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(54) METHOD FOR PRODUCING AN APERTURED WORK PIECE

(71) We, RCA CORPORATION, a corporation organized under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, 10020, United States of America, do hereby declare the invention, for which/we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method for producing an apertured work piece, particularly a shadow mask for a color television picture tube.

A shadow-mask-type color television picture tube includes a color-selection electrode closely spaced from a viewing-screen structure. The electrode is in the form of an apertured mask which shadows portions of the viewing screen from the electron beams during the operation of the tube. To reduce scattering of beam electrons off the sides of the shadow-mask apertures during electron-beam scanning, the apertures are tapered from the screen side towards the electron-beam source. For practical reasons, the narrowest part of each aperture is a "knife edge" which is located a short distance below the mask surface. This short distance is referred to as the "step height" of the knife edge.

United States Patent Nos. 2,750,524 and 3,679,500 describe methods for producing a shadow-mask with apertures having a small step height. Both methods, however, involve two separate etching steps and two separate resist-coating steps.

In the method of the invention, an array of tapered apertures is produced in a thin metal sheet by coating the opposite major surfaces of the sheet with etch-resistant patterns, one pattern comprising larger open areas surrounded by etch-resistant material, and the other pattern comprising similarly-shaped, but smaller effective open areas registered with the larger areas. Each of the smaller open areas has therewithin a still-smaller solid area of etch-resistant material. Preferably, in at least one dimension, the still-smaller solid area is at least 1.0 mil wide and at least 2.0 mils smaller than the smaller open area. Both sides of the coated sheet are etched simultaneously until the desired tapered apertures are produced therein. Then, the etching is stopped, and the etch-resistant patterns are removed from both majors surfaces.

By employing the still-smaller solid areas of etch-resistant material within the smaller open areas, the step height can be reduced, and the uniformity of the knife edge can be improved, relative to prior-art methods. The openings produced by the combination of patterns permits etching to occur from both surfaces of the sheet, but controllably limits the etching from the surface carrying the pattern comprising the smaller open areas. The method requires only a single coating step and a single etching step to achieve what is achieved in two steps with the above-cited prior-art methods.

In the drawings, Figure 1 is a plan view of a metal sheet produced according to the invention;

Figures 2 through 6 are sectional views through one aperture of the metal sheet, illustrating the steps of an example of the invention;

Figure 7 is a superimposed plan view of etch-resistant patterns for producing circular apertures according to an example of the invention;

Figure 8 is a superimposed plan view of etch-resistant patterns for producing slit apertures according to another example of the invention; and

Figure 9 is a superimposed plan view of etch-resistant patterns for producing slit apertures according to still another example

of the invention.

Figure 1 shows a plan view of an etched apertured mask blank 21 as it emerges from an etching machine used in an example of the invention. The mask blank 21 (which here is to be used in a color television picture tube) is in a metal sheet 23 comprising a succession of such mask blanks 21a, 21 and 21b. The mask blanks 21a, 21 and 21b are etched through at the margins 25 thereof, except at convenient points (not indicated) sufficient to hold the blanks in the sheet 23. The mask blank 21 is comprised of an apertured central portion 27, defined by the broken line 28 and a skirt or peripheral portion 29 which, although not apertured, may be etched partly through. The apertures may be circular holes arranged in a hexagonal, diamond-shaped or other array; rectangular slits arranged in vertical rows, for example, 6-mil by 30-mil slits on 30-mil centers; or of other shapes and arrangements. Also, the widths of the apertures may be uniform or graded across the array, as is known in the art.

The mask blank 21 is etched into a regular-carbon or low-carbon cold-rolled-steel sheet about 40 to 10 mils in thickness. The etching may also be conducted in sheets of other materials, such as invar alloy or a copper-nickel alloy. The sheet 23 is unwound from a first roll thereof, passed through the various operations including cleaning, coating, drying, exposing, developing, etching, washing and drying (as described below), then rewound on a second roll. Subsequently, the second roll is unwound and the mask blanks 21a, 21 and 21b are stripped or torn from the sheet 23. The blanks are then heat treated (annealed), roller leveled, formed on a press, and then blackened, as is known in the art, to produce masks suitable for assembly into a picture tube.

Figures 2 through 6 show a sequence of steps that may be used in making one of a hexagonal array of circular apertures in the central portion 27 of a 6-mil-thick sheet 23 of cold-rolled steel (as shown in Figure 1). The sheet 23 is coated on both major surfaces with suitable light-sensitive coatings 31 and 33 of etch-resistant materials, e.g., dichromate-sensitized fish glue, as shown in Figure 2. After the coatings have dried, the coated sheet is positioned in a chase (such as is shown in United States Patent No. 3,751,250) between two light-opaque master patterns, one master pattern 35 for the coating 31 on one major surface of the sheet 23, and the other master pattern 37 for the other coating 33 on the other major surface of the sheet 23, as shown in Figure 3. The light-opaque patterns may comprise chromium or nickel metal coated layers on the inner surfaces of glass plates 39 and 41, so that the patterns 35 and 37 are physically against the coatings 31 and 33 respectively. The one master pattern 35 is an annular ring of for example, about 5 mils outside diameter and 3 mils inside diameter. The other master pattern 37 is a disc or solid circle, for example, about 16 mils in diameter. Center lines of the two master patterns are coincident, but may be offset from one another if desired.

As shown in Figure 3, the coatings 31 and 33 are next exposed to hardening radiation (shown by the arrows above and below the glass plates 39 and 41), as from a carbon-arc source, which radiation passes through the glass plates 39 and 41 to be incident on the coatings 31 and 33. The radiation insolubilizes the coatings 31 and 33 except where the master patterns 35 and 37 shadow the coatings. When the coatings are suitably exposed, the exposure is stopped, and the master patterns are removed.

The coatings are then developed as by flushing with water or other aqueous solvent to remove the unexposed, shadowed portions of the coatings 31 and 33. As shown in Figure 4, after development the sheet 23 carries, on its one major surface, an etch-resistant coating having an annular opening 43 therein and on its other major surface, an etch-resistant coating 33 having a circular or disc-shaped opening 45 therein.

The sheet 23 with the etch-resistant coatings thereon is now etched in a single step to produce the desired tapered aperture. Figures 5 and 6 show the coated sheet 23 at an early stage (Figure 5) and then at the end of etching (Figure 6). The etching is conducted in the usual manner by employing a ferric chloride-hydrochloric acid liquid etchant. At the initial stage shown in Figure 5, the etchant dissolves a small amout of the surfaces of the sheet 23 in the uncoated areas thereof. Figure 5 also shows, by dotted lines, various subsequent etching surfaces that the etchant is believed to advance to.

The use of an annular opening 43 instead of a disc-shaped opening on the one major surface severely restricts the effective etching from that surface, thereby imparting only a small step height 47, as shown in Figure 6. If the annular opening 43 were replaced with a disc-shaped opening, the step height would be substantially greater. The coatings 31 and 33 on the major surfaces of the sheet 23 are removed after the etching has been completed, whereafter the work piece is ready for further processing.

Figure 7 shows, in plan view and superimposed upon one another, the master patterns in the working plates. The significant dimensions of the annular ring of the one master pattern 35 are the inside diameter 53; the outside diameter 55; and the width 59, which is one half the dif-

ference between the outside and inside diameters. For practical reasons, the inside diameter 53 should be about 1 to about 8 mils, preferably about 2 to above 3 mils, and the outside diameter 55 should be about 3 to about 10 mils, preferably about 6 to about 10 mils preferably also, the difference between the outside and inside diameters is at least 2 mils, so that the width 59 of the annulus is at least 1 mil. The significant dimension for the circular area of the other master pattern 37 is the diameter 57 which, for practical reasons is about 12 to about 20 mils.

Where the apertures are to be graded in size from the center to edge of the apertured portion 27, the diameters of the annular rings 35 are graded. Typically, the outside diameter of the annular rings 35 may grade from about 9.5 mils at the center of the mask to about 7.5 mils at the edge of the apertured portion 27 of the mask. The inner diameter 53 of the annualr ring 35 may also be graded, but the widths 59 are preferably at least 1 mil with present etch-resistant patterns. (As the width 59 decreases, the step height decreases to a minimum of about 1 mil and then increases.) In this example, the diameter 57 of the circular area on the reverse side is about 16 mils, but this dimension is not critical and may be between about 12 and about 20 mils. Where the apertures are graded in size, the larger circular areas may or may not be graded in size. A typical center-to-center aperture spacing is about 25 mils.

The invention may be employed also to produce rectangular slit apertures, as illustrated by the superimposed master patterns shown in Figure 8. The one master pattern 35′ (solid lines) and the other master pattern 37′ (dotted line) are shown with rectangles having rounded corners. For one example, the outside width 65 of the one master pattern 35′, is about 5 mils and the outside length is about 30 mils; the inside width 63 is about 2 mils and the inside length is about 27 mils. In other examples, the outside width may vary from 3 to 20 mils, preferably from about 4 to about 10 mils, and the inside width 63 may vary from 1 to 10 mils. However, the difference between the outside and inside widths is preferably at least 2 mils, so the width of the annulus 69, 61 is at least 1 mil. The other master patterns 37′ may vary between 12 and 24 mils in their width 67 and between 20 and 50 mils in length: however, each of the length and width dimensions of the other master pattern 37′ should be larger than the corresponding dimension of the one master pattern 35′.

Figure 9 shows another application of the invention for producing an array of rectangular slits. The slit aperture master patterns shown in Figure 9 differ from those of Figure 8 in that, for the one master pattern 35″ of the former, the length of the still-smaller solid area is equal to the length of the effective smaller open area defined jointly by the open sub-areas on either side of the central solid area. For practical reasons, the annular spacing 61 of the one master pattern of Figure 8 may be omitted, with substantially equivalent results to those obtained with the master patterns shown. Thus, in the example of Figure 9, only one, i.e., the horizontal, dimension of the one master pattern requires that the still-smaller solid area be at least 2 mils smaller than the smaller open area. It is therefore to be appreciated that reference to the smaller opening in the following claims is to be construed as including an arrangement of sub-openings separated by a solid area (the still smaller solid area referred to in the claims) and having the joint effect, in the etching process, of a single opening with a solid area within it.

WHAT WE CLAIM IS:—

1. A method for producing an array of tapered apertures in a thin metal sheet, comprising coating the opposite major surfaces of the sheet with etch-resistant patterns, the pattern on one of said surfaces comprising an array of open areas surrounded by etch-resistant material, and the pattern on the opposite one of said surfaces comprising smaller effective open areas of similar shape to and registered with the larger open areas and each having therewithin a still-smaller solid area of etch-resistant material, etching both sides of said coated sheet simultaneously to form said apertures therethrough, and then removing the etch-resistant patterns.

2. The method defined in Claim 1, wherein, in at least one dimension, said still-smaller solid area is at least 1 mil wide and at least 2 mils smaller than the corresponding smaller open area.

3. The method defined in Claim 2, wherein, in said one dimension, said still-smaller solid area is about 2 to about 3 mils wide and said corresponding smaller open area is about 6 to about 10 mils wide.

4. The method defined in Claim 1, wherein said larger open areas are substantially circular areas about 12 to about 20 mils in diameter and said smaller open areas are substantially circular areas about 6 to about 10 mils in diameter.

5. The method defined in Claim 1, wherein said larger open areas are substantially rectangular areas about 12 to about 24 mils wide and said smaller open areas are substantially rectangular areas about 4 to about 10 mils wide.

6. The method defined in Claim 5, wherein the length of said still-smaller area is equal to the length of the corresponding

ference between the outside and inside diameters. For practical reasons, the inside diameter 53 should be about 1 to about 8 mils, preferably about 2 to above 3 mils, and the outside diameter 55 should be about 3 to about 10 mils, preferably about 6 to about 10 mils preferably also, the difference between the outside and inside diameters is at least 2 mils, so that the width 59 of the annulus is at least 1 mil. The significant dimension for the circular area of the other master pattern 37 is the diameter 57 which, for practical reasons is about 12 to about 20 mils.

Where the apertures are to be graded in size from the center to edge of the apertured portion 27, the diameters of the annular rings 35 are graded. Typically, the outside diameter of the annular rings 35 may grade from about 9.5 mils at the center of the mask to about 7.5 mils at the edge of the apertured portion 27 of the mask. The inner diameter 53 of the annualr ring 35 may also be graded, but the widths 59 are preferably at least 1 mil with present etch-resistant patterns. (As the width 59 decreases, the step height decreases to a minimum of about 1 mil and then increases.) In this example, the diameter 57 of the circular area on the reverse side is about 16 mils, but this dimension is not critical and may be between about 12 and about 20 mils. Where the apertures are graded in size, the larger circular areas may or may not be graded in size. A typical center-to-center aperture spacing is about 25 mils.

The invention may be employed also to produce rectangular slit apertures, as illustrated by the superimposed master patterns shown in Figure 8. The one master pattern 35′ (solid lines) and the other master pattern 37′ (dotted line) are shown with rectangles having rounded corners. For one example, the outside width 65 of the one master pattern 35′, is about 5 mils and the outside length is about 30 mils; the inside width 63 is about 2 mils and the inside length is about 27 mils. In other examples, the outside width may vary from 3 to 20 mils, preferably from about 4 to about 10 mils, and the inside width 63 may vary from 1 to 10 mils. However, the difference between the outside and inside widths is preferably at least 2 mils, so the width of the annulus 69, 61 is at least 1 mil. The other master patterns 37′ may vary between 12 and 24 mils in their width 67 and between 20 and 50 mils in length; however, each of the length and width dimensions of the other master pattern 37′ should be larger than the corresponding dimension of the one master pattern 35′.

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2. The method defined in Claim 1, wherein, in at least one dimension, said still-smaller solid area is at least 1 mil wide and at least 2 mils smaller than the corresponding smaller open area.

3. The method defined in Claim 2, wherein, in said one dimension, said still-smaller solid area is about 2 to about 3 mils wide and said corresponding smaller open area is about 6 to about 10 mils wide.

4. The method defined in Claim 1, wherein said larger open areas are substantially circular areas about 12 to about 20 mils in diameter and said smaller open areas are substantially circular areas about 6 to about 10 mils in diameter.

5. The method defined in Claim 1, wherein said larger open areas are substantially rectangular areas about 12 to about 24 mils wide and said smaller open areas are substantially rectangular areas about 4 to about 10 mils wide.

6. The method defined in Claim 5, wherein the length of said still-smaller area is equal to the length of the corresponding

smaller open area.

7. A method of producing an apertured work piece substantially as hereinbefore described with reference to Figures 2-6 of the accompanying drawings.

8. A method according to any preceding claim used for producing a picture tube shadow mask.

9. A method of producing a color television picture tube shadow mask substantially as hereinbefore described with reference to Figures 2-6 and any one of Figures 7-9 of the accompanying drawings.

10. A color television picture tube shadow mask made by a method according to any preceding claim.

11. A work piece made by a method according to any of Claims 1-7.

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