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## ELECTRON MULTIPLIER MOSAICS

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This invention relates to electron multipliers in general and to devices for amplifying electron images received from a photocathode in particular.

In 1936, Mr. George Weiss, in the Journal for Technical Physics (German), vol. 12, pages 623-629, described an electron-multiplier comprising a photocathode spaced from and parallel to a phosphor plate anode with a series of planar metal mesh screens mounted between the cathode and the phosphor plate. The metal mesh screens were coated with secondary-emissive material and successively increasing potentials were applied to the screens in an attempt to obtain multiplication of the electrons originating at the photocathode. Attempts to use this multiplier for electron-image multiplication have failed largely because the electrons would move between successive meshes with considerable lateral spreading and hence would lose the resolution of the image. Another serious difficulty encountered consisted in the difficulty of applying uniform and efficient secondary emitting surfaces to the closely spaced mesh screens, since at that time the only efficient secondary emitters available were caesium-silver type layers which had to be formed by evaporation in vacuum through the pack of fine-mesh screens.

This invention contemplates the use of two new tools. First, glass may now be processed by acid etching to produce a thin glass plate with closely spaced well defined cylindrical openings through the plate of diameters of the order of .001" and 300 to 500 holes per linear inch. Mr. S. D. Stookey, in "Industrial and Engineering Chemistry, pages 115-118, January 1953, describes a silicate glass as containing ingredients that are capable of forming permanent photographic images in the otherwise clear glass when subjected to the excessive action of X-ray or ultraviolet radiation and heat treatment. When the glass contains trace quantities of gold, silver or copper metal particles, a three-dimensional crystallized pattern can be developed to distinguish the irradiated glass from the non-irradiated portions so that the glass may be selectively dissolved in a dilute hydrofluoric acid. The fineness of detail described by Stookey appears to be limited primarily by the resolving power of photographic negative employed for masking the glass during irradiation. When thin plates are exposed to collimated X-rays or ultraviolet rays, truncated conical holes .001 inch in diameter at the small end may be made 300 to 500 holes per linear inch.

The second important tool contemplated by this invention is the development of air-stable secondary emitters of high yield including silver-magnesium alloys which permit the forming of secondary emitter electrodes individually in air. Screens may thus be separately sensitized and assembled in a compact pack without loss of secondary emission.

According to this invention, photo-glass screens are made from a master mask, such as a photographic negative in the manner described by Stookey, to provide sheets with the requisite number of holes for good picture

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resolution. The interior of the holes is then sensitized with an air-stable silver-magnesium alloy and a pack of the screens are mounted side-by-side with the microscopic holes accurately aligned between a photocathode and a phosphor anode.

The object of this invention is an improved electron multiplier.

A more specific object of this invention is an improved amplifier for electron images received from a photocathode in which the resolution of the image is faithfully preserved.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a sectional view of two mesh screens, greatly enlarged, according to this invention;

Fig. 2 is a sectional view of an image multiplier embodying this invention; and

Fig. 3 is an enlarged sectional view of a portion of the mesh screens of Fig. 2.

In Fig. 1, two photo-glass screens 10 and 11 of thickness T and spacing S are mounted side-by-side with the holes 20 of diameter D aligned. Conductive metal coatings 12 and 13 are respectively applied to at least one surface of each of the two screens intermediate holes 20 thereby leaving the holes open and the walls thereof uncoated. Potentials are applied to the metal coatings to produce electrostatic fields represented by equipotential lines 14 in the space between the screens and in the holes. The interior surfaces of the holes are coated with a film 15 of particles of air-stable materials which will yield secondary emission, such as silver magnesium alloy or magnesium oxide coats produced by evaporation of magnesium in an oxygen atmosphere. It is not difficult to obtain secondary-to-primary electron ratios as high as 10. A primary source of electrons, which may be a photocathode, not shown, is placed above the screen 10, and a high potential anode is disposed below screen 11. An assembly of screens 10-11 may include any desired number, as shown in Fig. 2. Further, it is contemplated that the potentials between the metal layers 12 and 13 on the faces of the screens are sufficiently high to move electrons originating at one screen to the next. Bleeder resistors connected across a high voltage source between the photocathode and anode are intended, after the usual method of energizing high voltage accelerating electrodes in cathode ray tubes. In response to bombardment along the interior wall of each hole, secondary electrons, a, b, c, d and e will be emitted. Electron "a" will travel axially of the holes with little or no radial velocity and will miss screen 11 and produce no secondary electrons at screen 11. Electrons "b" and "c," dependent upon their point of origin on the side of the hole, will travel to spaced points on the aligned hole in screen 11. Other electrons "d" will escape from the focusing action of the electrostatic fields in the ends of the holes and will move out of the desired channel. Still other electrons "e," finding a decelerating field, will return to the surface from which they originated. It will now appear that the potentials on metal layers 12 and 13 and the spacing S between the screens may be adjusted to give the desired curvatures to the electrostatic equipotential lines to focus the electrons from one hole into the aligned hole in the next adjacent screen, and the number of electrons "d" which will cause loss of resolution can be minimized.

According to another and preferred embodiment of this invention, the space S between the screens may be filled with an insulating material which will prevent the escape

of all electrons "d" from its channel. Referring to Fig. 3, the screens 10 and 11 are clamped face-to-face with metal coatings 12a and 13a sandwiched therebetween, the metal plates being connected to successively positively increasing potentials, as in Fig. 2. The inner surface of the holes of each channel is coated with a secondary emissive film 15 and has high electrical resistance. Thus, the potential in each channel will increase uniformly from the upper to the lower end and electrons released from the wall of the channel will be accelerated by the uniform gradient E toward the lower end of the channel. The impact of a primary photo-electron at a point P near the upper end of the channel releases secondary electrons with a velocity  $V_0$ . This velocity may of course be resolved into its axial and radial components and it will be seen that the average electron may be accelerated from one screen section of the channel to the next by proper adjustment of the gradient E to produce a net gain in the secondary emission in each screen. Since the electrons cannot escape from their channels, the resolution of the system is limited only by the collimation of the electrons at the inlet and outlet ends of the channels. Because of the limited heat dissipation capacity of the sandwiched screens, the resistance of the emitter coatings 15 in the holes must of necessity be kept high.

Because the holes are dissolved in the glass screens, the holes will be slightly conical in shape. However, the taper of the holes is relatively small in thin sheets because of the extreme difference in solubility of the crystallized portions of the glass compared to the clear glass. The hole diameter can be decreased as long as the gradient E along the hole can be increased without voltage breakdown along the channels.

The screen assembly with the holes forming a mosaic may be clamped and mounted in an envelope as shown in Fig. 2. The assembly, 20a, is supported as by brackets 21 on the wall of the envelope and the photocathode may comprise the usual caesioted layer 22, on an end wall of the envelope. The phosphor plate 23, of Willemite or other materials which will luminesce when bombarded with electrons, is placed on the envelope wall opposite the photocathode. Each incremental area on the surface of the cathode can "see" a corresponding discrete incremental area on the phosphor plate. An optical image focused upon the photocathode 22 will produce an electron image, the electrons of which may be

accelerated and focused by conventional means not shown and directed into the holes in the mosaic screen. The various accelerating potentials between the cathode 22, mosaic metal plates 12a, 13a and phosphor plate 23 is conveniently supplied by the bleeder resistor 24 connected across high voltage source 25. Potential differences between plates 12a and 13a for spacings of .002 to .01 inch should be about 200 to 500 volts.

The interior surfaces of the holes may be sensitized with a coating of silver-magnesium alloy or magnesium oxide.

While the principles of the invention have been described in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. For use in an image tube having spaced planar photocathode and phosphor display elements, an electron multiplier comprising: a unitary laminated assembly of abutting sheets, alternate sheets being formed of insulating material and conductive material; each of said sheets having a plurality of holes extending therethrough from one surface to the other with the holes in each sheet being respectively in registry with the holes in every other sheet, each of said holes having its axis perpendicular to the planes of said sheets and of said photocathode and phosphor elements so that each of said holes directly communicates between said photocathode and phosphor elements; each of said insulating material sheets having the entire interior wall of each of the holes extending therethrough completely coated with secondary emissive material.

2. The combination of claim 1 in which said insulating material sheets are formed of glass.

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