IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: U.S. Patent No. 5,470,932

Issued: November 28, 1995

Assignee: Alcon Manufacturing, Ltd.

Attention: PATENT EXTENSION

CERTIFICATE OF MAILING
BY EXPRESS MAIL

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as "Express Mail," Mailing Label No. EV 225496334 US in an envelope addressed to: MS Patent Extension, Commissioner for Patents, P. O. Box 1450, Alexandria, VA 22313-1450, on this date:

July 10, 2003
Date

Jeannie Burke
Jeannie Burke

APPLICATION FOR EXTENSION OF TERM UNDER 35 U.S.C. §156

RECEIVED
JUL 23 2003
OFFICE OF PETITIONS

MS Patent Extension
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant, Alcon Manufacturing, Ltd. ("Alcon"), a partnership organized and existing under the laws of the Texas, and having a principal place of business at 6201 South Freeway, Fort Worth, Texas 76134-2099, represents that it is the assignee of the entire interest in and to U.S. Patent No. 5,470,932. An assignment is recorded in the U.S.P.T.O. on Reel 011667, Frame 0559.

Applicant, acting through its duly authorized attorney, hereby submits this application for patent term extension under 35 U.S.C. §156 by providing the following information required by 37 C.F.R. §1.710 – 1.785.

All references to "approved product" are to the Acrysof® Natural Single-Piece Posterior Chamber Intraocular Lens (Model SB30AL), which was approved by the FDA on June 24, 2003.

P-1172F-1442

APP 1

ELIGIBILITY

United States Patent No. 5,470,932 is eligible for extension under the provisions of 35 U.S.C. §156(a) and 37 C.F.R. §§1.710 and 1.720. The criteria for eligibility are set forth below:

(a) the '932 patent claims a product as defined in §1.710 (§1.710(b)(3));

(b) the term of the '932 patent has never been previously extended;

(c) this Application for extension is submitted in compliance with §1.740;

(d) the approved product has been subject to a regulatory review period as defined in 35 U.S.C. 156(g) before its commercial marketing or use;

(e) the FDA approval received on June 24, 2003 for the approved product is the first received permission for commercial marketing or use of the approved product under the provision of law under which the applicable regulatory review occurred;

(f) this Application is submitted within the sixty-day period provided in §1.720 (f), which period will expire on August 23, 2003;

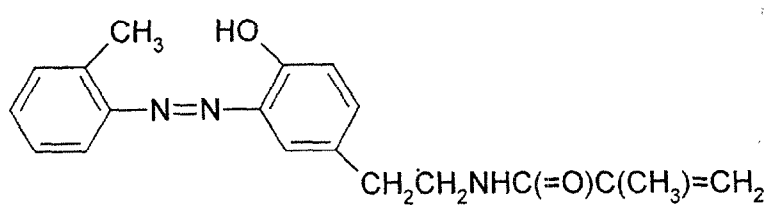
(g) the term of the '932 patent has not expired prior to submission of this Application;

(h) no other patent term has been extended for the same regulatory review period for the approved product.

APPLICATION

In accordance with the requirements of 35 U.S.C. §156(d) and 37 C.F.R. §§ 1.730 and 1.740, Alcon presents the following information. The paragraph numbers utilized below correspond to the paragraph numbers under subparagraph (a) of 37 C.F.R. §1.740:

(1) The approved product is an acrylic intraocular lens made of a polymeric material comprising N-2-[3-(2-methylphenylazo)-4-hydroxyphenyl]ethyl methacrylamide as a polymerizable yellow dye. This dye is also known as "2-propenamide, N-[2-[4-hydroxy-3-[(2-methylphenyl)azo]phenyl]ethyl]-2-methyl-" and has the CAS Registry No. 167094-66-8. The structural formula of this chromophore is



(2) The regulatory review occurred under Section 515 of the Federal Food, Drug, and Cosmetic Act.

(3) The approved product received FDA approval under Section 515 of the Federal Food, Drug, and Cosmetic Act on June 24, 2003. A copy of the approval letter is attached as Appendix A.

(4) The approved product in this Application is a device, not a drug product.

(5) This Application is being submitted within the sixty (60) day period specified in 35 U.S.C. §156(d)(1) and 37 C.F.R. §1.720(f), which period expires on August 23, 2003.

(6) The patent for which an extension is being sought is United States Patent No. 5,470,932. This patent was issued to David L. Jinkerson on November 28, 1995, and will expire on October 18, 2013.

(7) A copy of United States Patent No. 5,470,932 is attached as Appendix B.

(8) No disclaimer, certificate of correction or reexamination certificate has been issued in connection with United States Patent No. 5,470,932. The first maintenance fee has been paid. A copy of the first Maintenance Fee Statement is attached as Appendix C.

(9) United States Patent No. 5,470,932 claims the approved product. The approved product is an intraocular lens made of a polymeric lens material that contains N-2-[3-(2'-methylphenylazo)-4-hydroxyphenyl]ethyl methacrylamide as a polymerizable yellow dye. The polymeric lens material also comprises 2-phenylethyl acrylate and 2-phenylethyl methacrylate as lens-forming monomers and an ultraviolet absorbing compound.

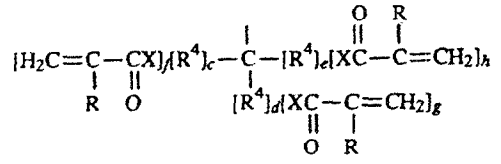
The '932 patent contains eleven claims, all of which read on the approved product.

Claim 1 of the '932 patent reads as follows:

1. A polymeric ophthalmic lens material comprising:

one or more lens-forming monomers selected from the group consisting of acrylate monomers and methacrylate monomers, and

one or more polymerizable yellow dyes having from one to four polymerizable acrylate or methacrylate groups, wherein each acrylate or methacrylate group is displaced from the dye moiety by a spacing group according to the formula



wherein

R=H or CH_3

R^4=acyclic organic spacing group of up to 10 atoms consisting of C, H, Si, O, N, P, S, Cl, Br or F, alone or in any combination;

X=O, NH or NR^5;

R^5=C_1 to C_{10} alkyl;

d, e, g, and h independently=an integer from 0 to 3; and

c and f independently=an integer from 1 to 4.

The approved product contains a polymerizable yellow dye having one polymerizable methacrylate group displaced from the dye moiety by a spacing group of the formula provided in Claim 1 wherein R is CH_3; R^4 is CH_2CH_2; *c* and *f* are 1; *d*, *e*, *g* and *h* are 0; and X is NH.

Claim 2 of the '932 patent reads as follows:

2. The lens material of claim 1 wherein the total amount of yellow dye is less than about 1 wt %.

The total amount of yellow dye in the approved product is less than 0.1 wt %.

Claim 3 of the '932 patent reads as follows:

> 3. The lens material of claim 2 wherein the total amount of yellow dye is less than about 0.25 wt %.

The total amount of yellow dye in the approved product is less than 0.1 wt %.

Claim 4 of the '932 patent reads as follows:

> 4. The lens material of claim 3 wherein the total amount of yellow dye is less than about 0.1 wt %.

The total amount of yellow dye in the approved product is less than 0.1 wt. %.

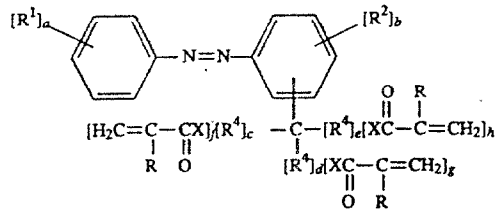
Claim 5 of the '932 patent reads as follows:

> 5. The lens material of claim 1 wherein the lens material comprises one or more lens-forming monomers selected from the group consisting of phenylethyl acrylate and phenylethyl methacrylate.

The lens material in the approved product comprises phenylethyl acrylate and phenylethyl methacrylate.

Claim 6 of the '932 patent reads as follows:

6. The lens material of claim 1 wherein the polymerizable yellow dye is



wherein

R=H or CH_3;

R^1=H, C_1 to C_{20} alkyl, OCH_3, OC_2H_5, OC_3H_7, or OC_4H_9;

a and b independently=the integer 1 or 2;

R^2=R^1, OH, NH_2, NHR^5, $N(R^5)_2$, SH, SR^5, OR^5, $OSi(R^5)_3$, or $Si(R^5)_3$;

R^4=an acyclic organic spacing group of up to 10 atoms consisting of C, H, Si, O, N, P, S, Cl, Br or F, alone or in any combination;

X=O, NH or NR^5;

R^5=C_1 to C_{10} alkyl;

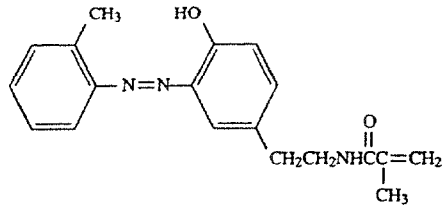
d, e, g, and h independently=an integer from 0 to 3; and

c and f independently=an integer from 1 to 4.

The approved product contains a polymerizable yellow dye having the formula provided in Claim 6 wherein R is CH_3; R^1 is CH_3; *a* is 1; R^2 is OH; *b* is 1; R^4 is CH_2CH_2; X is NH; *c* and *f* are 1; and *d, e, g* and *h* are 0.

Claim 7 of the '932 patent reads as follows:

7. The lens material of claim 6 wherein the polymerizable yellow dye is



The approved product contains a polymerizable yellow dye having the formula provided in Claim 7.

Claim 8 of the '932 patent reads as follows:

8. The lens material of claim 7 wherein the material comprises less than about 0.1 wt. % N-2-[3-(2'-methylphenylazo)-4-hydroxyphenyl]ethyl methacrylamide, and wherein less than about 10% of the material's blue light absorbancy is lost if the material is extracted with a solvent.

The lens material in the approved product contains less than 0.1 wt. % of the yellow dye of the formula provided in Claim 7and less than 10% of the approved product lens material's blue light absorbancy is lost if the material is extracted with a solvent.

Claim 9 of the '932 patent reads as follows:

9. The lens material of claim 1 wherein less than about 10% of the material's blue light absorbancy is lost if the material is extracted with a solvent.

The lens material in the approved product contains a polymerizable yellow dye having the formula provided in Claim 1 and less than 10% of the approved product lens material's blue light absorbancy is lost if the material is extracted with a solvent.

Claim 10 of the '932 patent reads as follows:

> **10.** The lens material of claim **1** further comprising an ultraviolet absorbing compound.

The lens material in the approved product contains an ultraviolet absorbing compound.

Claim 11 of the '932 patent reads as follows:

> **11.** The lens material of claim **10** wherein the total amount of polymerizable yellow dye and ultraviolet absorbing compound is less than about 1.9 wt. %.

The lens material in the approved product contains a total amount of polymerizable yellow dye having the formula provided in Claim 1 and ultraviolet absorbing compound less than 1.9 wt. %.

(10) The relevant dates and information specified in 35 U.S.C. §156(g) are as follows:

(v)(A) IDE G900110/S44

The investigational device exemption ("IDE") supplement application was filed on June 08, 2000. The IDE application was assigned serial number G900110/S44. The approval of the IDE application occurred on August 31, 2000.

(v)(B) PMA P930014/S009

The premarket approval ("PMA") supplement application was submitted on December 21, 2001. The PMA supplement application was assigned serial number P930014/S009.

(v)(C) PMA Approval

The PMA supplement application was approved on June 24, 2003.

(11) The activities undertaken by Alcon during the regulatory review periods identified in paragraph (10) above were as follows:

(A) 06/08/00 – 12/20/01

Investigational Device Exemption G900110/S44 (hereafter "IDE") was submitted to FDA under Section 520(g) of the Federal Food, Drug and Cosmetic Act on June 8, 2000. The notice of exemption was conditionally approved on July 7, 2000. A response to this conditional approval was submitted on July 31, 2000 that resulted in an IDE approval on August 31, 2000. A clinical investigation was then initiated with the first study lens implantation on September 14, 2000. Informational and protocol amendments were submitted as supplements to the IDE application in September 2000, November 2000, December 2000, April 2001 and July 2001. Additionally, during the time period of July 2000 through October 2001, Alcon participated in 8 teleconference calls with FDA regarding status of the IDE submission, clinical study and/or responding to FDA verbal inquiries.

(B) 12/21/01 – 06/24/03

Premarket Approval supplement P930014/S009 (hereafter "PMA") was submitted to FDA on December 21, 2001. Annual IDE Progress Report #1 was submitted to FDA on January 4, 2002. In April 2002, Alcon and FDA participated in a statutory "100-day" meeting to discuss the status of the PMA filing to date. Additional informational data were submitted to FDA as PMA-S amendments in January 2002, May 2002, June 2002, July 2002, March 2003, May 2003 and June 2003. During the time period of January 2002 through June 2003, Alcon participated in 27 teleconference calls with FDA regarding status of the PMA-S and/or with informational responses to FDA verbal inquiries. Subsequent to the PMA filing, Alcon continuously and diligently sought approval of its PMA covering this product. There were no periods between December 21, 2001 and June 24, 2003 that Alcon did not actively

- pursue approval from the FDA for commercial marketing of this product.

Annual IDE Progress Report #2 was submitted to FDA on January 26, 2003.

Statement of Applicant's Opinion Concerning Eligibility for an Extension and the Length of the Extension

(12) In the opinion of Alcon, United States Patent No. 5,470,932 is eligible for an extension of **832 days**. The length of the extension was calculated as follows:

(a) IDE Period

The IDE period began on June 8, 2000, and ended on December 20, 2001. The IDE period therefore included a total of 561 days. One-half of this total is 280.5 days or 281 days.

(b) PMA Period

The PMA period began on December 21, 2001, and ended on June 24, 2003. The PMA period therefore included a total of 551 days.

(c) Total Regulatory Review Period

The regulatory review period for purposes of patent term extension was 832 days (i.e., 281 days plus 551 days).

(d) Limitation on Extension (§1.777(d)(3) – (5))

Under the provision of 35 U.S.C. §156(c)(3), the term of a patent remaining after the date of product approval cannot exceed fourteen (14) years. In the present case, this means that the term of the '932 patent cannot be extended beyond June 24, 2017. Additionally, for patents issued

after September 24, 1984, the maximum term extension is 5 years. In this case, adding 832 days to the expiration date of the '932 patent does not extend the term for more than 5 years. Therefore, it is the opinion of Applicant that all 832 of the 832 regulatory review period days available for patent extension can be utilized.

(13) Alcon hereby acknowledges a duty to disclose to the Commissioner of Patents and Trademarks and the Secretary of Health and Human Services any information which is material to the determination of entitlement to the extension requested herein.

(14) The accompanying Transmittal Letter requests that the $1,120.00 fee required by 37 C.F.R. §1.20(j) be charged to Deposit Account No. 01-0682.

(15) Alcon requests that all correspondence and inquiries in connection with this Application be directed to the following individual:

Patrick M. Ryan
Patent Department, Q-148
Alcon
6201 South Freeway
Fort Worth, Texas 76134
Phone: (817) 551-3066
Fax: (817) 551-4610

As required by §1.740(b), two additional copies of this Application (for a total of three copies) are enclosed with this Application.

Based on the foregoing, it is believed that United States Patent No. 5,470,932 is entitled to an extension of 832 days. An official notice to that effect in the form of a certificate of extension is respectfully requested.

Respectfully submitted,

ALCON

Date July 10, 2003

By Patrick M. Ryan
Patrick M. Ryan
Registration No. 36,263

Address for Correspondence:
Patrick M. Ryan
R&D Counsel Q-148
Alcon Research, Ltd.
6201 South Freeway
Fort Worth, Texas 76134-2099
Phone: (817) 551-3066

DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Service

Food and Drug Administration
9200 Corporate Boulevard
Rockville MD 20850

Ms. Sherri Lakota
Manager, Regulatory Affairs
Alcon Research Ltd.
6201 South Freeway
Forth Worth, TX 76134-2099

JUN 24 2003

Re: P930014/S009
AcrySof® NATURAL Single-Piece Posterior Chamber Intraocular Lens (Model SB30AL)
Filed: December 26, 2001
Amended: January 28, May 16, June 20, and July 10, 2002 and
March 10, May 27, and June 17, 2003

Dear Ms. Lakota:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) has completed its evaluation of your premarket approval application (PMA) supplement, which requested approval for the AcrySof® NATURAL Single Piece Intraocular Lens (Model SB30AL). The device, as modified, will be marketed under the trade name AcrySof® NATURAL Single Piece Intraocular Lens (Model SB30AL) and is indicated for the replacement of the human lens to achieve visual correction of aphakia in adults when extracapsular cataract extraction or phacoemulsification are performed. These lenses are intended for placement in the capsular bag. Based upon the information submitted, the PMA supplement is approved. You may begin commercial distribution of the device as modified by your PMA supplement in accordance with the conditions described below and in the "Conditions of Approval" (enclosed).

The sale, distribution, and use of this device are restricted to prescription use in accordance with 21 CFR 801.109 within the meaning of section 520(e) of the Federal Food, Drug, and Cosmetic Act (the act) under the authority of section 515(d)(1)(B)(ii) of the act. FDA has also determined that, to ensure the safe and effective use of the device, the device is further restricted within the meaning of section 520(e) under the authority of section 515(d)(1)(B)(ii) insofar as the sale, distribution, and use must not violate sections 502(q) and (r) of the act.

CDRH does not evaluate information related to contract liability warranties, however you should be aware that any such warranty statements must be truthful, accurate, and not misleading, and must be consistent with applicable Federal and State laws.

Failure to comply with the conditions of approval as attached invalidates this approval order. Commercial distribution of a device that is not in compliance with these conditions is a violation of the act.

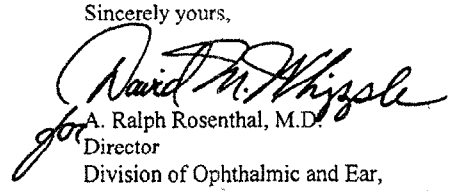
You are reminded that as soon as possible and before commercial distribution of your device you must submit an amendment to this PMA with copies of all approved labeling in final form. The labeling will not routinely be reviewed by FDA staff when PMA supplement applicants include with their submission of the final printed labeling a cover letter stating that the final printed labeling is identical to the labeling approved in draft form. If the final printed labeling is not identical, any changes from the final draft labeling should be highlighted and explained in the amendment.

All required documents should be submitted in triplicate, unless otherwise specified, to the address below and reference the above PMA number to facilitate processing.

PMA Document Mail Center (HFZ-401)
Center for Devices and Radiological Health
Food and Drug Administration
9200 Corporate Blvd.
Rockville, Maryland 20850

If you have questions concerning this approval order, please contact Kesia Alexander, Ph.D. at (301) 594-2053.

Sincerely yours,



for A. Ralph Rosenthal, M.D.
Director
Division of Ophthalmic and Ear,
Nose and Throat Devices
Office of Device Evaluation
Center for Devices and
Radiological Health

Enclosure

US005470932A

United States Patent [19]

Jinkerson

[11] Patent Number: 5,470,932

[45] Date of Patent: Nov. 28, 1995

[54] **POLYMERIZABLE YELLOW DYES AND THEIR USE IN OPTHALMIC LENSES**

[75] Inventor: **David L. Jinkerson**, Fort Worth, Tex.

[73] Assignee: **Alcon Laboratories, Inc.**, Fort Worth, Tex.

[21] Appl. No.: **138,663**

[22] Filed: **Oct. 18, 1993**

[51] **Int. Cl.**[6] **C08F 226/02**; C08F 220/10

[52] **U.S. Cl.** **526/312**; 526/328.5

[58] **Field of Search** 526/312, 328.5

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,573,998	3/1986	Mazzocco	623/6
4,619,657	10/1986	Keates et al.	623/6
4,619,662	10/1986	Juergens, Jr.	623/6
4,795,461	1/1989	Lindqvist et al.	623/6
4,863,466	9/1989	Schlegel	623/6
4,878,748	11/1989	Johansen et al.	351/44
5,047,447	9/1991	Gallas	523/106

FOREIGN PATENT DOCUMENTS

0259532	3/1988	European Pat. Off. .
0359829	3/1990	European Pat. Off. .
60-202-110-A	10/1985	Japan .
60-192712	10/1985	Japan .
1-299560	12/1989	Japan .
3-57629	3/1991	Japan .
3-128060	5/1991	Japan .
1516111A1	10/1989	U.S.S.R. .
89/03386	4/1989	WIPO .
91/01696	2/1991	WIPO .

OTHER PUBLICATIONS

Zigman, "Tinting of Intraocular Lens Implants," *Arch Opthalmol, vol. 100, 998 (1982).*

Hovis et al., "Physical Characteristics and Perceptual Effects of Blue-Blocking Lenses," *Optometry & Vision Science,* vol. 66(10), 682–689 (1989).

Lerman et al., "Spectroscopic Evaluation and Classification of the Normal, Aging, and Cataractous Lens," *Opthal. Res.* vol. 8, 335–353 (1976).

Nilsson et al., "Does a blue light absorbing IOL material protect the neuro-retina and pigment epithelium better than currently used materials!", *Lasers and Light in Ophthalmology,* vol. 3(1), 1–10 (1990).

Guthrie, "Polymeric Colorants," *Rev. Prog. Color Relat. Topics,* vol. 20, 40–52 (1990).

Ham, Jr. et al., "Retinal effects of blue light exposure," *SPIE vol. 229 Ocular Effects of Non-ionizing Radiation,* 46–50 (1980).

Ham, Jr., "Ocular Hazards of Light Sources: Review of Current Knowledge," *Journal of Occupational Medicine,* vol. 25(2), 101–103 (1983).

Primary Examiner—Joseph L. Schofer
Assistant Examiner—Wu C. Cheng
Attorney, Agent, or Firm—Patrick M. Ryan

[57] **ABSTRACT**

Novel polymerizable yellow dyes are disclosed. Additionally, novel and known dyes are used to block or lower the intensity of blue light transmitted through ocular lenses and other windows.

11 Claims, 3 Drawing Sheets

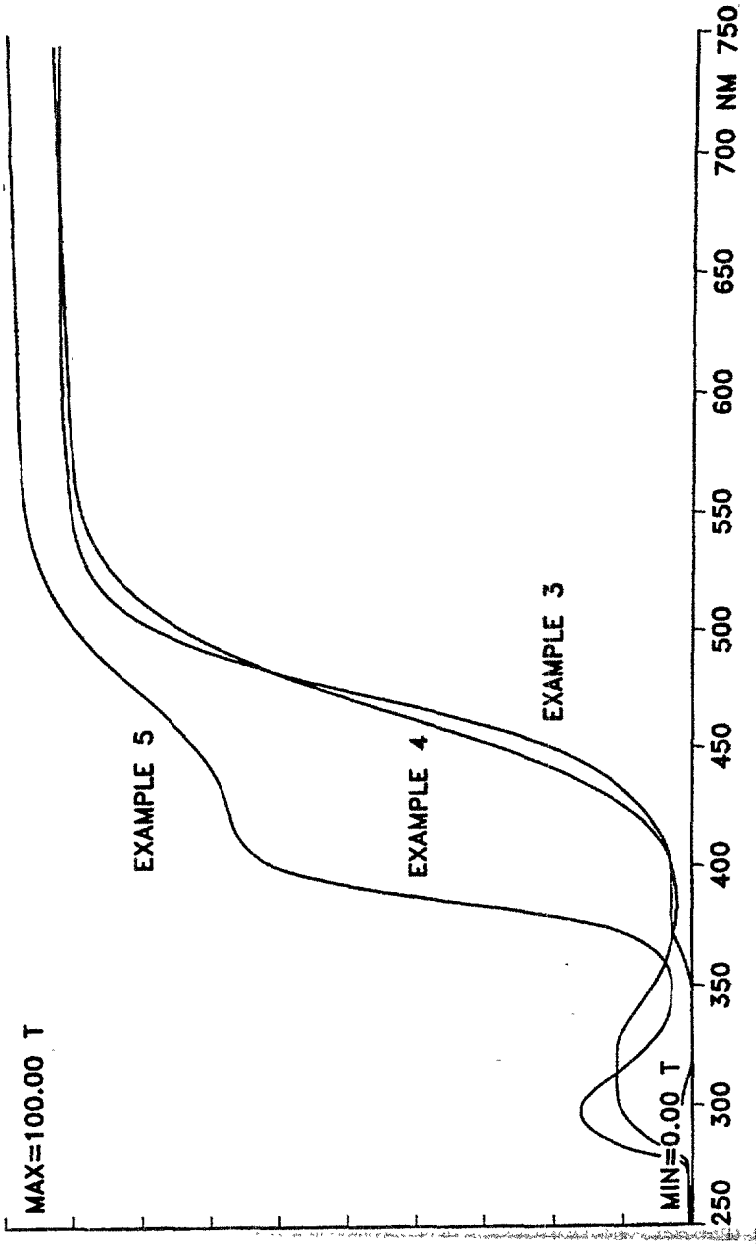

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FIGURE 1

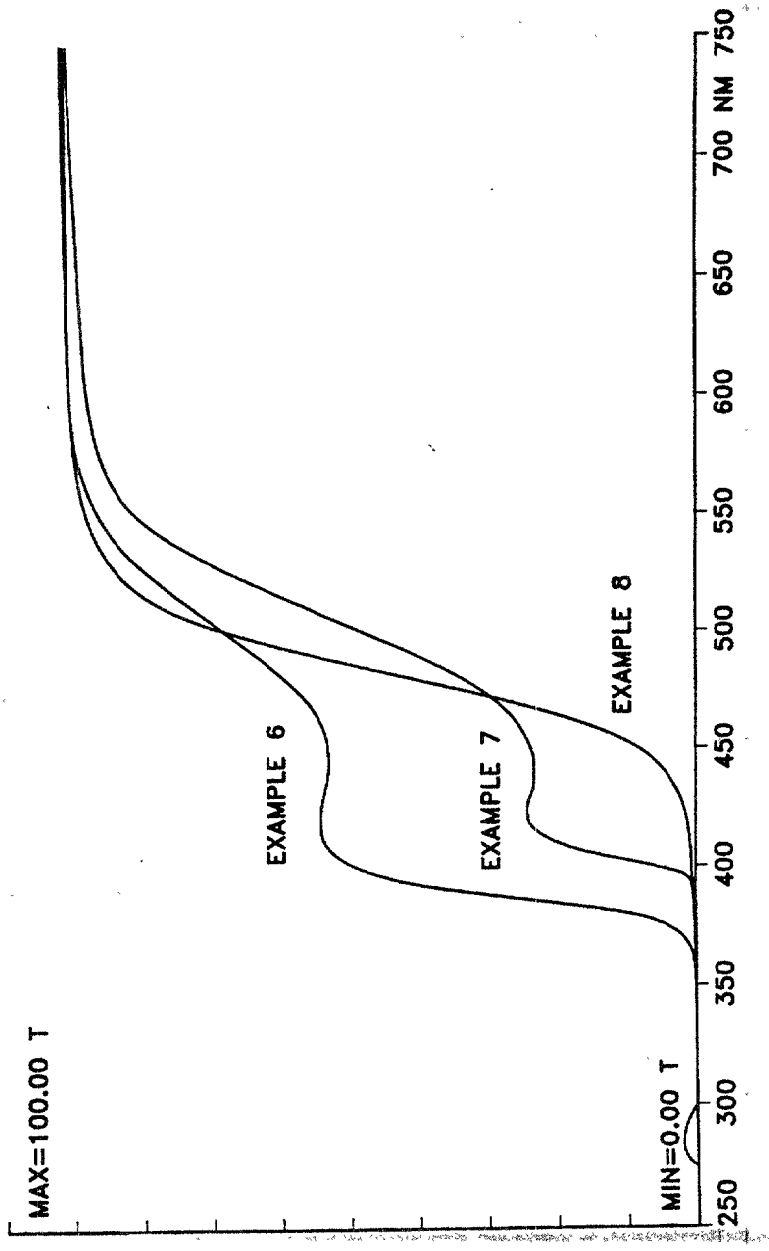
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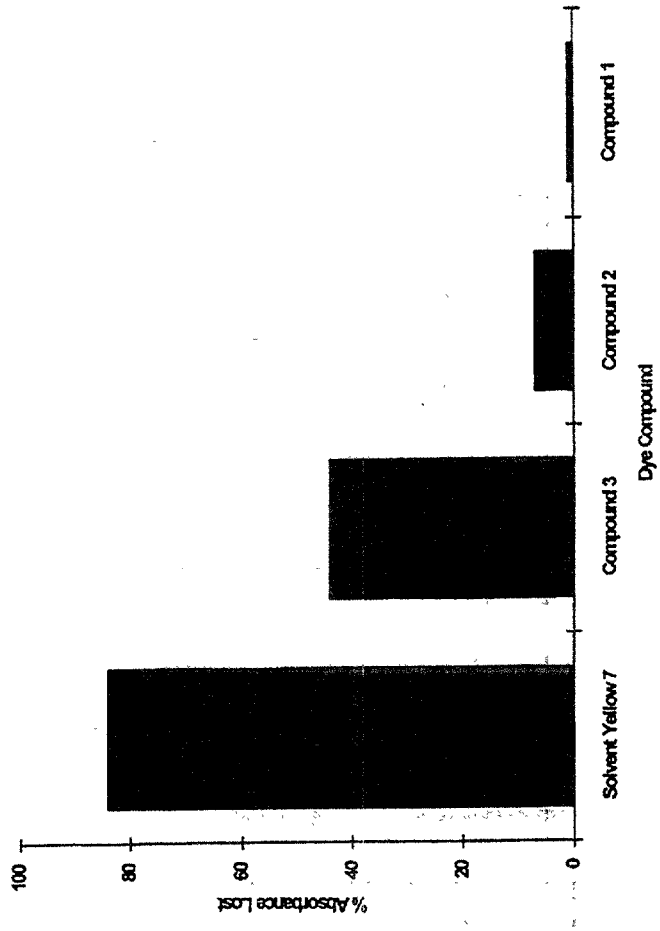
FIGURE 2

FIGURE 3


Solvent Yellow 7
Compound 3
Compound 2
Compound 1
Dye Compound
% Absorbance Lost
100
80
60
40
20
0

POLYMERIZABLE YELLOW DYES AND THEIR USE IN OPTHALMIC LENSES

FIELD OF THE INVENTION

This invention relates to polymeric yellow dyes and their use in ophthalmic lenses. In particular, this invention relates to polymerizable yellow dyes of the azo family in "blue-blocking" ophthalmic lenses.

BACKGROUND OF THE INVENTION

The assessment of optical hazards in recent years has led to the recognition of the possible hazards to the retina associated with blue light (400–500 nm). If the blue light hazard is a real threat to vision, then the UV/visible transmission characteristics of ophthalmic lenses, and intraocular lenses (IOLs) in particular, should be modified to provide adequate protection from blue light hazards encountered in the environment.

In the ambient environment solar radiation is the primary hazard to vision. The sun freely emits UV, visible and IR radiation much of which is absorbed by the atmosphere. The solar radiation that is transmitted through the atmosphere and reaches the earth's surface consists of UV-B radiation (230–300 nm), near UV or UV-A radiation (300–400 nm), visible light (400–700 nm) and near IR radiation (700–1400 nm). The ocular media of man in its normal, healthy state freely transmits near IR and most of the visible spectrum to the retina, but UV-B radiation is absorbed by the cornea and does not reach the retina. The transmission of near UV and the blue portion of the visible spectrum can be absorbed by the crystalline lens depending on age.

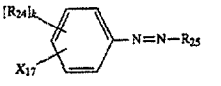
The human crystalline lens changes its UV and visible transmission characteristics as it ages. In infancy the human lens will freely transmit near UV and visible light above 300 nm, but with further aging the action of UV radiation from the environment causes the production of yellow pigments, fluorogens, within the lens. By age 54 the lens will not transmit light below 400 nm and the transmission of light between 400 and 500 nm is greatly diminished. As the lens ages it continuously develops a yellow color, increasing its capacity to filter out near UV and blue light. Therefore, after cataract removal the natural protection provided by the aged human lens is also removed. If the cataract is replaced by an IOL, usually UV protection is provided, but blue light protection is still lacking.

The use of conventional yellow dyes, such as commercially available 4 -phenylazophenol (Solvent Yellow 7), 2-(2'-methyl)-phenylazo-4-methyl phenol (Solvent Yellow 12) and N-(4-phenylazo)phenyl diethanol amine (Solvent Yellow 58), in IOLs to block blue light is not desirable because these dyes are not bound to the lens material and thus may leach out of the IOL after it is inserted in the eye. These nonbonded dyes also cause problems in the manufacture of polymer lenses that are extracted with a solvent after they are formed. In this extraction step, the solvent may remove up to 90% of the non-bonded dye from the lens.

Japanese Kokai Patent Application No. Hei 1[11989]-299, 560 ("Menikon Application") claims an intraocular lens material characterized by a polymerizable ultraviolet light absorber having a polymerizable group selected from an acrylol group, a methacrylol group, a vinyl group, an allyl group, and an isopropenyl group, and a polymerizable dye having a polymerizable group selected from an acryloyl group, an allyl group, and an isopropenyl group, which are

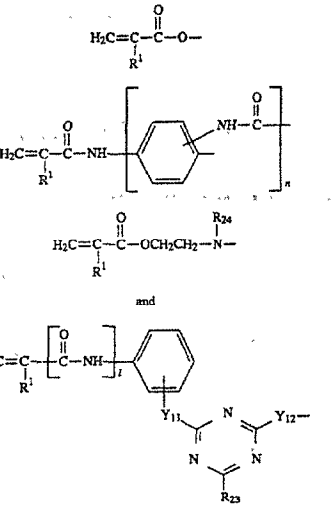
copolymerized with other polymerizable lens-forming monomer components. Also taught by the Menikon Application are polymerizable dyes having a polymerizable group selected from methacryloyl groups, vinyl groups, and acryl groups. The Menikon Application lists numerous formulas representing hundreds of dyes. As examples of the polymerizable dyes of the azo system, the Menikon Application lists those of the general formula:

Structure VI



where

X_{17} may be, among others, any of the groups represented by:



R^1 is —H or —CH_3;

R_{23} may be, among others, —H, —OH, or a halogen atom;

R_{24} may not be H, but may be —OH, —CH_3, —C_2H_5, —OCH_3, —OC_2H_5, and halogen atoms;

k, m, l, and n are integers of 0 or 1;

R_{25} may be, among others, a benzene derivative substituted with C_1–C_8 alkyl groups;

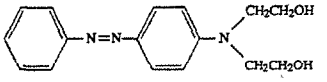
R_{26} is —H, or C_1 to C_3 lower alkyl; and

Y_{11} and Y_{12} are —NH— or —O—.

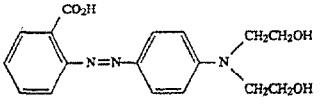
The azo dyes taught in the Menikon Application suffer the following disadvantages, however. Directly attaching reactive acrylic/methacrylic groups or other electron-withdrawing groups, such as carbonyl, carboxylic acid, or ester groups, to the dye moiety weakens dye strength and may change dye color.

The effect of electron-withdrawing groups on the color and relative strength of a yellow dye can be quite pronounced. For example, the yellow dye known as Solvent Yellow 58 is converted into a red dye, Pigment Red 100,

solely by the addition of a carboxylic acid group directly bonded to the phenylazophenyl dye moiety.



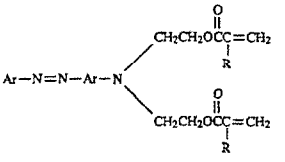
Solvent Yellow 58



Pigment Red 100

There is only one case in which the Menikon Application allows an acrylic/methacrylic group not directly bound to the azo dye moiety by an electron-withdrawing group. This case requires instead that an amino group be directly attached to the dye moiety. Even though amino azo dyes are useful, they are less desirable than phenolic azo dyes because the amino group accelerates the decomposition of peroxide initiators, such as those used in conventional free-radical polymerization processes.

Another example of dyes based on the amino azo system are the polymeric colorants based on acrylated chromophores of the type



wherein R=CH_3 or H; and the Ar group is phenyl, naphthyl, etc. Guthrie, "Polymeric Colorants," *Rev. Prog. Color Relat. Topics*, Vol. 20, 40–52 (1990). Substituents may be added to the aromatic groups to provide variations in color and other physical properties. The works of various people am summarized in this review article. Some of the work reviewed includes reactive azo dyes containing methacrylate, acrylate, epoxide and vinyl ester functionalities in the following applications and studies: optical recording materials, the non-linear optical susceptibility of copolymers containing acrylic azo monomers and methyl methacrylate, and the determination of copolymerization parameters and reactivity ratios for the copolymerization of azo dye monomers containing a methacryloyl functionality with styrene and with methyl methacrylate.

What is needed are additional polymerizable yellow dyes which are easily synthesized from commercially available dyes or other starting materials and which, when incorporated in ophthalmic lenses, will not be extracted out of the lens during solvent extraction or leach out of the lens after insertion in the eye.

SUMMARY OF THE INVENTION

The polymerizable yellow dyes of the invention are soluble in organic monomers, such as acrylic/methacrylic monomers, and contain in their chemical structure one or more acrylic or methacrylic functional groups which are reactive towards free radical polymerization. These dyes, when polymerized with organic monomers capable of forming a transparent material, will be bonded to the polymer and thus greatly reduce the amount of dye which can leach out of the material. As a result, these dyes can be used in transparent materials to decrease the intensity of blue light transmitted through them. These transparent materials with one or more of the bondable yellow dyes incorporated in them may be extracted with organic solvents to remove unreacted monomers, low molecular weight oligomers and low molecular weight polymers, as well as other impurities, and then used to make ocular lenses such as intraocular lenses (IOLs), contact lenses, eyeglasses and other windows. These transparent materials containing yellow dye may also be used to make lens coating materials.

Although like compounds can be expected to copolymerize more efficiently than unlike compounds, it has now been found that polymerizable yellow dyes having one or more polymerizable acrylate or methacrylate groups which have been copolymerized with one or more lens-forming acrylate or methacrylate monomers are much more efficiently incorporated into the polymeric lens materials than yellow dyes having other types of polymerizable groups, such as vinyl groups.

Additionally, it has now been found that polymerizable yellow dyes of the azo family which do not contain electron-withdrawing groups directly attached to the dye moiety are much stronger yellow dyes than those which do. Acrylic/methacrylic yellow dyes which do not have the polymerizable group directly bonded to the dye moiety are therefore stronger than those which do.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 show the transmittance of acrylic/methacrylic ophthalmic lens materials containing various yellow dyes.

FIG 3 presents a polymerization incorporation efficiency comparison of four dye compounds.

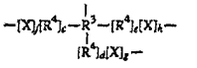
DETAILED DESCRIPTION OF THE INVENTION

The polymerizable yellow dyes of the present invention are based on the azo dye system and contain polymerizable acrylate/methacrylate groups. These dyes are characterized by a spacing group which separates the polymerizable acrylate/methacrylate group from the dye moiety. These dyes are further characterized by the absence of an electron-withdrawing group directly attached to the dye moiety.

As used herein, "dye moiety" refers to the portion of the dye molecule primarily responsible for causing the dye's intense color. In this invention, the dye moiety is thus the phenyl-azo-phenyl (Ph—N=N—Ph) portion of the polymerizable yellow dye structure.

The spacing groups of this invention may be any group which separates, by means of covalently bonded atoms, the dye moiety from the polymerizable acrylic/methacrylic group. The spacing group separates the dye moiety from the acrylic/methacrylic group in such a way as to minimize the effect of the acrylic/methacrylic group on dye strength and color. The minimum effect on dye strength and color is achieved by directly attaching the spacing group to the dye moiety with a non-electron-withdrawing residue.

Preferred spacing groups of the present invention are those of the formula:



where

R^3 is directly attached to the dye moiety and consists of an alkyl group of up to 6 carbon atoms;

R^4 is an acylic organic spacing group of up to 10 atoms which is composed of carbon, hydrogen, silicon, oxygen, nitrogen, phosphorous, sulfur, chloride, bromine, or fluorine alone or in any combination;

X=O, NH, NR^5;

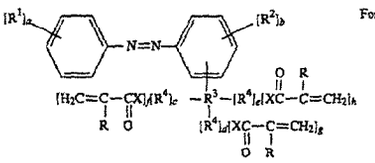
R^5=C_1 to C_{10} alkyl;

d, e, g, and h independently=an integer from 0 to 4; and

c and f independently=an integer from 1 to 4.

Electron-withdrawing groups are not permitted to be covalently bonded to the dye moiety because they can weaken the strength of the yellow dye and, in some cases, change the absorption nature of the dye sufficiently to cause a change in color. Examples of electron-withdrawing groups which are not permitted to be directly attached to the dye moiety include carbonyl groups, such as those found in ketones; carboxylic acid esters; amides; imines; immides; imminic acid esters (especially analogues derived from 1,3,5-triazeno systems); ureas; urethanes; and so on.

The novel dye compounds of the present invention include acrylates/methacrylates of the formula:



Formula 1

wherein

R=H or CH_3;

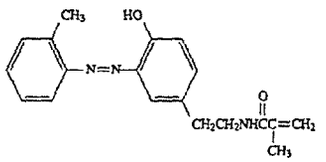
R^1=H, C_1 to C_{20} alkyl, OCH_3, OC_2H_5, OC_3H_7, or OC_4H_9;

a and b independently=the integer 1 or 2;

R^2=R^1, OH, NH_2, NHR^5, $N(R^5)_2$, SH, SR^5, OR^5, $OSi(R^5)_3$or $Si(R^5)_3$; and

R^3, R^4, R^5, X, c, d, e, f, g and h are as defined above.

The preferred compound of Formula 1 is N-2-[3-(2'-methylphenylazo)-4 -hydroxyphenyl]ethyl methacrylamide:



Compound 1

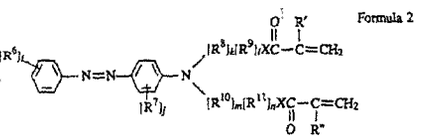
Compounds of Formula 1 may be prepared by starting with a phenolic, aniline, or other substituted benzene compound containing an organic spacing group terminated by one or more amino or hydroxyl moieties. One skilled in the art could form a reaction with methacrylic anhydride, acrylic anhydride, acryloyl chloride, methacryloyl chloride or other suitable acrylic/methacrylic reagent to give an intermediate acrylic/methacrylic compound. If necessary to induce the reactivity of the side chain amino or hydroxyl group, strong bases, such as sodium hydride or butyllithium, may be employed; weaker bases, such as triethylamine, may also be useful.

The intermediate acrylic/methacrylic compound may then be azo-coupled with an appropriate diazonium salt to yield the reactive azo yellow dyes of Formula 1. Such azo coupling reactions are performed in two stages. In the first stage, an appropriate aniline compound (optionally substituted) is converted into a reactive diazonium salt at low temperatures, such as 0° to 10° C., by reaction with sodium or other suitable nitrite salt in aqueous solution at about pH 2. In the second stage, the reactive diazonium salt is then azo-coupled with the intermediate acrylic/methacrylic compound described above to form the desired azo product. The azo coupling of phenolic compounds proceeds best at a solution pH of about 4 to 8. However, with increasing reaction pH, the diazonium salt has a tendency to form byproducts via side reactions.

These side reaction products are also phenolic compounds which can compete with the desired intermediate acrylic/methacrylic compound in the azo coupling reaction. As a result, changing the reaction stoichiometry from a 1:1 molar equivalence to a 4:1 excess of diazonium salt to acrylic/methacrylic intermediate compound is the preferred way to synthesize Compound 1. Other reaction stoichiometries may be more effective in the azo coupling of other acrylic/methacrylic phenolic intermediates as determined by someone skilled in the art.

In the case of Compound 1, tyramine [4-(2-aminoethyl)phenol] acts as the phenolic starting material. It is reacted with methacrylic anhydride without catalytic base being necessary to give the intermediate compound containing the reactive acrylic/methacrylic moiety, 4-(2-methacrylamidoethyl)phenol. The azo coupling reagent is then prepared by reacting ortho-toluidine (2-methylaniline) at about 0° C. and pH 2 with sodium nitrite in the presence of 6N hydrochloric acid. This produces the reactive diazonium salt of ortho-toluidine. This diazonium salt is then reacted in situ with the phenoxide of the intermediate compound, 4-(2-methacrylamidoethyl) phenol, by azo coupling to give the preferred compound of Formula 1, Compound 1.

Also included within the scope of the present invention are the diacrylates/dimethacrylates of the formula:



Formula 2

wherein

R' and R" independently=H or CH_3;

R^6 and R^7 independently=R^1;

i and j independently=the integer 1 or 2;

R^8, R^9, R^{10} and R^{11} independently=R^4;

k and m independently=an integer from 1 to 6;

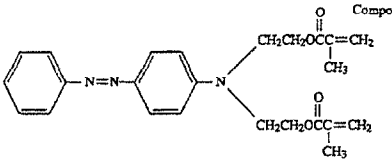
l and n independently=an integer from 0 to 6;

x=O, NH, NR^5; and

R^5=C_1 to C_{10} alkyl.

The preferred compound of Formula 2 is N,N-bis-(2-

methacroylethyl)-(4 -phenylazo)aniline:



Compound 2 may be prepared by the azo coupling reaction of aniline (optionally substituted) with N-phenyldiethanolamine under conditions described above for azo coupling reactions, except that only a 1:1 stoichometry is necessary for azo coupling of N-phenylamines with diazonium salts. The azo coupling proceeds well at a pH of about 2 to 4. The diazonium salt of aniline is reacted in-situ with N-phenyldiethanolamine to give the intermediate azo dye N-(4-phenylazo)phenyldiethanolamine (also known as Solvent Yellow 58). The dimethacrylate derivative can then be prepared by reacting the intermediate azo dye, N-(4-phenylazo)phenyldiethanolamine with methacrylic anhydride in the presence of a weak base, such as triethylamine, to yield the reactive dimethacrylic azo yellow dye, N-(4' -phenylazo)phenyl-2-bis-(2-methacrylo)ethylamine. In addition, other stronger bases, such as sodium hydride or butyllithium, might be used to form the disodium or dilithium salt followed by reaction with methacrylic anhydride, or other methacrylic/acrylic agent used to incorporate the polymerizable group.

As one skilled in the art would appreciate, other compounds of Formula 2 may be prepared using analogous reaction sequences and corresponding starting materials. In general, compounds of Formula 2 may be prepared by azo coupling aniline (optionally substituted) with a variety of N-phenylamines having two pendant organic spacing groups attached to the amine functionality. The organic spacing groups contain hydroxy or amino residues to which acrylic/methacrylic functional groups may be bonded.

The yellow polymerizable dyes of the present invention may be incorporated in a number of materials in a variety of applications where it is desirable to block blue light (approximately 400–500 nm.). Such applications may include, for example, contact lenses, eyeglasses and sunglasses. A preferred application is the use of yellow polymerizable dyes in intraocular lenses. As such, one embodiment of the present invention is an intraocular lens containing one or more polymerizable yellow dyes ("blue-blocking IOLs").

The blue-blocking IOLs of this invention may be made by co-polymerizing one or more lens-forming monomers with one or more polymerizable yellow dyes of Formula 1 or 2. In a preferred embodiment, these monomers are cured directly in a polypropylene mold so that a finished optic is produced. The time and temperature for curing vary with the particular lens-forming material chosen. The optic may be combined in a number of known ways with a variety of known haptics to produce an IOL.

The total amount of yellow dye used to form a blue-blocking IOL is typically less than about 1 wt. %. Preferably, the total amount of yellow dye is less than about 0.25 wt. %, and most preferably, the total amount of yellow dye is less than about 0.1 wt. %.

Suitable lens-forming monomers for use in the present invention include methyl methacrylate, 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, 3-hydroxypropyl acrylate, 3-hydroxypropyl methacrylate, n-vinyl pyrolidone, styrene, eugenol (4 -hydroxyvinylbenzene), α-methylstyrene. In addition, for high-refractive index foldable lens applications, suitable monomers include, but are not limited to: 2-ethylphenoxy methacrylate, 2-ethylphenoxy acrylate, 2-ethylthiophenyl methacrylate, 2 -ethylthiophenylacrylate, 2-ethylaminophenyl methacrylate, phenyl methacrylate, benzyl methacrylate, 2-phenylethyl methacrylate, 3-phenylpropyl methacrylate, 4-phenylbutyl methacrylate, 4-methylphenyl methacrylate, 4-methylbenzyl methacrylate, 2-2 -methylphenylethyl methacrylate, 2-3-methylphenylethyl methacrylate, 2-4 -methylphenylethyl methacrylate, 2-(4-propylphenyl)ethyl methacrylate, 2-(4-(1 -methylethyl)phenyl)ethyl methacrylate, 2-(4-methoxyphenyl)ethyl methacrylate, 2-(4 -cyclohexylphenyl)ethyl methacrylate, 2-(2-chlorophenyl)ethyl methacrylate, 2-(3 -chlorophenyl)ethyl methacrylate, 2-(4-chlorophenyl)ethyl methacrylate, 2-(4 -bromophenyl)ethyl methacrylate, 2-(3-phenylphenyl)ethyl methacrylate, 2-(4 -phenylphenyl)ethyl methacrylate), 2-(4-benzylphenyl)ethyl methacrylate, and the like, including the corresponding methacrylates and acrylates. N-vinyl pyrolidone, styrene, eugenol and α-methyl styrene may also be suitable for high-refractive index foldable lens applications. A preferred lens-forming monomer mixture is the mixture of 2 -phenylethyl methacrylate (PEMA) and 2-phenylethyl acrylate (PEA).

The copolymerizable cross-linking agent used in the lens-materials of this invention may be any terminally ethylenically unsaturated compound having more than one unsaturated group. Suitable cross-linking agents include, for example: ethylene glycol dimethacrylate, diethylene glycol dimethacrylate, allyl methacrylate, 1,3 -propanediol dimethacrylate, allyl methacrylate, 1,6-hexanediol dimethacrylate, 1,4 -butanediol dimethacrylate, and the like. A preferred cross-linking agent is 1,4 -butanediol diacrylate (BDDA).

Suitable crosslinkers also include polymeric crosslinkers, such as, Polyethylene glycol 1000 Diacrylate, Polyethylene glycol 1000 Dimethacrylate, Polyethylene glycol 600 Dimethacrylate, Polybutanediol 2000 Dimethacrylate, Polypropylene glycol 1000 Diacrylate, Polypropylene glycol 1000 Dimethacrylate, Polytetramethylene glycol 2000 Dimethacrylate, and Polytetramethylene glycol 2000 Diacrylate.

An ultra-violet absorbing material can also be included in the polymeric lenses of this invention in order that the lenses may have an ultraviolet absorbance approximately equivalent to that of the natural lens of the eye. The ultraviolet absorbing material can be any compound which absorbs ultraviolet light, i.e., light having a wavelength shorter than about 400 nm, but does not absorb any substantial amount of visible light. The ultraviolet absorbing compound is incorporated into the monomer mixture and is entrapped in the polymer matrix when the monomer mixture is polymerized. Suitable ultraviolet absorbing compounds include substituted benzophenones, such as 2-hydroxybenzophenone, and 2-(2 -hydroxyphenyl)benzotriazoles. It is preferred to use an ultraviolet absorbing compound which is copolymerizable with the monomers and is thereby covalently bound to the polymer matrix. In this way possible leaching of the ultraviolet absorbing compound out of the lens and into the interior of the eye is minimized. Suitable copolymerizable ultraviolet absorbing compounds are the substituted 2-hydroxybenzophenones disclosed in U.S. Pat. No. 4,304,895 and the 2-hydroxy-5-acryloxyphenyl-2 H-benzotriazoles disclosed in U.S. Pat. No. 4,528,311. The most preferred ultraviolet absorbing compound is 2-(3'-methallyl-2'-hy-

droxy-5'methyl phenyl)benzotriazole, also known as ortho-methallyl TinUVin P ("oMTP").

Since many ultraviolet absorbing compounds have phenolic substituents or residues within their structure that are known to inhibit polymerization, the less ultraviolet absorbing compound needed the better. Reducing the concentration of such ultraviolet absorbing compounds can be beneficial to the lens forming process. When the ultraviolet absorbing compound is oMTP, it is typically present in a concentration of approximately 1.8 wt. %. However, depending on the specific yellow dye chosen and the desired transmission at a given wavelength, considerably less than 1.8 wt. % of oMTP may be required to block the transmission of ultraviolet and blue light. The same is true for other ultraviolet absorbing compounds: the use of a yellow dye in conjunction with an ultraviolet absorbing compound requires less of the ultraviolet absorbing compound than the use of the ultraviolet absorbing compound alone. The total amount of both ultraviolet absorbing compound and polymerizable yellow dye required in the IOL monomer mixture to effectively block light of about 500 nm and below may be less than 1.9 wt. %. In some cases, depending on the specific ultraviolet absorbing compound and yellow dye chosen, the total amount may be considerably less than about 1.9 wt. %.

The lens materials of this invention are prepared by generally conventional polymerization methods. A mixture of lens-forming, ultraviolet absorbing and blue light blocking monomers in the desired proportions together with a conventional thermal free-radical initiator is prepared. The mixture can then be introduced into a mold of suitable shape to form the lens, and the polymerization carried out by gentle heating to activate the initiator. Typical thermal free radical initiators include peroxides, such as benzyl peroxide, peroxycarbonates, such as bis-(4 -t-butylcyclohexyl)peroxydicarbonate, azonitriles, such as azo-bis-(isobutyronitrile) (AIBN), and the like. A preferred initiator is bis-(4-t-butylcyclohexyl peroxydicarbonate) (PERK). Alternatively, the monomers can be photopolymerized by using a mold which is transparent to actinic radiation of a wavelength capable of initiating polymerization of these acrylic monomers by itself. Conventional photoinitiator compounds, e.g., a benzophenone-type photoinitiator, can also be introduced to facilitate the polymerization. Photosensitizers can be introduced as well to permit the use of longer wavelengths; however, in preparing a polymer which is intended for long residence within the eye, it is generally preferable to keep the number of ingredients in the polymer to a minimum to avoid the presence of materials which might leach from the lens into the interior of the eye.

The polymerizable yellow dyes of this invention may also be used in lens coatings. Such coatings are produced by polymerizing the monomeric dyes of this invention with soluble polymers and casting them onto transparent materials. After coating and evaporation of the polymer solvent, such polymer solutions would impart a yellow film onto the transparent material and give the material blue light protective properties. Also, the polymerizable yellow dyes of this invention can be dissolved into a suitable monomer formula, cast onto a transparent material, and cured by a suitable free-radical initiation procedure, such as exposure to heat or UV radiation. A common technique for casting such polymer or monomer solutions might include the spin casting technique for applying thin films to surfaces.

The polymerizable yellow dyes of this invention might also be dissolved into a suitable solvent or monomer formula, followed by immersion of the transparent material into the dye solution. The transparent material would then imbibe the dye into its matrix by absorbing the solution and swelling. The curing of the polymerizable dyes can be accomplished by heat, radiation or other means suitable to bond the dye into the polymer.

The invention will be further illustrated by the following examples which are intended to be illustrative, but not limiting.

EXAMPLE 1

Preparation of Compound 1

Step one: Synthesis of Compound 1 Precursor

Into a reaction flask was added 4.4834 g (32.68 mmoles) of tyramine and 100 mL of methanol. The tyramine was dissolved with stirring and sonnication. To the reaction flask was added 5.089 g (33.01 mmoles) of methacrylic anhydride (MAA) dropwise with constant stirring. The reaction was performed at room temperature and was monitored by high performance liquid chromatorgraphy (HPLC). Within the first hour after the MAA addition, the reaction was completed.

To the reaction flask was added 100 mL of 10% Aq. NaCl and an additional 30 g of salt was added to the flask. The excess salt was filtered off and the reaction flask was cooled overnight in a freezer. The next morning a white solid precipitate was filtered from the reaction solution and was washed with cold 50:50 methanol:water solution. The liquid supernatent was cooled again to obtain a second crop of crystals. After filtering the second crop, all the solid precipitant was combined together and 5.6668 g (27.61 mmoles) of Compound 1 precursor product was obtained, Yield=84.5%.

The product was recrystallized from $CHCl_3$. The solid product was filtered off, dried in air and had a melting point of 123° C. The MP for tyramine starting material is 161°–163° C. The Compound 1 precursor product identity was confirmed by comparison of FTIR, NMR and mass spectrum data to that of the tyramine starting material.

Step two: Synthesis of Compound 1 from the Compound 1 Precursor

Into a 1000 mL beaker was added 200 mL of deionized water followed by 6.2 g (100 mmoles) of boric acid (H_3BO_3). The boric acid was dissolved with stirring and the pH was monitored with the aid of a Orion EA940 Ion Analyzer and a Ross pH electrode. To the beaker was added dropwise 6N HCl to adjust the solution to about pH 2. o-Toluidine in the amount of 2.0831 g (19.94 mmoles) was added to the beaker and the solution pH was again adjusted to pH 2 with the addition of 6N HCl. Ice was added to the reaction solution to cool it down to 0°–10° C.

Into a separate beaker was weighed 1.3603 g (19.71 mmoles) of sodium nitrite, $NaNO_2$ and 20 mL of water. The sodium nitrite solution was added dropwise into the reaction solution with constant stirring and monitoring of the solution pH. The pH of the reaction was maintained at about 1.9 to 2.2 by the addition of 6N HCl. Ice was added periodically to the reaction to keep the temperature at 0°–10° C. and the reaction was stirred for about 10 minutes.

Into another beaker was placed 1.0048 g (4.90 mmoles) of Compound 1 precursor, 30 mL of water and 1.96 mL of 2.5N NaOH (4.90 mmoles) solution. This solution was added dropwise into the ice-cooled reaction solution with constant stirring. The reaction solution began to develop a light yellowish-green color which grew more intense as more of the Compound 1 precursor solution was added. The reaction solution was allowed to stir at 0°–10° C. for about 15 minutes at pH 2.0–2.5.

A 2.5N NaOH solution was added in small aliquots to the reaction solution to bring the pH up to about 8.5. With increasing pH the yellow color of the reaction solution grew brighter. The reaction solution was allowed to warm up to room temperature over about 2–3 hour time interval. As the solution warmed up a red solid floated on top of the solution and the reaction began to take on an orange color. At this point the total reaction volume was about 900 mL. Upon warming to room temperature the reaction solution darkened to a red-brown color and a very dark solid. floated on the surface of the solution. To the solution was added 14.2 g (100 mmoles) of dibasic sodium phosphate. To the reaction solution was added 6N HCl dropwise until the pH was adjusted to about 6.0.

The dark precipitate from the reaction solution was filtered off and was combined with solid skimmed from the reaction solution. The solid red product was washed with about 400 mL of ice water and air dried on the filter for about 20–30 minutes. From the reaction 6.121 9 g of the red solid was obtained.

HPLC analysis of the red solid indicated that the reaction had three products. The products were separated by column chromatography using a silica gel column. The column was eluted with methylene chloride (CH_2Cl_2) and acetonitrile (MeCN) mobile phases. Fractions of various colored bands were collected as they eluted off the column and analyzed by HPLC. Fractions whose chromatograms indicated similar composition and purity were combined. These combined fractions were separately filtered through a 0.5 μm filter via a glass syringe into separate round bottomed flasks. The flasks containing the combined fractions were sequencially placed onto a rotary evaporator and the solvents removed under vacuum with low heating (approx. 50° C.). Upon solvent removal the products from the combined fractions remained. The flasks containing desired products were dried at 50° C. under vacuum. The combined fractions of pure product were re-analyzed by HPLC and also analyzed by mass spectroscopy and NMR spectroscopy to confirm its identity. Less pure fractions were purified by repeated column chromatography runs in the same manner as the above run until the desired product purity (>95%) was obtained.

The melting range of the product was 157°–160° C. and the amount of pure Compound 1 product obtained was 0.5153 g (1.60 mmoles), Yield=32.7%.

EXAMPLE 2

Preparation of Compound 2

Step one: Synthesis of Compound 2 Precursor by the Azo Coupling of Aniline with N-Phenyldiethanolamine

Into a 1000 mL beaker was added 200 mL of water and 14.2 g (100 mmoles) of sodium phosphate, dibasic (Na_2HPO_4) followed by the addition of 6N HCl solution to adjust the reaction solution to pH 2. After the phosphate buffer salt was completely dissolved, 4.7351 g (50.84 mmoles) of aniline was added to the reaction solution. Ice was added to the reaction solution to cool it down to 0° C.

Into a separate beaker, 3.5151 g (50.94 mmoles) of sodium nitrite, $NaNO_2$, was dissolved in 20 mL of water. Ice was added to cool the solution. The sodium nitrite solution was added dropwise with constant stirring to the reaction solution while constantly monitoring the pH of the reaction using a Orion EA940 Ion Analyzer and a Ross pH Electrode. The pH of the reaction was maintained to about 1.9 to 2.2 by the addition of 6N HCl. After the addition of sodium nitrite solution was completed more ice was added to the reaction to keep the temperature at 0°–10° C. and the reaction was stirred for about 15 minutes.

Into another beaker was placed 9.1481 g (50.48 mmoles) of N-Phenyldiethanolamine, 100 mL of water, and enough 6N HCl was added to dissolve the solid. The N-Phenyldiethanolamine solution was added dropwise into the stirring reaction solution which was kept at 0°–10° C. by periodic addition of ice. Immediately the reaction solution began to develop a dark red to purple color which grew more intense as more of the N-Phenyldiethanolamine solution was added. After the addition was completed the solution was stirred for about an hour and warmed up to about 10° C. Then 50% w/v and 2N NaOH solutions were added to the reaction solution to pH 6.9. As the pH of the reaction solution rose, a dark red solid precipitated out of solution. At this point the total reaction volume was about 1 L. The solid was filtered off and washed with water. 27.7363 g of wet precipitate was obtained.

The solid obtained from the reaction was recrystallized from a methanol:water 91:9 solution. The Compound 2 precursor product crystals were filtered off and dried under vacuum overnight at 50° C. The identity of the Compound 2 precursor was confirmed by NMR and mass spectroscopic analysis. Compound 2 precursor in the amount of 11.1449 g (39.06 mmoles) was obtained, melting range 136°–138° C., Yield=77.4%.

Step two: Synthesis of Compound 2 by the Reaction of Compound 2 Precursor with Methacrylic Anhydride

Into a 100 mL round bottomed flask was placed 1.4299 g (5.011 mmoles) of Compound 2 precursor and 25 mL of tetrahydrofuran (THF), completely dissolving the Compound 2 precursor. Into a tared 16×125 mm testtube was weighed 1.5549 g (10.086 mmoles) of MAA. The MAA was then added dropwise to the stirring reaction solution using a transfer pipet and the time of MAA addition was noted. An HPLC analytical method was used to monitor the progress of the reaction with time. After about four hours, 1.0452 g (10.329 mmoles) of triethylamine (Et_3N) was added dropwise to the reaction solution. The reaction was stirred for 2 days, and then another aliquot of 4.1877 g (41.385 mmoles) of Et_3N was added to the reaction. The next day, the reaction was analyzed by HPLC and another aliquot of methacrylic anhydride, 3.5542 g (23.054 mmoles), was added to the reaction to complete the conversion of the Compound 2 precursor to Compound 2 product.

The crude Compound 2 product was purified by column chromatography using the same procedure as described above for Compound 1, except that lower heating was used for the solvent removal (30° C. instead of 50° C.). Less pure fractions and the remainder of the solid red product from the reaction were purified by repeated column chromatography runs in the same manner as the above run until the desired product purity was obtained. The identity of the Compound 2 product was confirmed by mass spectroscopy and NMR spectroscopy.

Compound 2 is a red gum solid at room temperature and atmospheric pressure. The residual products of three synthetic attempts were combined and purified by column chromatography. From this 1.701 g (4.04 mmoles) of pure Compound 2 product was obtained from a total of 6.25 g (21.94 mmoles) of Compound 2 precursor starting material, Yield=16.4%.

EXAMPLES 3–5

Preparation of Lens Material

The bondable yellow dyes of Examples 1 and 2, were weighed into individual test tubes. An appropiate amount of

a solution of monomers containing 66% PEA, 30.5% PEMA, and 3.3% BDDA by weight respectively, was added to each test tube to give a bondable yellow dye concentration of approximately 0.1% by weight, as shown in Table 1 below: To a third test tube, 15.6 mg. of 4-phenylazophenol allyl ether (a polymerizable yellow dye containing a polymerizable vinyl group) was added and an appropriate amount of the same monomer solution was added so that the yellow dye concentration was within the same range.

TABLE 1

Example	Bondable Yellow Dye	mg. Dye	g. PEA/PEMA BDDA Formula	Dye Conc. Wt. %
3	Compound 1	10.45	10.0326	0.104
4	Compound 2	9.67	9.0502	0.0966
5	4-phenylazophenol allyl ether	15.6	15.0049	0.104

After dissolving each bondable yellow dye into the PEN-PEMA/BDDA monomer solution an amount of bis(4-tert-butylcyclohexylperoxy dicarbonate (Perkadox-16, AZKO Corp.) was added as the polymerization iniator (catalyst) to make the initiator concentration approximately 0.5%. One mm thick sheetstocks of the materials were made by placing the individual bondable yellow dye/monomer solutions via syringe into molds formed between two glass plates and a 1 mm Teflon gasket. The glass plates were held together with metal clips. Polymerization was effected by placing the molds into a 65° C. oven and curing for 17 hours. The temperature of the oven was raised to 100° C. and the mold heated for 3 hours to effect post-cure of the sheetstock. Rectangles measuring about 1×2 cm. were cut from the sheets and soxhlet extracted for 4–5 hours with acetone. Following extraction the material samples were dried in air followed by drying at about 50° C. under vacuum. The UV/visible transmission and absorption spectra was measured for each example listed in Table 1 both before and after soxhlet extraction and drying. From the absorbance of the samples at appropiate wavelengths between 400 and 500 nm, the percentage of the dye which is removed in soxhlet extraction was calculated for each example: Example 3=1%, Example 4=7% and Example 5=44%. The UV/visible transmission curves for the lens materials of Examples 3–5 (post-extraction) are shown in FIG. 1.

EXAMPLES 6–8

Dye Strength Comparison

The bondable yellow dye of Example 1 and one of the bondable yellow dyes of the Menikon Application, 2-[2'-methylphenylazo]-4-methyl-phenyl methacrylate ("Compound 3"), were weighed into test tubes according to the amounts listed in Table 2 below. An appropriate amount of a solution of monomers containing 66% PEA, 30.5% PEMA, and 3.3% BDDA by weight, was added to two of the test tubes to form the lens materials of Examples 6 and 8. The lens material of Example 7 was formed by adding an appropriate amount of the following solution of monomers: 65% PEA, 30% PEMA, 3.2% BDDA and 1.8% MTP (a UV absorber).

Compound 3

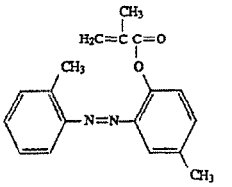


TABLE 2

Example	Bondable Yellow Dye	mg. Dye	g. monomer solution	Dye Conc. Wt. %
6	Compound 3	16.4	9.9708	0.164
7	Compound 3	40.7	9.9862	0.406
8	Compound 1	14.78	10.0174	0.147

After dissolving each bondable yellow dye into the indicated monomer solution, an amount of bis(4-tert-butylcyclohexylperoxy dicarbonate) (Perkadox-16, AZKO Corp.) was added as the polymerization iniator (catalyst) to make the initiator concentration approximately 0.5% for Examples 6 and 8 and 1.0% for Example 7. One-mm thick sheetstocks of the materials were made by placing the individual bondable yellow dye/monomer solutions via syringe into molds formed between two glass plates and a 1 mm Teflon gasket. The glass plates were held together with metal clips. For Examples 6 and 7, polymerization was effected by placing the molds into a 65° C. oven and curing for 15–17 hours with a post-cure at 100° C. for 2–3 hours. Example 8 was cured at 65° C. for 1.5 hrs. with a post-cure at 100° C. for 2 hrs. Rectangles measuring approximately 1×2 cm. were cut from the sheets and Examples 6 and 8 were soxhlet extracted for 4–5 hours with acetone. Following extraction the material samples of Examples 6 and 8 were dried in air and then under vacuum at about 50° C. Example 7 was not extracted. The UV/visible transmission and absorption spectra for each example listed above in Table 2 are shown in FIG. 2.

The dye strength of the yellow dyes in Examples 6–8 can be judged by comparing their transmission values at wavelengths in the blue light region, 400–500 nm. As shown in FIG. 2, Example 6 (0.164 wt. % of Compound 3) transmitted 53.1% at a wavelength of 450 nm. Example 7 (0.406 wt. % of Compound 3) transmitted 23 8% at this wavelength, and Example 8 (0.147 wt. % of Compound 1) transmitted only 8.3%.

Comparing Examples 6 and 8 which have approxiamately the same concentration of dye (0.164 wt. % vs. 0.147 wt. %), Compound 1 blocks almost 45% more light at 450 nm than does Compound 3.

Comparing Examples 7 and 8, Compound 1 blocks approximately 91.7% of light at 450 nm while more than twice as much of the Compound 3 (0.147 wt. % vs. 0.406 wt. %) blocks only approximately 76.2%.

EXAMPLES 9–10

Preparation of Finished IOLs Containing Compounds 1 & 2.

The bondable yellow dyes of Examples 1 and 2 were weighed into individual test tubes. To each test tube an appropriate amount of a solution of monomers containing 65% PEA, 30% PEMA, 3.2% BDDA and 1.8% oMTP by weight to give a bondable yellow dye concentration of approximately 0.05 and 0.2% by weight respectively, as

shown in Table 3 below:

TABLE 3

Example	Bondable Yellow dye	mg Dye	g. monomer formula	Dye Conc. Wt. %
9	Compound 1	4 0	8 0326	0.0498
10	Compound 2	92.4	47 3194	0.195

After dissolving the bondable yellow dye into the PEA/PEMA/BDDA/oMTP monomer formula an amount of bis(4-tert-butylcyclohexylperoxy dicarbonate (Perkadox-16, AZKO Corp.) was added as the polymerization initiator (catalyst) to make the initiator concentration approximately 1.8 wt. %. Lens optics of the materials were made by placing the individual bondable yellow dye/monomer solutions via syringe into polypropylene molds which formed lenses having a refractive power of 20 diopters with a central thickness of approximately 1 mm and a diameter of approximately 6 mm. For the samples of Example 9 the casting was performed on a plate assembly designed to hold up to. 16 polypropylene lens molds held together between the plate and spring compressed metal dies so that as many as 16 lenses could be formed simutaneously. The samples of Example 10 were cast into lens molds and held together individually with metal clips. Polymerization was effected by placing the molds into a 80° C. oven and curing for 1 hour. The temperature of the oven was raised to 100° C. and the mold heated for 1 hour to effect post-cure of the lenses. Following curing the polypropylene lens molds and optic were lathe cut to just less than the optic diameter to give an edge thickness of approximately 0.3 mm. Short holes approximately 1 mm deep were drilled into opposite sides of the lens for haptic attachment. The lathed polypropylene lens molds and optic were cooled in a freezer at −5° C. for about 30 min. and then carefully split apart while still cold. The lens optics removed from the polypropylene molds were placed into individual tissue capsules. The lens optics were soxhlet extracted for 4–5 hours with acetone. Following extraction the material samples were dried in air followed by drying at about 50° C. under vacuum. Two haptics composed of a flexible plastic fiber material such as polypropylene (Prolene) or of a flexible plastiized nonofilament PMMA material were attached to the lens optic using the holes drilled on each side of the lens earlier to make a finished intraocular lens.

EXAMPLE 11

Preparation of Lens Material Containing Solvent Yellow 7

4-Phenylazophenol, [Solvent Yellow 7 (SY7)], a conventional yellow dye obtained from Aldrich Chemical Company in the amount of 10.3 mg was dissolved into a 10.01 g solution of monomers containing 66% PEA, 30.5% PEMA, and 3.3% BDDA by weight respectively giving a SY7 concentration of 0.103 wt. %. After dissolving the SY7 into the monomer solution 52 3 mg of bis(4-tert-butylcyclohexylperoxy dicarbonate (Perkadox-16, AZKO Corp.) was added as the polymerization iniator (catalyst). One mm thick sheets were made by placing the SY7 monomer solution via syringe into a mold formed between two glass plates and a 1 mm Teflon gasket. The glass plates were held together with metal clips. Polymerization was effected by placing the mold into a 65° C. oven and curing for 17 hours. The temperature of the oven was raised to 100° C. and the mold heated for 3 hours to effect post-cure of the sheetstock. Approximately 1x2 cm. rectangles were cut from the sheet and the UV/visible measurements performed. The curve exhibited a strong attentuation of the short wavelengths of visible light in the 400 to 500 nm blue light region of the spectrum yielding a 50% transmission level at 473 nm. The rectangular samples were placed into individual tissue capsules and soxhlet extracted in acetone followed by drying in air then under vacuum at 50° C. Afterwards UV/visible measurements were performed again. The UV/visible transmission and absorption spectra were measured both before and after soxhlet extraction and drying. From the absorbance of the samples, at appropiate wavelengths between 400 and 500 nm, the percentage of the dye which is removed by soxhlet extraction was found to be 84%.

A comparison of the incorporation efficiency of the dyes of Examples 1, 2, 5 and 11 in the same lens material (66% PEA, 30.5% PEMA and 3.3% BDDA by weight) is shown in FIG. 3.

The amount of absorbance between 400–500 nm lost after extraction is an indication of the amount of dye removed from the lens material by the extraction process. Low absorbance loss for wavelengths between 400–500 nm indicates that very little dye failed to copolymerize with the lens forming monomers.

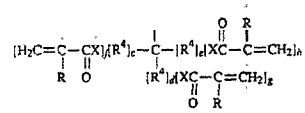
FIG. 3 shows that the largest loss of absorbance between 400–500 nm after extraction occurred with the Solvent Yellow 7 dye (84%). In contrast, the dyes containing polymerizable groups resulted in less than 50% absorption loss. Of the polymerizable dyes, 4-phenylazophenol allyl ether (containing a polymerizable vinyl group) resulted in a 44% absorbtion loss, while both Compounds 1 and 2 (containing polymerizable methacrylate groups) resulted in less than 10% absorbtion loss. As measured by the absorption loss at appropriate wavelengths between 400–500 nm, the lens material containing Compound 2 lost approximately 7% of its blue light absorption while Compound 1 lost only 1%.

I claim:

1. A polymeric ophthalmic lens material comprising:

one or more lens-forming monomers selected from the group consisting of acrylate monomers and methacrylate monomers, and

one or more polymerizable yellow dyes having from one to four polymerizable acrylate or methacrylate groups, wherein each acrylate or methacrylate group is displaced from the dye moiety by a spacing group according to the formula



wherein

R=H or CH_3

R^4=acyclic organic spacing group of up to 10 atoms consisting of C, H, Si, O, N, P, S, Cl, Br or F, alone or in any combination;

X=O, NH or NR^5;

R^5=C_1 to C_{10} alkyl;

d, e, g, and h independently=an integer from 0 to 3; and

c and f independently=an integer from 1 to 4.

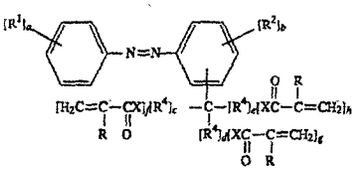
2. The lens material of claim 1 wherein the total amount of yellow dye is less than about 1 wt %.

3. The lens material of claim 2 wherein the total amount of yellow dye is less than about 0.25 wt %.

4. The lens material of claim 3 wherein the total amount of yellow dye is less than about 0.1 wt %.

5. The lens material of claim 1 wherein the lens material comprises one or more lens-forming monomers selected from the group consisting of phenylethyl acrylate and phenylethyl methacrylate.

6. The lens material of claim 1 wherein the polymerizable yellow dye is



wherein

R=H or CH_3;

R^1=H, C_1 to C_{20} alkyl, OCH_3, OC_2H_5, OC_3H_7, or OC_4H_9;

a and b independently=the integer 1 or 2;

R^2=R^1, OH, NH_2, NHR^5, $N(R^5)_2$, SH, SR^5, OR^5, $OSi(R^5)_3$, or $Si(R^5)_3$;

R^4=an acyclic organic spacing group of up to 10 atoms consisting of C, H, Si, O, N, P, S, Cl, Br or F, alone or in any combination;

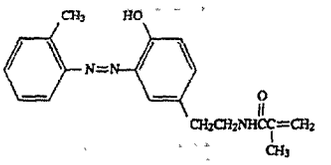
X=O, NH or NR^5;

R^5=C_1 to C_{10} alkyl;

d, e, g, and h independently=an integer from 0 to 3; and

c and f independently=an integer from 1 to 4.

7. The lens material of claim 6 wherein the polymerizable yellow dye is



8. The lens material of claim 7 wherein the material comprises less than about 0.1 wt. % N-2-[3-(2'-methylphenylazo)-4-hydroxyphenyl]ethyl methacrylamide, and wherein less than about 10% of the material's blue light absorbancy is lost if the material is extracted with a solvent.

9. The lens material of claim 1 wherein less than about 10% of the material's blue light absorbancy is lost if the material is extracted with a solvent.

10. The lens material of claim 1 further comprising an ultraviolet absorbing compound.

11. The lens material of claim 10 wherein the total amount of polymerizable yellow dye and ultraviolet absorbing compound is less than about 1.9 wt. %.

* * * * *

Public Health Service

Food and Drug Administration

5627 '03 AUG 29 P1:28

Memorandum

Date: August 28. 2003

From: Claudia Grillo, Paralegal Specialist
Office of Regulatory Policy (HFD-013)

Subject: Patent Term Restoration Application
for Acrysof

To: Dockets Management (HFA-305)

Attached please find a copy of the Application for Extension of Patent Term Under 35 U.S.C. § 156 for the above-referenced medical device, together with the cover letter from the Patent and Trademark Office. The applicant is Alcon and the product's trade name is Acrysof. Please assign a docket number to this application for patent extension and advise me of same.

If you have any questions, please contact me at 240 453-6699. Thank you for your assistance.

Attachment