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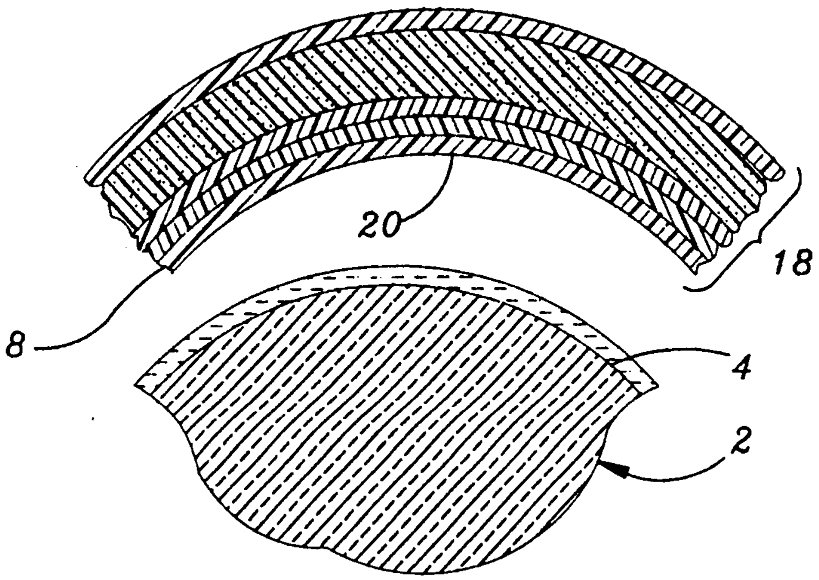

(57) Abstract

A new mirror structure (18) is based upon a composite resin laminate. The mirror surface (20) is provided by a gel coat resin layer (8) that has been applied to a forming tool (2) which has an optical quality surface (4), and a shape complementary to the desired mirror shape. The gel coat resin layer is cured so that it replicates the optical quality surface of the forming tool, and a rigid composite backing (10, 12, 14, 16) is then built up over its rear surface. A reflective metal coating (34, 42) is applied to the mirror's resin surface, either with a conventional vacuum deposition or with a new process. In the new process the microporous resin surface (20) is first degreased and cleaned, followed by the application of a bonding material (28) which extends into the resin micropores (22), and a conventional Brashear process to precipitate a silver coating (34, 42) onto the resin. The metal coating can be applied either after the resin layup has been completed, or it can be integrated into the layup process.

COMPOSITE MIRROR AND FABRICATION METHOD WITH PRECIPITATED REFLECTIVE COATING

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to reflective mirrors and fabrication methods therefore, and more particularly to mirrors with a composite resin structure and a precipitated reflective coating.

Description of the Related Art

Mirrors are conventionally formed from glass or plastic coated with a reflective surface. Another technique involves stretching a thin film of aluminized mylar over the opening of a pressurized chamber. In this practice, a partial vacuum or positive pressure is used to shape the aluminized mylar surface to the desired contour. All three types of mirrors can be quite expensive when large dimensions and/or a high quality surface are required.

Glass mirrors require lengthy grinding and polishing to obtain a high quality surface; this is not only time-consuming but also difficult when aspheric curved shapes are required, such as for parabolic reflectors. Glass mirrors are quite fragile, and accidents during handling, installation and maintenance cause major economic losses. Also, when it is desired to edge-butt a number of mirrors together to form a larger overall reflective surface, the edges of the glass segments are very susceptible to chipping. This results either in noticeable gaps between adjacent segments, or the necessity to stagger or inset and overlap adjacent segments; both of these approaches are visually distracting. For complicated surface geometries, very expensive specialized grinding and polishing equipment that is not widely available is required. In addition, glass mirrors are relatively heavy for a given reflective area.

The thermal forming of a plastic sheet, typically about 1.25-2.5cm thick, involves heating and stretching the sheet over a non-optical quality forming tool and then gluing a ribbed support structure onto its opposite side to provide rigidity. The surface of the stretched sheet must next be extensively ground and polished. The plastic mirror surface is not particularly durable, which can result in a limited lifetime for this type of mirror. Furthermore, since the thermal forming process is not consistently uniform over the full mirror surface, producing a curved plastic mirror without grinding and polishing has not been technically or economically successful to date. Vacuum formed aluminized mylar requires an active pump, sensor and servo system to maintain the proper shape. The surface of this film is much less durable than either glass or plastic mirrors.

Both glass and plastic mirrors require relatively large amounts of labor to fabricate each separate mirror. It would be preferable to have a mirror that can be fabricated with a more efficient mass production technique, which would reduce the overall cost significantly.

The process for forming reflective mirror coatings also has significant limitations. Conventional coating processes require vacuum chambers and the use of special protective overcoats that are also generally vacuum deposited over the metallized surface to prevent oxidation, tarnishing or damage during cleaning. There are few vacuum chambers available for coating very large mirrors, and the cost of the vacuum metallizations and overcoats are very expensive.

A different process that has been commonly used to apply a metal coating to a glass mirror in referenced to as the Brashear process, and is described in Ingalls, Amateur Telescope Making, 1970, pages 397-428. It involves first spraying the glass surface with a solution of stannous chloride, rinsing with distilled water, and then spraying a silver solution onto the surface so that the silver precipitates onto the stannous chloride within the porous surface of the glass. The surface is then rinsed again with distilled water, and any residual moisture is blown off the surface with filtered compressed air. For second-surface mirrors, the process is completed by spraying the silver coated surface with a coat of lacquer and allowing it to dry. This process is particularly useful with large glass mirrors for which an adequate vacuum chamber is not available. However, it has not been widely used for thermal formed plastic sheet mirrors because the silver coating does not adhere well to the plastic; a similar non-adherence would be expected for a resin surface.

SUMMARY OF THE INVENTION

The present invention seeks to provide a new mirror structure and related fabrication method that allows for the rapid replication of high quality mirrors of any desired shape, with a large reduction in processing time and cost compared to existing fabrication techniques. The invention also seeks to provide an efficient method for applying a reflective coating to the new mirror structure.

These goals are satisfied with a new type of mirror that has a composite resin structure and is fabricated on a shaped forming tool. The forming tool has an optical quality surface, and a shape that is complimentary to the desired mirror shape. A mold release agent is applied to the tool surface, followed by a mirror resin coating which assumes the shape and optical quality of the tool surface. After curing the resin coating, a rigid composite backing is formed over it. The composite backing together with the mirror resin coating are then removed as an integral unit from the forming tool, and a reflective metallic coating is applied and protected with a clear lacquer. At most only a minor amount of polishing of the resin surface prior to applying the metal coating will allow the metallic surface to basically replicate the optical quality of the original tool surface.

Instead of adding the reflective coating and lacquer after the mirror has been removed from the forming tool, the formation of the reflective coating can also be integrated into the mirror fabrication while still on the tool. This is accomplished by first applying a transparent preliminary resin coating over the mold release agent on the tool, forming a metallized reflective coating on the preliminary resin coating, and then completing the composite mirror with the mirror resin coating and composite backing as described above. The transparent preliminary resin coating protects the metallic surface after the mirror has been removed from the tool.

The metallic coating is preferably formed with a process that is similar to the Brashear glass silvering process described above. However, before the stannous chloride is applied, the microporous surface of the resin is first thoroughly degreased and cleaned, preferably with a cerum oxide solution followed by a diluted nitric acid cleansing. This allows the stannous chloride to enter the resin pores and act as a bonding agent for the metal. Rather than using the rough pads commonly employed in applying stannous chloride to a glass mirror, a cotton pile that does not scratch the optical quality resin surface is preferably employed for the degreaser and stannous chloride. The result, contrary to expectations, is that the metal coating successfully adheres to the mirror's resin surface. This metallization technique is particularly useful for large mirrors, but can also be used for smaller mirrors in lieu of the conventional vacuum metallization coating process.

These and other features and advantages of the invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view, not to scale, of a composite mirror as fabricated on a forming tool in accordance with the invention;

FIG. 2 is a sectional view, not to scale, showing the mirror or FIG. 1 after it has been removed from the forming tool;

FIGs. 3a-3f are fragmentary respective views, not to scale, showing successive steps in the formation of a reflective metallic coating on a composite resin mirror surface, in accordance with the invention; and

FIG. 4 is a sectional view, not to scale, showing the integrated fabrication of a composite mirror along with a metallic reflective coating and protective resin coat on a forming tool.

DETAILED DESCRIPTION OF THE INVENTION

In contrast to the prior mirror fabrication techniques that require extensive grinding and polishing, the present invention uses a forming tool that has an optical quality surface and a shape that is complimentary to the desired mirror shape to provide the mirror geometry and surface quality. Mirrors can then be quickly and inexpensively replicated from a common forming tool.

Such a forming tool is indicated by reference number 2 in FIG. 1. Its outer surface 4 has a spherical convex shape that is used to form mirrors with a complimentary spherical concave shape. Other mirror shapes can also be provided with an appropriate forming tool surface, including flat, elliptical and other aspherical geometries.

The tool 2 can be fabricated by establishing a concave cutout in a block of metal to the desired tool shape, heating a mass of glass within the cutout so that it assumes the cutout shape, mounting the glass to a rigid framework, and then grinding and polishing its outer surface to an optical quality. The term "optical quality" is generally understood as referring to a surface that, when supporting a metallized reflective coating, reflects incident light with little or no noticeable defects.

Instead of polished glass, other materials such as stainless steel or a high hardness thermosetting resin could be used for the forming tool. Whatever material is employed, its outer surface must be provided with an optical quality that can be replicated onto the mirror.

In fabricating a mirror, a conventional mold release agent 6 is first applied to the forming tool's optical quality surface, followed by a layer of gel coat resin material 8. The resin is preferably a vinylester because of its dimensional stability resulting from its low coefficient of thermal expansion as it cures, but other dimensionally stable resin materials could also be used. The resin layer 8 is applied in a conventional manner at room temperature, and allowed to cure and outgas. The mold release agent 4 prevents the resin from sticking to the tool.

A resinous gel coat layer 10, preferably vinylester, is then applied over the lower resin layer 8 to add stiffness and rigidity. It preferably includes a veil, which is a fine weave cloth commonly used in the fiber glass industry, to hold the resin at the surface adjacent the forming tool; the veil does not print through to the resin surface adjacent the tool that will eventually provide the mirror surface. Layer 8 is typically about 2-10mm thick, and the total thickness of layers 8 and 10 is typically about 10-20mm.

The gel coat layer 10 is followed by a layer of resin and chopped random fiber mat 12, typically about 30-40mm thick. A vacuum formed closed cell foam 14 is sandwiched between the layer 12 and an outer resin/chopped random fiber mat layer 16; the foam layer 14 is typically about 1cm thick or more, while the outer resin/chopped random fiber mat layer 16 is generally about 3 mm thick or greater. The combination of the three layers 12, 14 and 16 provides a light weight structure with high rigidity, the basic concept of which is well known in the field of composites. The gel coat 10 prevents the pattern of the random fiber mat in layer 12 from printing through to the first resin layer 8.

Each of the resin layers 8, 10, 12 and 16 is allowed to cure and outgas upon application to the composite structure. When the outer layer 16 has been completed, the composite mirror structure 18 is lifted off the forming tool 2, as illustrated in FIG. 2. At this point the exposed surface 20 of the first resin layer 8 either has the desired degree of optical quality as replicated from the tool surface 4, or can acquire the desired optical quality with only a small amount of polishing, similar to compounding the painted finish on an automobile.

The resin layer 8 is typically not reflective enough to serve as a mirror surface. A metallized reflective surface is therefore applied over resin layer 8 at this point. The metal deposition is performed so that the metal surface essentially replicates the optical quality of the surface of resin layer 8. The metal layer can be added with a conventional vacuum deposition process. However, particularly for larger mirrors, a unique process that is particularly suited for a resinous surface is preferably employed.

The new process for applying a metal coating is illustrated in FIGs. 3a-3f. It incorporates the Brashear process described above that is used for glass silvering, but modifies it with a preliminary treatment that has been found to cause the metal to adhere to the resinous substrate without scratching or damaging the optical surface of the resin part. Without this preliminary treatment, the metal would not adhere and could be easily removed, as when the Brashear process is attempted on a plastic surface.

As illustrated in a very simplified fashion in FIG. 3a, the outer surface 20 of the resin coating 8 has a microporous characteristic, with an array of micropores 22 in the surface. The first step of the metallization process is to thoroughly degrease and clean the resin surface 20. This is preferably accomplished with a degreasing agent such as cerum oxide that is dissolved in a liquid solution so that no abrasive particles are present to scratch the optical surface of the composite mirror. The solution is applied with a non-abrasive material such as a cotton pile, which may be a common cotton ball, rubbed onto the resin surface in a swirling manner. The solution should not be rubbed on too hard, so as to avoid scratches that are visible after the metallization has been applied. After rubbing on the degreaser, the resin surface is rinsed with distilled water, cleansed with a diluted nitric acid and then thoroughly rinsed again with distilled water. The degreasing, cleansing and rinsing steps are then preferably repeated to assure a properly prepared surface. The cleansing and rinsing of the resin surface is indicated by arrows 26 in FIG. 3b.

Once the resin surface has been prepared in this manner, a metal coating can be added with a conventional Brashear process. A solution of a bonding agent 28 (FIG.

3c), preferably stannous chloride, is first sprayed onto the surface of the resin coating 8, which is then rinsed with distilled water. When the surface is properly degreased and cleaned, the stannous chloride enters the micropores and bonds to the resin surface.

In the next step, illustrated in FIG. 3d, a twin nozzle is used to spray silver suspended in a solution 30 onto the surface. The solution typically consists of distilled water, nitric acid, alcohol and silver nitrate. The silver precipitates from the solution (as indicated by arrows 32) and establishes a silver coating 34 on the stannous chloride film.

The surface is then rinsed again with distilled water, and any residual moisture is blown off with filtered compressed air, as indicated by arrows 36 in FIG. 3e. The remaining silver layer 34 at this point will generally replicate the optical quality surface of the resin layer 8, which in turn is a complimentary replication of the forming tool's surface. A thin protective coating of clear lacquer 38 (FIG. 3f) is then sprayed on over the silver layer and allowed to dry. At this point the mirror is completed.

An alternate fabrication technique, in which the provision of metallic and protective coatings are integrated into the composite layup process, is illustrated in FIG. 4. In place of the opaque gel coat resin layer 8, a substantially transparent gel coat resin layer 40 is applied over the mold release agent 6 and allowed to cure and outgas. A reflective metal layer 42 is then formed over the transparent resin layer 40, either by vacuum deposition or with the new technique described above in connection with FIGs. 3a-3f. The remainder of the composite structure is then fabricated over the metal layer 42. The inner surface of the reflective metal layer 42 replicates the optical quality of the forming tool via the transparent resin layer 40, while the resin layer 40 provides a protective coating for the mirror in lieu of a lacquer coat.

While the new composite mirror structure is particularly useful for large mirrors, it offers significant cost and weight advantages for smaller mirrors also. Applications for the new mirror structure include architectural decorative exterior mirrors, design and large floor-to-ceiling mirrors for building interiors, side and rear view mirrors for automobiles, trucks and buses, flat lightweight mirrors for simulator visual optical systems, and high optical quality laser reflectors and visible light reflectors used in the electronics industry. The coated surface of the composite mirror is many times more durable than the coated surface of a stretched mylar mirror, and less brittle than a glass mirror. The shape and optical quality of the composite mirror surface are very accurate and repeatable (to better than 0.25mm), and the mirror is not subject to the problem of localized differences in material stretch that is inherent with stretched mylar mirrors. Once a suitable forming tool is provided, mirrors with complicated surface geometries can be replicated with little or no more cost and difficulty than simple flat or spherical mirrors.

While particular embodiments of the invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.

WE CLAIM:

1. A method of forming a mirror with a desired shape, comprising:

providing a forming tool that has an optical quality surface with a shape complementary to the desired mirror shape,

applying a mold release agent to said tool surface,

applying a gel coat resin coating to said tool surface over said mold release agent so that the gel coat resin coating assumes the shape and optical quality of said tool surface,

curing said gel coat resin coating,

forming a rigid composite backing on said cured gel coat resin coating, and

removing said rigid backing together with said gel coat resin coating as an integral unit from said tool.

2. The method of claim 1, wherein a metallized reflective coating is applied over the optical quality surface of said gel coat resin coating.

3. The method of claim 2, further comprising the steps, after removal of said composite backing and gel coat resin coating from said tool, of degreasing and cleaning the gel coat resin's optical quality surface, applying a film of bonding material to said gel coat resin optical quality surface which extends into micropores in said surface, and forming said metallized reflective coating on said film of bonding material so that it assumes the optical quality of said gel coat resin optical quality surface.

4. The method of claim 2, wherein said metallized reflective coating is applied over said gel coat resin

coating by vacuum deposition.

5. The method of claim 1, wherein said gel coat resin coating is substantially transparent and has a microporous surface on the other side of the coating from the forming tool, further comprising the steps of degreasing and cleaning the microporous surface of said gel coat resin coating, applying a film of bonding material to said gel coat resin coating which extends into its micropores, and applying a metallized reflective coating to said film of bonding material so that it assumes the optical quality of said gel coat resin coating, and wherein said rigid composite backing is formed over said reflective coating.

6. The method of claim 1, wherein said gel coat resin coating comprises vinylester.

7. A mirror structure, comprising:

a rigid composite substrate having an optical quality gel coat resin surface with a desired mirror shape, and

a coating of reflective material on said resin surface.

8. The mirror structure of claim 7, said gel coat resin optical quality surface comprising the surface of a gel coat resin layer that is approximately 2-10mm thick.

9. The mirror structure of claim 7, said gel coat resin surface having a microporous quality, further comprising a film of a bonding material on said gel coat resin surface that extends into its micropores, said coating of reflective material comprising a reflective metal layer on said film of bonding material.

10. The mirror structure of claim 9, further comprising a transparent protective coating on said metal layer.

11. The mirror structure of claim 9, said bonding material comprising stannous chloride.

12. A method of providing a reflective mirror coating on a resin substrate that has an optical quality microporous surface, comprising:

degreasing and cleaning the surface of said resin substrate,

applying a film of bonding material to the degreased and cleaned resin surface so that the bonding material extends into its micropores, and

applying a reflective coating to said film of bonding material so that it assumes the optical quality of said resin surface.

13. The method of claim 12, wherein said resin surface is degreased with a cerum oxide solution.

14. The method of claim 13, wherein said degreased resin surface is cleaned with diluted nitric acid.

15. The method of claim 12, wherein said bonding material comprises stannous chloride.

16. The method of claim 15, wherein said reflective coating is applied by precipitating silver from a silver solution onto the stannous chloride.

17. The method of claim 12, further comprising the step of applying a clear lacquer to said reflective coating.

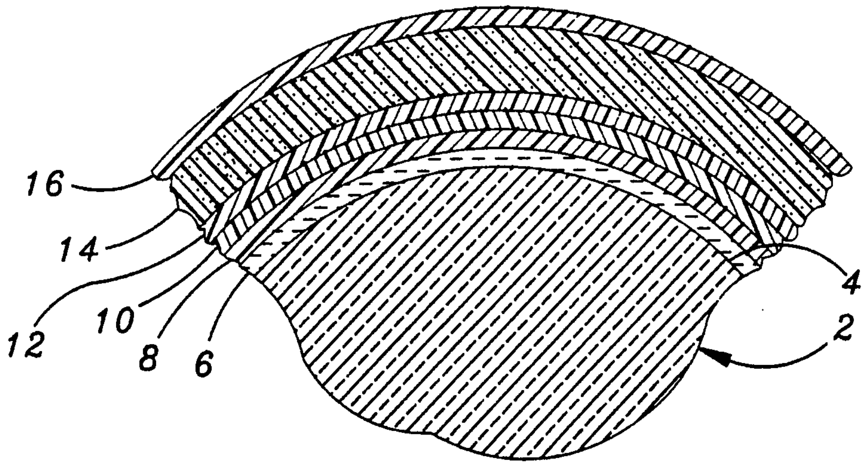

FIG. 1

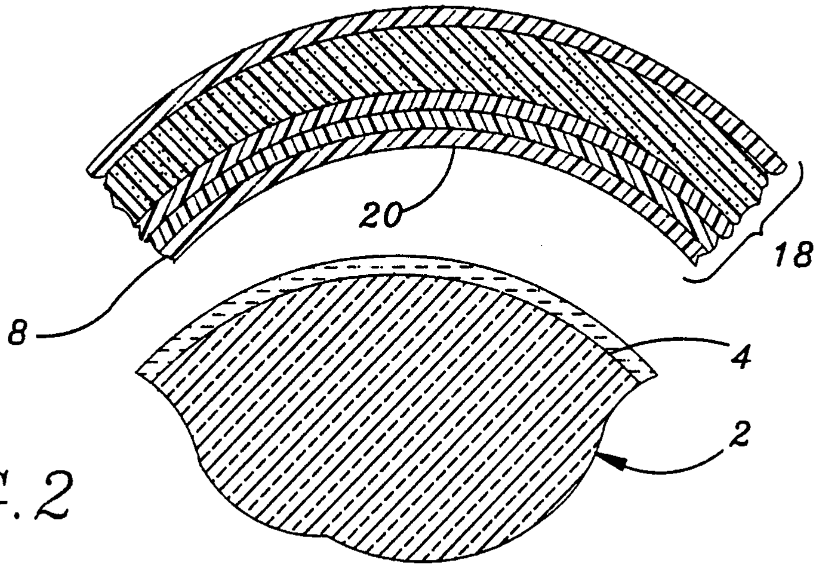

FIG. 2

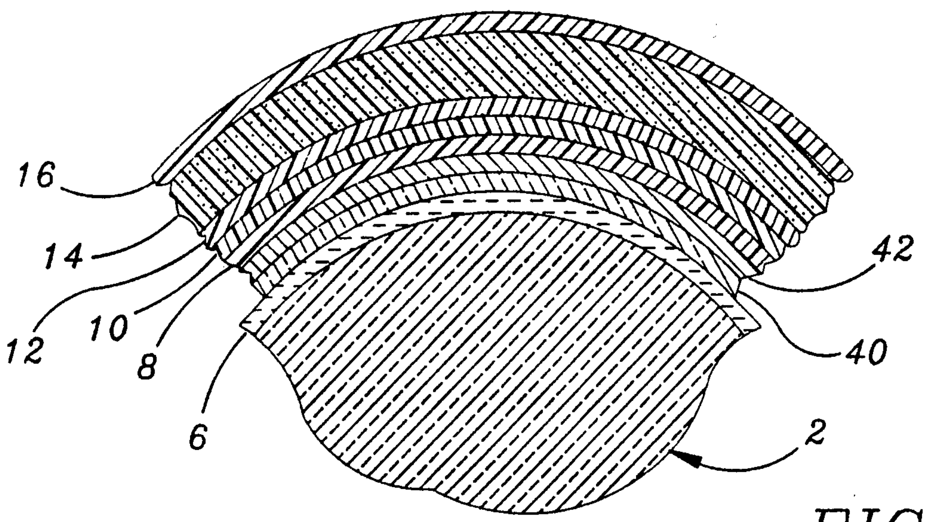

FIG. 4

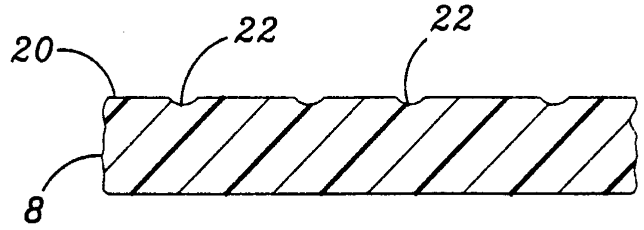

FIG.3a

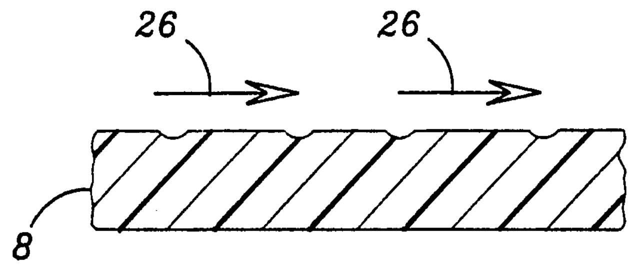

FIG.3b

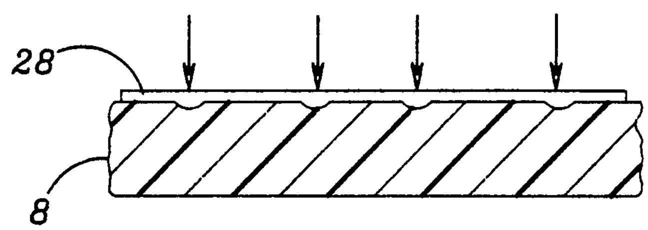

FIG.3c

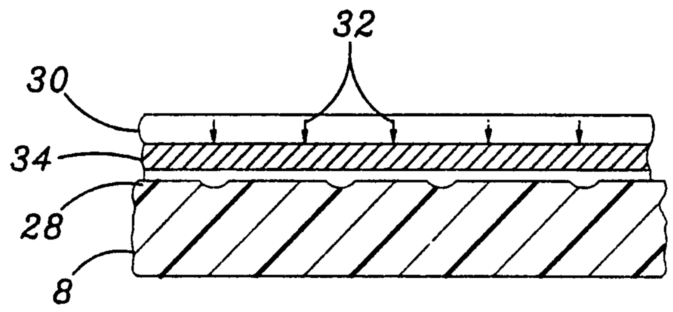

FIG.3d

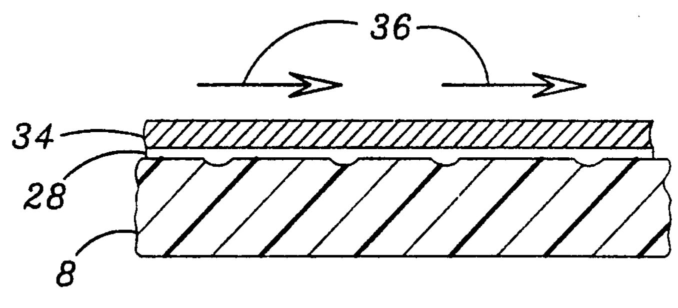

FIG.3e

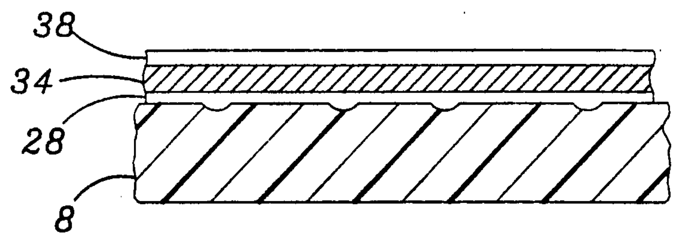

FIG.3f

INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/US 94/07883

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B5/08 G02B5/10 B29D11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B B29D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US,A,4 255 364 (TALBERT) 10 March 1981 see the whole document	1,2,4,7 12
X A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 111 (M-578) 8 April 1987 & JP,A,61 255 838 (MITSUBISHI) 13 November 1986 see abstract	1,2,4,7 12
A	US,A,3 873 191 (VERET ET AL) 25 March 1975 see the whole document	1,2,4,7,12
A	DE,A,37 23 245 (MITSUBISHI) 21 January 1988 see the whole document	1,2,4,7,12

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 1994	25. 11. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Ward, S

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SOLAR ENERGY MATERIALS, vol.6, no.2, January 1982, AMSTERDAM, NL pages 221 - 232 PEDERSON 'Comparison of Stannous and Stannic Chloride as Sensitizing Agents in the Electroless Deposition of Silver on Glass using X-Ray Photoelectron Spectroscopy' see the whole document -----	12,15,16

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 94/07883

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