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P. R. JOCHIM
ELECTROFORMING TECHNIQUE AND STRUCTURE
FOR REFLECTING MIRRORS
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3,378,469

Fig. 1

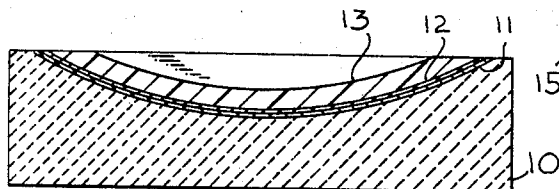


Fig. 2

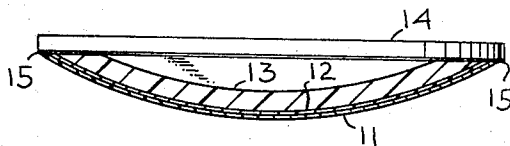


Fig. 3

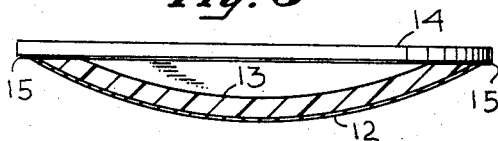


Fig. 4

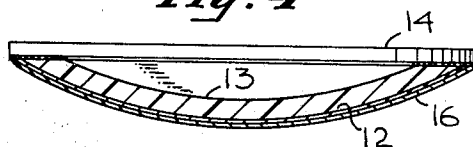


Fig. 5

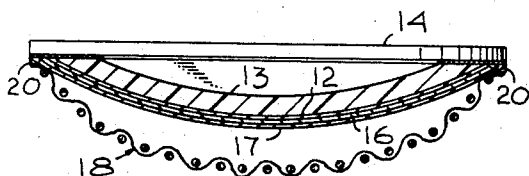


Fig. 5(a)

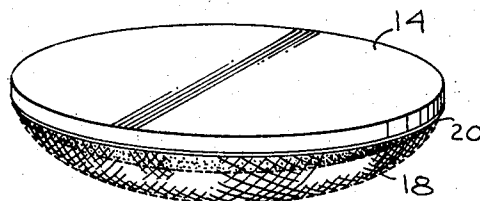


Fig. 6

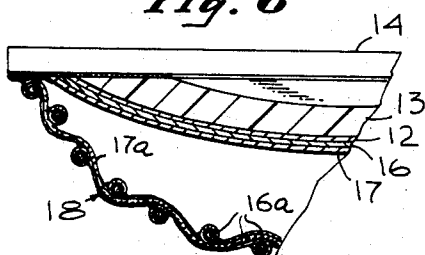


Fig. 6(a)

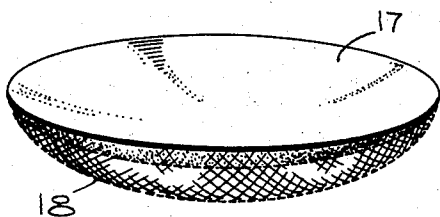
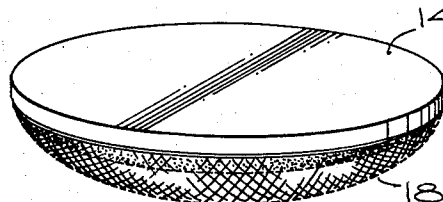


Fig. 7

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ELECTROFORMING TECHNIQUE AND STRUCTURE FOR REFLECTING MIRRORS

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7 Claims. (Cl. 204—7)

The present invention relates in general to the electroforming arts and more particularly relates to the provisions of a backing or rigidizing structure for an electroformed product.

In electroforming various kinds of devices, such as mirrors, it is necessary to provide a backing structure for these devices, primarily because the electroformed metal layer is thin and will buckle or otherwise distort unless properly supported. In providing such a support structure, it has been generally necessary in the past to go through a number of steps which were not only time consuming and not only increased the cost of fabrication but, very importantly, because of the additional handling, exposed the thin electroformed surface to the danger of damage.

More specifically, in fabricating a device by means of the electroforming process, such as a parabolic reflecting mirror, for example, a layer of release material, such as copper, is vacuum deposited on the concave surface of a parabolic glass master. A layer of silicon monoxide is then vacuum deposited over the release layer, the silicon monoxide being used to provide a hard surface. After this, an epoxy resin mixture is poured in over the silicon monoxide layer and cured while the master is rotated at a uniform speed. By so doing, the epoxy material spreads outward because of the centrifugal forces involved and thereby assumes the shape of the glass master. The epoxy cures in this parabolic shape and, together with the silicon monoxide layer beneath it, forms what is known as the sub-master. A backing structure, such as a stiff plate, is then mounted onto the sub-master for support and thereafter separated from the glass master itself.

At this point, chemical silver is sprayed onto the working surface of the sub-master and the sub-master is then mounted as the cathode on a rotating spindle, the entire combination being immersed in a plating bath or tank wherein, as the spindle is rotated, a uniform layer of nickel is plated over the silver. When the nickel is at the right thickness, the structure is removed from the tank and a backing or rigidizing structure mounted upon the nickel layer to provide it with the necessary support. The nickel layer, together with its backing structure, constitutes the electroformed mirror and, at this point, it is physically separated from the sub-master structure.

As has already been mentioned, a major disadvantage of this technique is that a rigidizing structure for the electroformed mirror is mounted only after the nickel layer, which provides the reflecting surface for the mirror, is fully formed. As a result, the nickel layer and, therefore, the mirror itself, is exposed to the danger of being damaged which, in turn, makes the entire electroforming process a highly vulnerable one. Accordingly, there has existed a long-felt need for a comparatively "safe" method for providing these backing structures. The present invention fulfills this need.

More particularly, according to the basic concept of the invention, the backing or rigidizing structure is also electroformed and, therefore, can be provided simultaneously with the electroformed device itself, whether it be a mirror or some other device. As will be explained in greater detail later, this is done by halting the electroplating of the device before it is finished and applying a properly shaped mesh to it. The electroplating is then continued so that the mesh becomes permanently affixed to and becomes an integral part of the device being electro-

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formed, thereby providing the backing structure for it in substantially the same step in which the device is formed.

Accordingly, it is an object of the present invention to provide a new plating technique by means of which an electroformed surface and the backing structure for it are fabricated at the same time.

It is another object of the present invention to provide an electroforming technique which very greatly reduces the possibility of the device being electroformed from being prematurely damaged.

It is a further object of the present invention to provide a technique by means of which a backing structure is provided for a thin electroformed layer with minimum risk of damage to the layer.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and is not intended as a definition of the limits of the invention.

FIGURE 1 is a front view, in cross-section, of a glass master and the steps involved in the formation of a plastic sub-master from it;

FIGURE 2 is a front view, in cross-section, of the plastic sub-master maintained in its shape by a rigidizing structure;

FIGURE 3 is the FIG. 2 sub-master but with its outermost layer, namely, the release layer, removed;

FIGURE 4 is a repeat of the FIG. 3 sub-master but with an additional outer conductive or sensitizing layer coated on it;

FIGURE 5 is a front view, in cross-section, of a mesh backing structure after it has been affixed to the surface being electroformed;

FIGURE 5(a) is a perspective view of the FIG. 5 structure;

FIGURE 6 is a front view, in cross-section, of the mesh backing structure after it has become permanently mounted to the surface being electroformed;

FIGURE 6(a) is a perspective view of the FIG. 6 structure; and

FIGURE 7 is a perspective view of the final electroformed mirror product.

In considering the invention in detail, it should be emphasized and recognized at the outset that although the mounting and fabrication of a backing structure for a parabolic mirror will be described below as well as the process by which it is made, the process is not limited to the fabrication of mirrors alone but, rather, is applicable to the fabrication and rigidizing of all other kinds of electroformed devices or products.

With this in mind, reference is now made to FIG. 1 wherein is shown a parabolically-shaped glass master 10 that may be used in the fabrication of the electroformed parabolic mirrors. In practicing the invention, the glass master is first mounted on a suitable support (not shown) that holds the master in an undistorted position during the first steps of the process. Because such mounts or supports are so well known and are conventional in the electroforming art and, furthermore because they are not a part of the present invention, a mount or support is not shown herein.

Having mounted the glass master for the reason mentioned, the optical surface area of the master is then thoroughly cleansed by any good glass cleaning technique that is known and employed by the optical coating industry. Following this, a non-adherent and pin hole free metal

release layer 11 is vacuum deposited on the optical surface of the glass master. A number of different kinds of metal may be used as the release layer, such as copper, which is the preferred metal, silver, gold, etc., the only criterion being that it should be thick enough to be opaque but not too thick or else its surface will become granular, a condition that is preferably avoided. Vacuum chambers and vacuum deposition are well known in the arts and sciences and, therefore, it is not deemed necessary here to describe a vacuum chamber in detail or the manner in which it is used. If a hard protective surface coating or other special surface coating is required over release layer 11, it may be also vacuum deposited at this time. Thus, in FIG. 1, a hard protective layer 12, namely, a layer of silicon monoxide, is shown coated over release layer 11.

At this point, the coated master is removed from the vacuum chamber and firmly mounted either on a spin fixture or on a casting fixture of some kind, the particular fixture employed being dependent upon the requirement for a parabolic or other shape. Since a parabolic figure is involved in the present instance or description, the coated glass master is mounted upon a spin fixture of the kind disclosed by Burt J. Bittner in the patent that issued Nov. 28, 1961, Patent No. 3,010,153, for his invention entitled "Construction of Paraboloid Surfaces." With the master mounted on the spin fixture, a plastic, such as an epoxy resin mixture, is then poured in over silicon monoxide layer 12, the fixture then being activated to rotate at a uniform speed. By so doing, the plastic material spreads outward because of the centrifugal forces involved, with the result that it assumes the parabolic shape of the glass master. The plastic is cured as it rotates to ultimately produce a plastic layer having substantially the same shape and optical accuracy as the glass master itself. The plastic layer spoken of above is designated 13.

Having reached the stage shown in FIG. 1, the next step in the process is that of parting or separating the plastic submaster from the glass master. However, prior to this step, the plastic submaster is rigidized with a suitable stable structure, such as a plate or weldment, etc., which is fixed to the plastic layer at its edge. Referring now to FIG. 2, the abovesaid stable structure is designated 14 therein and is fixed to a plastic layer 13 by means of an epoxy or other adhesive 15 interposed between the plastic layer and the rigidizing structure, as is shown in the figure. With member 14 properly mounted, glass master 10 is removed to leave the remaining structure shown in FIG. 2. Release layer 11 having now served its purpose, it is removed with nitric acid or other chemical materials to leave the plastic submaster which, in FIG. 3, is shown to comprise plastic layer 13 and its hard optical surface 12 made of silicon monoxide or some equivalent material.

With the completion of the plastic submaster, the next major part of the process is initiated, namely, that of electroforming the desired parabolic mirror. To do so, the plastic submaster is immersed in an electroplating bath but, before it is immersed, it must be properly prepared for it. Accordingly, the optical surface of the submaster is first cleaned in the same well-known manner as was the glass master during the first steps of the process and then it is sensitized or rendered electrically conducting by coating it with a thin film or layer of electrically conductive material, such as chemical silver, which is customarily used for this purpose. In the event that silver is used, it may be sprayed on the optical surface as is done in commercial mirror fabrication. A thin film or layer of silver is shown deposited on the optical surface of the plastic submaster in FIG. 4 and is designated 16 therein. At this point, the submaster is ready for the electroplating bath and, therefore, it is mounted as the cathode and thereafter immersed in the electroplating solution.

Although any one of a number of different kinds of plating solutions may be utilized, as is well known by

those skilled in the electroplating art, a nickel plating solution is preferred in the present instance. Accordingly, employing necessary controls to insure a uniform stress-free deposition, a layer of nickel 17 is electroplated over silver layer 16. What is meant by "necessary controls" is already known in the art. Suffice it to say, therefore, that it involves proper circulation and temperature maintenance of the electroplating solution, uniform rotation of the submaster cathode, maintaining a uniform composition or strength of the electroplating solution, etc., all of which contribute to the deposition of a nickel layer of uniform thickness and that is relatively stress-free.

When the nickel layer is still but a fraction of the desired thickness, the submaster is removed from the bath for the purpose of applying a mesh structure to it that will ultimately become a rigid backing structure that will support the nickel layer so that it won't buckle, bend or otherwise distort. Thus, following the removal of the submaster, a mesh backing structure 18 is mounted over nickel layer 17, the backing structure being of such shape and dimension that it makes contact with the nickel layer along the edge of the latter. However, at this stage, the backing structure need not be and, therefore, is not, permanently mounted or fixed to the nickel. Rather, it is only necessary that the backing structure make good contact with the nickel all along its edge and remain in good contact with it when the electroplating sequence is resumed. Accordingly, it is only necessary to apply a temporary holding material or substance to the mirror elements whereat they are in contact with each other, such as a wax coating, a suitable paint, or the like.

A backing structure thusly held in position on the nickel layer is shown in cross-section in FIG. 5, a perspective view of it being illustrated in FIG. 5(a). As was previously indicated, the nickel layer is designated 17 and the backing structure 18, the substance applied to hold the two of them together being designated 20.

With respect to the kind of materials that may be used for the backing structure, any mesh-type or porous material may be used, such as a fabric of some sort, or a metal screen or a porous plastic sheet. Nylon netting is an example of a fabric that may be used and a cooper or aluminum screen is an example of a metal screen that may be used. In using the backing material, the first step is that of forming or giving it the desired shape. This is not a problem where a fairly rigid material is used such as the wire screen or porous plastic mentioned above, but it would be a problem where a fabric or cloth material is used. Accordingly, in the case where a fabric or similar type of material is employed, it is necessary to first sufficiently rigidize the material so that it will hold its shape. Toward this end, the fabric may be painted or sprayed with or immersed in a substance that will rigidize it and thereby allow it to hold the configuration into which it has been shaped. Wax or paraffin is an example of one substance that may be used although many are available. Next, after shaping the backing structure material, it is essential to make sure that the material is electrically conducting. Here again, no problem is presented in the case of a metal screen, but the use of a fabric or plastic material does present a problem. Hence, in the event that any one of the latter materials is used, it is necessary to coat it with an electrically conductive substance such as chemical silver which, as was previously mentioned, can be sprayed on.

With the backing structure affixed to the nickel layer thus far deposited, the entire sub-master structure is returned to the electroplating bath until the nickel layer has attained its desired thickness. A novel feature of this further electroplating of the nickel layer is that the electroplating occurs through the mesh backing structure. Stated differently, after being returned to the bath, nickel is deposited on both the backing structure and the nickel layer, the flow of nickel ions and their deposition on nickel layer 17 occurring through the openings or pores

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in the backing structure. Thus, as has already been mentioned, the final nickel layer and backing structure as well as the permanent connection or mounting between the two are formed simultaneously. In other words, in one step backing structure 18 becomes integrally affixed to nickel layer 17, which constitutes an improvement over the method as it was previously practiced.

At this point, the entire structure is removed from the bath, washed, cleaned and dried, and the plastic submaster structure separated from the mirror structure. The mirror structure that separates from the submaster structure is shown in FIGS. 6 and 6(a) and, as shown therein, includes silver layer 16 which adhered to and separated with nickel layer 17. The separation may be effected by means of pneumatic, hydraulic, mechanical or other means, the techniques for providing such separations being well known in the arts and practiced with great finesse.

The next step is that of chemically stripping the silver layer from the nickel layer and to do so in such a manner that the optical surface of the mirror, which is the common surface between the silver and nickel layers, is not degraded. To achieve this end, a solution composed of ammonium hydroxide (NH_4OH), hydrogen peroxide (H_2O_2) and distilled water can be used to strip the silver from the nickel without etching the nickel. Assuming that this has now been done, the final electroformed mirror product comprising nickel layer 17 and its rigidizing or support structure 18 is shown in FIG. 7. It should be mentioned, however, that if deemed necessary, a hard scratch and abrasion resistant surface may be provided over the nickel face to protect it and such materials as rhodium or chromium may be plated on as the protective film.

Although a particular structure and process have been illustrated and described above by way of example, it is not intended that the invention be limited thereto. Thus, for example, the submaster may be made in other ways than as herein described, such as by electroforming it, and used in the same manner to produce the final product. In this regard, it must be emphasized once again that the present method for supplying a backing structure may be adapted and applied to the electroforming of devices other than mirrors. Accordingly, the invention should be considered to include any and all modifications, alterations or equivalent arrangements falling within the scope of the annexed claims.

Having thus described the invention, what is claimed is:

1. A reflecting mirror comprising: a layer of metal electroformed as the reflecting surface of the mirror; and a rigid mesh backing structure mounted on said metal layer at least substantially on the edge thereof for the firm and undistorted support thereof, said backing structure including a pliable mesh material and an electroformed film of said metal that covers said pliable mesh material to rigidize it, said metal film blending with said metal layer as a continuation thereof to firmly and permanently mount said backing structure as an integral part of said reflecting surface layer.

2. An apparatus comprising: a thin layer of metal electroformed into a predetermined shape; and a rigid mesh backing structure mounted on said metal layer at least substantially on the edge thereof for the firm and undistorted support thereof, said backing structure including a pliable mesh material and an electroformed film of said metal that coats said material to rigidize it, said metal film blending with said metal layer as a continuation thereof to firmly and permanently mount said backing structure as an integral part of said metal layer.

3. An apparatus comprising: a thin layer of metal electroformed into a predetermined shape; and a rigid mesh backing structure mounted on said metal layer at least substantially on the edge thereof for the firm and undistorted support thereof, said backing structure in-

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cluding a pliable electrically non-conducting mesh material, a thin coating of a sensitizing substance over said mesh material to render it electrically conducting, and an electroformed film of said metal that covers said coating to rigidize said mesh material, said metal film blending with said metal layer as a continuation thereof to firmly and permanently mount said backing structure as an integral part of said metal layer.

4. A reflecting mirror comprising: a layer of metal electroformed as the reflecting surface of the mirror; and a rigid mesh backing structure mounted on said metal layer along the edge thereof and spaced from it therebetween, said backing structure including a pliable electrically non-conducting mesh material, a thin coating of a sensitizing substance over said mesh material to render it electrically conducting, and an electroformed film of said metal that covers said coating to rigidize said mesh material, said metal film blending with said metal layer as a continuation thereof to firmly and permanently mount said backing structure as an integral part of said metal layer.

5. A method of fabrication of an electroformed device, said method comprising the steps of: forming a mold having the desired shape of the device; electroplating a first portion of a metal layer over the working surface of said mold; affixing a mesh backing structure onto said first portion of said metal layer at least substantially on the edge thereof; further electroplating a second portion of said metal layer onto said backing structure and through the openings in said backing structure onto said first portion of metal; and separating said mold from the device.

6. A method of fabricating an electroformed reflecting mirror, said method comprising the steps of: forming a mold whose working surface has the desired shape of the mirrors reflecting surface; electroplating a first layer of metal over the working surface of said mold; positioning an appropriately-shaped mesh backing structure over said first layer so that the backing structure is in contact with the metal layer all along its edge; affixing said mesh backing structure to said first layer whereat the two are in contact; electroplating a second layer of metal over both said first metal layer and said backing structure; and separating said mold from the mirror.

7. A method of fabricating an electroformed reflecting mirror, said method comprising the steps of: forming a mold whose working surface has the desired shape of the mirror's reflecting surface; sensitizing the working surface of said mold by coating it with a film of electrically-conductive material; mounting said mold as the cathode in an electroplating bath and keeping it there until a first layer of metal is deposited over the sensitized working surface of the mold; removing said mold from the bath and positioning an appropriately-shaped mesh backing structure over said first layer so that the backing structure is in contact with the metal layer all along its edge; applying a substance all along the line of contact between the backing structure and the first layer of metal to cause them to adhere to each other; immersing said cathode in said bath until a second layer of metal is electroplated over both said first metal layer and said backing structure; and separating said mold from the mirror.

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