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Development of UV blocking lens with photochromic function with refractive index of 1.67

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Index Terms - Blue light, UV, Lens, Sunglass, Photochromic

INTRODUCTION

Recently, sunglasses are widely used to block UV rays in summer. Sunglasses of uniform thickness are often produced with durable materials such as polycarbonate, but people who wear mat or sloppy glasses have used regular lenses by coloring them. Those who use regular lenses need glasses that can be used as regular glasses at night when there is no UV rays and can be used as sunglasses during the day when the sunlight is strong. In this case, it is possible to use glasses material that perfectly blocks UV rays and add a photochromic function that darkens when exposed to sunlight and brightens when it is darkened, and can be used as general glasses and sunglasses at the same time [1-5]. However, since photochromic materials require UV rays and UV blocking materials do not allow UV rays to pass through, the two materials cannot be mixed. Therefore, a special technique is required to install different materials adjacent to each other without marking. Sunglasses can also use polarized lenses to reduce reflected light [6-8]. On the other hand, it has been found that the blue light emitted from LEDs is harmful to the eyes, so a blue light blocking function is needed [9-11]. UVA, UVB, and UVC are mainly occupied by UV rays, but 98.7% of UV rays reaching the earth's surface are UVA.

Exposure to UV rays can cause burns, erythema, freckles, wrinkles, keratinization, or skin cancer. UV rays can be blocked by multi-layer coating on the surface of the lens, but when the coating is peeled off, the blocking function decreases and it is harmful to the eyes. If UV blocking function is given to eyeglass material, UV protection function can be maintained even if the surface is damaged [12-16]. In this study, a multi-layer coating was applied to the lens surface to give it an anti-reflection function, and a photochromic layer and a UV complete blocking layer were placed next to each other to implement a spectacle lens that was used as sunglasses during the day and as general glasses at night. The earliest plastic spectacle lenses were made in 1947 by the Armorlite Lens Company in California. The lens is made using a plastic polymer called CR-39, which stands for "Columbia Resin 39," because it is the 39th formulation of thermosetting plastic developed by PPG Industries in the early 1940s. CR-39 plastic remains a popular material for spectacle lenses today because of its light weight (about half the weight of glass), low cost and excellent optical properties. In this study, a urethane-based material with a refractive index of 1.67 was used for the spectacle lens material.

PHOTOCHROMIC AND UV-BLOCKING MATERIALS

A. *Photochromic material*

Photochromism refers to the fact that normally colorless substances change to dark gray or brown when exposed to ultraviolet light. Photochromic lenses respond to high-energy ultraviolet or violet light. It appears transparent indoors without the influence of UV rays, but changes to dark brown or dark gray under the influence of UV rays when exposed to sunlight. The photochromic raw material is used by mixing a small amount with the lens monomer.

When a relatively large amount of the photochromic compound is used, the photochromic property is improved, but the surface hardness is weakened. Therefore, it is very important to control the mixing ratio of the photochromic compound and the basic monomer of the lens. The photochromic layer needs to have a constant thickness. This is because different thicknesses result in different color depths. In this paper, we solved this problem by first making a photochromic layer of a certain thickness and then making a layer that reduces ultraviolet and blue light. Adhesion was not easy, so the polymerization temperature and time were adjusted and the adhesion was successful. Figure 1 collects examples of the mechanism of photochromic action.

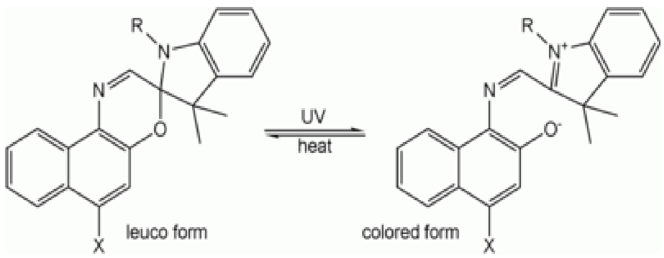

FIGURE. 1
EXAMPLE OF PHOTOCHROMIC ACTION MECHANISM

B. UV protection

Ultraviolet radiation refers to electromagnetic waves in the 410-100nm region shorter than the wavelength of visible light and longer than the wavelength of X-rays. Ultraviolet light is produced in the gas discharge tube of an ultraviolet LED or ultraviolet device. Table I shows the types and properties of UV rays. The UV protection function is widely requested in cosmetics, etc., and various materials are used. Sunblock, which is often used in summer, is a typical example. However, in order to be applied to spectacle lenses, it must be optically transparent and transmit a lot of light. To meet these requirements, three types of sunscreens were prepared. Table II summarizes the mixed types of developed sunscreens.

TABLE I

TYPES AND PROPERTIES OF UV RAYS

Name	Wavelength	Energy/ photon
UVA	400–315nm	3.10–3.94eV
UVB	315–280nm	3.94–4.43eV
UVC	280–100nm	4.43–12.4eV

TABLE II

UV BLOCKING MONOMERS

Type	Materials	Portion(%)
A	2,3-Bis(2-mercaptoethylthio)propane-1-thiol	84
	[1,4]Dithian-2-yl-methanethiol	10
	2-9[1,4]Dithian-2-ylmethylsulfanyl)-ethanelthiol	6
B	1,6-diisocyanatohexane	54
	2,5-diisocyanatomethylbic	46
C	Pentaerythritoltetrakis	80
	3-Mercapto-propionic acid 3-hydroxy 2,2-bis-propylester	16
	3-Mercapto-propionic acid 3-hydroxy-2-hydroxymethyl-2-propyl ester	4

C. Anti-reflection coatings and surface-enhancing coatings

An anti-reflection coating for reducing reflection of incident light is provided on an entrance/exit surface of an optical element constituting an optical device. All lenses used in optical devices each have a required refractive index, and since these refractive indexes have a value different from that of air, 1.0, the light incident on the lens surface is reflected. All lenses have an anti-reflective coating. In optical devices such as cameras used in the visible light region that the human eye can recognize, the anti-reflection coating is designed so that the bandwidth exhibiting the anti-reflection effect is within the range of 400 to 700 nm, which is the visible light region. As an anti-reflection coating formed on the lens surface, there is a single-layer coating using a material having a refractive index lower than the refractive index of the lens, or a multi-layer coating using a high refractive index material and a low refractive index material alternately. Among them, a multilayer coating that can widen the reflectance bandwidth is preferred.

D. Blue light reduction

If you use LED backlight among home appliances these days, you can see a sharp blue light peak. Blue light is part of the visible spectrum in the 380-450 nm range. Figure 2 shows the spectral pattern of the LED flat screen. Natural light consists of a relatively continuous spectrum, including all colors. We should be concerned about the blue light peak of the LED flat panel. The blue frequency peak is clearly visible, an imbalanced energy distribution never seen in natural light. This spectrum also shows an almost complete absence of red light. Not only does this artificial lighting cause oxidative stress in the eyes, which promotes medical conditions like age-related macular degeneration, but it can also disrupt hormonal balance, leading to chronic disease. Quite a few people suffer from temporary side effects when working on screens such as burns, stinging eyes, eye stains, headaches, and unstable vision. However, blue light at 465-496 nm is beneficial to health as it regulates the 24-hour rhythm.

Therefore, it is advisable to limit exposure to wavelength bands exhibiting potentially harmful blue light and especially to the increased risk.

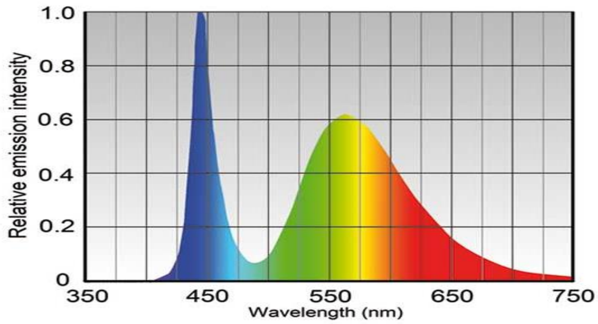

FIGURE 2
SPECTRUM OF LED LIGHT

Sample Lens Fabrication and Characterization

A. Manufacturing process

Step 1: Tap the upper mold using the first tape.
Step 2: Drop the discoloration composition on the upper mold recess. The color-changing composition includes a urethane-based monomer and a photochromic dye.
Step 3: Prepolymerization of the color-changing composition. Pre-polymerization is preheated to 15° C. for 5 minutes, followed by polymerization at 15° C. for 6 hours, 15 to 60° C. for 4 hours, 60° C. for 10 hours, and 60 to 15° C. for 2 hours.
Step 4: The upper and lower molds to which the gel-like upper lens and polarizing film formed by prepolymerization of the color-changing composition are coupled are spaced apart and taped using a second tape. The sunscreen composition includes a urethane-based monomer and a sunscreen.
Step 5: Inject the sunscreen composition through the empty space of the polarizing film and the lower mold.
Step 6: Mainly polymerize the gel-type upper lens and UV-blocking composition. This polymerization is preheated to 25°C for 5 minutes, at 25-40°C for 7 hours, at 40-50°C for 3 hours, at 50-65°C for 2 hours, at 65-95°C for 3 hours, at 95-120°C for 1 hour. time, at 120°C for 2 hours, at 120-70°C for 2 hours. Figure 3 shows the injection process after taping.

FIGURE 3
THE PROCESS OF INJECTION

B. Blue light blocking

For the photochromic lens specimen, the photochromic properties were evaluated as follows.

1) Maximum absorption wavelength (λmax): This is the maximum absorption wavelength after color development determined by a spectrophotometer (UVS-3100). The maximum absorption wavelength is related to the color at the time of color development.

2) Color development concentration (A0): The difference between the absorbance {ε(120) } and {ε(0) } of the maximum absorption wavelength before and after light irradiation for 120 seconds. It can be said that the photochromic property is excellent, so that this value is high.

3) Fading rate (τ1/2(sec)): After UV light irradiation for 120 seconds, when light irradiation is stopped, the absorbance at the maximum number of wavelengths of each specimen is {ε(120)-ε(0)} time required to degrade to 1/2 of The shorter this time, the faster the discoloration rate.

4) Fading rate (τ4/5(sec)): When the light irradiation is stopped after 120 seconds of ultraviolet light irradiation, the absorbance at the maximum absorption wavelength of each specimen is {ε(120)-ε(0)} The time required to degrade up to 4/5 of it. The shorter this time, the less the residual color of the photochromic dye upon fading.

5) Initial coloration {ε(0)}: Absorbance in the unirradiated state at the maximum absorption wavelength. For example, in an optical material such as a spectacle lens, it can be said that the lower this value, the better the photochromic property.

6) Residual ratio (A200/A0×100): The following accelerated test was performed to evaluate the durability of color development by light irradiation and heat. The obtained specimen was placed in a Q-Sun Xenon Tester Xe-3-HS manufactured by Q Labs under accelerated conditions (0.51 W/m at 340 nm).

2, temperature 65 degrees, relative humidity 50%, 200 hours) was accelerated test. Thereafter, the color development density is evaluated before and after the test, and the color development concentration before and after the test (A0) and after the test (A200) are measured. was taken as an indicator. The higher the residual ratio, the higher the durability of color development.

The test results are shown in Table III below.

TABLE III

DISCOLORATION TEST RESULTS

Division	λmax	Color density	Fade rate		Initial staining	Remaining rate
	nm	A0	1/2s	4/5s	s(0)	A200/A0×100
Case 1	570	0.71	24	120	0.17	87
Case 2	570	0.74	55	280	0.2	80
Case 3	570	0.75	62	326	0.2	84
Case 4	560	0.72	58	297	0.2	85

The lens was manufactured in the same way, and transmittance in the ultraviolet and visible light regions was measured for the blue light blocking soft lens that was manufactured in this way, and the blue light blocking rate was about 30%.

C. Photochromic

Photochromism was measured using Jasco's MV-3150 and LUS-373. The handheld spectrophotometer MV-3150 measures the spectrum at least every 5 msec. Because the spectrum is measured at high speed, the time required for product inspection can be reduced by monitoring production lines, etc. and mapping measurements. Because it uses a diffraction grating driving function and optical fiber-free structure, it is compact, easy to handle, and can be widely used for field measurements and other applications. The portable spectrophotometer MV-3000 consists of a spectrophotometer body and a light source device. MV-3100/3150 measures between 200 and 800 nm in wavelength range, and LUS-373 uses light source D 2 + halogen light source in wavelength range of 200 to 1600 nm. When monitoring long lines, a pseudo-dual-beam mechanism can be integrated into the accessory to increase reliability. Reference calibration is performed between measurements using an optical path-switching mirror (included in the accessory). Since the stability of the spectrophotometer is affected by the ambient temperature, this mechanism is indispensable for long-term measurements such as date crossings. The change in transmittance with respect to the time of the light reaction and the dark reaction was measured using this device, and the result shown in Figure 4 was obtained. Here, it can be seen that the light reaction takes about 2 minutes and the dark reaction takes about 5 minutes.

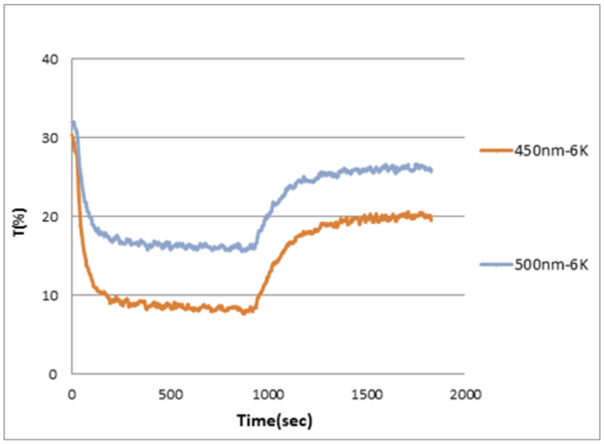

FIGURE 4
PHOTOCHROMIC EXPERIMENT

D. UV protection

We tested regular and manufactured lenses with a purple laser pointer. The purple laser pointer has a power of 5 mW and a wavelength of 405 nm. Figure 5 shows a typical spectacle lens effect after 405 nm projection. The purple dots are clearly visible on the screen. Figure 6 shows the effect of the newly developed spectacle lens, and the purple dot cannot be seen.

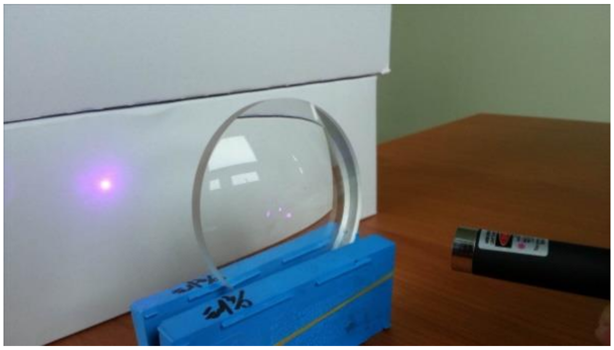

FIGURE 5
PURPLE TRANSMISSION PROPERTY OF CR39 LENS

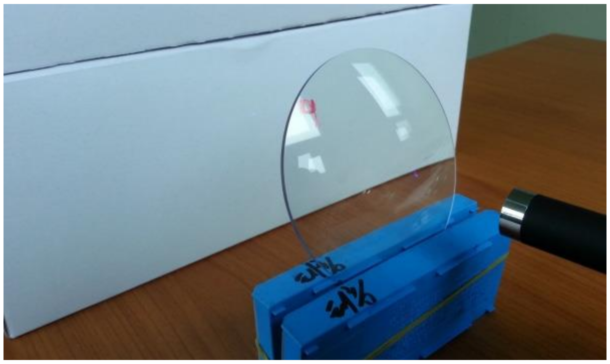

FIGURE 6
UV BLOCKING LENS, PURPLE BEAM CUT OFF

The transmittance of the developed sample lens was measured using an ultraviolet visible light spectrophotometer. Figure 7 shows the transmittance of the developed sample lens and the conventional CR39 lens. In Figure 7, blue is the spectrum of a general lens and brown is the spectrum of a developed lens.

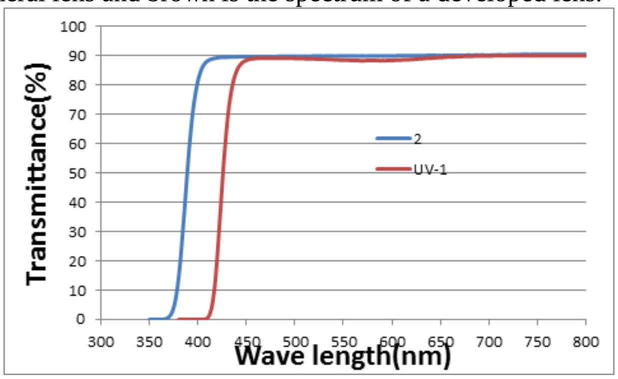

FIGURE 7
COMPARISON SPECTRUM OF SAMPLE LENS AND GENERAL LENS

E. Anti-reflective coating

All lenses used in optical devices each have a required refractive index, and since these refractive indexes have a value different from that of air, 1.0, the light incident on the lens surface is reflected. All lenses have an anti-reflective coating. In optical devices such as cameras used in the visible light region that the human eye can recognize, the anti-reflection coating is designed so that the bandwidth exhibiting the anti-reflection effect is within the range of 400 to 700 nm, which is the visible light region. The antireflection coating formed on the lens surface includes a single layer coating using a material having a refractive index lower than the refractive index of the lens, or a multilayer coating using a high refractive index material and a low refractive index material alternately. Among them, a multilayer coating that can widen the reflectance bandwidth is preferred. Figure 8 shows an example of an anti-reflective coating according to the prior art. Referring to the drawings, an anti-reflection coating is formed in a structure in which first to sixth layers are sequentially stacked on a substrate 0 . Table 4 below shows the material, refractive index, and thickness of each component. Figure 8 shows the reflectance of the manufactured spectacle lens. It shows a reflectance of about 0.3% between 400nm and 700nm.

TABLE IV

MULTI-LAYER ANTI-REFLECTION COATING

Layer no.	Mmterials	Refration ratio	Depth(nm)
6	SiO2	1.47197	90.44
5	TiO2	2.36626	31.19
4	SiO2	1.47197	8.05
3	TiO2	2.36626	76.07
2	SiO2	1.47197	17.42
1	TiO2	2.36626	18.34
0	Lens	1.67	

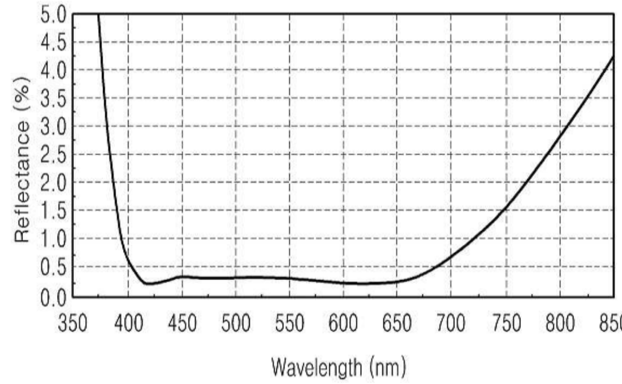

FIGURE 8
REFLECTANCE BY ANTI-REFLECTIVE COATING

CONCLUSION

Using a urethane-based monomer with a refractive index of 1.67, a bright sunglasses combined spectacle lens that blocks photochromism, UV rays and blue light has been developed. The photochromic layer maintained a constant thickness to make the concentration uniform. The photochromic layer was first molded, and then the UV blocking layer was molded one after the other, and the temperature and time of the polymerization reaction were appropriately controlled to achieve perfect adhesion. There was a 30% blocking effect of blue light emitted from LEDs when passing through this lens. Photochromism took 2 minutes in light reaction and 5 minutes in dark reaction, and transmittance of less than 20% was obtained during light reaction. UV protection was completely blocked below 410 nm.

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REFERENCES

[1] Kim Jun-won, Ahn Kwang-hyeon, Kim Hong-doo, Jang Tae-hyun, “Photochromic 2- (1' , 2' - dimethyl - 3' - indolyl)-3-(2" - methyl -3"-benzo [b] thiophenyl) maleic anhydride and Synthesis and Characterization of Polystyrene Derivatives”, *Polymers*, 21(3), 1997, 512-520

[2] Moonsik Cho, Im Sanghyeon, and Junsoon Kim, “Clinical usefulness and effectiveness evaluation of photochromic spectacle lenses”, *Journal of the Korean Ophthalmology Society*, 46(9), 2005, 1563-1568

[3] Shin-Won Kang, Kang-Min Cho, Park Soo-Young, Yoon Jeong-Hyeon, Lim Seon-Jeong, A Study on the Light-Induced Refractive Index Change of Photochromic Diarylethene Derivatives Using Optical Fiber-Planar Waveguide Couplers. *Journal of the Korean Optical Society*, 15(2), 2004, 109-113

[4] Chang-Nam Choi, Hee-Suk Ryu, Hyeong-In Park, Jong-Bae Kim, and Sang-Ryul Kim, Synthesis of Diarylethene Photochromic Pigments and Their Characteristics. *Journal of the Korean Society of Textile Engineering*, 36(2), 1999, 140-147

[5] Doo Hee Han, Development of a polarized lens for viewing stereoscopic movies. *Proceedings of the Korean Society for Industry-Academic Technology Conference*, (), 918-920

[6] Doo Hee Han. 2018. A Study on Polarized Glasses Lenses with Refractive Index 1.60 Photochromic UV Protection. *Journal of Convergence Information*, 8(1), 2014, 147-152

[7] Kim Ha-rim and Jeong Ju-hyun, A Study on the Optical and Physical Properties of Polarized Lenses. *Journal of the Korean Ophthalmic Optics Society*, 24(3), 2019, 309-313

[8] Youngkook Yoo and Eunjung Choi, A Study on the Blue Light Blocking Performance and Prescription of Blue Light Blocking Lenses. *Journal of the Korean Ophthalmic Society*, 18(3), 2013, 297-304

[9] Sangil Park, Photooxidation effect of A2E, lipofuscin in retina, by smartphone illumination and photooxidation prevention effect by blue light blocking lens. *Journal of the Korean Ophthalmic Society*, 23(4), 2018, 511-517

[10] Moonchan Park, Design of Coated Blue Light Blocking Lenses and Optical Characteristics According to Blue Light Blocking Rate. *Journal of the Korean Ophthalmic Optics Society*, 24(3), 2019, 301-307

[11] Ji-Hye Kim, Ha-Yeon Um, Eun-Ji Jo, So-Ra Kim, Mi-Jeong Park, Effect of blue light blocking lenses on readability and subjective symptoms when working with smart devices with different background colors. *Journal of the Korean Ophthalmic Society*, 24(1), 2019, 51-59

[12] Doo Hee Han, Development of UV-blocking spectacle lenses. *Proceedings of the Korean Society for Industry-Academic Technology Conference*, (), 2015, 266-267

[13] Park Sang-il, Effects of brown tinted lenses and UV-A blocking spectacle lenses on photooxidation of senile fluorescent pigments in the retina. *Journal of the Korean Ophthalmic Society*, 17(1), 2012, 91-97

[14] Choong-Seo Park, Young-Min Park, Dae-Hyun Kim, and Mi-Jung Park, Effect of UV-blocking lenses on UV-A-induced denaturation of antioxidant enzymes. *Journal of the Korean Ophthalmic Society*, 12(3), 2007, 97-103

[15] Heung-Soo Kim, Evaluation of UV blocking performance for convergence technology development of eyeglass lenses for vision correction. *Journal of the Korean Convergence Society*, 9(4), 2018, 93-98

[16] Ha Tae-wook, Lee Yong-hee, Choi Kyung-seo, Cha Jeong-won, Study on the UV-blocking effect of sunglasses lenses using nickel ferrite thin film $NixFe_3$-xO_4", *Korea Ophthalmology Journal of the Korean Society of Science and Technology*, 8(2), 2003, 25-29

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