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(54) **SURFACE CLEANING AND MODIFYING METHOD AND SURFACE CLEANING AND MODIFYING APPARATUS**

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(57) **ABSTRACT**

A self-cleaning step for cleaning an elastic abrasive body **231** itself by pressing the rotating elastic abrasive body **231** against a pressing member **221** to deform the elastic body **231** while supplying slurry L containing abrasive to the elastic abrasive body **231** so as to clean the elastic abrasive body **231** is added to a scrub cleaning step in which a plastic optical component **1** is rotated and the rotating elastic abrasive body **231** is pressed against a surface of the plastic optical component **1** while supplying slurry L containing abrasive between the surface of the plastic optical component **1** and the elastic abrasive body **231** so as to clean the plastic optical component **1**.

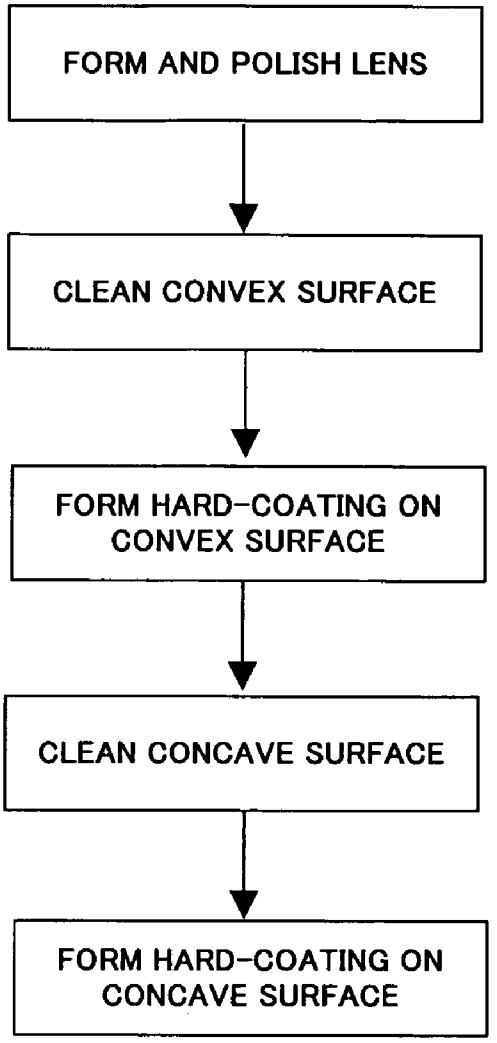


FIG. 1A

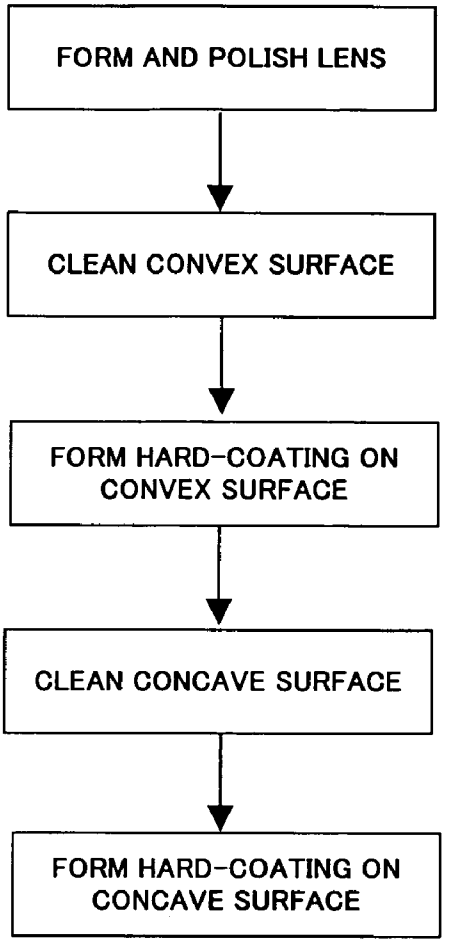

FORM AND POLISH LENS
CLEAN CONVEX SURFACE
FORM HARD-COATING ON CONVEX SURFACE
CLEAN CONCAVE SURFACE
FORM HARD-COATING ON CONCAVE SURFACE

FIG. 1B

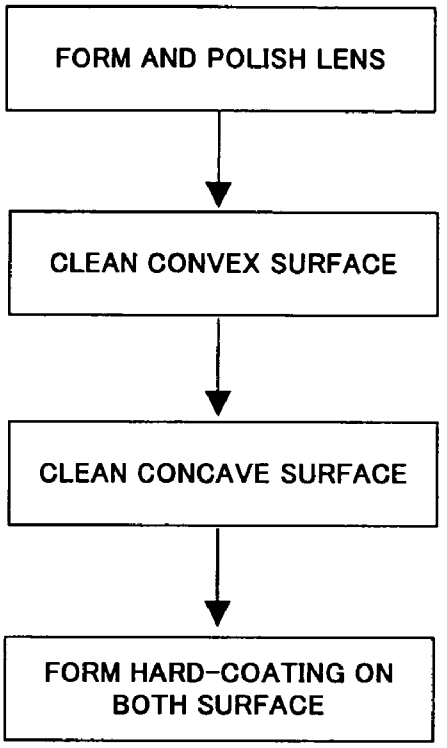

FORM AND POLISH LENS
CLEAN CONVEX SURFACE
CLEAN CONCAVE SURFACE
FORM HARD-COATING ON BOTH SURFACE

FIG. 2A

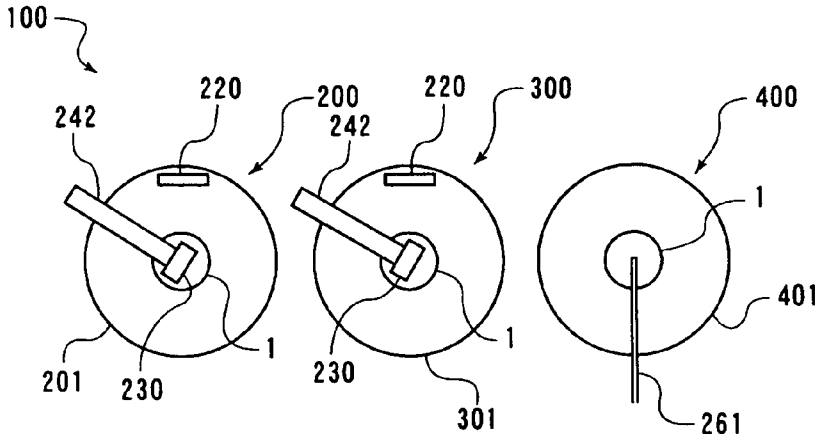

100
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200
242
220
300
400
242
1
401
201
230
230
1
301
261

FIG. 2B

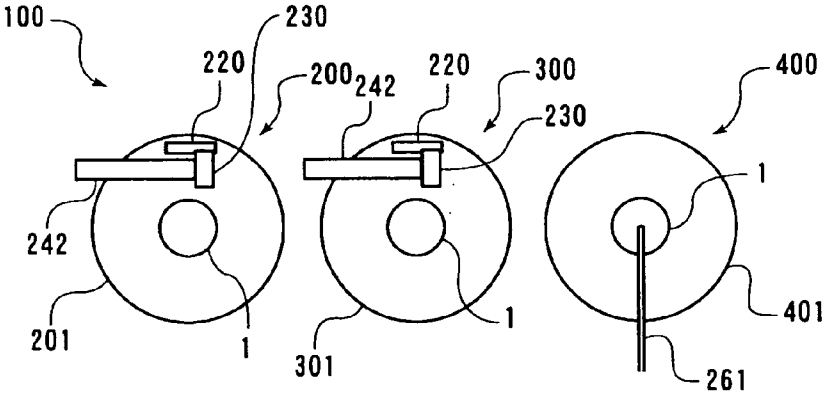

100
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FIG. 3

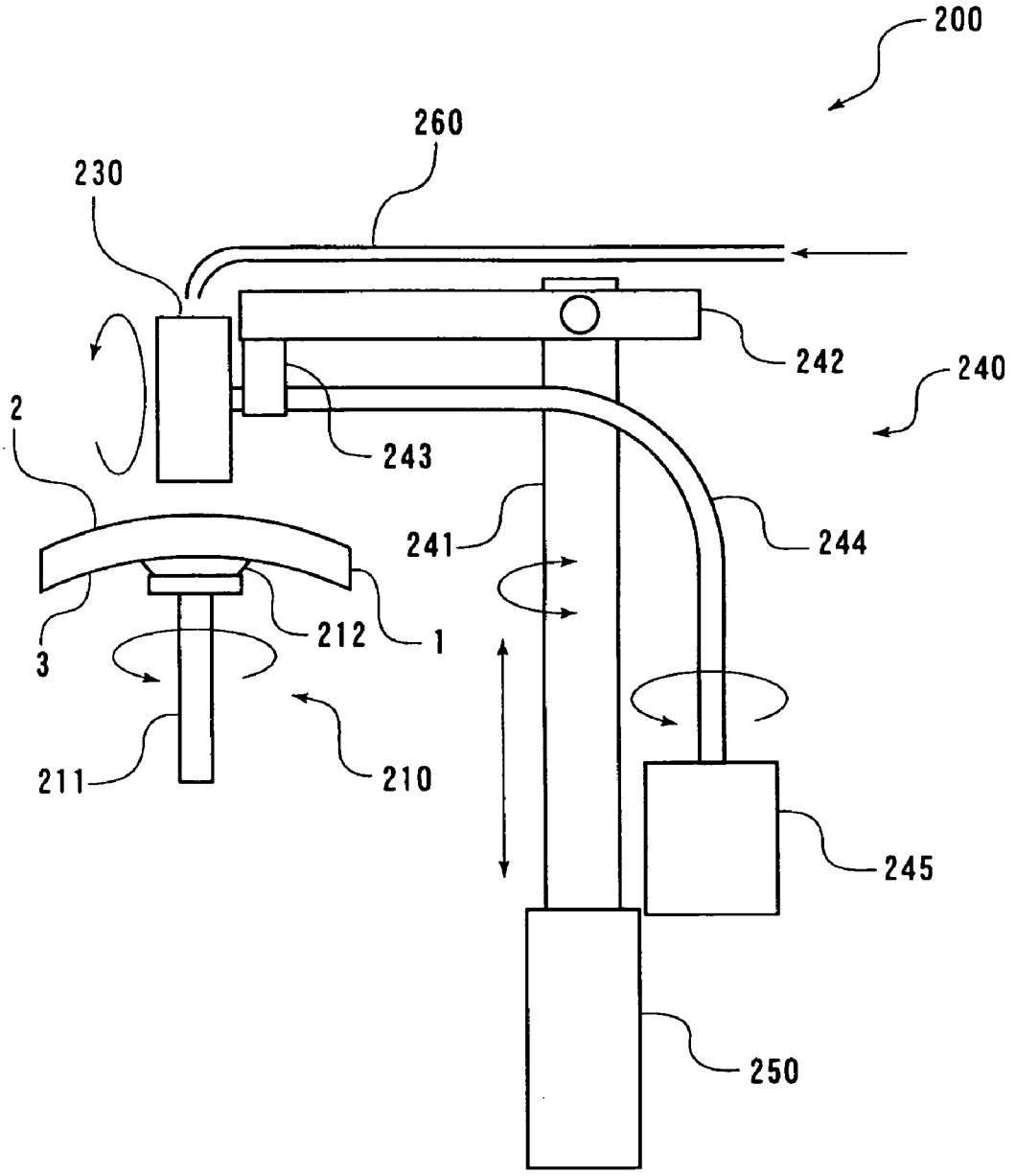


FIG. 4

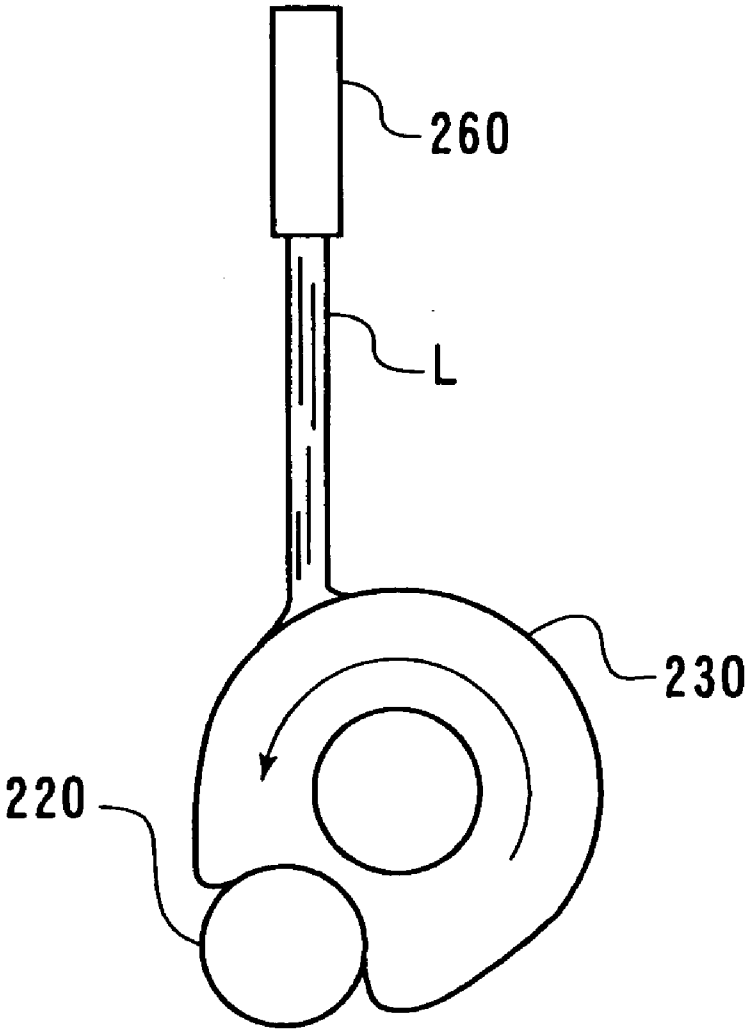


FIG. 5

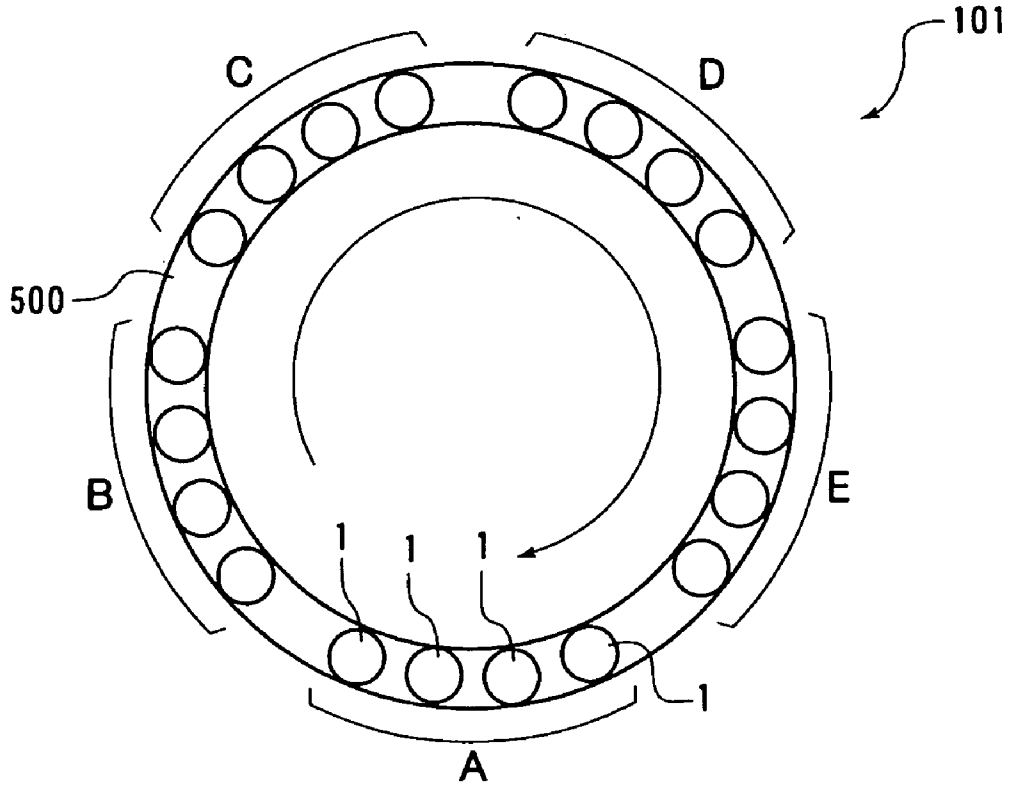


FIG. 6A

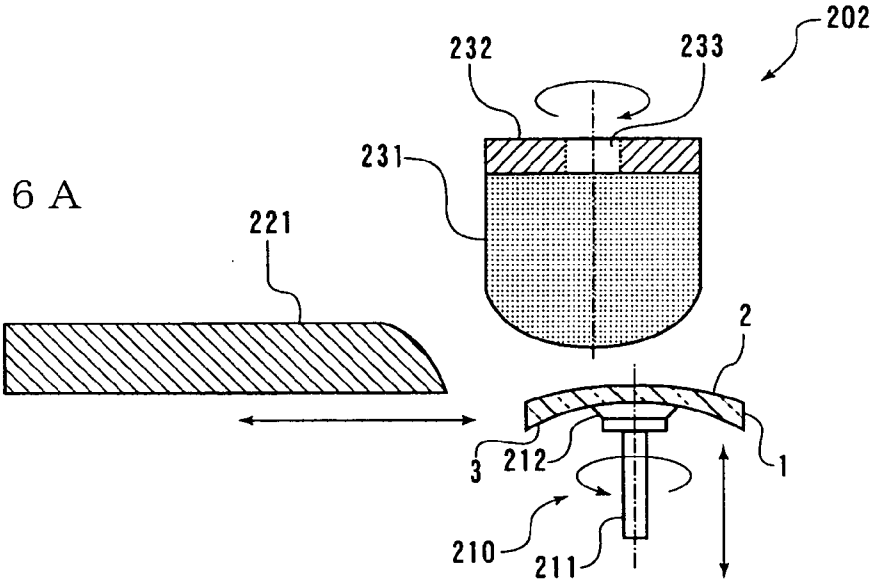


FIG. 6B

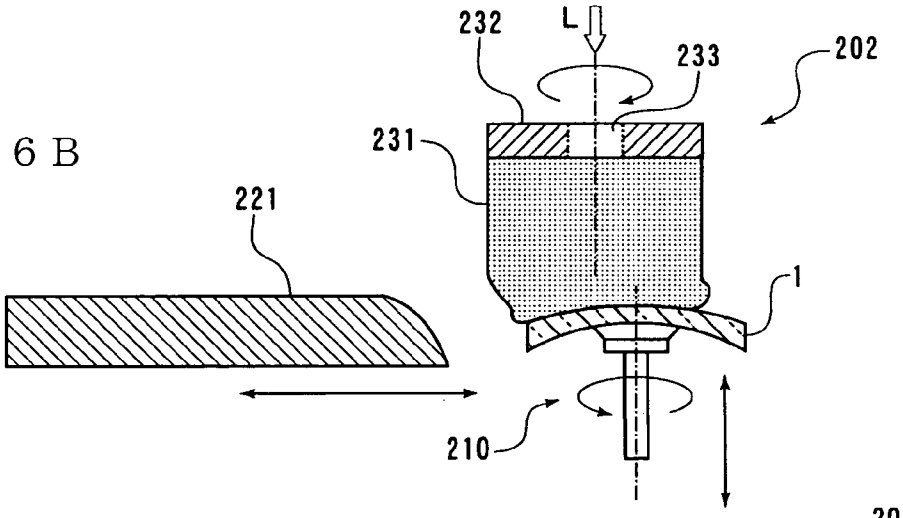
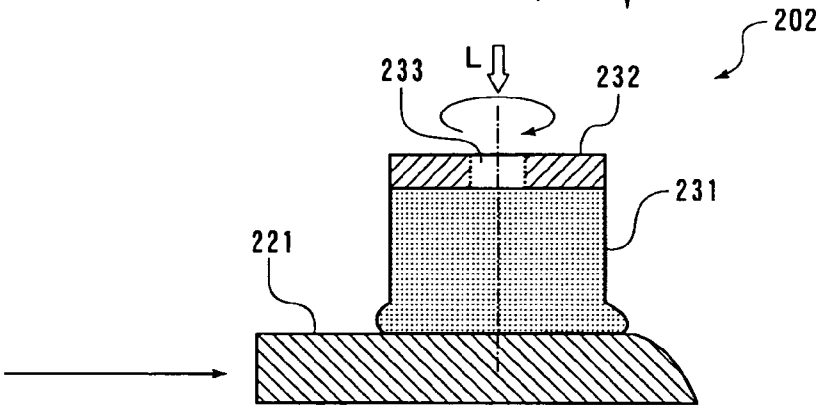


FIG. 6C



SURFACE CLEANING AND MODIFYING METHOD AND SURFACE CLEANING AND MODIFYING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from Japanese Patent Application JP 2003-384070 filed Nov. 13, 2003, which is incorporated by reference, herein, in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to a surface cleaning and modifying method and surface cleaning and modifying apparatus capable of effectively cleaning a surface of a plastic optical component such as a plastic lens.

BACKGROUND OF THE INVENTION

[0003] A drawback to a plastic optical component is that it is easily scratched due to its softness. Thus, a hard-coating for providing anti-friction and anti-scratch properties is formed on a surface of the plastic optical component, and an anti-reflection coating is overlaid on the hard-coating, thereby improving the performance and function of the plastic optical component.

[0004] Particularly for a plastic spectacle lens, hard-coating formation is a surface treatment essential to improve the hardness of the lens surface and the tight connection with an evaporated coating and to provide colorability.

[0005] As a pretreatment for hard-coating formation, it is necessary to carry out a cleaning step for cleaning the surface of the plastic optical component so as to remove dust and dirt adhering thereto for the achievement of sufficient reaction between a hard-coating and a material. When cleaning in the cleaning step is insufficient, the appearance and durability of the surface of the plastic optical component are adversely affected, resulting in lowered yields. Thus, the cleaning step is an important pretreatment.

[0006] In a conventional method for cleaning the plastic optical component, the dirt adhering to the surface of the optical component is dissolved and separated using a dip-type cleaning apparatus.

[0007] An improvement to the conventional cleaning method has been proposed in JP-A-5-70615 and in JP-A-11-48117. According to these proposals, a scrub cleaning method for polishing the surface of the optical component with abrasive is performed by supplying slurry, which contains abrasive dispersed in water, while scrubbing the surface of the optical component with an elastic abrasive body (or by scrubbing the surface of the optical component with an elastic abrasive body, which contains abrasive dispersed therein, while pouring water).

[0008] This scrub cleaning method is a surface cleaning and modifying method capable of removing dirt adhering to the surface of the plastic optical component and a non-uniform surface formed due to degradation or other caused during or after shaping by physically polishing the surface of the plastic optical component with abrasive. By this method, drawbacks in appearance such as cissing caused by dirt are prevented, and hard-coating is sufficiently tight-connected and bonded with the surface of the optical component without hindrance by a non-uniform layer, thereby enhancing the tight connection between the surface and the hard-coating. Additionally, the connection tightness is further increased due to activation of the surface caused by polishing and an anchor effect caused by minute polishing scratches.

[0009] However, in the above-described scrub cleaning method, dirt or contaminant sometimes remains on the elastic abrasive body after cleaning the plastic optical component. If the next plastic optical component is cleaned with the elastic abrasive body to which dirt or contaminant adheres, the dirt or contaminant may be transferred to the surface of the plastic optical component or may scratch the surface deeply. Thus, the dirt, contaminant and deep scratches existing on the surface of the plastic optical component have been the cause for lowering yields of the hard-coating formation treatment.

SUMMARY OF THE INVENTION

[0010] The present invention has been developed to solve the above-described problem. It is an object of the invention to provide a surface cleaning and modifying method and surface cleaning and modifying apparatus capable of polishing and cleaning a plastic optical component with abrasive using an elastic abrasive body without leaving dirt or deep scratches on a surface of the plastic optical component.

[0011] In order to achieve the above object, a first aspect of the invention is to provide a surface cleaning and modifying method. This method provides for scrub cleaning a plastic optical component, including rotating the plastic optical component, pressing a rotating elastic abrasive body against a surface of the plastic optical component, and, during the pressing, supplying a liquid between the surface of the plastic optical component and the elastic abrasive body, the liquid being a slurry with dispersed abrasive. This method also provides for self-cleaning of the elastic abrasive body, including deforming the elastic abrasive body, and during the deforming, supplying a liquid, to the elastic abrasive body, the liquid being a slurry including dispersed abrasive.

[0012] The plastic optical component is scrub-cleaned with abrasive using the elastic abrasive body in the scrub cleaning step, and the elastic abrasive body itself used for the cleaning is cleaned to remove dirt or contaminant adhering to the elastic abrasive body in the self-cleaning step. The self-cleaning step prevents dirt or contaminant from re-adhering to the plastic optical component from the elastic abrasive body. In addition, the self-cleaning step prevents desiccation of the elastic abrasive body. As a result, the plastic optical component can be cleaned without being deeply scratched by the dried elastic abrasive body.

[0013] A second aspect of the invention is to provide the surface cleaning and modifying method described in the first aspect of the invention, wherein said self-cleaning further comprises placing said elastic abrasive body and a pressing member in contact to deform said elastic abrasive body.

[0014] Since the elastic abrasive body is largely deformed by pressing the pressing member and the elastic abrasive body against each other, the elastic abrasive body can be effectively self-cleaned.

[0015] A third aspect of the invention is to provide the surface cleaning and modifying method as in the first aspect

of the invention, further comprising alternately performing said scrub cleaning and said self-cleaning.

[0016] Since the scrub cleaning is performed using the elastic abrasive body which is always cleaned by providing the self-cleaning step between the scrub cleaning steps, the plastic optical component can be cleaned without leaving dirt and large scratches thereon.

[0017] A fourth aspect of the invention is to provide a surface cleaning and modifying method. In this method, there is a scrub cleaning a plastic optical component, including rotating the plastic optical component, pressing a rotating elastic abrasive body against a surface of the plastic optical component, the elastic abrasive body including dispersed abrasive, and during the pressing, supplying a liquid including water between the surface of said plastic optical component and said elastic abrasive body. This method also provides for the self-cleaning of the elastic abrasive body, including deforming the elastic abrasive body, and, during the deforming, supplying a liquid including water to the elastic abrasive body.

[0018] The plastic optical component is scrub-cleaned with abrasive using the elastic abrasive body in the scrub cleaning step, and the elastic abrasive body itself used for the cleaning is cleaned to remove dirt or contaminant adhering to the elastic abrasive body in the self-cleaning step. The self-cleaning step prevents dirt or contaminant from re-adhering to the plastic optical component from the elastic abrasive body. In addition, the self-cleaning step prevents desiccation of the elastic abrasive body. As a result, the plastic optical component can be cleaned without being deeply scratched by the dried elastic abrasive body.

[0019] A fifth aspect of the present invention is to provide the surface cleaning and modifying method as described in the fourth aspect of the invention, wherein the self-cleaning further includes placing the elastic abrasive body and a pressing member in contact to deform the elastic abrasive body.

[0020] Since the elastic abrasive body is largely deformed by pressing the pressing member and the elastic abrasive body against each other, the elastic abrasive body can be effectively self-cleaned.

[0021] A sixth aspect of the invention is to provide the surface cleaning and modifying method as described in the fourth aspect of the invention, further including alternately performing the scrub cleaning and the self-cleaning.

[0022] Since the scrub cleaning is performed using the elastic abrasive body which is always cleaned by providing the self-cleaning step between the scrub cleaning steps, the plastic optical component can be cleaned without leaving dirt and large scratches thereon.

[0023] A seventh aspect of the invention is to provide a surface cleaning and modifying apparatus. This apparatus includes an optical component holder holding and rotating a plastic optical component, a pressing member separate from said optical component holder, an abrasive body holder holding and rotating an elastic abrasive body, an operation section operating one or more of the optical component holder and the abrasive body holder so as to perform operations. The operations include a cleaning action of pressing the elastic abrasive body against the plastic optical component, and a self-cleaning action of placing the elastic abrasive body in contact with the pressing member. This apparatus also includes a liquid supply member for supplying liquid to the elastic abrasive body during the cleaning action and the self-cleaning action.

[0024] In the scrub cleaning step, the elastic abrasive body is held and rotated by the abrasive body holder with the plastic optical component held and rotated by the optical component holder. In this condition, the elastic abrasive body is pressed against the surface of the plastic optical component by the operation section while supplying liquid from the liquid supply member to conduct the scrub cleaning. In the self-cleaning step, the elastic abrasive body rotated by the abrasive body holder is pressed against the pressing member by the operation section while supplying liquid from the liquid supply member to conduct the self-cleaning.

[0025] An eighth aspect of the invention is to provide the surface cleaning and modifying apparatus as described in the seventh aspect of the invention, wherein the operation section conducts the cleaning action and the self-cleaning action alternately.

[0026] Since the scrub cleaning is performed using the elastic abrasive body which is always cleaned by providing the self-cleaning step between the scrub cleaning steps, the plastic optical component can be cleaned without leaving dirt and large scratches thereon.

[0027] A ninth aspect of the invention is to provide the surface cleaning and modifying apparatus as described in the seventh aspect of the invention, wherein the liquid is a slurry that includes dispersed abrasive.

[0028] The surface of the plastic optical component is polished and modified with abrasive by supplying slurry which contains abrasive dispersed in liquid to the surface of the plastic optical component.

[0029] A tenth aspect of the invention is to provide the surface cleaning and modifying apparatus as described in the seventh aspect of the invention, in which the elastic abrasive body includes dispersed abrasive.

[0030] And an eleventh aspect of the invention is to provide the surface cleaning and modifying apparatus as described in the tenth aspect of the invention, such that the liquid includes water.

[0031] The surface of the plastic optical component is cleaned and modified with abrasive by polishing the surface using the elastic abrasive body which contains abrasive dispersed therein while supplying water. The elastic abrasive body is cleaned with water while being pressed against the pressing member, thereby removing dirt and contaminant adhering to the elastic abrasive body itself.

[0032] A surface cleaning and modifying method and surface cleaning and modifying apparatus of the present invention are utilized for cleaning a surface of a plastic optical component such as a plastic lens, and for pretreatment before forming a hard-coating or other.

[0033] The invention is taught below by way of various specific exemplary embodiments explained in detail, and illustrated in the enclosed drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] The drawing figures depict, in highly simplified schematic form, embodiments reflecting the principles of the invention. Many items and details that will be readily understood by one familiar with this field have been omitted so as to avoid obscuring the invention. In the drawings:

[0035] **FIG. 1**(*a*) is a flowchart of manufacturing steps in which cleaning and hard-coating formation are carried out first on one side of a plastic lens and subsequently on the other side.

[0036] **FIG. 1**(*b*) is a flowchart of manufacturing steps in which both sides of the plastic lens are cleaned and subsequently coated with hard-coatings at a time.

[0037] **FIG. 2** illustrates arrangements of lens cleaning equipment in a first embodiment.

[0038] **FIG. 3** schematically illustrates a structure of surface cleaning and modifying apparatus in the first embodiment.

[0039] **FIG. 4** schematically illustrates a structure of a self-cleaning device.

[0040] **FIG. 5** illustrates a disposition of a lens cleaning device in a second embodiment.

[0041] FIGS. **6**(*a*), **6**(*b*), and **6**(*c*) schematically illustrate a structure of surface cleaning and modifying apparatus in the second embodiment. In particular: **FIG. 6**(*a*) shows a condition before cleaning starts; **FIG. 6**(*b*) shows a condition during scrub cleaning; and **FIG. 6**(*c*) shows a condition during self-cleaning.

DETAILED DESCRIPTION

[0042] The invention will now be taught using various exemplary embodiments. Although the embodiments are described in detail, it will be appreciated that the invention is not limited to just these embodiments, but has a scope that is significantly broader. The appended claims should be consulted to determine the true scope of the invention.

[0043] In other words, embodiments of a surface cleaning and modifying method and surface cleaning and modifying apparatus according to the present invention are hereinafter described, but the invention is not limited to those embodiments.

[0044] Plastic optical components to which the surface cleaning and modifying method of the invention is applicable involve a plastic spectacle lens, a plastic lens constituting an optical system in various types of cameras, a cover glass used as a protective cover for a display device of portable equipment and so forth. Examples of the material include diethylene glycol bisallyl carbonate (CR-39) resin, polyurethane resin, thiourethane resin, polycarbonate resin, acrylic resin and other material.

[0045] Unlike inorganic glass, a plastic optical component is easily scratched due to its softness. Especially for a spectacle lens, formation of hard-coating is essential surface treatment so as to improve the hardness of the lens surface and tight connection with an evaporated coating and provide colorability. Described below is an example of a plastic lens as a plastic optical component.

[0046] In a hard-coating forming step, a film of hard-coating liquid is formed on the surface of the plastic lens by dipping the plastic lens in the hard-coating liquid containing fine particles of metal oxide, binders, catalysts and others, or by spin-coating or other coating method. Subsequently, the hard-coating film is hardened by heating for two to three hours at 120 to 140 degrees Celsius to form a hard-coating. Formation of the hard-coating is necessary on both sides of the plastic lens.

[0047] AS pretreatment before the hard-coating forming step, a cleaning step for cleaning the surface of the plastic lens to remove contaminant or dirt remaining on the surface of the plastic lens is indispensable. There are two methods for cleaning both sides of the plastic lens and forming the hard-coating thereon.

[0048] Flowcharts in **FIG. 1** show two methods for cleaning both sides of the plastic lens and forming the hard-coating thereon. **FIG. 1**(*a*) is a flowchart of manufacturing steps in which cleaning and hard-coating formation are carried out first on one side of a plastic lens and subsequently on the other side, while **FIG. 1**(*b*) is a flowchart of manufacturing steps in which both sides of the plastic lens are cleaned and subsequently coated with hard-coatings at a time. The processing order of a convex surface and a concave surface may be reversed.

[0049] In the surface cleaning and modifying method of the present invention, a self-cleaning step for cleaning an elastic abrasive body itself is added to a scrub cleaning step for polishing and cleaning one side of the plastic lens with abrasive using the elastic abrasive body as described above.

[0050] **FIG. 2** illustrates arrangements of lens cleaning equipment in a first embodiment. **FIG. 2**(*a*) shows a condition during scrub cleaning, while **FIG. 2**(*b*) shows a condition during self-cleaning. Lens cleaning equipment **100** includes surface cleaning and modifying apparatus **200** for scrub-cleaning one side of a plastic lens **1** with abrasive, water cleaning apparatus **300** for water-cleaning the side of the plastic lens polished by the surface cleaning and modifying apparatus **200** to wash off the abrasive and the like, and a drier **400** for drying the side of the plastic lens which is wet after cleaning. The surface cleaning and modifying apparatus **200**, the water cleaning apparatus **300** and the drier **400** are disposed in series and their peripheries are veiled by bottom-attached cylindrical covers **201**, **301** and **401**, respectively. A not-shown carrier for carrying the plastic lens in and out of these apparatus is also provided.

[0051] Since the surface cleaning and modifying apparatus **200** and the water cleaning apparatus **300** have similar basic structures, only the structure of the surface cleaning and modifying apparatus **200** is herein described. **FIG. 3** schematically illustrates the structure of the surface cleaning and modifying apparatus **200** in the first embodiment. The surface cleaning and modifying apparatus **200** includes an optical component holder **210** for holding and rotating the plastic lens **1** approximately at a center of the cylindrical cover **201** (see **FIG. 2**). The optical component holder **210** has a rotational shaft **211** and an absorption chuck **212** positioned on the upper end of the rotational shaft **211**. The rotational shaft **211** is hollow and rotated around a vertically extending axis by a not-shown driving motor. The absorption chuck **212** holds the plastic lens **1** by absorption and communicates with the hollow portion of the rotational shaft

211. The not-shown carrier carries the plastic lens **1** in so as to bring the lower surface of the plastic lens **1** into contact with the absorption chuck **212** while aligning a geometrical center of the round-shaped plastic lens **1** with a center of the rotational shaft **211**.

[**0052**] A not-shown vacuum piping is connected to the hollow portion of the rotational shaft **211**, by which piping the absorption chuck **212** is evacuated after the lower surface of the plastic lens **1** comes into contact with the absorption chuck **212** such that the absorption chuck **212** can hold the lower surface of the plastic lens **1** by absorption. An upper surface of the plastic lens **1** thus held is a convex surface **2** or a concave surface **3** in need of cleaning and modifying. Described below is an example of cleaning the convex surface **2**, and the same method is applicable to the concave surface **3**. Additionally, a pressing member **220** in the shape of a round bar, for example, is disposed within the cover **201** away from the optical component holder **210** and close to the cover **201** (see **FIG. 2**). The pressing member **220** will be described later.

[**0053**] An elastic abrasive body **230** in a cylindrical shape having a short axis is supported by an abrasive body holder **240** such that the peripheral surface of the elastic abrasive body **230** is rotatable around a horizontal axis. The abrasive body holder **240** has a vertically standing support **241** which is disposed outside the cover **201**. The support **241** is rotated clockwise and anticlockwise by a driving force of an operation section **250**, and is also capable of rising and descending in a fixed range. A base end of a support arm **242** as a cantilevered boom extending horizontally is securely attached to the upper end of the support **241**. A horizontal bearing **243** is fixed to the tip of the support arm **242**. One end of a flex shaft **244** is supported by the bearing **243**, and the end of the flex shaft **244** passing through the bearing **243** is secured to a hollow portion positioned at the center of the elastic abrasive body **230**. The other end of the flex shaft **244** is directly connected with a rotational shaft of a motor **245**. The rotation of the motor **245** is transmitted through the flex shaft **244** to the elastic abrasive body **230**. Thus, the elastic abrasive body **230** is so supported by the abrasive body holder **240** as to be rotatable around the horizontal rotation axis. The elastic abrasive body **230** also circles with the rotation of the support **241** rotated by the operation section **250** and moves upward and downward with the rising and descending of the support **241**.

[**0054**] The rotations and the rising and descending motions of the support **241** by the driving of the operation section **250** are sequentially controlled, for example. The operation section **250** performs the following actions: a cleaning action for lowering the elastic abrasive body **230** positioned approximately above the center of the plastic lens **1** which is supported and rotated by the optical component holder **210** to press the rotating elastic abrasive body **230** against the rotating plastic lens **1** and deform the elastic abrasive body **230**, and subsequently shifting the rotating elastic abrasive body **230** from the center to the edge of the plastic lens **1** at a predetermined speed; an action for raising the elastic abrasive body **230** which has reached the edge of the plastic lens **1** to separate the elastic abrasive body **230** from the plastic lens **1**; a self-cleaning action for shifting the elastic abrasive body **230** positioned above the edge of the plastic lens **1** in a horizontal direction to press the elastic abrasive body **230** against the pressing member **220**; and an action for shifting the elastic abrasive body **230**, which has been pressed against the pressing member **220**, to a position above the center of the next plastic lens **1** after the plastic lens **1** thus cleaned is transferred from the optical component holder **210** to the next step by the carrier and the next plastic lens **1** is attached to the optical component holder **210**. These actions are repeated.

[**0055**] The elastic abrasive body **230** may be a liquid-permeable abrasive sponge which is made from PVA, urethane, PP or other material. A sponge made from PVA, urethane, PP or other material in which abrasive is dispersed during shaping may also be used. The elastic abrasive body **230** in which abrasive is dispersed may be employed for both of the surface cleaning and modifying apparatus **200** and the water cleaning apparatus **300**. PVA is a hard material when dried, and softens like a sponge when wet.

[**0056**] The shape of the elastic abrasive body **230** is generally a cylindrical shape having a short axis. However, the shape may be dome-shaped, for example, and is not specifically limited. The peripheral surface of the elastic abrasive body **230** used for polishing the plastic lens **1** may have concaves and convexes or may be smooth.

[**0057**] A liquid outlet **260** is secured on the horizontal arm **242** of the abrasive body holder **240** above the elastic abrasive body **230** to deliver liquid to the elastic abrasive body **230** from above. The liquid outlet **260** is so designed as to supply liquid to the elastic abrasive body **230** all the time even when the elastic abrasive body **230** is shifted. The elastic abrasive body **230** is formed by a liquid-permeable sponge, and the liquid supplied to the elastic abrasive body **230** passes through the elastic abrasive body **230** to reach the surface of the plastic lens **1**. While the elastic abrasive body **230** is being pressed against the convex surface **2** of the plastic lens **1**, the liquid having passed through the elastic abrasive body **230** enters between the elastic abrasive body **230** and the convex surface **2** of the plastic lens **1**.

[**0058**] The scrub cleaning step is performed while the elastic abrasive body **230** pressed against the plastic lens **1** is moving from the center to the edge of the plastic lens **1**, and the self-cleaning step is performed while the elastic abrasive body **230** is being pressed against the pressing member **220**. During these actions, the elastic abrasive body **230** keeps rotating. When the plastic lens **1** is successively cleaned, the scrub cleaning step and the self-cleaning step are alternately conducted.

[**0059**] When the plastic lens **1** is not carried in during operation, the rotation of the elastic abrasive body **230** is stopped with the elastic abrasive body **230** pressed against the pressing member **220**, along with an interruption of liquid supply. However, the elastic abrasive body **230** is rotated and the liquid is supplied at predetermined time intervals to periodically conduct the self-cleaning step.

[**0060**] **FIG. 4** is a conceptual view showing a condition during the self-cleaning step. The rotating elastic abrasive body **230** is pressed against the round-bar-shaped pressing member **220**, thereby deforming the peripheral surface of the elastic abrasive body **230**. Liquid L is poured from the liquid outlet **260** to the upper surface of the deformed elastic abrasive body **230**. The liquid L is water when the elastic abrasive body **230** contains abrasive dispersed therein, or slurry which contains abrasive dispersed in liquid such as

water when the elastic abrasive body **230** does not include abrasive. The foregoing statements do not rule out the possibility of abrasive being in the liquid and also in the elastic body.

[**0061**] The abrasive employed herein may be any type available on the market for abrasive purpose, including metal oxide such as Al_2O_3, CeO_2, SiO_2, Sio, ZrO_2 and Cr_2O_3, or carbide such as sic and C. For the plastic lens **1**, abrasive made of Al_2O_3 is preferably used. The particle diameter and configuration of the abrasive is arbitrarily determined in accordance with the material, shape and objects adhering to the surface, or a desired surface roughness of the plastic optical component to be polished. Slurry which contains abrasive dispersed in water is used so as to diffuse frictional heat caused between the elastic abrasive lens **230** and the plastic lens **1** and improve fitness with the shape of the convex surface **2**.

[**0062**] As described above, the self-cleaning step is a process in which the elastic abrasive body **230** itself is cleaned by supplying liquid while deforming the elastic abrasive body **230** to remove dirt therefrom. By providing the self-cleaning step, dirt and contaminant adhering to the elastic abrasive body **230** are removed and their re-adhesion to the plastic lens **1** is prevented. Thus, the possibility of dirt adhering to and large scratch formed on the plastic lens **1** is eliminated. When the plastic lens **1** is cleaned with the elastic abrasive body **230** which is dried after a long non-cleaning period, the plastic lens **1** may be largely scratched. Thus, a function for preventing desiccation of the elastic abrasive body **230** and resultant large scratch formed on the plastic lens **1** is also provided. When the plastic lens **1** is not carried in for more than a predetermined time period during operation, the self-cleaning is compulsively performed at predetermined time intervals to securely prevent the elastic abrasive body **230** from being dried.

[**0063**] Generally, the elastic abrasive body **230** is deformed by pressing the round-bar shaped or cylindrical pressing member **220** and the elastic abrasive body **230** against each other in the self-cleaning step. The pressing member **220** is required to have a size sufficient to contact the entire peripheral surface of the elastic abrasive body **230** used for cleaning when the elastic abrasive body **230** is rotated. The cross-sectional shape of the pressing member **220** may be either round or rectangular, but is preferably round when the pressing member **220** is easy to be scratched by the material of the elastic abrasive body **230**.

[**0064**] The material employed for the pressing member **220** may include iron, stainless steel, plastic, ceramic and other materials, but its cleaning effect will be lowered if the material is too soft to withstand the pressing by the elastic abrasive body **230**. Additionally, a material which may reversely contaminate the elastic abrasive body **230** by rusting or bleeding out cannot be used. The pressing member **220** is preferably disposed in such a position that the portion of the pressing member **220** contacting with the elastic abrasive body **230** lies parallel to the rotation axis of the elastic abrasive body **230** when the abrasive body holder **240** is circled to separate the elastic abrasive body **230** away from the plastic lens **1**, thereby bringing the pressing member **220** into contact with the peripheral surface of the elastic abrasive body **230** uniformly.

[**0065**] The scrub cleaning step performed by the surface cleaning and modifying apparatus **200** is now described. The not-shown carrier transfers the plastic lens **1** from a stand-by position to the surface cleaning and modifying apparatus **200**. The absorption chuck **212** of the optical component holder **210** holds the concave surface **3** of the plastic lens **1** by absorption with the convex surface **2** on the upper side. The optical component holder **210** rotates the plastic lens **1** at 500 to 1,000 rpm. The operation section **250** circles the support **241** to dispose the elastic abrasive body **230** above the plastic lens **1** while the abrasive body holder **240** rotates the elastic abrasive body **230** at 30 to 500 rpm.

[**0066**] Subsequently, the operation section **250** lowers the elastic abrasive body **230** to press the elastic abrasive body **230** against the center of the plastic lens **1**. Slurry containing abrasive is supplied from the liquid outlet **260** to the upper-side peripheral surface of the elastic abrasive body **230**. Dirt on the plastic lens **1** is not sufficiently removed when the supply amount of slurry is too small, while slurry may scatter outside the cover **201** due to the rotations of the plastic lens **1** and the elastic abrasive body **230** when the supply amount of slurry is too large.

[**0067**] It is thus necessary to determine the amount of slurry appropriately. When the amount of slurry supplied during self-cleaning is sufficient for scrub cleaning, replenishment of slurry during scrub cleaning is not needed. The rotating elastic abrasive body **230** pressed against the plastic lens **1** is shifted from the center to the edge of the plastic lens **1** to polish the convex surface **2** of the plastic lens **1** with abrasive. By providing the scrub cleaning step in which the plastic lens **1** is rotated and the rotating elastic abrasive body **230** is pressed against the plastic lens **1** while supplying slurry containing abrasive between the elastic abrasive body **230** and the surface of the plastic lens **1** so as to movably clean the plastic lens **1**, dirt or contaminant on the entire convex surface **2** of the plastic lens **1** can be scrubbed off with abrasive and also a non-uniform surface created during shaping or due to degradation after shaping or by other cause can be removed.

[**0068**] After the scrub cleaning step, the self-cleaning step is performed in the following manner. The operation section **250** circles the support **241** to shift the elastic abrasive body **230** from the shaped lens body **2** to the pressing member **220**. The abrasive body holder **240** rotates the elastic abrasive body **230** at 30 to 500 rpm while pressing the elastic abrasive body **230** against the pressing member **220**. In this condition, the liquid supply member **260** supplies slurry containing abrasive to the elastic abrasive body **230** along with the deformation of the elastic abrasive body **230** caused by the pressing member **220** so as to conduct the self-cleaning step.

[**0069**] The time required for the self-cleaning differs depending on the level of dirt on the elastic abrasive body **230**. However, it is desirable to finish this process with the least possible delay in the cleaning time schedule, generally only in several seconds during carrying-in of the plastic lens **1**. Additionally, the elastic abrasive body **230** may scratch the plastic lens **1** if the elastic abrasive body **230** is dried before the start of cleaning or after a long period of stop. Thus, it is preferable to moisten and soften the elastic abrasive body **230** by the self-cleaning step in such a case.

[**0070**] In the surface cleaning and modifying process where the scrub cleaning step and the self-cleaning step are alternated, since the scrub cleaning step is performed using

the elastic abrasive body **230** which is always cleaned by the self-cleaning step conducted between the scrub cleaning steps, the plastic lens **1** can be cleaned without leaving dirt or large scratch thereon.

[**0071**] When the elastic abrasive body **230** in which abrasive is dispersed is employed, the scrub cleaning step and the self-cleaning step are conducted under the same conditions as described above except that water is used in lieu of slurry.

[**0072**] Next, a water cleaning process performed by the water cleaning apparatus **300** is described. The scrub cleaning step and the self-cleaning step are similarly involved in the water cleaning process. For example, the not-shown carrier transfers the plastic lens **1**, which has been cleaned by the surface cleaning and modifying apparatus **200** in the surface cleaning and modifying process, to the water cleaning apparatus **300**. The absorption chuck **212** of the optical component holder **210** holds the lower surface of the plastic lens **1** by absorption with the convex surface **2** on the upper side.

[**0073**] The optical component holder **210** rotates the plastic lens **1** at 500 to 1,000 rpm. The operation section **250** shifts the elastic abrasive body **230** to a position above the plastic lens **1**, while the abrasive body holder **240** rotates the elastic abrasive body **230** at 30 to 500 rpm. Subsequently, the operation section **250** lowers the elastic abrasive body **230** to press the elastic abrasive body **230** against the center of the plastic lens **1**. Water is supplied from the liquid outlet **260** to the upper peripheral surface of the elastic abrasive body **230**. Pure water is preferably used for rinsing off. The elastic abrasive body **230** pressed against the plastic lens **1** is shifted from the center to the edge of the plastic lens **1** to scrub the entire convex surface **2** of the plastic lens **1** using the elastic abrasive body **230**.

[**0074**] By providing the water cleaning step in which the plastic lens **1** is rotated and the rotating elastic abrasive body **230** is pressed against the plastic lens **1** while supplying water between the surface of the plastic lens **1** and the elastic abrasive body **230** so as to clean the plastic lens **1** with water, abrasive and the like remaining on the convex surface **2** of the plastic lens **1** can be scrubbed off.

[**0075**] After the cleaning process, the elastic abrasive body **230** is shifted from the plastic lens **1** to the pressing member **220**. The elastic abrasive body **230** rotating at 30 to 500 rpm is pressed against the pressing member **220** while supplying water to the elastic abrasive body **230** so as to perform the self-cleaning step. The elastic abrasive body **230** may scratch the plastic lens **1** if the elastic abrasive body **230** is dried before the start of cleaning or after a long period of stop. Thus, it is preferable to moisten and soften the elastic abrasive body **230** by the self-cleaning step in such a case.

[**0076**] Also in the water cleaning process where the scrub cleaning and the self-cleaning are alternated, since the water cleaning is performed using the elastic abrasive body **230** which is always cleaned by the self-cleaning step conducted between the cleaning steps, the plastic lens **1** can be cleaned without leaving dirt or any large scratch thereon.

[**0077**] In the example described above, cleaning of the plastic lens **1** and the self-cleaning are performed by shifting the elastic abrasive body **230**. However, the scrub cleaning of a plastic optical component and the self-cleaning can be similarly conducted by shifting the optical component holder **210** for holding the plastic lens **1** and the pressing member **220** with the elastic abrasive body **230** fixed to press the pressing member **220** against the elastic abrasive body **230**.

[**0078**] Additionally, in the above description, the liquid supply member is shifted together with the elastic abrasive body to supply the same liquid in both of the scrub cleaning step and the self-cleaning step. However, a liquid supply member may be provided in each of the scrub cleaning step and the self-cleaning step so as to supply different liquid in each step.

[**0079**] Described now is the drier **400**. The drier **400** includes the optical component holder **210** for holding and rotating the plastic lens **1** and a volatile liquid supply member **261** for dropping volatile liquid such as isopropyl alcohol approximately onto the center of the plastic lens **1** (see **FIG. 2**).

[**0080**] In a drying process performed by the drier **400**, the not-shown carrier transfers the plastic lens **1** from the water cleaning apparatus **300** to the drier **400** after the water cleaning process. The absorption chuck **212** of the optical component holder **210** holds the concave surface **3** of the plastic lens **1** by absorption with the convex surface **2** on the upper side. The optical component holder **210** rotates the plastic lens **1** at 200 to 3,000 rpm, preferably 800 to 2,000 rpm. Volatile liquid is dropped on the rotating plastic lens **1**. The dropped volatile liquid is spread out by a centrifugal force. Consequently, water existing on the convex surface **2** is replaced by a thin film of the volatile liquid, and the convex surface **2** is dried by volatilization of the thin film of the volatile liquid.

[**0081**] Additionally, in the drying process, heated water may be employed as volatile liquid. In this case, the drier preferably includes a dry air supply member for supplying dry air to the plastic lens **1** from above, an outlet provided at a bottom wall or a lower portion of a side wall of the cover **401** for discharging the dry air supplied from the dry air supply member, and a hot water supply member for supplying heated water at temperatures ranging from 30 to 100° C., preferably from 50 to 70° C. in lieu of the volatile liquid supply member.

[**0082**] In a hot water supply step, hot water is dropped from the hot water supply member onto the convex surface **2** of the plastic lens **1** while the optical component holder **210** rotates the plastic lens **1** at revolution of 50 to 300 rpm, preferably at 100 to 200 rpm. The dropped hot water is spread out by a centrifugal force, forming a uniform thin film on the convex surface **2** of the plastic lens **1**. Subsequently, the dry air supply member supplies dry air to the surface of the plastic lens **1** while the optical component holder **210** rotates the plastic lens **1***at* high rotational speed of 200 to 3,000 rpm, preferably 800 to 2,000 rpm to drain water. As a result, the film of hot water formed on the convex surface **2** of the plastic lens **1** is evaporated and the plastic lens **1** is thus dried.

[**0083**] After the convex surface **2** of the plastic lens **1** is thus cleaned and modified by the surface cleaning and modifying apparatus **200**, the water cleaning apparatus **300** and the drier **400**, hard-coating liquid is applied to the convex surface **2** by spin-coating, for example. Then, the

convex surface **2** is burnt to form a hard-coating thereon. Similarly, after the concave surface **3** of the plastic lens **1** whose convex surface **2** has been coated with the hard-coating is cleaned and modified by the surface cleaning and modifying apparatus **200**, the water cleaning apparatus **300** and the drier **400**, hard-coating liquid is applied to the concave surface **3** by spin-coating, for example, and subsequently the concave surface **3** is burnt to form a hard-coating thereon. Thus, the hard-coating is now formed on both sides of the plastic lens **1**.

[**0084**] As an alternative method, a hard-coating may be formed simultaneously on both sides of the plastic lens **1** by employing a dipping method in which: after the convex surface **2** of the plastic lens **1** and subsequently the concave surface **3** on the opposite side are cleaned and modified by the surface cleaning and modifying apparatus **200**, water cleaning apparatus **300** and the drier **400**, hard-coating liquid is applied to the plastic lens **1** by dipping the plastic lens **1** into hard-coating liquid.

[**0085**] When a hard-coating is simultaneously formed on both sides of the plastic lens **1** by the dipping method, it is possible to successively clean the convex surface **2** and the concave surface **3** by using lens cleaning equipment of a second embodiment illustrated in **FIGS. 5 and 6**.

[**0086**] Lens cleaning equipment **101** shown in **FIG. 5** includes a rotary carrier **500** capable of carrying and processing four plastic lenses **1** simultaneously. The rotary carrier simultaneously carries four plastic lenses **1** which are supplied to A, B, C, D, E and again A in **FIG. 5** in this order to process the plastic lenses **1**. Four plastic lenses **1** are supplied to a supply and removal section A with the convex surfaces **2** on the upper side. A convex surface cleaning and modifying section B includes four surface cleaning and modifying apparatus so as to simultaneously clean and modify the convex surfaces **2** of the supplied four plastic lenses **1**. At a shower-cleaning and turning-over section C, water cleaning is performed by pouring pressurized water onto the convex surfaces **2** of the four plastic lenses **1** from above, and the plastic lenses **1** thus cleaned are turned over to dispose the concave surfaces **3** on the upper side.

[**0087**] A concave surface cleaning and modifying section D includes four surface cleaning and modifying apparatus so as to simultaneously clean and modify the concave surfaces **3** of the four plastic lenses **1** which have been turned over. At a shower cleaning section E, water cleaning is performed by pouring pressurized water onto the concave surfaces **3** of the four plastic lenses **1** from above. After the cleaning and modifying process is completed on both sides of the plastic lenses **1**, the four plastic lenses **1** are removed at the supply and removal section A.

[**0088**] A rather facilitated method of shower cleaning is employed for the water cleaning, since a dipping step is practiced as pretreatment for the hard-coating formation after both surfaces are cleaned and modified by the lens cleaning equipment **101**. However, water scrub-cleaning using the elastic abrasive body as described above may be carried out instead of shower cleaning.

[**0089**] FIGS. **6**(*a*), **6**(*b*), and **6**(*c*) together schematically illustrate a structure of surface cleaning and modifying apparatus provided at the convex surface cleaning and modifying section B of the lens cleaning equipment **101** in a second embodiment. The surface cleaning and modifying apparatus provided at the concave surface cleaning and modifying section D has the same structure. **FIG. 6**(*a*) shows dispositions of respective components in a condition where scrub cleaning and self-cleaning are not performed, **FIG. 6**(*b*) shows a condition during scrub cleaning, and **FIG. 6**(*c*) shows a condition during self-cleaning.

[**0090**] Surface cleaning and modifying apparatus **202** in this embodiment includes: an elastic abrasive body **231**; the optical component holder **210** for holding the lower surface of the plastic lens **1** and rotating the plastic lens **1**; a pressing member **221**; and a not-shown operation section for driving and controlling the optical component holder **210** and the pressing member **221**. The elastic abrasive body **231** which is vertically disposed is cylindrical in shape having a dome-shaped lower surface. An upper end surface of the elastic abrasive body **231** is integrally connected with a lower surface of a disc-shaped elastic abrasive body fixing member **232** which is made from a hard material and has approximately the same diameter as that of the elastic abrasive body **231**. The elastic abrasive body **231** is supported by a not-shown abrasive body holder in such a manner as to be rotatable around a vertical center axis of the elastic abrasive body **231**. A through hole **233** is provided at the center of the elastic abrasive body fixing member **232**. The outside diameter of the elastic abrasive body **231** is larger than the radius of the plastic lens **1**, and is rather close to the diameter of the plastic lens **1**.

[**0091**] The elastic abrasive body **231** may be a liquid-permeable abrasive sponge which is made from PVA, urethane, PP or other material. Alternatively, a sponge made from PVA, urethane, PP or other material in which abrasive is dispersed during shaping may be used.

[**0092**] Though not shown, also provided is a liquid supply member for supplying liquid to the through hole **233** positioned at the center of the elastic abrasive body fixing member **232**. The liquid supplied to the through hole **233** passes through the elastic abrasive body **231** by its gravity and flows out mainly from its dome-shaped lower surface.

[**0093**] The optical component holder **210** in this embodiment is similar to that in the above-described embodiment, and includes the rotational shaft **211** and the absorption chuck **212** positioned at the upper end of the rotational shaft **211**. The rotational shaft **211** is hollow and rotated around a vertically extending axis in a direction opposite to the rotation direction of the elastic abrasive body **231** by a not-shown driving motor. The absorption chuck **212** holds the plastic lens **1** by absorption and communicates with the hollow portion of the rotational shaft **211**. The optical component holder **210** is movable upward and downward, and its position is controlled by the operation section. The rotation center of the optical component holder **210** in the vertical direction and the rotation center of the elastic abrasive body **231** in the vertical direction deviate from each other so as to prevent insufficient polishing at the rotation center.

[**0094**] The pressing member **221** in the shape of flat plate is disposed in a horizontal direction. The front end of the pressing member **211** on the elastic abrasive body side is tapered with the upper side in this portion cut off. The pressing member **221** is movable in the horizontal direction, and its position is controlled by the operation section. The

pressing member **221** is disposed in such a position as to carry the entire lower surface of the elastic abrasive body **231** when the pressing member **221** is moved to the most advanced position. The upper surface of the pressing member **221** is positioned slightly above the tip of the lower surface of the elastic abrasive body **231**. The material of the pressing member **221** is the same as that of the pressing member **220** described above.

[**0095**] A surface cleaning and modifying method using the surface cleaning and modifying apparatus **202** as mentioned is now described. The rotary carrier **500** carries the plastic lens **1** in the surface cleaning and modifying apparatus **202** such that the geometrical center of the plastic lens **1** is aligned with the center of the rotational shaft **211** of the optical component holder **210** and that the concave surface **3** of the plastic lens **1** contacts the absorption chuck **212**. A not-shown vacuum piping is connected with the hollow portion of the rotational shaft **211**, by which piping the absorption chuck **212** is evacuated after the lower surface of the plastic lens **1** comes into contact with the absorption chuck **212** so that the absorption chuck **212** can hold the concave surface **3** of the plastic lens **1** by absorption.

[**0096**] In the scrub cleaning step, the optical component holder **210** which holds the plastic lens **1** by absorption and rotates the plastic lens **1** at revolution of 50 to 300 rpm, preferably 100 to 200 rpm is raised by the control of the operation section to press the convex surface **2** of the plastic lens **1** against the lower surface of the elastic abrasive body **231** rotating at 50 to 100 rpm as illustrated in **FIG. 6**(*b*). The lower surface of the elastic abrasive body **231** contacts at least a region corresponding to the radius of the plastic lens **1**. As a result, the entire area of the rotating plastic lens **1** can be polished without shifting the elastic abrasive body **231**.

[**0097**] During the scrub cleaning step, slurry containing abrasive as liquid L is supplied to the through hole **233** from a not-shown liquid supply member. The scrub cleaning continues for several seconds to about one minute, generally for about twenty seconds.

[**0098**] By providing the scrub cleaning step in which the plastic lens **1** is rotated and the rotating elastic abrasive body **231** is pressed against the plastic lens **1** while supplying slurry containing abrasive between the elastic abrasive body **231** and the surface of the plastic lens **1** so as to polish the plastic lens **1** with abrasive, dirt or contaminant on the entire convex surface **2** of the plastic lens **1** can be scrubbed off with abrasive and also a non-uniform surface created during shaping or due to degradation after shaping or by other cause can be removed.

[**0099**] Next, in the self-cleaning step, the optical component holder **210** is lowered by the control of the operation section while continuing the rotation of the elastic abrasive body **231** and the supply of the liquid L from the liquid supply member after the scrub cleaning as illustrated in **FIG. 6**(*c*). Then, the pressing member **221** is advanced while pressing against the tip of the dome-shaped portion of the elastic abrasive body **231** used for polishing, thereby deforming that portion carried on the pressing member **221**. By providing the cleaning step in which the portion of the rotating elastic abrasive body **231** used for polishing is pressed against the pressing member **221** into deformation while supplying the liquid L to the elastic abrasive body **231** so as to clean the portion of the elastic body **231** used for polishing, contaminant or dirt adhering to the elastic abrasive body **231** can be cleaned off, preventing re-adhesion of the dirt or contaminant to the plastic lens **1** to be cleaned next.

[**0100**] During the self-cleaning step, the scrub-cleaned plastic lens **1** is transferred to the next shower-cleaning and turning-over section C by the rotary carrier **500**, and the plastic lens **1** supplied at the supply and removal section A is carried in the convex surface cleaning and modifying section B. After the self-cleaning step, the operation section retreats the pressing member **221** to its original position, and then raises the optical component holder **210** holding the next plastic lens **1** by absorption to perform the scrub cleaning step.

[**0101**] In the above example, slurry which contains abrasive dispersed in liquid such as water is employed as the liquid L. However, water may be used as the liquid L when the elastic abrasive body **231** contains abrasive dispersed therein, in which case the scrub cleaning and the self-cleaning can be performed exactly in the same manner as above.

[**0102**] In the surface cleaning and modifying process where the scrub cleaning step and the self-cleaning step are alternated, since the cleaning is performed with the elastic abrasive body **231** which is always cleaned by the self-cleaning step conducted between the scrub cleaning steps, the plastic lens **1** can be cleaned without leaving dirt or large scratch thereon.

[**0103**] In the above example, the scrub cleaning step and the self-cleaning step are conducted by raising and lowering the optical component holder and shifting the pressing member in the horizontal direction by the control of the operation section. However, these steps can be similarly practiced by shifting the elastic abrasive body with the optical component holder and the pressing member fixed. Additionally, the flat-plate-shaped pressing member is employed herein as an example, but a bar-shaped type which can similarly deform the lower surface of the elastic abrasive body may be used.

[**0104**] In the above example, hard-coating is formed as surface treatment after the surface cleaning and modifying step, but other surface treatment such as formation of a primer layer may be given.

[**0105**] Many further variations to the above-identified embodiments are possible without departing from the scope and spirit of the invention.

There is claimed:

1. A surface cleaning and modifying method, comprising:

scrub cleaning a plastic optical component, including:

rotating the plastic optical component,

pressing a rotating elastic abrasive body against a surface of said plastic optical component, and

during the pressing, supplying a liquid between the surface of said plastic optical component and said elastic abrasive body, wherein the liquid is a slurry comprising dispersed abrasive; and

self-cleaning said elastic abrasive body, including:

deforming said elastic abrasive body, and

during the deforming, supplying a liquid, to said elastic abrasive body, the liquid being a slurry comprising dispersed abrasive.

2. The surface cleaning and modifying method as set forth in claim 1, wherein said self-cleaning further comprises placing said elastic abrasive body and a pressing member in contact to deform said elastic abrasive body.

3. The surface cleaning and modifying method as set forth in claim 1, further comprising alternately performing said scrub cleaning and said self-cleaning.

4. A surface cleaning and modifying method, comprising:

scrub cleaning a plastic optical component, including:

rotating the plastic optical component,

pressing a rotating elastic abrasive body against a surface of said plastic optical component, the elastic abrasive body comprising dispersed abrasive, and

during the pressing, supplying a liquid comprising water between the surface of said plastic optical component and said elastic abrasive body; and

self-cleaning said elastic abrasive body, including:

deforming said elastic abrasive body, and

during the deforming, supplying a liquid comprising water to said elastic abrasive body.

5. The surface cleaning and modifying method as set forth in claim 4, wherein said self-cleaning further comprises placing said elastic abrasive body and a pressing member in contact to deform said elastic abrasive body.

6. The surface cleaning and modifying method as set forth in claim 4, further comprising alternately performing said scrub cleaning and said self-cleaning.

7. A surface cleaning and modifying apparatus, comprising:

an optical component holder holding and rotating a plastic optical component;

a pressing member separate from said optical component holder;

an abrasive body holder holding and rotating an elastic abrasive body;

an operation section operating one or more of said optical component holder and said abrasive body holder so as to perform operations, including:

a cleaning action of pressing said elastic abrasive body against said plastic optical component, and

a self-cleaning action of placing said elastic abrasive body in contact with said pressing member; and

a liquid supply member for supplying liquid to said elastic abrasive body during said cleaning action and said self-cleaning action.

8. The surface cleaning and modifying apparatus as set forth in claim 7, wherein said operation section alternately conducts said cleaning action and said self-cleaning action.

9. The surface cleaning and modifying apparatus as set forth in claim 7, wherein said liquid is a slurry comprising dispersed abrasive.

10. The surface cleaning and modifying apparatus as set forth in claim 7, wherein said elastic abrasive body comprises dispersed abrasive.

11. The surface cleaning and modifying apparatus as set forth in claim 10, wherein said liquid comprises water.

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