the prisms d and e , so as to bring back the beam of light toward the axis, but this is only an approximate method. A more accurate method is that shown in Fig. 4, wherein the pile of plates is split up into two sets c^1 and c^2 placed at opposite angles to the axis, with a double prism k between them and a prism l behind similar to d . A single prism k is used at the center in place of two prisms equivalent to e , and e reversed, as there would be no point in making two separate prisms to be united in that way. Evidently however, the middle prism k is optically equivalent to two prisms e placed back to back. The ray of light parallel to the axis, but displaced therefrom as indicated while passing through the middle prism k , is brought back again to the axis in passing through the second pile of plates c^2 and out again through the rear prism l . At the same time chromatic aberration is corrected as the combination comprises two parts, one the replica of the other in a reverse position. If twelve plates are required for polarizing, half of this number can be placed in the pile c^1 , and the other half in the pile c^2 , as the polarizing effect is continued through the two piles. One or two additional plates may be used in each pile however, to render the polarizing action as complete as possible.

Figs. 5 and 6 illustrate the complete combination of Fig. 4, in a cylindrical mount f closed by a flanged ring g , and such com-

bination can be used for optical purposes where effective polarization without lateral displacement or chromatic aberration is of great importance.

5 For polarizers of larger sizes, even with the pile of plates at an angle of 35° to the vertical plane the depth or thickness of the combination would become considerable if a single continuous pile of plates were used.
 10 In such cases the pile may be split up into any required number of sections, according to the size of the polarizer. For example, Figs. 7 and 8 illustrate a polarizer with the pile split up into two sections, reducing the
 15 width or depth of the combination to a substantial extent. Where only two sections are used as in Figs. 7 and 8, the piles of plates may be oppositely inclined to the axis as shown, to prevent risk of appreciable
 20 separation of the two parts of the beam of light at the transverse diameter where the two sections abut one against another. In a combination of more than two sections however, they would all preferably be
 25 placed with the piles of plates inclined in the same direction, and it is found that the planes of separation between the units of the combination cannot be detected at any great distance from the polarizer, although
 30 close to the polarizer there are narrow dark bands, of approximately two millimeters depth between the light emitted from one section and the next, as is evident from the considerations stated in connection with Fig. 4.
 35 The sections of the combination in Figs. 7 and 8 are made up and united by optical cement such as Canada balsam, and in order that the faces may be as closely as possible in the same plane, glass disks o and p are preferably placed in the mount in front and
 40 behind all the sections, cemented to these latter, and making up with them a complete optical structure with plane front and rear faces. This is shown as being arranged in a cylindrical mount f with a flanged ring g
 45 at the rear as before. The front prisms of the sections are marked d^1 and d^2 and the rear prisms e^1 and e^2 in Fig. 7, their form corresponding with that which would be obtained by diagonal cleavage of a semi-cylindrical block of glass. At the diametral
 50 plane of cleavage, the sections of the combination are preferably cemented together with an opaque varnish which will absorb reflected light, and the same opaque varnish may be used around the circumference of the whole combination for the same purpose. Such a varnish can be made from
 55 Canada balsam mixed with lamp-black or a black dye.

It will be apparent that all of the prisms hereinbefore described are reversible, as the one side is always a reversed replica of the other. Polarizing prisms made as above

described can be used both for projecting 65 beams of polarized light, and also as analyzers for detecting polarized light. The term "polarizer" therefore is intended to include "analyzer" wherever used therein. They can be used for a variety of practical and scientific purposes involving polarization and the
 70 detection of polarization, or of the turning of polarized beams of light. Polarizers such as that of Figs. 5 and 6 are more particularly useful in connection with optical systems where the light passes through lenses
 75 and so forth, after passing through the polarizer. Chromatic aberration might be emphasized by transmission of the light through such lenses, whereas the polarizer
 80 of Figs. 5 and 6 avoids such aberration.

Various modifications of the constructions described are possible and may be used without departing from the scope of the invention. For example, in the system of
 85 Figs. 4, 5 and 6 the whole of the pile of plates may be placed in the one position corresponding to c^1 for example, while in place of an oppositely inclined pile at c^2 , an air gap may be left of a width just sufficient to allow the beam of light emerging
 90 from the prism k to return to its former axis before it strikes the face of the last prism l . This simultaneously allows of course of the re-combining of the dispersed
 95 chromatic light. In the combinations of Figs. 4, 5 and 6 the apex of the prism k and the ends of the piles of plates c^1 and c^2 adjacent thereto, may project a little beyond the bases of the prisms d and l in order as
 100 far as possible to retain in the system the whole of the beam of light entering through the face of prism d , and to utilize the whole of the prism l for transmitting this light. This makes a rather inconvenient construction,
 105 however, to mount, and it is more convenient as a rule to make the aperture of the flanged ring g such as to cut off any irregularities in the light at the edges of the combination.
 110

I claim:—

1. A polarizing device comprising a plurality of prisms, a plurality of glass plates between said prisms arranged at an angle
 115 to the axis of the polarizing device, said prisms being so arranged that one prism deflects the light in one direction so that it strikes the plates at the polarizing angle, while the next deflects it in the opposite
 120 direction, and a mount for holding said prisms and plates.

2. A polarizing device comprising a plurality of prisms, a plurality of glass plates between said prisms arranged at an angle
 125 of approximately 35° to the axis of the polarizing device, said prisms being so arranged that one prism deflects the light in one direction so that it strikes the plates at

the polarizing angle, while the next deflects it in the opposite direction, and a mount for holding said prisms and plates.

3. A polarizing device comprising a plurality of prisms, a plurality of glass plates between said prisms arranged at an angle to the axis of the polarizing device, said prisms being so arranged that one prism deflects the light in one direction so that it strikes the plates at the polarizing angle, while the next deflects it in the opposite direction, a mount for holding said prisms and plates, and means disposed in front of the prism through which the light issues, for cutting off any rays of light diverging from a line parallel to the axis of the system.

4. A polarizing device comprising a plurality of prisms, a plurality of glass plates between said prisms arranged at an angle to the axis of the polarizing device, said prisms being so arranged that one prism deflects the light in one direction so that it strikes the plates at the polarizing angle, while the next deflects it in the opposite direction, a mount for holding said prisms and plates, and a tubular structure mount-

ed at the rear end of the device, having a number of passages of relatively small diameter arranged therein parallel to the axis of the polarizing device, the walls of said tubes being blackened internally.

5. A polarizing device comprising a plurality of plates divided into a plurality of sets disposed at opposite inclinations to the axis of the polarizing device, a double prism between the sets of plates, a single prism on each of the remaining sides of the sets of plates, and a mount for holding the combination, all arranged so that the light is caused to strike the plates at the polarizing angle.

6. A polarizing device comprising a plurality of plates divided into a plurality of sets disposed at opposite inclinations of approximately 35 degrees to the axis of the polarizing device, a double prism between the sets of plates, a single prism on each of the remaining sides of the sets of plates, and a mount for holding the combination, all arranged so that the light is caused to strike the plates at the polarizing angle.

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