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Makas [45] *May 16, 1972

[54] HIGH ORDER WAVE PLATE CORRECTION OF POLARISCOPIC EFFECTS IN WINDOWS HAVING INFRARED FILTERING

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[73] Assignee: **Polaroid Corporation,** Cambridge, Mass.

[*] Notice: The portion of the term of this patent subsequent to Sept. 15, 1987, has been disclaimed.

[22] Filed: **July 1, 1970**

[21] Appl. No.: **51,593**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 771,970, Oct. 30, 1968, Pat. No. 3,528,722, which is a continuation-in-part of Ser. No. 697,113, Jan. 11, 1968, abandoned.

[52] **U.S. Cl.** **350/147,** 350/1, 350/155, 350/157, 350/158

[51] **Int. Cl.** **G02b 5/30**

[58] **Field of Search** 350/1, 154–155, 350/157–158, 147

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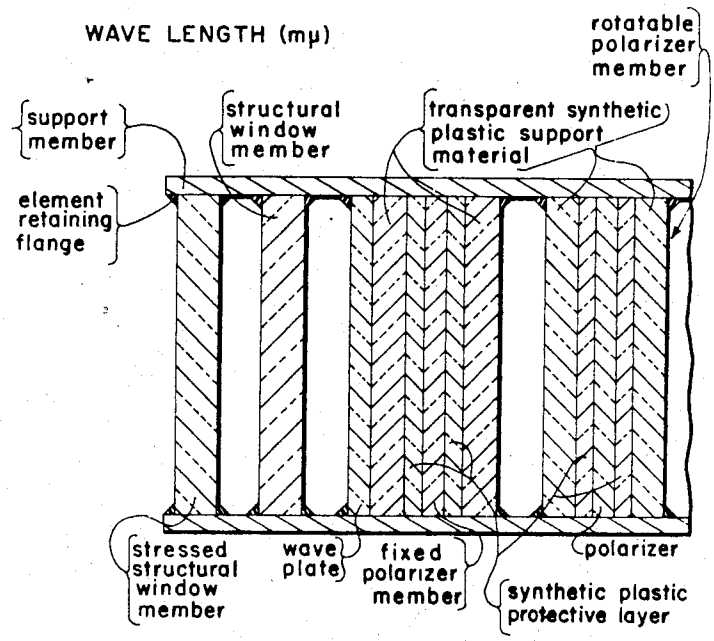
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[57] **ABSTRACT**

A light-transmitting window apparatus including a system which impedes the transmission of infrared radiation and comprises a light-polarizing element and a high order wave plate.

40 Claims, 7 Drawing Figures



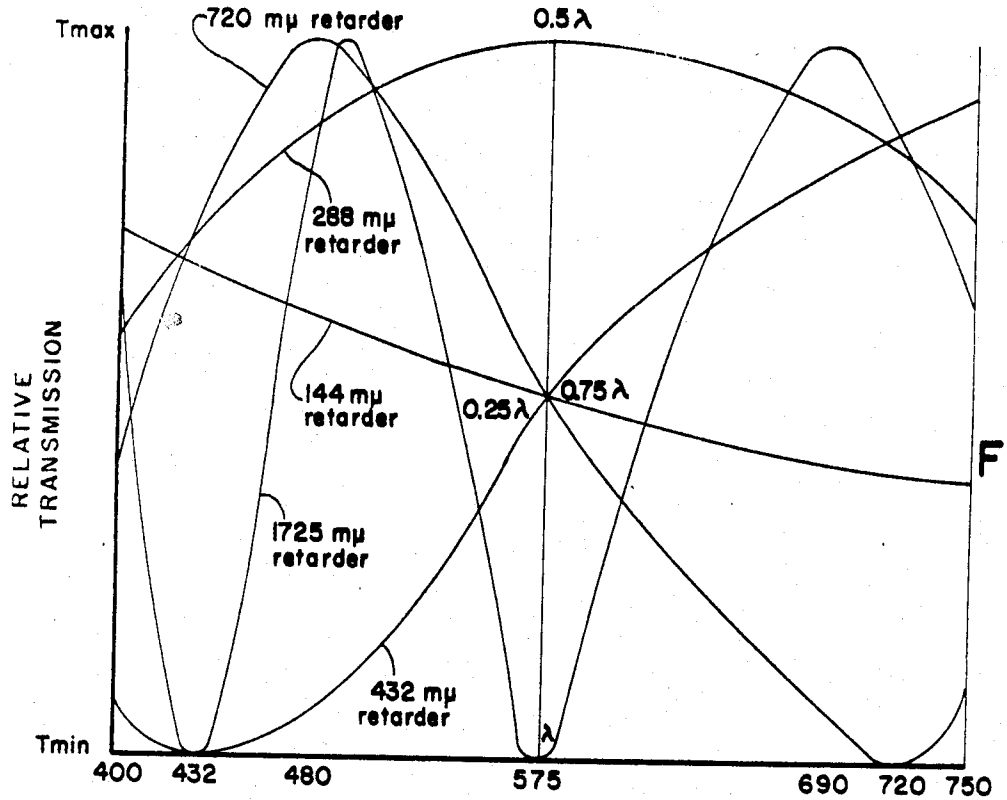


FIG. 1

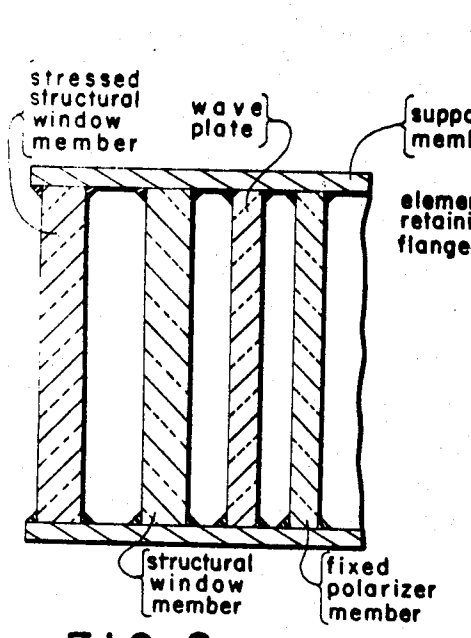


FIG. 2

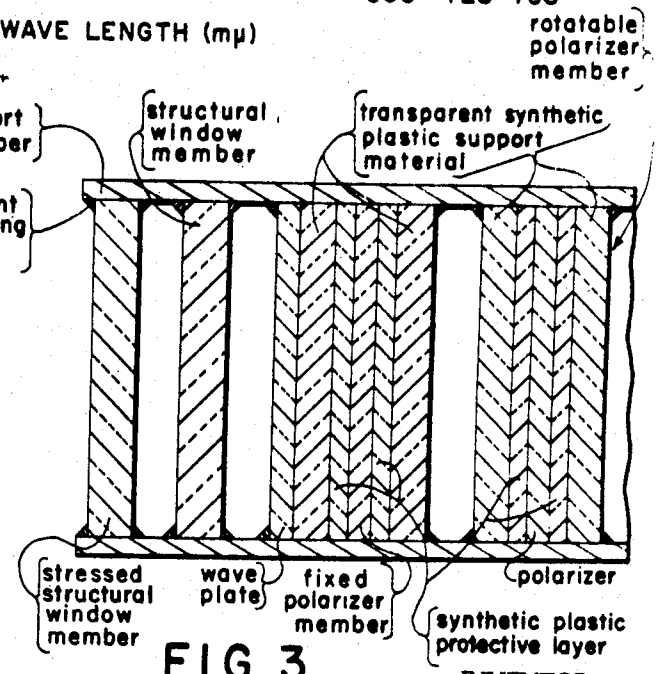


FIG. 3

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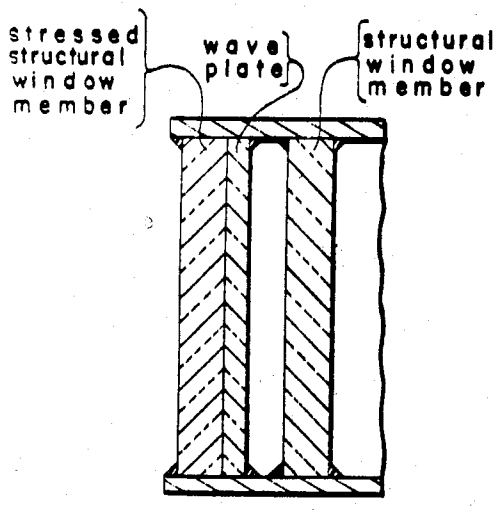


FIG. 4

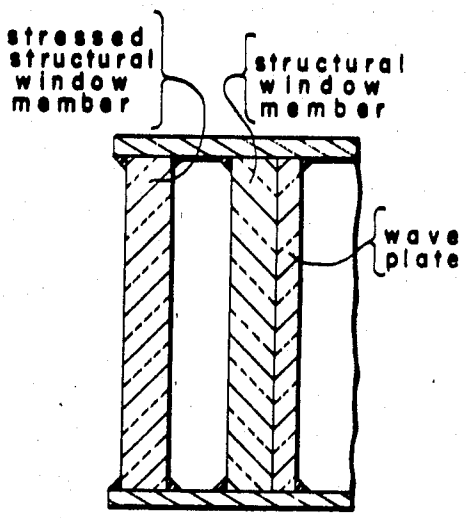


FIG. 5

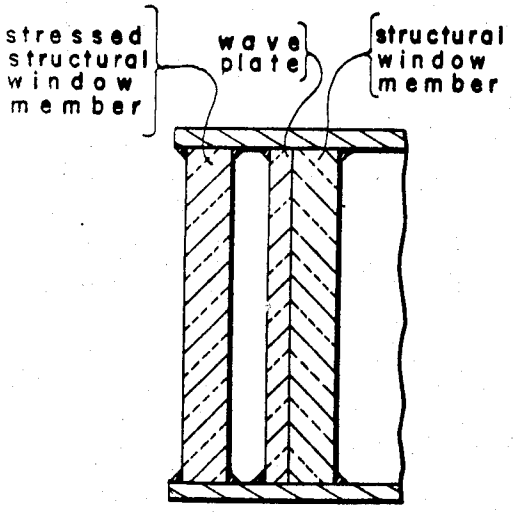


FIG. 6

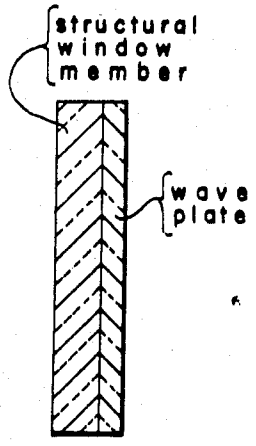


FIG. 7

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HIGH ORDER WAVE PLATE CORRECTION OF POLARISCOPIC EFFECTS IN WINDOWS HAVING INFRARED FILTERING

This application is a continuation-in-part of copending application Ser. No. 771,970, filed on Oct. 30, 1968, now U.S. Patent No. 3,528,722, which is in turn a continuation-in-part of copending application Ser. No. 697,113, filed on Jan. 11, 1968, in the name of Albert S. Makas, now abandoned.

This invention relates to the utilization of light polarizers and systems for impeding the transmission of infrared radiation in conjunction with stressed synthetic plastic materials in a composite window environment. More particularly, this invention relates to the utilization of high order wave plates to eliminate interference spectra which result from the polariscopic effect produced when a stressed transulcent material is viewed between two light polarizers.

It is a primary object of the present invention to eliminate undesirable interference spectra associated with the polariscopic effect produced when a stressed translucent material is viewed between sources of polarized light.

It is another object of the present invention to provide a composite window structure which is particularly useful in pressurized airplanes and comprises a stressed transparent member and a light polarizer, wherein light passing therethrough is free of chromatic aberration associated with the polariscopic effect.

It is an additional object of the present invention to provide a synthetic plastic wave plate capable of at least seven wave lengths of retardation.

Still another object of the present invention is to provide a variable density window comprising a plurality of light-polarizing elements and means associated therewith for controlling the light transmitted therethrough.

An additional object of the present invention is to provide a window comprising a system for impeding the transmission of infrared radiation.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the product possessing the features, properties and the relation of components which are exemplified in the following detailed disclosure, and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a graphical representation of wave length vs. relative transmission of white light passing through various retardation zones, T_{max} and T_{min} being the maximum and minimum light transmission possible, respectively, with a given system;

FIGS. 2 and 3 are cutaway side views of composite window structures within the scope of the present invention;

FIGS. 4, 5 and 6 are cutaway side views of composite window structure subcombinations within the scope of the present invention; and

FIG. 7 is a cutaway view of a window member having a high order wave plate laminated thereto.

It is very often desirable to attenuate light entering a room or a transportation vehicle by the utilization of light-polarizing material. It may be additionally desired, and in fact is well known, to utilize a technique which comprises rotating one light-polarizer relative to another in order to achieve substantially complete extinction of any light incident thereto at the option of the operator. The need for such attenuation is generally most profound with respect to transportation vehicles and particularly airplanes which are often exposed to direct skylight without benefit of natural attenuation provided by cloud formations.

Skylight, by its nature, is rather highly polarized; that is, there is preferential alignment of the vibrating light waves due to particle scattering, etc. which produces a more or less ordered, rather than random wave configuration. This effect

may easily be experienced by rotating a polarizer against skylight and noting the differences in intensity of the light passing therethrough. When the absorption axis of the polarizer is parallel to the primary plane of vibration of incident light, partial extinction occurs to a greater extent than would be achieved were the transmission axis of the polarizer aligned therewith.

In order to achieve a high degree of pressurization and safety for the interior of modern aircraft, the outer structural window members thereof are made of very highly stressed synthetic plastic material, usually polymethyl methacrylate (Plexiglas, Lucite), although polycarbonates such as Lexan, the condensation product resultant from the reaction of bisphenol A and phosgene, and diethylene glycol bis allyl carbonate, sold by Pittsburg Plate Glass Company under the trade name CR-39, or any other suitable transparent material may be used. As a backup or failsafe procedure a second synthetic plastic structural window member, comprising a stressed or unstressed material, at the option of the operator, is inserted inboard of the outer stressed member. In the event that a light-polarizer is placed inboard of said stressed member or members, a polariscopic effect is noted; that is, the polarized light outboard of the window and the polarizer inboard of the window form an analyzer which vividly and chromatically portrays the stress pattern of the synthetic plastic window members. The maximum effect occurs when the polarizer absorption axis is 90° to the axis of the incoming polarized light. This polariscopic phenomenon is quite undesirable aesthetically and often causes passengers on an airplane needless worry since the pattern changes with changes in pressure.

The stress pattern observed in airplane windows comprising a light-polarizing element, is due to birefringence occurring in the stressed material. In polymethyl methacrylate and similar type windows the maximum retardation produced by this birefringence is up to approximately three wave lengths, which is in a vividly colored area.

Retardation may be regarded as the product of birefringence and the thickness of a given material. Thus, if the two refractive indices of a given birefringent material are denoted as n and n_1, the birefringence as $(n-n_1)=\Delta n$, and the thickness of the material is denoted as t, the retardation may be visualized as

$$\Gamma = (\Delta n)\, t\,.$$

Since the thickness range and the birefringence of the members utilized in window configurations anticipated by the present invention are such that the retardations which result are of the order of magnitude of approximately three wave lengths, some method must be devised for causing a depolarization effect to thereby produce substantially white light.

It may be beneficial at this time to briefly mention the theory producing the various chromatic effects achieved with stressed synthetic plastic material of the type utilized herein in a polariscopic environment. Let us assume, for example, that at one point in said material the stress produces a birefringence which causes approximately one-quarter wave length of retardation relative to 575 μ light, which is in about the center of the visible spectrum, thus producing a 144 μ retardation. Unless otherwise denoted, reference to retardation herein are considered applicable to 575 μ light. Looking at FIG. 2, the inboard polarizer is positioned to produce maximum extinction with the incoming skylight, i.e., the absorption axis of the polarizer is parallel to the primary plane of vibration of the entering light. It will be seen, as is illustrated in FIG. 1, that for midspectrum light there will be an effect on transmission of a one-quarter wave length retardation; for 400 μ light there will be 144/400 or approximately one-third wave length retardation; and for the 750 μ light there will be approximately one-fifth wave length retardation. It is evident that the resultant light will be slightly blue colored. If approximately three-fourths wave length of retardation is produced relative to 575 μ light, again, with reference to FIG. 1, it may be seen that the

resultant light would be approximately amber; while one-half wave length retardation relative to 575 μ light produces greenish yellow light. Also included are graphical representations of the effect of 1.25 and 3.0 wave lengths of retardation, relative to 575 μ light, on light which may be incident to the system of the present invention. For orders up until approximately 3.5 wave lengths retardation is achieved, very vivid simple colors are progressively evident. Over 3.5 wave lengths the colors are so profuse that they cannot be distinguished individually and are viewed as a less colorful mixture or as white light. Graphically, they may be visualized as curves containing many maxima and minima.

It is known that one light-polarizing member will not cause substantial extinction of polarized light when its absorption axis is parallel to the plane of vibration of said light if a birefringent material is placed between said polarizer and said polarized light because the birefringent material changes the linearity of the penetrating polarized light waves and causes the emission of waves which may be helical or elliptical in nature. It has additionally been found that when an axis of stress is 45° to either transmission or absorption axes of the crossed polarizers a maximum intensity of the interference spectra is reached. Where the axis of stress coincides with either transmission or absorption polarizer axis no effect is seen. The resultant pattern, therefore, evident to a viewer, appears as 4 distinct quadrants with maximum intensity at the center of each sector and minimum intensity along the polarizer axes.

It has been found that if a wave plate with approximately 10 to 15 wave lengths of retardation is inserted in a stressed window — light polarizer combination, outboard of the polarizer, effective depolarization of penetrating light is achieved, i.e., the polariscopic effect is obviated. Assuming that the retardation of the wave plate and window material are additive, it is evident that a wave plate with about four wave lengths retardation would be adequate to produce substantially white light. However, if the wave lengths of retardation capable of being provided by the wave plate, in relation to those of the stressed window, are subtractive, about seven or eight wave lengths of retardation would be required. In order to provide maximum effectiveness and account for retardation which may be imparted to the system by imperfect laminations, utilization of retarders on the order of 10 to 15 wave lengths of retardation is considered ideal. However, practically speaking, any material which will provide approximately 7 or more wave lengths of retardation may be utilized as, for example, oriented polyvinyl alcohol, various oriented polyesters, etc. It has been unexpectedly found that the best results are obtained when polyethylene terephthalate (Mylar, Melinex) is utilized, it having been uniaxially oriented. With material of this type up to 20 wave lengths of retardation, and perhaps more, may be achieved. An additional advantage is gained with uniaxially oriented polyethylene terephthalate over other materials since the optical axes of this material are not evident to the viewer no matter what position is assumed, the critical angle being internal. Thus, there is no possibility of the viewer looking down an optical axis of the material and seeing only a black area surrounded by a chromatic environment.

In all embodiments of the instant invention, greatest efficiency will be achieved when the plane of the optic axes of the wave plate is at a 45° angle to the axes of the fixed light-polarizing element. As the plane of the optic axes of the wave plate approaches an axis of the light-polarizing element, efficiency is lost until the polarizer axis and plane of the wave plate axes coincide — at which point the wave plate fails to produce the intended results.

Any suitable material which will produce the desired light-polarization effect may be utilized in the present invention. It has been found, however, that polymeric light-polarizing sheet material lends itself most readily to this function. The preferred material is a transparent sheet of polyvinyl alcohol containing substantially oriented molecules of dehydrated polyvinyl alcohol and deriving its light-polarizing properties essentially from said dehydrated molecules. The manufacture and utilization of such sheet material may be appreciated with reference to U.S. Pat. Nos. 2,173,304; 2,255,940; 2,306,108; 2,397,231; 2,445,555; 2,453,186 and 2,674,159, all incorporated herein by reference.

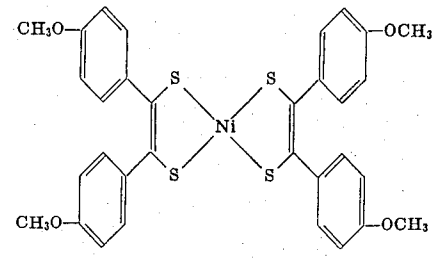
The solar radiation transmitted to the Earth's surface through the atmosphere comprises a total radiant power of about 170 milliwatts/cm² through one atmosphere for the sun at zenith and a clear sky. About 83 percent of this constitutes radiation involving the ocular media. Radiation from the upper end of the visible range, at about 720 μ, to about 1,400 μ, comprises the near infrared region which can conceivably deleteriously effect the unprotected eye under certain conditions and cost the receptor of such radiation discomfort. Substantially all infrared energy above 1,400 μ wave length is absorbed and readily dissipated by the cornea and aqueous humor of the eye prior to reaching the retinal area.

The normal human eye is physiologically adapted to accommodate the average brightness level which might be encountered at usual jet aircraft operating altitudes up to 40,000 feet (about 1,000 millilamberts). The pupil diameter at this brightness level is about 2.0 mm (about 3.45 mm² aperture). When a single light-polarizing element of the type contemplated herein is utilized in such a high altitude environment as an aircraft window component, the visible brightness level is reduced to about 400 millilamberts with a corresponding increase in pupil diameter to about 2.4 mm (about 4.52 mm² aperture) to accommodate the lower visible brightness.

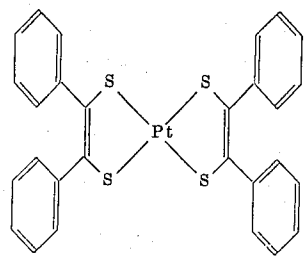
When two light-polarizing elements are employed as functional components of an aircraft window variable light transmission system, the visible brightness level is reduced to about 300 millilamberts with the axes of the polarizers in parallel position and to about 30 millilamberts when the polarizer axes are perpendicular to one another, resulting in increases in pupil diameter of about 2.5 mm (about 4.90 mm² aperture) and about 3.1 mm (about 7.25 mm² aperture), respectively.

Although the brightness level in the interior of an aircraft utilizing the variable light-transmission type windows contemplated herein is reduced to substantial extinction, the infrared component of transmitted radiation is generally only reduced when the polarizers are in the crossed position to about 60 percent of its original intensity. Accordingly, it will be appreciated that in order to provide optimum comfort to an inboard viewer of light transmitted through the window apparatus of the present invention, it is most preferable to incorporate therein a system for substantially reducing or eliminating the infrared component of light transmitted therethrough.

Without being limited thereto, two particular types of infrared reduction systems are suggested for use herein - one being a system of absorbers to substantially absorb and dissipate infrared radiation and the other being a reflection system to reflect infrared radiation away from the eyes of the viewer. The former system is preferred for utilization herein and most preferably will comprise infrared absorbers which are metal complexes of bis-[cis-1,2-(alkyl, hydrogen, aryl or heterocylcic)ethylene-1,2-dithiolates] as disclosed in copending U.S. application of Stanley M. Bloom, Ser. No. 577,576, assigned to Polaroid Corporation, filed on Sept. 2, 1966, now U.S. Pat. No. 3,588,216. Infrared absorbing materials also suggested for utilization herein are disclosed in copending U.S. application of Stanley M. Bloom, Ser. No. 880,614, assigned to Polaroid Corporation, filed Nov. 28, 1968. The absorbers disclosed in the aforementioned copending applications may be utilized alone or in combinations of two or more. The most preferred absorbing system comprises a 1.79:1 ratio, by weight, of



and



While specific infrared radiation absorbers have been alluded to herein, it will be evident to one of ordinary skill in the art that any infrared absorbing material which will not deleteriously effect the window structure may be utilized in the apparatus of the present invention. Furthermore, such absorbers may be incorporated in substantially any element comprising the light-transmitting apparatus hereof but will preferably be placed in a synthetic plastic protective layer preferably comprising cellulose acetate butyrate which is bonded to opposed sides of either light-transmitting element.

Also useful for eliminating infrared radiation are reflecting systems generally comprising thin layers of metals, and particularly gold, as disclosed in Belgian Pat. No. 729,300. As is disclosed therein, such films may be deposited by vapor deposition, preferably under vacuum. As disclosed in the denoted Belgian patent, thin gold films, for example, will transmit light with wave lengths between about 450 and 600 nm and will substantially reflect light over 600 nm.

Other patents disclosing the utilization of metallic films for retarding transmission of infrared radiation are U.S. Pat. Nos. 2,854,349; 2,087,802; and 3,118,781. As with the absorptive systems, the denoted infrared reflecting systems may be incorporated within the light-transmitting apparatus hereof at any convenient point desired by the operator. Preferably, however, a metallic infrafred reflecting film will be incorporated in, for example, the fixed light-polarizing element containing member of FIG. 3 between the wave plate and transparent synthetic plastic support material.

As a general rule, it may be stated that neither the polarizer nor the wave plate are structurally sufficiently rigid to be used by themselves. Therefore, in the most preferred embodiment of the present invention, both the polarizer and wave plate are laminated to a rigid synthetic plastic material such as, for example, polymethyl methacrylate, before insertion in the composite window structure. In the case of the wave plate, it has been found preferable to laminate it to the composite light-polarizing element. However, it is to be understood that, at the option of the operator, the wave plate may be laminated to a stressed or unstressed synthetic plastic airplane window component part. In the event it is laminated to a stressed member which, in the standard configuration, will comprise the outermost window component, it will preferably be on the inboard side thereof, as denoted in FIG. 4. Technically speaking, the wave plate will be operative for its intended purpose if laminated on the outboard side of the outermost member; however, constant exposure to the elements militates against such an embodiment. Regarding the inner, or failsafe component, the wave plate may be laminated on either the inboard or outboard side thereof as denoted in FIGS. 5 and 6, respectively. The prime criterion for determining a satisfactory position for the wave plate is that it must be located between the sources of polarized light, i.e., the sky and the light-polarizing element.

FIG. 2 denotes an embodiment of the present invention wherein a wave plate is used outboard of a light-polarizing element and inboard of a stressed window member in an airplane window configuration. FIG. 3, which will be more completely described below, depicts a preferred embodiment of the present invention wherein a first light-polarizing material is laminated between structural members comprising a transparent synthetic plastic support material, with a wave plate laminated on the outboard side of said composite light-polarizing unit. Inboard of said member is a second light-polarizer laminated between structural transparent synthetic plastic support material, which composite member may be rotated at the option of the operator so that the axes of said second light-polarizer may be placed at varying angles to said first light-polarizer thereby providing varying degrees of extinction or transmission of penetrating light. Any adhesive materials suitable for laminating the wave plate-polarizer-support material composite structure may be utilized as long as said adhesive does not hinder the transmission of light. Adhesives which may be used in the environment of the present invention generally comprise low molecular weight polyesters which are cross-linked in situ with a suitable cross-linking agent. Exemplary of such materials is Adcote 1069, sold by Morton Chemical Company, which is a low molecular weight polyethylene terephthalate material, probably hydroxyl terminated, in conjunction with a polyisocyanate cross-linking agent. Other polyester materials found suitable for this purpose are duPont Adhesive No. 46960 and National Starch Adhesives Numbers 76–2575, 30–9057 and 30–9066. These adhesives are, typically, polyesters utilized in conjunction with a suitable cross-linking agent, such as a polyisocyanate. The adhesives may be used alone or applied in conjunction with other adhesives. The most preferred embodiment of the instant invention utilizes a uniaxially oriented polyethylene terephthalate wave plate bonded directly to a polymethyl methacrylate support member. The preferred bonding technique is to subcoat the wave plate with a polyester adhesive comprising duPont Adhesive 46960 with a polyisocyanate cross-linking agent. Over that subcoat is applied a thin layer of cellulose acetate butyrate from solution. Thereover is applied a thin layer of Adcote 1069, described above, with a polyisocyanate cross-linking agent. This subcoated structure is then laminated using a standard pressure roll technique to the polymethyl methacrylate support member by utilizing an adhesive material which consists of approximately 4 percent cellulose nitrate, whose viscosity is approximately 600 to 1,000 seconds^{-1}, dissolved in methyl methacrylate, and utilized with a diisopropyl percarbonate catalyst present in an amount of about 1 percent by weight. This latter defined adhesive is further described in application Ser. No. 697,019, filed in the name of Harold O. Buzzell on Jan. 11, 1968.

In order to gain optimum qualities with regard to shrinkage and crazing of the light-polarizing material, it has been found beneficial to laminate the polarizer between layers of cellulose acetate butyrate or similar materials, as described in U.S. Pat. No. 2,674,159 and in the applications of Buzzell and Bloom, Ser. Nos. 577,578 and 577,576, now U.S. Pat. No. 3,588,216, respectively, both filed on Sept. 2, 1966. Lamination of the cellulose acetate butyrate layers to the light-polarizing material may be accomplished, for example, either by subcoating the cellulose acetate butyrate material with a suitable compound such as, for example, cellulose nitrate, and then laminating the subcoated material to the polyvinyl alcohol light-polarizing sheet using a well-known pressure roll technique with a typical adhesive for such material, such as a 2 percent polyvinyl alcohol solution; or, alternatively, the lamination may be accomplished by the conversion of the surface of the cellulose acetate butyrate to cellulose, subcoating the surface with polyvinyl alcohol and pressure laminating the subcoated cellulose acetate butyrate to the light-polarizing material, as more fully discussed in the Buzzell application mentioned above.

The instant invention may be further appreciated with reference to FIG. 3, which is the preferred embodiment, wherein a stressed window member of about 0.5 inch in thickness is placed outboard of a stressed or unstressed failsafe window member about 0.25 to 0.5 inch thick, which is, in turn, outboard of a fixed light polarizing member comprising a laminate consisting of, in order, from the outboard side; a wave plate approximately 1.5–5 mils in thickness and preferably 3 mils; a transparent synthetic plastic support member approximately 30–125 mils in thickness and

preferably about 60 mils thick; a transparent synthetic plastic protective material layer approximately 4–30 mils in thickness and preferably about 5 mils thick; a light-polarizing member, as described above, approximately 0.75–1.5 mils in thickness and preferably about 0.75 mils thick; and a second synthetic plastic protective material layer and a second transparent support layer of the same dimensions as said first support layer. Inboard of the member just described is a rotatable member comprising a synthetic plastic support material; a synthetic plastic protective material layer; a light-polarizing material, a second synthetic plastic protective material layer; and a second transparent support member; all of the same dimensions as described for the preceding element. In the preferred embodiment, the synthetic plastic protective material layers comprise cellulose acetate butyrate. The respective constituents of the composite window structure may be held together by any suitable mounting structure including an aperture capable of retaining the above-described light-transmitting means transverse thereof, such as a cylindrical member with suitable element-retaining flanges.

FIGS. 4, 5 and 6 depict subcombinations of alternate embodiments of the present invention and graphically denote various positions which the wave plate may occupy in the apparatus claimed herein. The bonding techniques and adhesives utilized in joining the wave plate to a given window member are identical to those described hereinbefore for laminating a wave plate to a support member.

In the variable density embodiment of the apparatus of the instant invention, at the option of the operator, a second, fixed light-polarizing element may be positioned with its axes parallel to the first light-polarizing element. Rotation of the rotatable light-polarizing element will then provide more complete extinction of incoming light, thereby increasing the efficiency of the system. In such an embodiment it is preferred to place said rotatable member between said fixed light-polarizing elements.

Throughout the specification the terms "inboard" and "outboard" have been extensively used. "Outboard" is considered to be the side through which light may enter the apparatus of the present invention, while "inboard" relates to the side through which transmitted light exits from said apparatus.

In addition, the term "structural," when applied to component elements of the herein claimed apparatus, defines such elements as being capable of maintaining the structural integrity of the article in which it is used, e.g., an aircraft, train, boat, etc., in conjunction with the body of said article.

Since certain changes may be made in the above product without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A light-transmitting window apparatus comprising an inboard side through which transmitted light may exit from said apparatus, and an outboard side, through which light may enter said apparatus, said apparatus comprising, in combination, a mounting structure having an aperture therein, said aperture containing a multiplicity of light-transmitting layer-like members mounted substantially transverse to the plane of the aperture including, from the outboard side, a first, structural, transparent, stressed plastic member; a wave plate of at least four wave lengths retardation; a fixed light-polarizing member; and a system for retarding, by absorption or reflection, the transmission of infrared radiation through said apparatus.

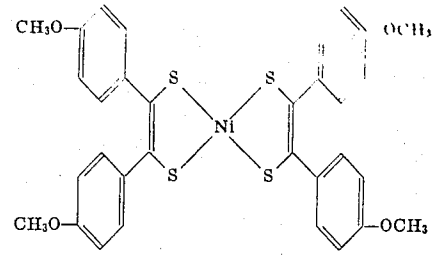
2. The invention of claim 1 wherein said wave plate is capable of providing at least seven wave lengths of retardation.

3. The invention of claim 2 wherein the plane of the optic axis of the wave plate is at about a 45° angle to an axis of the fixed light-polarizing element.

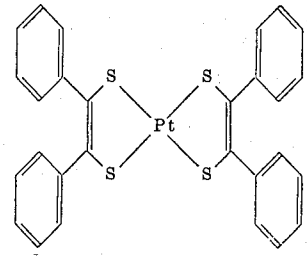
4. The invention of claim 2 wherein said system to substantially reduce the transmission of infrared radiation comprises infrared absorbing dyes.

5. The invention of claim 4 wherein said infrared absorbing dyes comprise bis-[cis-1,2-(alkyl, hydrogen, aryl or heterocyclic)ethylene-1,2-dithiolate]s.

6. The invention of claim 5 wherein said bis-[cis-1,2-(alkyl, hydrogen, aryl or hetercyclic)ethylene-1,2-dithiolate]s comprise a mixture of



and



7. The invention of claim 2 wherein said system comprises a thin metallic infrared reflecting layer.

8. The invention of claim 7 wherein said metallic layer comprises gold.

9. The invention of claim 3 wherein said wave plate comprises uniaxially oriented polyethylene terephthalate.

10. The invention of claim 3 wherein said wave plate is laminated to said stressed plastic member on the inboard side thereof.

11. The invention of claim 3 wherein said apparatus additionally contains a second transparent, synthetic plastic member inboard of said first structural member and outboard of said light-polarizing member.

12. The invention of claim 11 wherein said wave plate is laminated to said second synthetic plastic member.

13. The invention of claim 3 wherein said wave plate and said light-polarizing member comprise a single composite structure comprising, from the outboard side, said wave plate; a transparent synthetic plastic support element; a first transparent protective layer for said light-polarizing member; said light-polarizing member; and a second transparent protective layer for said light-polarizing member.

14. The invention of claim 13 wherein said composite structure additionally contains a transparent synthetic plastic support element inboard of said second transparent protective layer for said light-polarizing material and affixed thereto.

15. The invention of claim 3 wherein a rotatable light-polarizing member is positioned inboard of said fixed light-polarizing member.

16. The invention of claim 15 wherein said rotatable light-polarizing member comprises said system for substantially reducing the transmission of infrared radiation.

17. The invention of claim 15 wherein said apparatus additionally contains a second structural, transparent, synthetic plastic member inboard of said first structural member and outboard of said light-polarizing member.

18. A light-transmitting window apparatus comprising an inboard side through which transmitted light exits from said apparatus and an outboard side through which light enters said apparatus, said apparatus comprising, in combination, a mounting structure having an aperture therein, said aperture containing a multiplicity of light-transmitting layer-like members mounted substantially transverse to the plane of the aperture comprising, from the outboard side; a first structural, transparent, stressed plastic member comprising polymethyl methacrylate of approximately 0.5 inch in thickness; a second structural, transparent plastic member comprising polymethyl methacrylate of approximately 0.25 inch in thickness; a composite structure comprising a synthetic plastic wave plate of at least four wave lengths retardation approximately 1.5 to 5

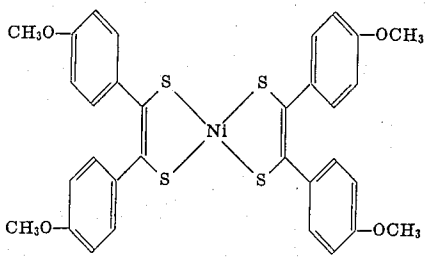
mils, in thickness; a transparent plastic support element approximately 30 to 125 mils. in thickness; a first transparent protective layer of cellulose acetate butyrate approximately 4 to 30 mils. in thickness; a polymeric light-polarizing member approximately 0.75 to 1.5 mils. in thickness; a second transparent protective layer of cellulose acetate butyrate of approximately 4 to 30 mils. in thickness; and a second transparent plastic support element of approximately 30 to 125 mils. in thickness; and a rotatable member comprising a transparent plastic support element of approximately 30 to 125 mils. in thickness; a first transparent protective layer of cellulose acetate butyrate approximately 4 to 30 mils. in thickness; a polymeric light-polarizing member approximately 0.75 to 1.5 mils. in thickness; a second transparent protective layer of cellulose acetate butyrate approximately 4 to 30 mils. in thickness; a second plastic transparent support element approximately 30 to 125 mils. in thickness; and a system for retarding, by absorption or reflection, the transmission of infrared radiation through said apparatus.

19 The invention of claim **18** wherein said wave plate is capable of providing at least seven wave lengths retardation.

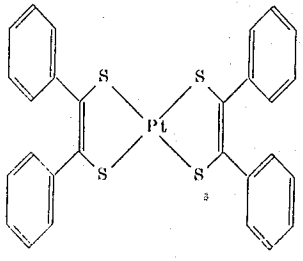
20. The invention of claim **19** wherein the plane of the optic axis of the wave plate is at about a 45° angle to an axis of the fixed light-polarizing element.

21. The invention of claim **20** wherein said system to substantially reduce the transmission of infrared radiation comprises infrared absorbing dyes.

22. The invention of claim **21** wherein said dyes are incorporated in a cellulose acetate butyrate protective layer.



and



23. The invention of claim **22** wherein said dyes are incorporated in said second cellulose acetate butyrate protective layer of said rotatable member.

24. The invention of claim **23** wherein said infrared absorbing dyes comprise bis-[cis-1,2-(alkyl, hydrogen, aryl or heterocyclic)ethylene-1,2-dithiolate]s.

25. The invention of claim **24** wherein said bis-[cis-1,2-(alkyl, hydrogen, aryl or heterocyclic)ethylene-1,2-dithiolate]s comprise a mixture of

26. The invention of claim **19** wherein said system comprises a thin metallic infrared reflecting agent.

27. The invention of claim **26** wherein said metallic layer comprises gold.

28. The invention of claim **27** wherein said thin metallic film is incorporated between said wave plate and said transparent plastic support element next adjacent thereto.

29. The invention of claim **20** wherein each of said light-polarizing members comprise a transparent sheet of polyvinyl alcohol containing substantially oriented molecules of dehydrated polyvinyl alcohol.

30. The invention of claim **28** wherein said wave plate comprises uniaxially oriented polyethylene terephthalate.

31. The invention of claim **30** wherein said plastic support elements comprise polymethyl methacrylate.

32. A light-transmitting window apparatus which comprises a stressed synthetic plastic light-transmitting element having stress-induced birefringent areas; a wave plate of at least four wave lengths of retardation; and a system for retarding, by absorption or reflection, the transmission of infrared radiation through said apparatus.

33. The invention of claim **32** wherein said wave plate comprises at least seven wave lengths of retardation.

34. The invention of claim **33** wherein said wave plate comprises uniaxially oriented polyethylene terephthalate.

35. A light-transmitting window apparatus which comprises a composite structure comprising a light-polarizing element; a wave plate of at least seven wave lengths of retardation bonded thereto; and a system for retarding, by absorption or reflection, the transmission of infrared radiation through said apparatus.

36. The invention of claim **35** wherein said wave plate comprises uniaxially oriented polyethylene terephthalate.

37. The invention of claim **36** wherein the optic axis of said wave plate is at a 45° angle to the axis of said light-polarizing element.

38. The invention of claim **37** wherein said wave plate and said light-polarizing element are each interposed between synthetic plastic protective layers.

39. The invention of claim **38** wherein said synthetic plastic protective layers comprise cellulose acetate butyrate.

40. The invention of claim **39** wherein at least one surface of said composite structure has coated thereon a marresistant coating.

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