May 3, 1938. H. E. HOLMAN 2,115,855

CATHODE RAY TUBE

Filed Oct. 1, 1936 2 Sheets-Sheet 1

Fig. 1

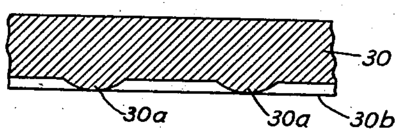


Fig. 2

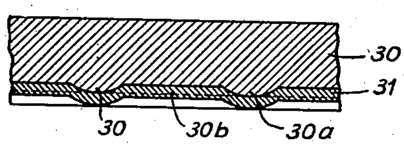


Fig. 3

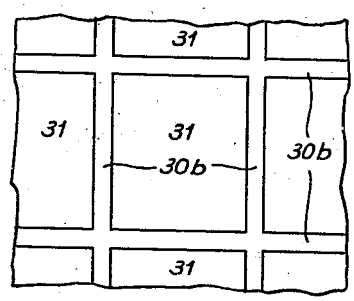


Fig. 4

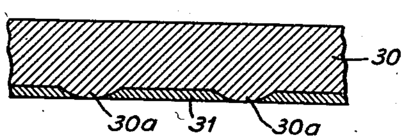


Fig. 5

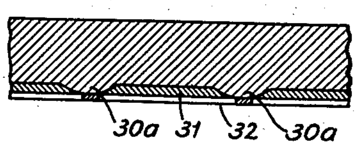


Fig. 6

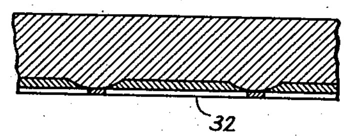


Fig. 7

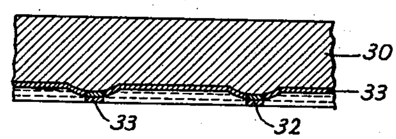


Fig. 8

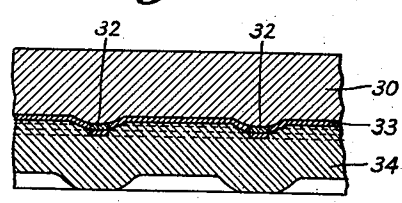


Fig. 9

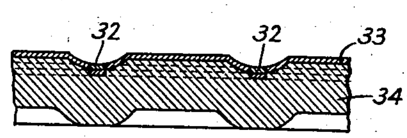
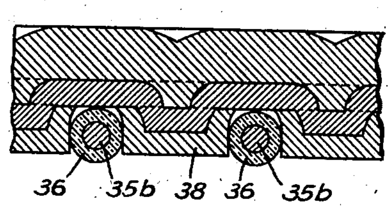


Fig. 10



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CATHODE RAY TUBE

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Fig. 10a.

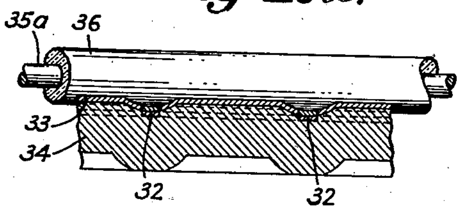


Fig. 11.

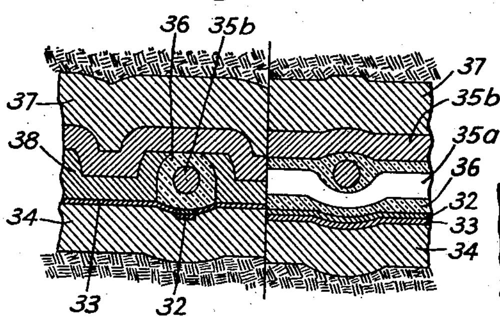


Fig. 13.

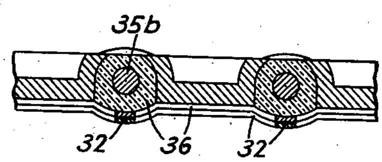
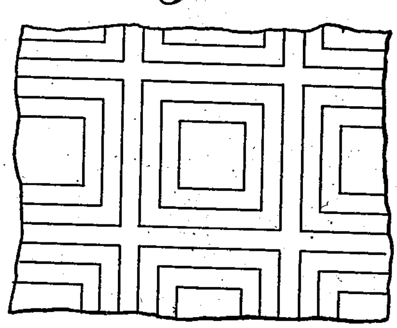


Fig. 12.



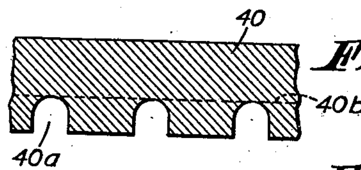


Fig. 14

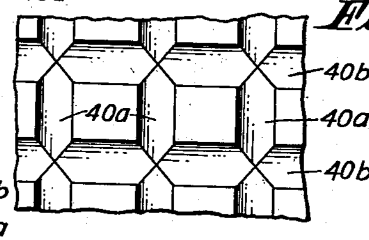


Fig. 15

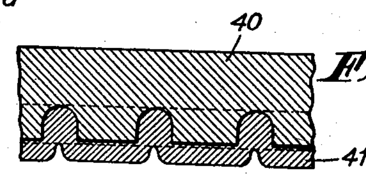


Fig. 16

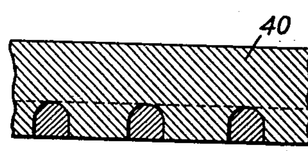


Fig. 17

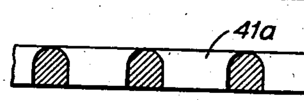


Fig. 18

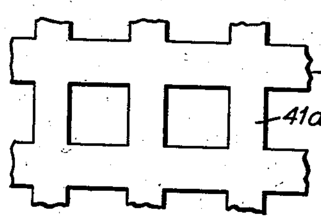


Fig. 19

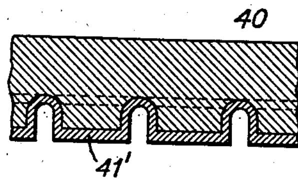


Fig. 20

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2,115,855

UNITED STATES PATENT OFFICE

2,115,855

CATHODE RAY TUBE

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Application October 1, 1936, Serial No. 103,511
In Great Britain May 23, 1935

14 Claims. (Cl. 250—27.5)

The present invention relates to the manufacture of metal mesh screens of meshes ranging in pitch down to a fraction of a millimetre, and to the application of such screens as electrodes in electron discharge devices, such for example as cathode ray tubes.

A form of cathode ray tube used in the electrical transmission of pictures comprises a mosaic electrode which includes a metal mesh screen coated with insulating material, the interstices in the screen accommodating insulated metal elements.

A tube of this form used in television transmission apparatus has one end of each of the mosaic elements coated with photo-electrically active material, and in operating such apparatus an optical image is projected on to the photo-electrically active side of the mosaic screen, while the opposite side of the screen is scanned by a cathode ray, the picture signals being generated in an external circuit associated with the metal mesh grid. A screen used in this way is known as a "double-sided" mosaic.

It is sometimes desirable to provide in photo-electric devices a metal screen of fine mesh. For example, in a cathode ray tube having a double-sided mosaic screen, a metal screen, the meshes of which conform with the insulated photo-sensitive elements of the mosaic screen, may be mounted on or closely adjacent to the mosaic screen and maintained at a particular potential, the mesh screen serving to assist in stabilizing the mosaic elements at some desired potential and/or in preventing secondary electrons, released by bombardment of any particular element of the mosaic screen by the scanning cathode ray, from spreading to neighboring elements of the screen and thereby reducing its efficiency of operation.

An object of the present invention is to provide an improved method of producing metal mesh screens of fine pitch.

A further object of the invention is to provide an improved method of forming a mosaic screen combined with a metal mesh screen for use as an electrode in an electron discharge device.

A still further object is to provide an improved mosaic screen and mounting therefor suitable for use in a cathode ray tube.

According to the present invention in one aspect, a method of forming a metal mesh screen includes the steps of forming an electrically conducting matrix having ribs corresponding to the finished screen, coating the ribbed surface of the matrix with a layer of electrically-insulating material, removing the parts of said layer that lie on the top of the ribs, depositing by electro-plating a layer of metal on the exposed tops of the ribs, and removing the remainder of the layer of insulating material and the matrix from the metal screen thus formed.

According to the invention in a further aspect, a method of forming a metal mesh screen includes the steps of forming a matrix having grooves corresponding to the finished screen, coating the matrix with a layer of metal, removing the metal coating from the tops of the portions of the matrix between the grooves, and thereafter removing the matrix from the metal screen thus formed. The matrix may be of electrically-conductive material, the metal coating being deposited by electro-plating.

The invention, in its first aspect hereinbefore set forth, will be further described with reference to the method of producing a mosaic screen described in British Patents Nos. 447,824 and 455,233. That method involved the following steps. Wire, which may be of tungsten 0.05 mm. in diameter, is coated with an insulating material, such as glass, to a diameter of say 0.07 to 0.09 mm. and cut into equal lengths. Two metal matrix plates are prepared each having two series of parallel grooves pitched at say 0.25 mm. and crossing each other at an angle—preferably 90 deg. One of these plates is relatively deep, the depth of the grooves being about 90 per cent of the diameter of the glass covered wire; in the other plate the grooves are correspondingly shallow. The deep plate is provided, by the method described in British Patent No. 455,233 referred to above, with gold cups of more or less rectangular section separated from each other and covering each of the projecting portions between adjacent grooves. The shallow plate has grooves which will register exactly with the grooves of the deep plate. The insulated wires are suitably fixed in the grooves in the two plates in such a way that, when the plates are juxtaposed face to face, the parallel wires in one plate are at right angles to the parallel wires in the other plate. The two plates, each loaded with its series of wires, are placed face to face in the predetermined register, and subjected to heat and pressure so that the glass is fused at each crossing point and reshaped in such a way as to hold the gold cups firmly in the interstices of the insulated mesh. The matrix plates are finally removed by an acid bath.

In adapting that method to the present invention, a matrix plate adapted for moulding an insulated mosaic screen may be prepared by a method involving the steps of forming an electrically-conducting negative matrix having ribs corresponding to the grid wires of the finished mosaic screen, coating the ribbed surface of the matrix with a layer of electrically-insulating material, removing the parts of said layer that lie on the top of the ribs, depositing by electroplating a layer of metal of the exposed tops of the ribs, removing the remainder of the layer of insulating material, depositing a positive matrix on said negative matrix and the metal mesh screen formed thereon, and removing said negative matrix. The positive matrix formed in this way is used to mold the insulating material of the mosaic screen so that the metal mesh screen adheres to the mosaic screen.

This last mentioned process will now be described in more detail with reference to Figs. 1 to 20 of the accompanying drawings, in which:

Figs. 1, 2, 4, 5, 6 and 7 are sectional side elevations of a part of a ribbed matrix in various stages of preparation;

Fig. 3 is a view from the under side of Fig. 4;

Fig. 8 is a sectional side elevation of a part of the prepared ribbed matrix with a positive matrix deposited thereon;

Fig. 9 is a sectional side elevation of a part of the positive matrix after the ribbed matrix has been removed;

Fig. 10*a* shows in section parts of two cooperating positive matrixes loaded with insulated wires;

Fig. 11 is a composite section showing parts of these two matrixes after pressing together to form a mosaic screen;

Fig. 12 is a view of part of a face of the mosaic screen as viewed from the under side of Fig. 13;

Fig. 13 is a section of part of the mosaic screen after the matrixes have been removed;

Figs. 14, 16 and 17 are sectional side elevations of portions of a matrix plate in various stages of preparation;

Fig. 15 is a view from the under side of Fig. 14;

Fig. 18 is a sectional side elevation of part of a metal mesh screen;

Fig. 19 is a view from the under side of Fig. 18; and

Fig. 20 shows an alternative stage of preparation of a matrix corresponding to that shown in Fig. 16.

The shallow negative (ribbed) matrix **30** (Fig. 1) is preferably of copper, produced from a wax original by electro-typing. It is provided with a series of parallel ribs **30*a*** disposed at right angles to similar ribs, one of which is visible and is denoted by **30*b***. The ribs in each series are preferably pitched at 0.25 mm. centre to centre. The matrix is completely coated with a layer **31** of asphalt varnish (Fig. 2) thick enough to cover the ribs. This coating is then scraped away until the tops of the ribs just appear as bright copper lines on a black ground. The matrix plate **30** is next carefully lapped until the exposed copper surface corresponds to the desired proportions of the metal mesh screen required to be formed. The matrix now appears as shown in Figs. 3 and 4. The plate is now chemically cleaned and placed in an electro-gilding bath until a deposit **32** (Fig. 5) of the desired thickness of gold is formed on the exposed tops of the copper ribs **30*a*** and **30*b***.

It is convenient to make a pair of plates at a time, and to solder the two plates together round their edges, when placed back to back, to obviate the necessity for applying a stopping coating to the parts not required to be plated. The asphalt is removed by boiling the plate in ether, which now appears as shown in Fig. 6. Next a thin film **33** of nickel is deposited over the copper and gold, completely covering both, as shown in Fig. 7, and on this is formed a relatively thick deposit **34** of silver (Fig. 8) which may be 0.08 mm. thick. The nickel and silver together form the positive matrix, the nickel serving to prevent diffusion of the gold and silver when the matrix is subsequently heated and pressed. The copper negative matrix **30** may now be removed by dissolving it in a suitable reagent. Alternatively, a pair of plates may be soldered at their edges face to face, and placed in a copper bath, the copper matrix **30** being removed by making the twin plates the anode. The positive matrix just described and shown in Fig. 9 is used with a deep matrix, prepared in the manner described in specification No. 11622/35 hereinbefore referred to, to mould the mosaic screen of insulated wire and to fix the metal mosaic elements in the mosaic.

Fig. 10*a* shows in section a portion of the shallow positive matrix plate just described and loaded with a series of glass insulated tungsten wires, one of which is visible being denoted by **35*a***. The glass insulation is denoted by **36**. Fig. 10 shows, juxtaposed to the shallow plate, a portion of the deep matrix plate **37** having a series of gold cups **38** and loaded with a series of glass insulated tungsten wires **35*b***.

The deep plate and the shallow plate, each loaded with its series of wires, after having been placed face to face in predetermined register, are clamped between heavy steel plates, soft sheet asbestos packing being interposed between the steel plates and the matrix plates. The whole assembly is then heated until the glass is soft. The plates are pressed together while still hot, so as to fuse the glass covering of the wires at each crossing point, to reshape the glass insulation to the desired substantially circular cross section, and to cause the gold mesh screen **32** to adhere firmly to the glass insulation. Fig. 11 is a composite section of the assembly after the two matrix plates have been pressed together. The section in the left-hand part of the figure is taken on a plane lying midway between grooves accommodating the wires **35*a***, while the section in the right-hand part of the figure is taken along a pair of these grooves.

When the assembly is cool, the clamping plates are separated and the packing is removed. The electro-types, which are now fused to the glass, are placed in nitric acid which dissolves the matrix plate **37** and the silver and nickel layers **34** and **33**, leaving the gold cups **38** locked in the interstices of the glass covered wire mesh, and the gold mesh screen **32** fused on to the insulation **36** (Figs. 12 and 13). The screen may be finally washed in sulphuric acid to remove the last traces of nickel.

Thus, according to the present invention in a further aspect, there is provided an improved mosaic screen which includes a mesh composed of wire coated with a fusible insulating material and held together by adhesion between the insulating coatings of the crossed wires, the insulating material supporting the separate electrically conductive mosaic elements and also supporting a continuous metal mesh screen which is thus insulated from the mesh wires and from the mosaic elements and which frames the individual mosaic elements.

If it is desired to produce a metal mesh screen by itself, the process hereinbefore described may be used as far as the step of removing the asphalt varnish (Fig. 6). Thereafter it is merely necessary to remove the copper matrix.

However, when a separate metal mesh screen is required, it may be preferred to use the method now to be described with reference to Figs. 14 to 20 of the accompanying drawings, which can be used to provide a mesh the elements of which are relatively deep or of channel section, and therefore stiffer for a given thickness than a flat mesh.

In this alternative process a positive electrotype **40** (Figs. 14 and 15) is used, which may be of copper, having crossed grooves **40***a* and **40***b* corresponding to the required mesh pattern. These grooves may have a pitch of 0.25 mm. and their section, instead of being U-shaped as shown, may be triangular or part-circular, or the grooves may have a flat bottom and outwardly inclined sides. It is desirable that these two series of grooves should have the same depth, otherwise the mesh will have a warp and a weft at different levels, which is undesirable when the mesh is to be enamelled.

The positive plate **40** is next plated on its grooved side with a suitable metal, for example, when the mesh screen is to be subsequently enamelled, it may be plated with nickel to a thickness of 0.08 mm., care being taken to render the deposit as firmly adherent as possible. When the desired thickness is obtained, the nickelled positive electrotype is removed from the plating bath and has the appearance shown in Fig. 16, where the nickel deposit is denoted by **41**.

The next process consists in the grinding or lapping of the nickeled surface of the positive electrotype in order to remove the nickel coating from its surface, while leaving the grooves **40***a* and **40***b* filled with nickel. As the nickel is lapped away, the first portion of the original copper to be exposed is the top of the squares produced by the grooving (Fig. 17). This process is continued until the surface of the copper electrotype appears as a chequered plane of square copper lands isolated by nickel lines of the desired width.

It is essential that care be taken during the grinding or lapping process to prevent nickel burrs of flash from extending into the copper lands. If these burrs are present, the final screen will present irregular meshes with consequent difficulties in enamelling. If correct abrasives are used, however, this trouble can be avoided.

If grooves of a triangular or semi-circular or other tapering cross section are used, the width of the nickel hands will be determined by the amount of grinding; if the plate is reduced in thickness, the width of the bands will be proportionally reduced, and thus an adjustment of size of aperture and wire thickness can be effected. The extent of grinding can be readily determined by suitable measuring microscopes. Alternatively, if the grooves are of U-section as shown, variation of grinding will not alter the relationship of the width of the nickel band to the size of the meshes.

If the copper electrotype **40** is completely removed, a nickel mesh screen will be left as shown in Figs. 18 and 19, where it is denoted by **41***a*; the shape and size of this screen corresponds with the grooving on the original positive. This mesh screen is perfectly flat and quite homogeneous, being formed by a uniform deposit of nickel. The cross section of the mesh wires is also the same as that of the grooves and in consequence, the screen can be made of great stiffness for a given weight of metal.

The nickel deposit may be so thin that it does not fill the grooves, as indicated at **41'** in Fig. 20, so that the mesh wires are of channel section. In this way a light and strong mesh can be made when necessary.

The copper may be conveniently removed by stopping off the ruled surface by a suitable resistive varnish, and making the copper electrotype the anode in a copper electrodeposition bath, any final copper being removed in a solution of ferric chloride or ammonium presulphate which have a negligible action on the nickel. The screen is now placed in a bath of nitric acid which by its solvent action removes the sharp edge produced by the grinding process. The removal of this edge is necessary to prevent cleavage at this point of the enamelled surface to be applied subsequently. The acid also slightly roughens the surface, thus assisting the adhesion of the enamel; care must however be taken to limit the action of the acid.

The screen may be mounted by superimposing two nickel wire rectangles of suitable size on each other with the screen between, and resistance welding the corners of the wire frames together. The corners of the screen may be cut off to allow the wire frames to be welded directly together at these points. Electrical connection between these wires and the screen, if required, may be ensured by welding the wire frame to the screen at a few points along the edge.

An alternative method of mounting is as follows. After the lapping and grinding are completed, the copper positive, which is at the stage represented in Fig. 17, is stopped off over its grooved face, a suitable width of margin being exposed. The stopping off may conveniently be done by sticking a thin rectangular sheet of ebonite or of the material known by the registered trade-mark "Paxolin" over the area to be stopped off with a cement which is not affected by the nickel solution. The positive is now placed in a nickel electrodeposition bath and the edge is plated until a frame is produced which is thick enough to support the screen when the copper is finally removed as previously described. Supporting wires may be welded on to the screen, which is now ready for the enamelling process. A similar process is obviously also applicable to a screen made by the method described with reference to Figs. 1 to 6.

Before a vitreous enamel is applied to a metal surface, it is desirable to form an oxide film thereon. This film may be readily produced by heating the screen, in an atmosphere containing oxygen, long enough to produce a deep blue colour on the bright nickel. It is of course essential that the screen should be quite free from grease, and such cleaning may be accomplished by the use of an electrolytic cleaning bath.

The enamels may be of standard commercial manufacture. These are insufficiently fine when received from the suppliers, and are therefore reground in a ball mill until satisfactory. The enamel is now mixed with additional water, and a suspension of very small particles is obtained by the usual decantation methods. This suspension is sprayed on to the screen, by a spraying gun (such as that known by the registered trade mark "Aerograph") fed with nitrogen at about

50 lbs. per sq. in. pressure, and the coating is dried, its thickness being measured by microscope prior to firing.

Any convenient furnace may be used, provided accurate temperature control is possible. Electric radiation furnaces are preferred. The enamel on fusion covers the screen, provided the oxidation is complete, except for small pits or bare places which may be present here and there. A second coating may then be applied, which usually covers these, thus completing the coating.

It has been found that a light copper deposit on the nickel greatly facilitates complete covering, the copper being thermally oxidized prior to enamelling. Where, however, it is important to maintain the electrically insulating properties of the enamel, this copper coating should be very thin. The enamel coating may be fused in a vacuum in order to eliminate small gas bubbles.

Screens produced by the process described with reference to Figs. 14 to 20 may be used for a variety of purposes. For example, in the production of blocks for photographic reproduction of pictures, etc., in the printing industry, use is made of fine-mesh screens commonly produced by a photo-etching process. Such screens have certain inherent faults due firstly to the irregularity of the action of light on the sensitive coating which has to be rendered insoluble by these means. It is very difficult to prevent some scattering of the light, and in consequence the edges of the mesh, when the unaffected portions are dissolved away, are somewhat rugged. These uneven edges of the mesh are further accentuated by the etching process, since the action of the acid naturally is itself irregular within fine limits.

In the present process, owing to the support given to the nickel mesh by the copper matrix during the lapping, such ruggedness does not occur, the nickel bounding the spaces being quite straight and true.

A further use of such screens is for classifying granular materials by sieving processes. In good quality wire cloth, as used for this work, wide variations of size necessarily occur, and in consequence particles considerably exceeding the nominal size may pass the mesh, or alternatively the process of sieving may be retarded, as only a portion of the mesh is actually used. In addition, the present invention enables such screens to be made very much stronger than is possible with woven wire, because the depth of the members forming the mesh may be several times their width in the plane of the mesh, so that these members virtually form a flat bar "edge on" to the load.

It is sometimes desirable to provide in cathode ray tubes an open mesh screen of metal that does not oxidize readily and to mount this screen near to but spaced from another electrode, for example a mosaic screen.

The process hereinbefore described with reference to Figs. 14 to 20 may be employed in the production of such a screen, a gold plating process being substituted for the nickel plating. The copper matrix may be removed, after the lapping operation is completed, by placing the composite plate in nitric acid.

As the gold screen formed in this way is relatively fragile, it is desirable to attach it to a mounting frame before the backing of the matrix metal has been entirely removed. Thus the copper matrix may be dissolved away until its thickness is about 0.06 mm. The composite plate is then washed and dried and its gold side is electrically welded by the resistance method to a metal frame, of for example nickel wire 1.5 mm. in diameter, and shaped to enclose the mesh area. The frame may be provided with glass bead insulation by which it can subsequently be joined to a mosaic screen or other apparatus. The frame and gold screen are then immersed in the nitric acid bath until all the copper is dissolved; since the copper backing is thin, the reduction in size of the nickel due to the acid is unimportant.

As an alternative method of mounting, the nickel frame may be welded to the gold mesh before the copper matrix has been removed, or after the matrix has been partly reduced in thickness. A coating of asphalt varnish is then applied to the whole of the surface of the grid area and to the copper backing. The assembly of composite plate and frame is then placed in a gold plating bath and an acid-resisting coating is applied to the frame and welds. The asphalt is next removed by boiling in ether, and the assembly is finally transferred to the nitric acid bath, where all the copper is removed without damage to the frame.

A further alternative method of removing the copper matrix, which can be used in the manufacture of screens of either nickel or gold, is to place the matrix, with the screen formed therein, and if desired having a nickel frame secured to the screen, in a solution of ammonium persulphate (approximately 20 per cent. at 25° C.). This solution has but a slight solvent effect on nickel.

Having now described my invention, what I claim as new and novel is:

1. The method of forming a metal mesh screen which includes the steps of forming an electrically-conductive matrix having ribs corresponding to the finished screen, coating the ribbed surface of the matrix with a layer of electrically-insulating material, removing the parts of said layer that lie on the top of the ribs, depositing by electro-plating a layer of metal on the exposed tops of the ribs, and removing the remainder of the layer of insulating material and the matrix from the metal screen thus formed.

2. The method of forming a metal mesh screen which includes the steps of forming a matrix having grooves corresponding to the finished screen, coating the matrix with a layer of metal, removing the metal coating from the tops of the portions of the matrix between the grooves, and thereafter removing the matrix from the metal screen thus formed.

3. The method of forming a metal mesh screen which includes the steps of forming an electrically conductive matrix having grooves corresponding to the finished screen, electrically depositing upon the matrix a layer of metal, controlling the deposition of metal to only partly fill the grooves, removing the metal coating from the tops of the portions of the matrix between the grooves, and thereafter removing the matrix from the metal screen thus formed.

4. The method of forming a metal mesh screen which includes the steps of forming a copper matrix having grooves corresponding to the finished screen, electrically depositing upon the matrix a layer of gold, controlling the deposition of gold to only partly fill the grooves, removing the deposited gold from the tops of the portions of the matrix between the grooves, and remov-

ing the matrix from the gold mesh screen by immersion in an ammonium persulphate solution.

5. The method of forming a metal mesh screen which includes the steps of forming a copper matrix having grooves corresponding to the finished screen, electrically depositing upon the matrix a layer of nickel, controlling the deposition of nickel to only partly fill the grooves, removing the deposited nickel from the tops of the portions of the matrix between the grooves, and removing the matrix from the nickel mesh screen by immersion in an ammonium persulphate solution.

6. A method of forming a metal mesh screen as claimed in claim 2 and comprising in addition, the step of affixing a peripheral supporting frame to the screen before removing the matrix.

7. The method as claimed in claim 2, which comprises in addition, the steps of stopping off the matrix and the mesh screen deposited thereon to leave only a border portion exposed, and depositing a supporting frame by electroplating on this exposed border portion before removing the matrix.

8. The method as claimed in claim 2, which comprises in addition, the steps of partly removing the matrix plate by etching, and subsequently attaching a relatively thick supporting frame to the mesh screen before removing the remainder of the matrix plate.

9. The method as claimed in claim 5 which comprises in addition, the step of lightly etching the nickel screen in nitric acid for the purpose of eliminating sharp edges thereon.

10. The method claimed in claim 2 and comprising the additional steps of coating the formed screen with enamel and subsequently fusing the enamel in a vacuum.

11. The method claimed in claim 5 and comprising the additional steps of depositing a thin coating of copper over the nickel screen, thermally oxidizing the coating of copper, coating the oxidized screen with enamel, and fusing the enamel in a vacuum.

12. The method of preparing a matrix plate for moulding an insulated mosaic screen, which includes the steps of forming an electrically-conductive negative matrix having ribs corresponding to the grid wires of the finished mosaic screen, coating the ribbed surface of the matrix with a layer of electrically-insulating material, removing the parts of said layer that lie on the top of the ribs, depositing by electro-plating a layer of metal on the exposed tops of the ribs, removing the remainder of the layer of insulating material, depositing a positive matrix on said negative matrix and the metal mesh screen formed thereon, and removing said negative matrix.

13. The method of forming a metal mesh screen which includes the steps of forming an electrically conductive matrix having intersecting grooves corresponding to the mesh of the finished screen, electro-plating the matrix with a layer of metal, removing the electro-plated metal from the tops of the portions of the matrix between the grooves, and thereafter removing the matrix from the metal screen thus formed.

14. The method of forming an acid resisting metal mesh screen which comprises the steps of forming an acid soluble metal matrix having grooves corresponding to the mesh of the finished screen, coating the matrix with a layer of metal, removing the metal coating from the tops of the portions of the matrix between the grooves, affixing a supporting frame to the mesh screen thus formed, stopping off the matrix and at least the middle part of the mesh screen, plating the stopped off assembly with an acid resisting metal, removing the stopping, and dissolving the matrix in an acid bath.

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