

Description

This invention concerns adjustable transparency spectacles. More particularly, the invention concerns spectacles equipped with liquid crystal means allowing the user to adapt the transparency of lenses to the variation, even if sudden, of the conditions of external luminosity.

As it is well known, whenever the external luminosity is suddenly reduced or increased, the sun-spectacles of conventional type, being now employed, show the difficulty of an annoying sensation of darkening or of dazzling, with an objective and sudden lessening of visual capacity, capable of entailing heavy risks for the user.

This takes place, for instance, to the driver of a car upon entering or exiting from a road tunnel.

There presently are available some sun spectacles, with lenses in photochromic glass, which allow to lessen, even if only in part, the said difficulties. Actually said type of glass enjoys the property of becoming absorbent, and therefore dark, under the action of light, and clear under conditions of reduced luminosity, thus allowing the production of lenses with transparency adjustable in an adequate manner, but not with that speed of intervention being required and needed in special situations.

Actually the time of variation for the transparency should not exceed 1/10th of a second in order to minimize the referred to phenomena of darkening and of dazzling, while that typical of the photochromic glasses is in the order of several seconds.

Furthermore, with the photochromic glasses it is not possible to operate directly upon the transparency of the lenses, since the latter keeps to depend directly from the quantity of light recently absorbed.

Other means are also known, capable of regulating the transparency of an opening, such as for instance the devices formed by two polarizers in plastic material, placed the one upon the other and assembled in such a way as to be able to be rotated one against the other, thus allowing the adjustment of the transparency within wide limits. However the same are not suitable for being advantageously assembled within a pair of spectacles, since in order to allow the mechanical operation above described, there would be required a structure quite different from that compact and light which is typical of spectacles.

The simultaneous evolution of electronic technology in the field of display devices, used for the presentation of images, has led to the implementation of electrooptical cells, as well as of similar contrivances which, in some special embodiments, are capable of implementing the function of trans-

parency's adjustment with quick times of intervention.

However it is to be remarked that, for the specific application to adjustable transparency lenses for spectacles, the devices of the type referred to should necessarily be able to satisfy the following specifications:

- absence of light diffusion phenomena
- adequate width of the visual angle
- uniformity of light transmission
- sufficient transparency
- no need of polarizers

Adjustable transparency spectacles including liquid crystal cells are disclosed in WO 81/02795. In that case, however, the lenses are provided with layers of polarization material.

For the implementation of lenses for adjustable transparency spectacles, showing the above referred to specifications, which is the main object of this invention, it has been considered as suitable to take preliminarily into consideration the liquid crystals cells of the dichroic type.

There actually exist in this class cells capable of allowing the variation of transparency without any phenomenon of light diffusion, and without requiring the use of polarizers.

As a general rule, by dichroic cells we mean those in which the liquid crystal has dichroic properties. They mostly are derived from a small percentage of one or more dichroic dyes, whose molecules show an average alignment parallel to that of the liquid crystal holding them in solution.

The fundamental property of the dichroic means is that of absorbing the light in a greater measure when the electric field of the electromagnetic wave (perpendicular to the direction of propagation and being oriented along the plane of polarization) is parallel to a characteristic direction of the means.

By dichroic ratio is meant that between the maximum and minimum optical densities, which can be measured, under polarized light, parallel-wise and perpendicular-wise in reference to the characteristic direction of means.

A liquid crystal containing in solution a dichroic dye behaves as a dichroic means, whose characteristic direction can be modified, for instance under the action of an electrical field.

Several types of dichroic liquid crystal cells are already known. The first ones to be studied made use of relatively simple alignments of the liquid crystal, in combination with a polarizer (Guest-Host effect, as the words themselves mean).

Since the latter absorbs - ideally - at least the half of the incident light, it is not possible to obtain a maximum high transmission of light.

However there exist some other types of dichroic cells, known as phase change cholesteric-

nematic, or White-Taylor type cells which, thanks to more complex alignments of the liquid crystal, allow to exclude the use of the polarizer devices.

In the case of the latter, the possible conditions of molecules' orientation can be resumed as it follows (for an exact description we use, in the following text of description and of claims, the term "horizontal" in order to show a direction parallel to the planes of the walls containing the liquid crystal within the cell, and the term "vertical" for identifying the orthogonal direction).

In a first, extreme condition, in correspondence with the various layers of the liquid crystal, there are obtained the different orientations of the molecules in the horizontal plane, or under a small angle with reference to same, in such a way that all the components of light propagating vertically are absorbed in different layers, according to the plane of polarization.

In a second extreme condition, the orientation of molecules is vertical or nearly so, and the light propagating vertically is not (in ideal operation) absorbed.

Intermediate conditions between these two extreme conditions, corresponding to intermediate angles of molecules with the horizontal plane, allow to continuously change the absorption of light.

Said conditions can practically be obtained in the above referred to White-Taylor type cells, owing to the presence of a liquid crystal showing a torsion when it is horizontally aligned. It can be due, in part or totally, to different horizontal directions imposed to the liquid crystal by the two walls. Besides, a spontaneous torsion, that is in absence of constraints on the walls, being due to the presence of optically asymmetrical molecules, is a well known phenomenon, which is easily checked through the addition of chiral molecules. It characterizes the cholesteric liquid crystals and it can be quantized through the pitch (rightwise or leftwise) of the helicoidal configurations which are obtained. The ratio between the thickness and the pitch supplies the spontaneous torsion (in round angles). The nematic liquid crystals can be considered a particular case in which the pitch is infinite.

In the liquid crystals the index of refraction quite near to 1,5 implies that angles even high, with reference to the vertical direction, of the direction of propagation of light in the air, correspond to relatively small angles within the liquid crystal.

There follows from it an operation of the cell even for directions of light different from the vertical one, which satisfies one of the essential requirements for implementing the invention.

However, in order that all light be absorbed efficiently by the twisted structure, it is required that the product of the pitch by the optical anisotropy (difference between the extraordinary and

the ordinary indexes of refraction) be small in reference to the wave length. In particular, the double refraction of the liquid crystal should be small (please refer to the Digest of the 1984 S.I.D. (Society for Informations Displays) Symposium, which can be obtained from the aforesaid Company, the contribution 13.3 by J.F.Clerc and al.), owing to the fact that the pitch cannot be too small with reference to the thickness of the liquid crystal, since otherwise with the transitions there tend to be formed as many disorderly alignments which cause an undesired diffusion of light, so that the liquid crystal appears to darken.

It is also right to keep in account the fact that the contrast to be obtained with the cells depends upon the alignment of the molecules of the dichroic dye, which oscillate continuously around their middle positions, while such phenomenon is expressed through an "order parameter" which can vary between 0 (lack of alignment) and 1 (no oscillations).

The requirement for some high value of the order parameter is the limit for the concentration of the dyes, and therefore for their absorbing power, so that the thickness of the liquid crystal cannot go under a given value, being practically adopted the thicknesses of 4-15 μm , with the consequence of unavoidable increases of the pitch's value.

In any case the cells as described by White and Taylor (Journal of Applied Physics, Vol. 45, page 4718 foll., November 1974) in their generality did not show the specifications required for avoiding the mentioned difficulties of light diffusion, and therefore they cannot be considered as suitable for the objects of this invention.

However there exist, starting from 1980, some cholesteric-nematic phase change cells that have been shown, according to the present invention, to be capable of varying their transparency without showing any phenomenon of light diffusion.

They have been obtained through a narrow control of the alignment imposed upon the liquid crystal by the surfaces and by the pitch of the spontaneous torsion of the liquid crystal. There belong to this category the cells suitable for the objects of this invention.

A first type of dichroic cells that has been found to be non diffusing does absorb the light at rest (that is in absence of electrical excitation). In their case the use is made of a liquid crystal having a positive dielectric anisotropy, in which the dielectric constant, measured along the orientation's direction of the molecules, is greater than that perpendicularly measured. Under the action of an electrical field the molecules tend to arrange themselves in a parallel way to the former, and therefore vertically (in the presence of flat electrodes on the surfaces).

From a structure of the cholesteric type one therefore passes to another of nematic type, and the cell from absorbent becomes a transparent one.

In a first subtype of said cells, which can be employed in this invention, the alignment as imposed to the liquid crystal from at least one of both walls is parallel or almost parallel to them, according to a prefixed direction.

Among them there are to be preferred the cells of the type in which the said alignment is almost parallel, and more precisely it is inclined with reference to an horizontal plane, preferably by 2° - 15° , and in any case no more than 25° .

Besides, the orientation at rest of the liquid crystal through the thickness of the cell should have an effective total torsion included between about $1/4$ of round angle and 2 round angles, and preferably between 0.5 and 1.5 round angles.

This is obtained by selecting the pitch in ratio to the thickness of the liquid crystal, and/or actually stressing a fixed total torsion, which can even be more than $1/4$ round angle more or less than the spontaneous one, through a parallel, or almost parallel, alignment also on the second wall.

In any case the alignment should be prefixed in an uniform way also on the second wall; however there can be accepted all inclinations being included between the vertical and the horizontal.

In a second subtype the alignment as imposed upon the liquid crystal by both walls is almost a vertical one, but the ratio between the thickness and the pitch is but little greater (1-2 times) to a critical value being quite near to one (equal to $K_{33}/2K_{22}$). Then the orientation of the liquid crystal in the central parts of the layer is almost horizontal and twisted. However, upon the variation of the electric field, the transparency shows a progress by hops, with phenomena of hysteresis. The same renders this second subtype of cells unsuitable for obtaining a gradual adjustment of the transparency.

There does exist a second type of dichroic cells that have been shown non diffusing, which transmit the light at rest while they absorb the same in the excited state, which appear to be completely suitable for the scopes of this invention.

In their case also the alignment as imposed by the walls is almost vertical, but the ratio between thickness and pitch is lower than the aforesaid critical value, and therefore the orientation at rest happens to be almost vertical.

In said cells there is employed a liquid crystal with negative, instead of positive, dielectric anisotropy, the molecules of which tend to place themselves perpendicularly to the electric field. To the aims of this invention, there are to be preferred the cells in which the almost vertical alignment on the walls be well controlled, with directions skidded

by 1-10 degrees from the vertical, preferably 2-5 degrees and preferably according to planes forming between themselves the angles being quite near to the spontaneous, total torsion of the liquid crystal, through a thickness being equal to that of the cell, which in this case is included between $1/4$ and 1.1. round angle (Swiss Patent No. 629001, Ebauches S.A., inventor F. Gharadjedaghi).

These latter cells are the most suitable for the adjustable transparency spectacles according to this invention, inasmuch they avoid the risk that when the electric excitation is missing, the spectacles might dangerously be darkened. However even the above referred to cells, non diffusing and absorbing the light at rest, can be employed for the objects of this invention, by only waiving the above referred to safety requirement.

Therefore the specific object of this invention includes adjustable transparency spectacles including lenses formed by non diffusing liquid crystal cells, means suitable for applying an electric voltage to said cells and means for adjusting said voltage, characterized in that said cells are cholesteric-nematic phase change dichroic liquid crystal cells which transmit the light at rest and absorb it in their excited state, with a liquid crystal having a double refraction lower than 0.12 and a negative dielectric anisotropy, an alignment vertical or almost so being imposed to the molecules of the crystal by the walls, and the value of the spontaneous pitch being equal to 0.9-4 times the thickness of said cell.

Preferably the pitch is equal to 1.1-1.7 times the said thickness; to said values there corresponds a spontaneous, total torsion of the liquid crystal through the thickness of the cell being included between $6/10$ and $9/10$ round angle.

Advantageously the said alignment shows a deviation from the vertical equal to 1° - 10° , and it preferably takes place along planes mutually forming some angles almost equal to the spontaneous total torsion of the liquid crystal through the thickness of the cell. The value mostly preferred for this deviation are 2° - 5° .

Alternatively, as already stated, there can be employed according to this invention also the non diffusing dichroic cells, which absorb the light at rest and transmit the same in their excited state, with a liquid crystal having a double refraction lower than 0.12 and a positive dielectric anisotropy, an alignment being imposed upon the crystal from at least one of the walls, which alignment is parallel or almost so to the latter, according to a prefixed direction, the value of the pitch being higher than half of the thickness of the cell itself, and the effective torsion, at rest, being equal to $1/4$ -2 round angles, and, preferably, to $1/2$ - $3/2$ round angles.

Preferably the said alignment makes with the horizontal an angle not greater than 25° , while in the most preferred embodiment it makes an angle of about 2° - 15° .

For instance, the technique which allow to impose upon the liquid crystal a prefixed orientation and inclination in correspondence of the walls which it is contact with, are well described (T. Uchida and AA.: "Liquid Crystal Orientation on the Surface of Obliquely Evaporated Silicon Monoxide with Homeotropic Surface Treatment", Japanese Journal of Applied Physics, vol. 19 p. 2127 (1980)).

They typically consist of processes of molecular projection, in vacuo, of a thin layer (5 - 100 nm) of SiO_2 , ZrO_2 , CaF_2 or MgF_2 , followed by the treatment with a surface-active agent (for instance lecithin or several components within the families of silans or of the metal-organic complexes) and/or by the unidirectional wiping of the surface with a soft cloth, possibly impregnated with very thin particles of abrasive, under controlled conditions of pressure and duration.

The technique of production and the theory of operation of the cells transparent at rest, are described by F. Gharadjedaghi in "A Positive Contrast Guest-Host Display Using a Liquid Crystal of Negative Dielectric Anisotropy", Molecular Crystal and Liquid Crystals, vol. 68, pag. 126 foll. (1981) and by F. Gharadjedaghi and R. Voumard, in "Mathematical Simulation of a Positive Contrast Guest-Host Display Using Nematic Cholesteric Phase-Change", Journal of Applied Physics, vol. 53, pag. 7306 foll. (1982).

The absorbing at rest cells, employed in this invention, are described, for instance, by K. Suzuki et AA. in "A Multiplexed Phase-Change Type Color LCD", Trans. on Electronic Devices, Vol. 28 pag. 719 foll. (1981), by K. Suzuki and S. Hasegawa in "Design Considerations for Phase Change Type Guest-Host Colour LCD", Proceedings of the first European Display Research Conference, Munich, September 81, pag. 72 foll. (as published by S.I.D.), and by F. Gharadjedaghi and E. Saurer in: "A novel type of invented Dichroic Display Employing a Positive Dielectric Anisotropy L.C.", IEEE Trans. on Electronic Devices, vol. 27, page 2063 foll. (1980).

Suitable mixtures of a dye and combinations of a dye with liquid crystals, are described, for instance, in the contribution 13.2 by U. Classen et al. (Bayer, Leverkusen) of the 1984 S.I.D. Symposium (on pag. 209 of the Digest), as well as in the article by B. Scheuble et al. (Merck's, Darmstadt) "New Black L.C. Guest-Host Systems for Indoor and Outdoor Applications", S.I.D. Proceedings, vol. 25, pag. 25 (1984).

The processes also for deposition of the required layers of transparent conductor are well

known in the art, as well as is the possibility of providing the cells between supports of plastic material (poliesther resins) (H. Inoue and A. Kikuyama; "Homogeneous Molecular Alignment Technique for Polymer Film LCD", Proceedings of the First European Research Conference, pag. 28 (Munich 1981), and P.A. Penz, J.B. Sampsel and D.R. Collins, "A Plastic LCD Design with High Reliability and Color-Free Readability", IEEE Trans. on Electronic Devices, vol. 22 (1985), pag. 2206).

It is well known that in order to obtain uniform transparencies also at intermediate levels, the dichroic cells we have dealt with, require a very high precision (better than $\pm 10\%$) in the control of interspace thickness, upon the variation of which there also changes the applied voltage to transparency relationship.

For that purpose the known technologies propose to interpose between the internal walls a plurality of spacers, for instance some microscopic lengths of glass fibers, and to ensure some pressure on the spacers by the walls. This can be obtained through the sealing of the inside interspace, under conditions of some light depression as compared to atmospheric pressure, and/or by coupling surfaces whose camber is slightly different, which result, after some gluing in correspondence of their edges, pressed one against the other, owing to internal stresses (U.S. Patent nr. 4,150,878, Barzilai et al.). It is anyway required that the start surfaces have differences of depth and camber, with reference to the ideal one, contained respectively within a few micrometers and within a few micrometers/squ. cm.

The standard technique of the liquid crystal cells provides the use of glass flat supports, obtained by the float process, that is causing the plates to solidify as they float on a molten metal. However there is no knowledge of descriptions relating to liquid crystal cells with curved rigid supports, certainly more suitable for the protective glasses according to this invention, since they allow to reduce any undesired effect of astigmatism (as well as of dispersion of colours) in the side vision (Tscherning's diagram).

As already known, the normal absorbent lenses are obtained through processes of blowing and casting of either glass or organic glass. The higher quality and cost lenses are obtained by working the glass through grinding processes in contact with metallic "coats", followed by polishing ones, using the same technique suitable for graduated lenses and obtaining the same limits for the results.

Said limits are (as a total) currently considered as equal to $\pm 1/8$ diopter: f.i. refer to V. Ronchi, "Lenses for spectacles", Zanichelli, 1962. Said limits however are utterly unsuitable for producing the curved lenses capable of meeting the aims of this

invention. On the other side, it is well known that the processes of optical manufacture, that is those of grinding and polishing, under conditions of closer control, allow to attain a degree of precision within the tenths of a micrometer, as requested by precision optics and more than suitable for dichroic cells.

For the implementation of the adjustable transparency spectacles it is therefore proposed to employ the lenses processed, at least on their inner side, with the improved technologies above referred to, with such a precision as not to give way to a difference of dimension and of camber, with respect to the ideal surface, respectively limited within a few micrometers and within a few micrometers/sq. cm.

Said lenses will be made out of glass or of a plastic material, and they will be preferably treated or coloured in such a way as to absorb the ultraviolet rays as well as to protect the dichroic dyes from losing colour.

Besides, in the spectacles according to this invention, the above referred to means for applying the electric voltage are formed by an electronic circuit which generates, at the terminals of the cell, an adjustable voltage, whose effective value is higher than the threshold, does not contain any direct current components and has a frequency sufficiently high as not to allow the passage of ions into the liquid crystal.

Preferably the said electronic circuit includes an inductor, electrically resonant with the cells' capacitances.

The voltage being generated by the electronic circuit is adjusted by manual and/or automatic means. The latter may be formed, in particular, by electronic circuits being actuated by a photocell.

The manual means can on the contrary be formed by electronic circuits controlled by lightly touched keys, or by a potentiometer, by a variable capacitor or by a variable inductor, or by any combination of the former.

Besides, as far as their shape is concerned, the spectacles according to this invention can be implemented, instead than with two separate lenses, with just one continuous element, in plastic material, visor shaped.

Figure 1 of the enclosed drawings shows, as an exemplification, the simplified diagram of operation for the spectacles according to this invention.

In the figure there is shown generically with 1 the liquid crystals cell making up one lens, while with 2 are shown both supports of glass or of a plastic material, sealed with resin or frit in 3, in such a way as to form the interspace 4, filled with liquid crystal and suitable for making up a dichroic cell.

Upon the surfaces 5 there are placed a transparent conducting layer, as well as the layers required for the alignment of the liquid crystal, while between the said surfaces the spacers 6 are deployed.

The peripheral sealing 3 has a thin interruption (not shown) for the in vacuo filling of the inner space with the liquid crystal, to be later on sealed. Said interruption can also be replaced with one hole in any of the glasses.

By 7 there are shown the contacts for the connection, through both wires 8 of the 1 cell, to an electronic circuit 9, which forms the above referred to means for applying an electric voltage to the cell. Said circuit generates, at the terminals of the cell, an adjustable voltage, whose effective value is higher than the threshold, does not contain any direct current components and has a frequency sufficiently high as not to allow the passage of ions into the liquid crystal.

The power source 10 for feeding the circuit, formed in practice by one battery, could be absent if the photocell 11 generates enough power. The photocell 11 and the manual means 12 for adjusting the voltage, which can be for instance an electronic circuit, controlled by lightly touched keys, allow, together or alternatively, the adjustment of the voltage generated by the circuit, as well as the control of lens' transparency.

The device being shown, is supported by a suitable frame for spectacles, which can house the miniaturized circuit, or, alternatively, the circuit can be contained in a small box hanging from the arms, through a string.

This invention will now be described, at an illustrative and not limitative title, in the following examples concerning some of its specific embodiments.

EXAMPLE I

Transparent lenses (possibly graduated), made out of glass or of the organic material known as CR39, dyed still in their molten condition, in such a way as to absorb the ultraviolet rays, whose thickness in about 0.7 mm. in the case of glass, and about 1 mm. in the case of plastic, are worked in pairs, with a difference in camber equal to about 2 $\mu\text{m/sq.cm.}$, according to the US Patent No. 4,150,878 of Barzilai, Maltese and Ottavi, on the faces which are to enclose the liquid crystal, and they are then cut according to the shape of the frame.

The internal surfaces are activated by "plasma etching" and treated with "magnetron sputtering", by firstly depositing a blocking layer of 0.1 μm of Al_2O_3 , and then a second layer, thick some 0.1 μm , of indium and tin oxide (ITO), having a surface

resistivity of about 100 ohm/sq.cm. and a transparency better than 85%. The said treatment is also performed on the edges, where successively some gold is evaporated, in order to obtain some contact areas. Still, through in vacuo thermal evaporation of 0.04 μm of SiO_2 , at a grazing angle equal to approximately 60° from the normal, followed by a rubbing with abrasive, one can obtain the surfaces which will allow an almost horizontal orientation of the liquid crystal, with an inclination equal to 3° with reference to the walls. On the edge of the convex face there is furtherly deposited, by silk screen printing, a peripheral ring of epoxidic resin, non polymerized (Allestik No. 517), with an interruption through which the liquid crystal shall be caused to enter. Minute lengths of glass fibers, whose diameter is 8 μm , are scattered upon the convex surface and furtherly the concave surface is pressed upon the former. Said operation is performed by sealing in vacuo a packet of thermoplastic material containing the lens. There follows the baking of the resin at 80°C for 5 hours. The internal surfaces come to be compressed through the spacers and it is obtained the required uniformity of thickness for the inner space. The liquid crystal is then made to enter in vacuo.

Said operation is performed at about 80°C and inside a vacuum chamber, by plunging for a sufficient time (some minutes) into the liquid crystal the edge of the lens in correspondence with the discontinuity of the glueing. Said discontinuity is furtherly sealed with some resin.

It is employed a liquid crystal having positive dielectric anisotropy $\Delta\epsilon = 5$ and low double refraction ($\Delta n = 0.08$), additioned with dichroic dye and chiral additive. The structure of the frame is completely independent. As it is possible to see in the enclosed figure 2, the same is made out by three parts (1, 2 and 3) hinged through special platinum plated metallic hinges, 4 and 5, supplying several separated electric connections. One of the hinges (5), besides, is built in such a way as to break the feeding of the circuits whenever it is being closed. The central part 2 employs one core (one millimeter thick) of resin loaded with carbonium fiber, being laminated with layers of copper connection and the correspondent hinge's element, and said parts are embedded in the resin. Successively the lenses 9 are pressure moulded into the central part of the frame which, for this purpose, is built in its lower part with the thermoplastic resin only. The construction of the arms now described, allows their hot bending for better matching to any user.

It is so obtained a pair of spectacles, weighing about 55 g., normally dark, showing a transparency around 15-25%, respectively for light rays being orthogonal to, or at 45° with the surface. Said values can be adjusted up to maximum transpar-

encies, equal to respectively 70-80% when the maximum voltage is applied to the lenses.

The integrated circuit controls automatically the transparency of lenses; furthermore the employer is able, by pressing on the two keys 10, to brighten or darken them. The lenses can operate between 5° and 40°C , with the liquid crystal in use, and the duration of the battery is equal to at least 200 hours, depending upon the conditions of use.

EXAMPLE 2

A variation of the construction shown, more and manufactured like the normal printed circuits.

On such core there are soldered the electronic components and the spring contacts for the lenses. In the zone 6 between both lenses, there are lodged the monolithic integrated circuit, itself operating also as a photocell, and the discrete components. Through a process of hot moulding there are applied two external layers of thermoplastic resin. The arms 1 and 3 are manufactured in thermoplastic resin with the lodgings for the lithium battery 7 and for the ferrite microtransformer 8, in correspondence with their ends. Said transformer 8 has the function of minimizing the electrical consumption and to allow the use of a battery 7 having its voltage lower than the threshold one of the liquid crystal.

It has been employed a microtransformer of special make, whose dispersed inductance resonates with the capacitance of the liquid crystal cells, at the piloting frequency.

The control of voltage's amplitude on the secondary is obtained by varying the duration of the pulses which excite the primary.

Each connection spring is manufactured in just one piece of steel, together with the electrical suitable for lenses of the corrective type also, as well as for spectacles which are worn for longer times, provides the use of various aligning layers, and of a different liquid crystal. In this case the grazing evaporation is performed at 80°C with CaF_2 and it is followed by a surface treatment through the immersion in a diluted DMOAP solution (N,N-dimethyl-N-octadecyl-3-amino-propyltrimethoxylil chloride).

As the liquid crystal, it is employed a mixture having low double refraction ($\Delta n = 0.08$) and negative dielectric anisotropy ($\Delta\epsilon = -1.5$), plus a chiral additive and some dichroic dye.

The integrated photodiode is differently connected to the remainder of the circuit, in such a way as to invert its action. It is so obtained a pair of spectacles normally clear (80-70%), being capable of darkening up to 30-40% (for the orthogonal direction and for that inclined by 45°C , respectively). The endurance of the battery de-

depends upon the conditions of use and it appears to be 400 hours at least.

EXAMPLE 3

Another example of construction calls for the use of laminated sheets, made out by transparent and flexible plastic material, for containing the liquid crystal. It is so obtained a visor-like spectacle, in which the lenses are replaced by a continuous element, shown in the enclosed figure 3. In the said figure, the elements corresponding to those shown in figure 2, are marked with the same numbers. The central part of the spectacle is built through a lamination process, in which some layers of polyester resin (Mylar) are assembled together with a liquid crystal and an epossidic adhesive. It is employed a continuous manufacturing process, starting from ribbons of sheeted mylar, 0.5 mm. thick, which are made to pass through the vacuum chambers and the machines in which they undergo the same treatments which have been already described. In this case, the uniformity of the thickness for the inner space is guaranteed by the residual internal depression after the filling up with liquid crystal and the polymerization of the epossidic resin. The latter takes place in a mold, in which the surfaces are glued to their final curved shape, after having cut from the ribbon the required shapes. The conductive tracks are embedded into the lamination and there is obtained a visor 9, cylindrically bent, as shown in the figure. The same is glued to an arc 2 carrying the circuits and the hinges, 4 and 5, connecting them to the arms 1 and 3, which are implemented as in the former case. It is so obtained a rather lighter structure (40 gr.), which is also more economical in the case of its production on a sufficiently large scale.

Claims

1. Adjustable transparency spectacles including lenses formed by non diffusing liquid crystal cells, means suitable for applying an electric voltage to said cells and means for adjusting said voltage, characterized in that said cells are cholesteric-nematic phase change dichroic liquid crystal cells which transmit the light at rest and absorb it in their excited state, with a liquid crystal having a double refraction lower than 0.12 and a negative dielectric anisotropy, an alignment vertical or almost so being imposed to the molecules of the crystal by the walls, and the value of the spontaneous pitch being equal to 0.9-4 times the thickness of said cell.

2. Spectacles according to claim 1, in which said pitch is equal to 1.1-1.7 times the thickness of the cell, and the spontaneous total torsion is included between $6/10$ and $9/10$ of a round angle of 360° .

3. Spectacles according to claims 1-2, in which the said alignment is such that the molecules of the crystal show a deviation from the vertical being equal to 1° - 10° .

4. Spectacles according to claim 3, in which the said alignment is such that the molecules of the crystal show a deviation from the vertical being equal to 2° - 5° .

5. Spectacles according to claims 1-4, in which the said alignment is such that the molecules of the crystal are arranged in vertical planes, the orientation of the planes through the thickness of said cell being rotated by an angle which is near to the spontaneous total torsion of the liquid crystal.

6. Adjustable transparency spectacles including lenses formed by non diffusing liquid crystal cells, means suitable for applying an electric voltage to said cells and means for adjusting said voltage, characterized in that said cells are cholesteric-nematic phase change dichroic liquid crystal cells which absorb the light at rest and transmit it in their excited state, with a liquid crystal having a double refraction lower than 0.12 and a positive dielectric anisotropy, an alignment being imposed upon the crystal from at least one of the walls, which alignment is parallel or almost so to the latter, according to a prefixed direction, the value of the pitch being higher than half of the thickness of the cell itself, and the effective torsion, at rest, being equal to $1/4$ -2 round angles.

7. Spectacles according to claim 6, in which the said effective total torsion, at rest, of the liquid crystal through the thickness of said cell, is included between $1/2$ and $3/2$ round angles.

8. Spectacles according to claims 6-7 in which the said alignment is such that the molecules of the crystal make with the horizontal an angle not greater than 25° .

9. Spectacles according to claim 8, in which the said alignment is such that the molecules of the crystal makes with the horizontal an angle equal to 2° - 15° .

depends upon the conditions of use and it appears to be 400 hours at least.

EXAMPLE 3

Another example of construction calls for the use of laminated sheets, made out by transparent and flexible plastic material, for containing the liquid crystal. It is so obtained a visor-like spectacle, in which the lenses are replaced by a continuous element, shown in the enclosed figure 3. In the said figure, the elements corresponding to those shown in figure 2, are marked with the same numbers. The central part of the spectacle is built through a lamination process, in which some layers of polyester resin (Mylar) are assembled together with a liquid crystal and an epossidic adhesive. It is employed a continuous manufacturing process, starting from ribbons of sheeted mylar, 0.5 mm. thick, which are made to pass through the vacuum chambers and the machines in which they undergo the same treatments which have been already described. In this case, the uniformity of the thickness for the inner space is guaranteed by the residual internal depression after the filling up with liquid crystal and the polymerization of the epossidic resin. The latter takes place in a mold, in which the surfaces are glued to their final curved shape, after having cut from the ribbon the required shapes. The conductive tracks are embedded into the lamination and there is obtained a visor 9, cylindrically bent, as shown in the figure. The same is glued to an arc 2 carrying the circuits and the hinges, 4 and 5, connecting them to the arms 1 and 3, which are implemented as in the former case. It is so obtained a rather lighter structure (40 gr.), which is also more economical in the case of its production on a sufficiently large scale.

Claims

1. Adjustable transparency spectacles including lenses formed by non diffusing liquid crystal cells, means suitable for applying an electric voltage to said cells and means for adjusting said voltage, characterized in that said cells are cholesteric-nematic phase change dichroic liquid crystal cells which transmit the light at rest and absorb it in their excited state, with a liquid crystal having a double refraction lower than 0.12 and a negative dielectric anisotropy, an alignment vertical or almost so being imposed to the molecules of the crystal by the walls, and the value of the spontaneous pitch being equal to 0.9-4 times the thickness of said cell.

2. Spectacles according to claim 1, in which said pitch is equal to 1.1-1.7 times the thickness of the cell, and the spontaneous total torsion is included between 6/10 and 9/10 of a round angle of 360°.

3. Spectacles according to claims 1-2, in which the said alignment is such that the molecules of the crystal show a deviation from the vertical being equal to 1°-10°.

4. Spectacles according to claim 3, in which the said alignment is such that the molecules of the crystal show a deviation from the vertical being equal to 2°-5°.

5. Spectacles according to claims 1-4, in which the said alignment is such that the molecules of the crystal are arranged in vertical planes, the orientation of the planes through the thickness of said cell being rotated by an angle which is near to the spontaneous total torsion of the liquid crystal.

6. Adjustable transparency spectacles including lenses formed by non diffusing liquid crystal cells, means suitable for applying an electric voltage to said cells and means for adjusting said voltage, characterized in that said cells are cholesteric-nematic phase change dichroic liquid crystal cells which absorb the light at rest and transmit it in their excited state, with a liquid crystal having a double refraction lower than 0.12 and a positive dielectric anisotropy, an alignment being imposed upon the crystal from at least one of the walls, which alignment is parallel or almost so to the latter, according to a prefixed direction, the value of the pitch being higher than half of the thickness of the cell itself, and the effective torsion, at rest, being equal to 1/4-2 round angles.

7. Spectacles according to claim 6, in which the said effective total torsion, at rest, of the liquid crystal through the thickness of said cell, is included between 1/2 and 3/2 round angles.

8. Spectacles according to claims 6-7 in which the said alignment is such that the molecules of the crystal make with the horizontal an angle not greater than 25°.

9. Spectacles according to claim 8, in which the said alignment is such that the molecules of the crystal makes with the horizontal an angle equal to 2°-15°.



10. Spectacles according to each of the claims 1-9, in which the said means for applying the electric voltage are formed by an electronic circuit which generates, at the terminals of the said cell, an adjustable voltage, whose effective value is higher than the threshold, does not contain any direct current components, and has a frequency sufficiently high as not to allow the passage of ions into the said liquid crystal. 5
11. Spectacles according to claim 10, in which the said means for applying the electric voltage include an inductor, electrically resonant with the cells' capacitances. 10
12. Spectacles according to claims 10 or 11, in which the said voltage, as generated by the said electronic circuit, is adjusted by manual and/or automatic means. 15
13. Spectacles according to claim 12, in which the said automatic means for adjusting the voltage are made out by electronic circuits being actuated by a photocell. 20
14. Spectacles according to claims 12-13, in which the said manual means for adjusting the voltage include some electronic circuits controlled by lightly touched keys. 25
15. Spectacles according to claims 12-13, in which the said manual means for adjusting the voltage include a potentiometer. 30
16. Spectacles according to claims 12-13, in which the said manual means for adjusting the voltage include a variable condenser. 35
17. Spectacles according to claims 12-13, in which the said manual means for adjusting the voltage include a variable inductor. 40
18. Spectacles according to any of the previous claims, in which the said glass or plastic material is treated or dyed in such a way as to absorb the ultraviolet rays. 45
19. Spectacles according to any of the previous claims, in which the supports of said cells are made out by curved lenses for spectacles, in glass or in a plastic materials worked, at least from their internal side, with a precision such as to give way to differences of dimension and of camber, with reference to the ideal surface, being contained respectively within a few micrometers and within a few micrometers/cm². 50

20. Spectacles according to claims 1-18, in which the said lenses are obtained in just one continuous element of visor shaped plastic material. 55

Patentansprüche

1. Brille mit einstellbarer Lichtdurchlässigkeit, welche durch nichtstreuende Flüssigkristall-Zellen gebildete Linsen, Mittel zum Anlegen einer elektrischen Spannung an die genannten Zellen und Mittel zum Einstellen der genannten Spannung aufweist, dadurch gekennzeichnet, dass die genannten Zellen dichroitische Flüssigkristall-Zellen mit cholesterisch-nematischem Phasenwechsel sind, welche das Licht im Ruhezustande durchlassen und es im angeregten Zustande absorbieren, mit einem Flüssigkristall, welcher eine Doppelbrechung von weniger als 0,12 und eine negative elektrische Anisotropie aufweist, wobei den Molekülen durch die Wände des Kristalls eine vertikale oder beinahe vertikale Ausrichtung aufgezwungen wird, und wobei der Wert der spontanen Steigung gleich dem 0,9- bis 4-Fachen der Dicke der genannten Zelle ist.
2. Brille nach Anspruch 1, worin die genannte Steigung das 1,1- bis 1,7-Fache der Dicke der Zelle und die spontane Gesamtverdrehung 6/10 bis 9/10 des Vollwinkels von 360° beträgt.
3. Brille nach den Ansprüchen 1 und 2, worin die genannte Ausrichtung derart ist, dass die Moleküle des Kristalls eine Abweichung von der Vertikalen von 1 bis 10° aufweisen.
4. Brille nach Anspruch 3, worin die genannte Ausrichtung derart ist, dass die Moleküle des Kristalls eine Abweichung von der Vertikalen von 2 bis 5° aufweisen.
5. Brille nach den Ansprüchen 1 bis 4, worin die genannte Ausrichtung derart ist, dass die Moleküle des Kristalls in vertikalen Ebenen angeordnet sind, wobei die Orientierung der Ebenen über die Dicke der genannten Zelle um einen Winkel verdreht ist, welcher nahe bei der spontanen Gesamtverdrehung des Flüssigkristalls liegt.
6. Brille mit einstellbarer Lichtdurchlässigkeit, welche durch nichtstreuende Flüssigkristall-Zellen gebildete Linsen, Mittel zum Anlegen einer elektrischen Spannung an die genannten Zellen und Mittel zum Einstellen der genannten Spannung aufweist, dadurch gekennzeichnet,



- dass die genannten Zellen dichroitische Flüssigkristall-Zellen mit cholesterisch-nematischem Phasenwechsel sind, welche das Licht im Ruhezustande absorbieren und es im angeregten Zustande durchlassen, mit einem Flüssigkristall, welcher eine Doppelbrechung von weniger als 0,12 und eine positive elektrische Anisotropie aufweist, wobei den Molekülen des Kristalls durch mindestens eine der Wände eine parallele oder beinahe parallele Ausrichtung zu derselben, entsprechend einer vorgegebenen Richtung, aufgezwungen wird, und wobei der Wert der Steigung grösser als die halbe Dicke der Zelle selbst ist und die effektive Verdrehung im Ruhezustande $1/4$ bis 2 Vollwinkel beträgt.
7. Brille nach Anspruch 6, worin die genannte effektive Gesamtverdrehung des Flüssigkristalls im Ruhezustande über die Dicke der genannten Zelle $1/2$ bis $3/2$ Vollwinkel beträgt.
 8. Brille nach den Ansprüchen 6 und 7, worin die genannte Ausrichtung derart ist, dass die Moleküle des Kristalls mit der Horizontalen einen Winkel von höchstens 25° bilden.
 9. Brille nach Anspruch 8, worin die genannte Ausrichtung derart ist, dass die Moleküle des Kristalls mit der Horizontalen einen Winkel von 2 bis 15° bilden.
 10. Brille nach einem der Ansprüche 1 bis 9, worin die genannten Mittel zum Anlegen einer elektrischen Spannung durch einen elektronischen Schaltkreis gebildet werden, welcher an den Ausschlüssen der genannten Zelle eine einstellbare Spannung erzeugt, deren Effektivwert höher als der Schwellenwert ist, welche keine Gleichstromkomponente enthält und welche eine Frequenz aufweist, die hoch genug ist, um den Übergang von Ionen in den genannten Flüssigkristall nicht zu erlauben.
 11. Brille nach Anspruch 10, worin die genannten Mittel zum Anlegen einer elektrischen Spannung einen mit den Kapazitäten der Zelle in Resonanz schwingenden Induktor aufweisen.
 12. Brille nach Anspruch 10 oder 11, worin die genannte Spannung, wie sie vom genannten elektronischen Schaltkreis erzeugt wird, durch von Hand betätigte und/oder automatische Mittel reguliert wird.
 13. Brille nach Anspruch 12, worin die genannten automatischen Mittel zur Regulierung der Spannung durch elektronische Schaltkreise,

welche durch Photozellen betrieben werden, gebildet werden.

14. Brille nach den Ansprüchen 12 und 13, worin die genannten von Hand betätigten Mittel zur Regulierung der Spannung durch leichtgängige Tasten gesteuerte elektronische Schaltkreise aufweisen.
15. Brille nach den Ansprüchen 12 und 13, worin die genannten von Hand betätigten Mittel zur Regulierung der Spannung ein Potentiometer aufweisen.
16. Brille nach den Ansprüchen 12 und 13, worin die genannten von Hand betätigten Mittel zur Regulierung der Spannung einen veränderlichen Kondensator aufweisen.
17. Brille nach den Ansprüchen 12 und 13, worin die genannten von Hand betätigten Mittel zur Regulierung der Spannung einen veränderlichen Induktor aufweisen.
18. Brille nach einem der vorangehenden Ansprüche, worin das genannte Glas oder Kunststoff-Material derart behandelt oder gefärbt ist, dass es ultraviolette Strahlen absorbiert.
19. Brille nach einem der vorangehenden Ansprüche, worin die Träger der genannten Zellen aus gekrümmten Brille-Linsen aus Glas oder einem Kunststoff-Material gebildet werden, welche mindestens an ihrer Innenseite mit einer solchen Präzision gefertigt sind, dass die Abweichungen bezüglich Abmessung und Krümmung von der idealen Oberfläche innerhalb weniger Mikrometer bzw. weniger Mikrometer/cm² liegen.
20. Brille nach einem der Ansprüche 1 bis 18, worin die genannten Linsen als ein einziges, kontinuierliches Element aus visierförmig geformtem Kunststoff-Material ausgebildet ist.

Revendications

1. Lunettes à transparence réglable comprenant des lentilles formées par des cellules à cristal liquide non diffusantes, des moyens appropriés pour l'application d'une tension électrique auxdites cellules, et des moyens de réglage de cette tension, caractérisées en ce que lesdites cellules sont des cellules à cristal liquide dichroïques à changement de phase cholestériques-nématiques qui transmettent la lumière au repos et l'absorbent dans leur état excité, avec un cristal liquide ayant une double



- réfraction inférieure à 0,12 et une anisotropie diélectrique négative, un alignement vertical ou presque vertical étant imposé aux molécules du cristal par les parois, et la valeur du pas spontané étant égale à 0,9-4 fois l'épaisseur de ladite cellule.
2. Lunettes suivant la revendication 1, dans lesquelles ledit pas est égal à 1,1-1,7 fois l'épaisseur de la cellule, et la torsion spontanée totale est comprise entre 6/10 et 9/10 d'un angle circulaire de 360°.
 3. Lunettes suivant les revendications 1 et 2, dans lesquelles ledit alignement est tel que les molécules du cristal présentent un écart de 1° à 10° par rapport à la verticale.
 4. Lunettes suivant la revendication 3, dans lesquelles ledit alignement est tel que les molécules du cristal présentent un écart de 2° à 5° par rapport à la verticale.
 5. Lunettes suivant les revendications 1 à 4, dans lesquelles ledit alignement est tel que les molécules du cristal sont disposées dans des plans verticaux, l'orientation des plans à travers l'épaisseur de ladite cellule subissant une rotation suivant un angle qui est proche de la torsion spontanée totale du cristal liquide.
 6. Lunettes à transparence réglable comprenant des lentilles formées par des cellules à cristal liquide non diffusantes, des moyens appropriés d'application d'une tension électrique auxdites cellules, et des moyens de réglage de cette tension, caractérisées en ce que lesdites cellules sont des cellules à cristal liquide dichroïques à changement de phase cholestériques-nématiques qui absorbent la lumière au repos et la transmettent dans leur état excité, avec un cristal liquide ayant une double réfraction inférieure à 0,12 et une anisotropie diélectrique positive, un alignement étant imposé au cristal par au moins une des parois, cet alignement étant parallèle ou presque parallèle à cette dernière, conformément à une direction préfixée, la valeur du pas étant plus grande que la moitié de l'épaisseur de la cellule elle-même, et la torsion effective au repos étant égale à 1/4-2 angles circulaires de 360°.
 7. Lunettes suivant la revendication 6, dans lesquelles ladite torsion effective totale, au repos, du cristal liquide à travers toute l'épaisseur de ladite cellule est comprise entre 1/2 et 3/2 angles circulaires de 360°.
 8. Lunettes suivant les revendications 6 et 7, dans lesquelles ledit alignement est tel que les molécules du cristal font avec l'horizontale un angle non supérieur à 25°.
 9. Lunettes suivant la revendication 8, dans lesquelles ledit alignement est tel que les molécules du cristal font avec l'horizontale un angle égal à 2°-15°.
 10. Lunettes suivant chacune des revendications 1 à 9, dans lesquelles lesdits moyens d'application de la tension électrique sont formés par un circuit électronique qui engendre, aux bornes de ladite cellule, une tension réglable dont la valeur effective est supérieure au seuil, qui ne contient pas de composantes de courant continu et qui a une fréquence suffisamment élevée pour ne pas permettre le passage d'ions dans ledit cristal liquide.
 11. Lunettes suivant la revendication 10, dans lesquelles lesdits moyens d'application de la tension électrique comprennent une inductance en résonance électrique avec les capacitances des cellules.
 12. Lunettes suivant les revendications 10 ou 11, dans lesquelles ladite tension, engendrée par ledit circuit électronique, est réglée par des moyens manuels et/ou automatiques.
 13. Lunettes suivant la revendication 12, dans lesquelles lesdits moyens automatiques de réglage de la tension sont constitués par des circuits électroniques activés par une photocellule.
 14. Lunettes suivant les revendications 12 et 13, dans lesquelles lesdits moyens manuels de réglage de la tension comprennent des circuits électroniques commandés par des touches à effleurement.
 15. Lunettes suivant les revendications 12 et 13, dans lesquelles lesdits moyens manuels de réglage de la tension comprennent un potentiomètre.
 16. Lunettes suivant les revendications 12 et 13, dans lesquels lesdits moyens manuels de réglage de la tension comprennent un condensateur variable.
 17. Lunettes suivant les revendications 12 et 13, dans lesquelles lesdits moyens manuels de réglage de la tension comprennent une inductance variable.



18. Lunettes suivant une quelconque des revendications précédentes, dans lesquelles ledit verre ou ladite matière plastique est traité ou coloré de manière à absorber les rayons ultraviolets.

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19. Lunettes suivant une quelconque des revendications précédentes, dans lesquelles les supports desdites cellules sont constituées par des lentilles courbes pour lunettes, en verre ou en matière plastique, travaillées, au moins sur leur côté interne, avec une précision engendrant des différences de dimension et de cambrure, par rapport à la surface idéale, qui sont contenues respectivement dans des limites de quelques μm et de quelques $\mu\text{m}/\text{cm}^2$.

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20. Lunettes suivant les revendications 1 à 18, dans lesquelles lesdites lentilles sont obtenues en un seul élément continu en matière plastique en forme de visière.

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