United States Patent [19]

Bakewell

[11] **3,900,359**

[45] **Aug. 19, 1975**

[54] **METHOD AND APPARATUS FOR TELEVISION TUBE SHADOW MASK**

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[73] Assignee: **Dynamics Research Corporation,** Wilmington, Mass.

[22] Filed: **Feb. 26, 1973**

[21] Appl. No.: **335,503**

[52] **U.S. Cl.** ..... **156/242;** 313/85 S; 96/36.1; 29/25.11; 118/504; 164/13; 156/150; 156/232; 264/219; 264/129; 204/11

[51] **Int. Cl.** **B44d 1/18;** H01j 29/46

[58] **Field of Search** ..... 313/85 S; 96/36.1; 117/212; 118/504

[56] **References Cited**

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Primary Examiner—John D. Welsh

Attorney, Agent, or Firm—Weingarten, Maxham & Schurgin

[57] **ABSTRACT**

A television tube shadow mask and a method for electroforming a plurality of identical shadow masks on a mandrel curved in the shape of the shadow masks as used in a television tube. Positioning of electron beam apertures in the shadow masks according to the invention is precise and repeatable to provide interchangeability of the shadow masks and predictable optical properties.

22 Claims, 13 Drawing Figures

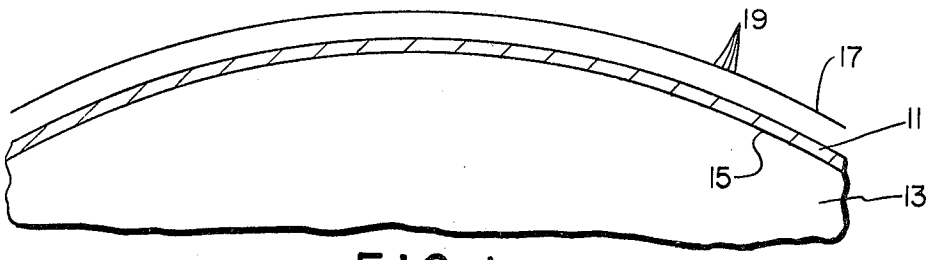


FIG. 1

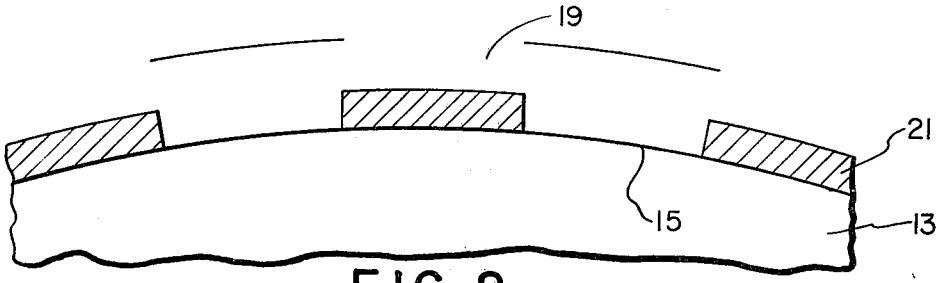


FIG. 2

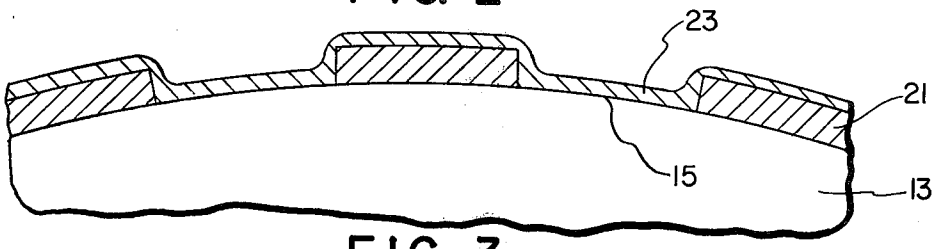


FIG. 3

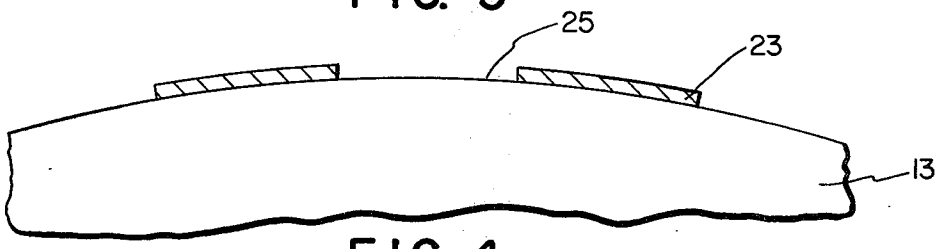


FIG. 4

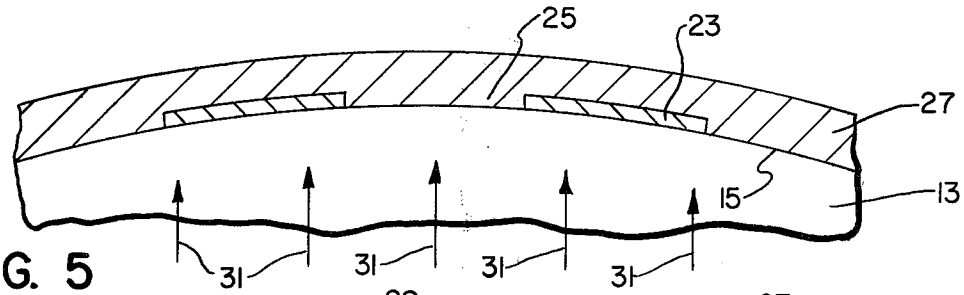


FIG. 5

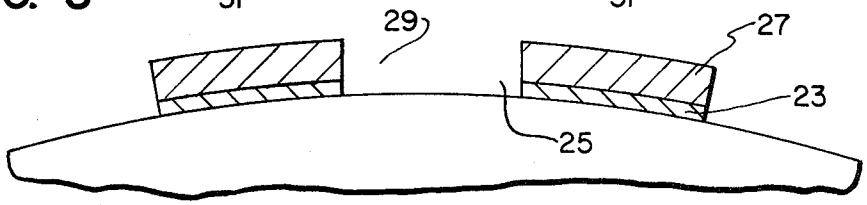


FIG. 6

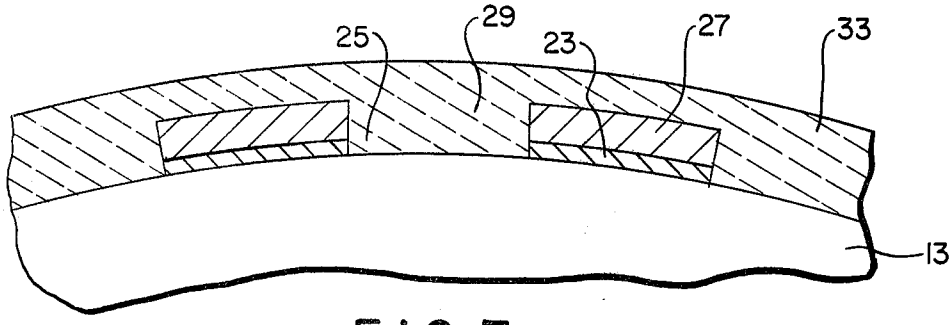


FIG. 7

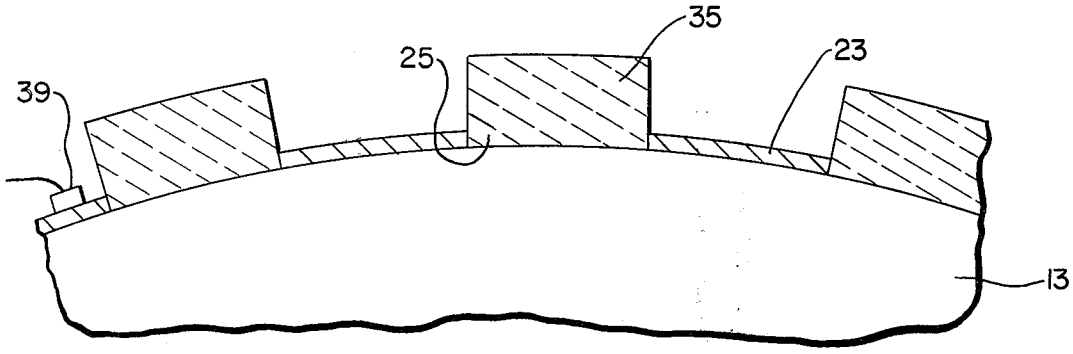


FIG. 8

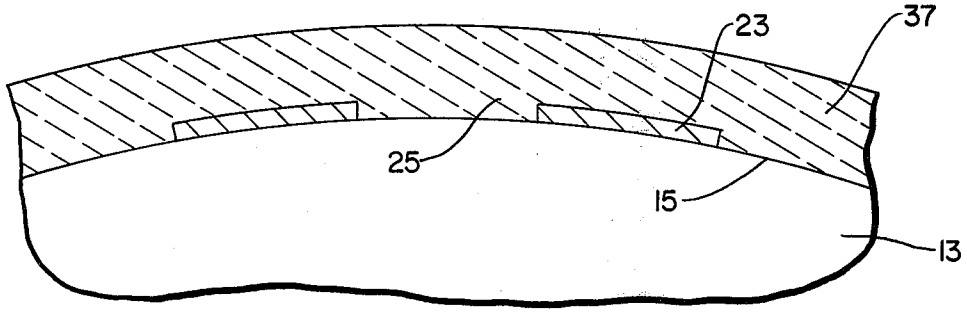


FIG. 9

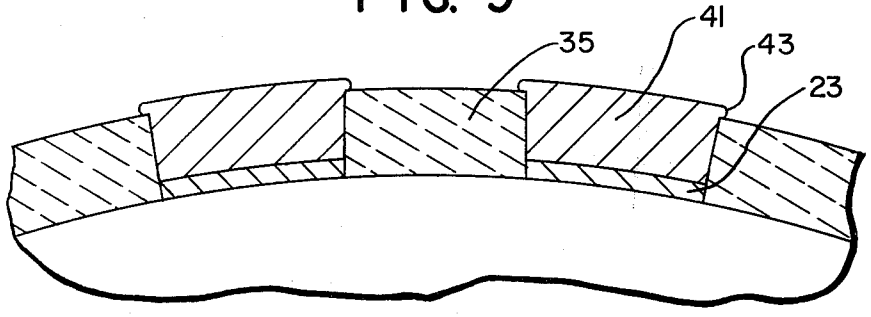


FIG. 10

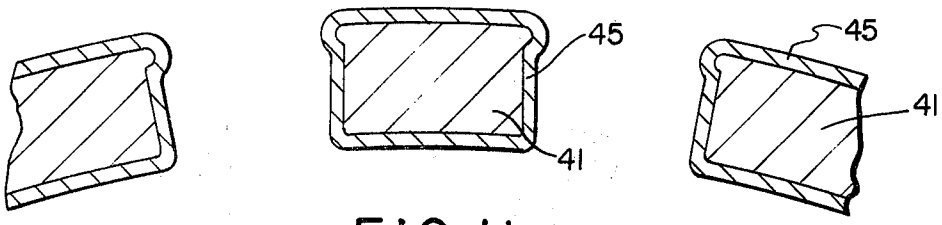


FIG. 11

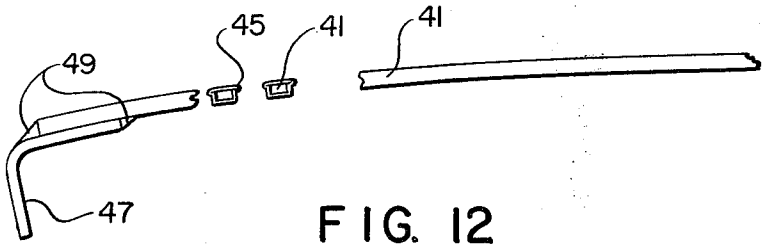


FIG. 12

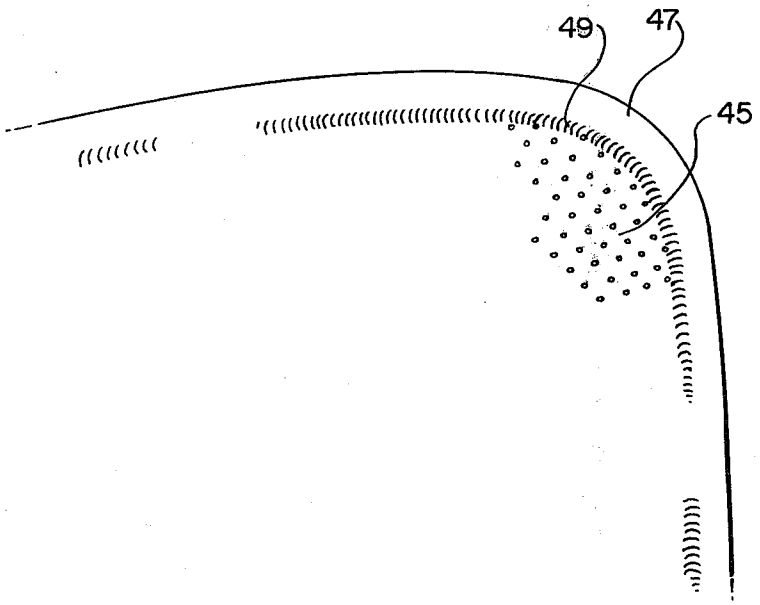


FIG. 13

METHOD AND APPARATUS FOR TELEVISION TUBE SHADOW MASK

FIELD OF THE INVENTION

This invention relates to television shadow masks and methods for their fabrication and more particularly to shadow masks with repeatable and uniform properties.

BACKGROUND OF THE INVENTION

Shadow masks are typically used in color television picture tubes to direct the electron beams for each of the primary colors through holes in the mask to illuminate phosphor dots of corresponding color on the screen surface without illuminating dots of other colors. To provide this function, the shadow mask is positioned between the source of the electron beams and the screen. The mask is parallel to and in close proximity to the screen and has predetermined alignment between phosphor dots on the screen and holes in the mask. It can be appreciated that the holes in the shadow mask should be precisely positioned with respect to the phosphor dots on the screen to provide good electron beam optical properties for the picture tube and to insure that these properties are uniform across the viewing surface of the tube screen. If even some holes are out of registration with their respective dots, picture quality and color reproducibility is decreased.

The conventional process for manufacturing color television tubes to secure high picture quality employs a master shadow mask from which the holes in the individual masks are formed by photoetching through thin, flat sheet steel. The flat sheet is then stressed into a curvature matching that of the surface of the picture tube screen with which it is to be employed. This process produces a random distortion in the pattern of holes in the shadow mask after stressing to the desired curvature. Each mask thus produced has a distinct pattern of apertures and, therefore, the particular mask used in each picture tube must be used as a mask for placing the phosphor dot pattern on the screen of that tube.

Thus beyond this point in the manufacturing process, the screen and the mask must remain associated with each other, an inconvenient and costly necessity. Even with this precaution, irregularities result in picture quality due at least in part to the difference between the optical properties of the photographic process used to place the dots and the optical properties of the electron beam which control the illumination of the dots in operation of the tube.

While other techniques, such as that shown in U.S. Pat. No. 3,676,914, have been devised to overcome these difficulties, the particular advantages of the present invention can be appreciated from the disclosure below.

SUMMARY OF THE INVENTION

In accordance with the preferred embodiment of the present invention a television tube shadow mask is electroformed in a process which provides a physically rugged mask, having accurate and uniform beam transmission characteristics that are repeatably achieved from mask to mask.

Initially, a transparent mandrel of predetermined curvature typically complementing the curvature of the inner surface of the picture tube is covered with a thin layer of conductive metal having an array of apertures

in positions corresponding to the locations of holes in the shadow mask which is to be produced. The aperture array may be selected for specific optical properties. Using this layer as a photographic master and employing rear exposure techniques, columns of insulating material are formed in the apertures to a substantial height above the thin metal layer to define the edges of the mask holes. A first portion of the mask is then electroformed onto the thin metal layer to the approximate height of the insulating columns which produce perforations in the electroplated metal layer in exact registration with those on the original master. The thus-formed metal layer is then lifted off the thin metal layer and mandrel and is finally reinforced with a frame and a further metal coating applied by electroless plating. The mandrel with the thin layer of metal may be reused for producing a large number of identical shadow masks.

DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description of the preferred embodiment presented for purposes of illustration, and not by way of limitation, and from the accompanying drawings which present the invention in a distorted scale for purposes of illustration and of which:

FIG. 1 is a plain sectional view of the glass mandrel and the master pattern mask employed in the invention and illustrates an initial step in the process of the invention;

FIG. 2 is an enlarged plane sectional view illustrating the result of exposure and development of the FIG. 1 structure to produce photoresist islands on the mandrel in registration with the apertures in the master mask;

FIG. 3 illustrates the step of depositing a thin metal layer over the glass mandrel and the photoresist islands of FIG. 2;

FIG. 4 illustrates the thin metal layer resulting from dissolving the remaining photoresist;

FIG. 5 illustrates the result of depositing a layer of photoresist over the thin metal layer of FIG. 4;

FIG. 6 illustrates development of apertures in the layer of photoresist in registration with apertures in the thin metal layer;

FIG. 7 illustrates the configuration of FIG. 6 covered with a layer of insulating resist;

FIG. 8 illustrates columns of the insulating resist which remain in the apertures of the thin metal layer after stripping the resist;

FIG. 9 illustrates an alternative to the steps of FIGS. 5, 6 and 7;

FIG. 10 illustrates a layer of metal electroformed onto the thin metal layer to the height of the insulating columns;

FIG. 11 is a plane sectional view showing the mask of the invention reinforced by a metal coating as a final step in fabricating the mask;

FIG. 12 is an enlarged plane sectional view of an edge of the shadow mask mounted in a frame; and

FIG. 13 is a pictorial view of a completed shadow mask in the frame.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the present invention, a shadow mask and method for its manufacture are disclosed whereby improved color television tube performance

and manufacturing efficiency results from more accurate and repeatable positioning of shadow mask holes. This invention represents an improvement on my U.S. Pat. No. 3,703,450 incorporated herein by reference.

In the practice of the invention, one will typically have a master shadow mask prepared by any of several known methods with holes in a predetermined pattern which produces a shadow mask of predetermined characteristics when made according to the present invention. While it will be assumed that the master shadow mask has these properties, it is not essential to the practice of the invention. In addition, a curved transparent mandrel is provided with a surface ground and polished to the desired curvature of the shadow mask to be produced, typically, complementary to the curvature of the inner surface of the screen of the picture tube to be used. It is to be noted that either a concave or convex mandrel surface may be employed.

The production of a shadow mask, according to the invention, it best described in conjunction with FIGS. 1–12, which depict the several stages of the process of generating each of a plurality of identical shadow masks.

Referring to FIG. 1, a mandrel 13, typically of glass, is shown with a layer 11 of negative photoresist on its convex surface 15. A master shadow mask 17, with curvature typically matching that of the mandrel surface 15 is positioned in registration over the photoresist layer 11 on the convex mandrel surface 15. The photoresist layer 11 is then exposed to light through apertures 19 in mask 17 from a source, not shown, above the mask 17 in accordance with conventional contact printing techniques.

Alternatively, a flat master pattern for the mask may be used in conjunction with suitable optical projection apparatus to expose the photoresist layer on the mandrel in the desired pattern. In such a case, the aperture distribution on the master pattern would not necessarily be substantially the same as that of the resulting shadow mask. Conventional registration techniques would be used to align the image projected by the master pattern on the mandrel.

As shown in expanded scale in FIG. 2, the exposed photoresist layer 11 is developed to leave a pattern of photoresist islands 21 on the surface of the mandrel corresponding to the apertures 19 on the master shadow mask. Subsequently, a thin metal layer 23, typically of Inconel or Nichrome is evaporated to a thickness which provides a generally opaque layer on the surface 15 of the mandrel 13. Conventional evaporation techniques may be used and the resulting structure is shown in FIG. 3. Other suitable means of depositing the thin metal layer 23 on the surface 15 may alternatively be employed.

The photoresist islands 21 are removed by means of a suitable solvent to leave a series of perforations or apertures 25 in the thin metal layer 23 as shown in FIG. 4.

A layer of positive photoresist 27 is then applied to the surface 15 of the mandrel 13, covering the thin metal layer 23 and filling in the apertures 25 to result in the structure of FIG. 5. The photoresist layer 27 is exposed through the apertures 25 in the layer 23 to light 31 from a second source which is positioned below the mandrel. The layer 23 masks the light 31 except in the area of the apertures 25 so that subsequent developing of the photoresist layer 27 results in a plurality of apertures 29 through the layer 27 in alignment with apertures 25 as shown in FIG. 6.

A layer 33 of insulation, for example, silicon monoxide is next formed on the surface 15 of the mandrel 13, covering the layer 27 of photoresist and filling in the apertures 25 and 29 as shown in FIG. 7. The layer 27 of photoresist and covering insulation is subsequently removed by means of a suitable solvent, for example, acetone to leave an array of pillars or columns 35 remaining from the insulating layer 33 and extending through the apertures 25 of the thin metal layer 23 to a predetermined height, typically 0.003 in., as shown in FIG. 8.

The columns 35 of insulating material may also be produced in an alternative method, according to which the steps depicted in FIGS. 5, 6 and 7 may be replaced by the steps illustrated with reference to FIG. 9. To the structure of FIG. 4, a layer 37 of negative photoresist which is a good electrical insulator is applied to a typical thickness of 0.003 in. onto the surface of the thin metal layer 23 and the surface 15 of the mandrel 13 where exposed through the apertures 25 in the metal layer. Using the thin metal layer 23 as a mask, the layer 37 of insulating photoresist is exposed by light 31 from a source positioned below the mandrel. The exposed photoresist is developed so as to remove the unexposed photoresist and to leave columns, like columns 35 in FIG. 8, extending from the surface 15 of the mandrel 13 through the apertures 25.

The exposed surface of the thin metal layer 23 in FIG. 8 is next preferably passivated by conventional techniques to provide a balance between adherence of the mask to be formed thereon and ultimate removability of that mask.

One or more electrical contacts 39 are applied to the thin metal layer 23 to evenly distribute plating current discussed below. This completes the form on which the shadow masks may be produced.

In the production of each shadow mask, the mandrel surface 15 with the metal layer 23 and the array of insulating columns 35 thereon is immersed in an electroplating bath. Electrical current is passed through the circuit comprising the bath and thin metal layer 23 and the electrical contacts 39 to electroplate an apertured metal layer 41, typically nickel, onto the thin metal layer 23 until a thickness approximately equal to, or just above, the height of the columns 35 is achieved. By plating just above the columns 35 a lip 43 is formed which narrows the holes defined by the pillars 35 to provide the optical function of a fixed diaphragm.

The metal layer 41 is then lifted off the glass mandrel without distorting its shape and provides a shadow mask of accurate and repeatably positioned holes. This lifting step may be facilitated by directing a liquid or air flow between layers 23 and 41, breaking adhesion by thermal shock or simply using a mechanical lifting tool.

The metal layer 41 defining the shadow mask will benefit from the application of a rigid outer coating such as a layer 45 of electroless nickel as shown in FIG. 11. Conventional electroless techniques are typically employed, although other methods may also be used. The coating 45 gives to layer 41 a rigid frame and a typical total mask thickness of 0.006 inches to help maintain the predetermined curvature of the shadow mask. This reinforcement step may optionally be carried out with the mask in fixed registration with a glass form of

identical shape to the shape of the surface 15 of mandrel 13.

A mask mounting frame 47 may optionally be attached around the periphery of the shadow mask prior to electroless plating as illustrated in FIG. 12. The frame 47 may be temporarily attached to the edges of the mask by adhesive bonding, spot welding, mechanical clamping or any suitable means. If the confronting portions of the frame and the mask are maintained in close spatial relationship, subsequent electroless plating will produce a fillet 49 between the shadow mask and the mounting frame, the fillet 49 holding the shadow mask more securely to the mounting frame 47. A section of a completed shadow mask fixed in a mounting frame is illustrated in FIG. 13.

Once the shadow mask has been removed from the mandrel, the surface may be cleaned by a suitable solvent. The glass mandrel with the perforated thin layer 23 of metal and insulating columns 35 may immediately be reused to produce another shadow mask by carrying out one or more of the steps in FIGS. 10–12. It may be possible to repeat the process from FIG. 5 as well, if the columns 35 are removed or damaged, by suitable cleaning of the remains of the columns 35.

A suitable mask may also be produced by employing the above steps on a concave mandrel of predetermined curvature.

It will be apparent that the illustrations incorporated in the drawing are not necessarily drawn to the scale ultimately desired for the invention but may include distortions which more clearly illustrate the particular features of the invention. It will occur to those skilled in the art that other modifications and alternations to the disclosure can be achieved without departing from the spirit of the invention. Accordingly, it is intended to limit the scope of the invention only as indicated in the following claims.

What is claimed is:

1. A method of fabricating a picture tube shadow mask in a predetermined curvature employing a mandrel having said predetermined curvature to a curved surface thereof and further having a plurality of columns extending outward from regions of said curved surface arranged in a preset pattern, said method comprising the steps of:
   - forming a curved layer of a material onto said surface to a predetermined thickness surrounding said columns;
   - said columns substantially defining holes through said layer; and
   - separating said layer from said surface to provide said shadow mask.

2. The method of fabricating a picture tube shadow mask according to claim 1 further comprising the step of passivating said curved surface prior to forming said curved layer of material onto said curved surface.

3. The method of fabricating a picture tube shadow mask according to claim 2 further comprising the step of coating the separated layer with a reinforcing material to maintain in said shadow mask the predetermined curvature of said curved surface.

4. The method of claim 3 wherein said coating step includes an electroless plating step.

5. The method of claim 3 further including the step of applying a frame to said shadow mask with adhesion produced by the material coated in said coating step.

6. The method of fabricating a picture tube shadow mask according to claim 1 wherein said curved layer forming step includes the step of forming in a portion of said layer adjacent to said holes a significant narrowing in the diameter of said holes to provide a diaphragm.

7. The method of fabricating a picture tube shadow mask according to claim 1 including the steps of forming said plurality of columns by:
   - forming on said curved mandrel surface an opaque layer with a plurality of light transmissive areas;
   - forming a photoresist layer onto said curved surface of said mandrel;
   - exposing the photoresist layer through said light transmissive areas to light from a source positioned to the side of said curved mandrel surface opposite said photoresist layer; and
   - generating said columns in the region defined by the exposed photoresist layer and extending outward from regions of said curved surface coextensive with said light transmissive areas.

8. The method of claim 7 wherein said generating step includes the step of developing said photoresist layer to leave columns of said photoresist layer.

9. The method of claim 7 wherein said generating step includes:
   - developing said photoresist layer to leave apertures therethrough exposing said light transmissive areas on the curved surface of said mandrel;
   - applying an insulating material to the photoresist layer apertures; and
   - removing said photoresist layer to leave columns of said insulating material as said plurality of columns.

10. The method of fabricating a multiplicity of picture tube shadow masks of claim 7 wherein said step of forming an opaque layer includes the steps of:
   - forming at least one photoresist layer onto said surface of said mandrel;
   - exposing the photoresist layer in registration with light from light transmissive areas in a master mask; and
   - providing said opaque layer on said mandrel in the regions defined by the unexposed portions of said at least one photoresist layer.

11. The method of claim 1 further including the step of repeating said forming and separating steps.

12. The method of claim 1 wherein said curved surface is convex.

13. The method of claim 1 wherein said curved surface is concave.

14. A method of fabricating a multiplicity of picture tube shadow masks having substantially identical predetermined curvature and aperture placement employing a mandrel having said predetermined curvature to a curved surface thereof and further having a plurality of areas thereon arranged in a preset pattern, said method comprising the steps of:
   - forming a plurality of columns to extend outward from regions of said curved surface coextensive with said plurality of areas;
   - forming a first layer of a material onto said surface to a predetermined thickness surrounding said columns;
   - separating said layer from said surface to provide a single shadow mask; and

repeating the first and second mentioned forming steps and said removing step to provide an identical one of said shadow masks on each repetition.

15. The method of fabricating a multiplicity of picture tube shadow masks according to claim **14** further comprising the step of passivating said curved surface prior to each step of forming said layer of material onto said surface.

16. The method of fabricating a multiplicity of picture tube shadow masks according to claim **14** further comprising the step of coating the separated layer with material to maintain the predetermined curvature of said mandrel in said shadow mask.

17. The method of fabricating a multiplicity of picture tube shadow masks according to claim **14** wherein said predetermined thickness to which said material is formed onto said mandrel surface is slightly in access of the height of said columns thereby providing apertures in said shadow mask which have a narrowed opening on one side of said mask.

18. A method of fabricating a curved form suitable for electroforming a picture tube shadow mask thereon with a predetermined curvature and aperture pattern comprising the steps of:

providing a glass mandrel having a surface of a predetermined curvature which generally matches the curvature of the picture tube face;

producing on the curved surface of said mandrel a first layer of material with a predetermined array of apertures therethrough corresponding to the desired location of holes in said shadow mask; and

forming by photoresist techniques a plurality of columns extending from said curved surface in the regions coextensive with said apertures.

19. The method of fabricating a picture tube shadow mask according to claim **19** including as the steps of forming said plurality of columns:

forming a photoresist layer onto the curved surface of said mandrel;

exposing the photoresist layer through said apertures to light from a source positioned to the side of said curved mandrel surface opposite said photoresist layer; and

providing said columns in the region defined by the exposed photoresist layer and extending outward from regions of said curved surface coextensive with said apertures.

20. The method of claim **18** wherein said providing step includes the step of developing said photoresist layer to leave columns of said photoresist layer.

21. The method of claim **18** wherein said providing step includes:

developing said photoresist layer to leave openings therethrough exposing said apertures in said layer;

applying an insulating material to the photoresist layer openings; and

removing said photoresist layer to leave columns of said insulating material as said plurality of columns.

22. A method of fabricating a picture tube shadow mask in a predetermined curvature comprising the steps of:

providing a glass mandrel having a surface generally with said predetermined curvature;

forming a first photoresist layer on said surface of said mandrel;

exposing and developing said first photoresist layer to retain islands of photoresist on said surface of said mandrel;

forming a conductive layer over the surface of said mandrel having said islands;

removing said islands of said first photoresist layer and their super adjacent conductive material to form apertures in said conductive layer;

forming a layer of photoresist over said conductive layer and over said mandrel surface in the areas of said apertures;

exposing said layer of photoresist using light from a light source behind said mandrel surface, said conductive layer being operative as a mask;

forming insulating pillars in the exposed portions of said photoresist layer;

passivating the surface of said conductive layer;

forming a metal layer onto said conductive surface to a predetermined thickness surrounding said pillars;

lifting said metal layer from said mandrel; and

coating said metal layer with a further layer for maintaining the prescribed shape of said metal layer.

* * * * *