This invention relates to improvements in phototubes and to a method of treating phototubes, particularly to differential heating steps in stabilizing photomultiplier tubes.

Photomultiplier tubes are phototubes comprising electron multipliers, which operate to multiply within the tube the number of electrons emitted by a photosensitive cathode within the tube. This operation depends on the characteristic ease with which electrons may be freed from certain materials, such as cesium antimony and silver magnesium. The former is used primarily as a photo-emissive material, while both may be used as a secondary-emissive material which coats the surfaces of electrodes, or dynodes, in the electron multiplier section of photomultiplier tubes.

It is known that a cesium antimony coating has a higher ratio of freed electrons to impinging electrons (the multiplication ratio, or gain) over the corresponding ratio of dynodes coated with silver magnesium when used as the secondary-emissive coating of a dynode. However, this improvement in gain is obtained at the expense of stability since the gain of silver magnesium dynodes is substantially constant over the life of the tube while the gain of a cesium antimony dynode decreases appreciably as the tube ages. Furthermore, the deleterious leakage current of cesium antimony dynode structures is greater than the leakage current of silver magnesium dynode structures by a factor of as much as to 500:1. However, it is preferable to use cesium antimony as a photo-emissive material. Unfortunately though, when the desirable cesium antimony photo-emissive surface is formed by vaporizing cesium, the material also condenses on the silver magnesium secondary emissive layer of the dynode, thus adversely affecting their secondary emission characteristics. The present invention provides a method of increasing the gain of silver magnesium dynode structures without impairing the stability thereof. Broadly, this method consists in heating the dynode structure of such tubes to a temperature higher than the tube walls so as to evaporate from the dynode surfaces the cesium, which acts as a deleterious impurity. In addition to improving the gain of each dynode, this differential heating process increases the sensitivity of the photocathode because the cesium which is an undesirable impurity on the dynode surface is just the reverse on the photocathode, and by cooling as much as possible the portion of the tube wall on which the photocathode is located, the material evaporated from the dynode condenses on the relatively cool photocathode and improves its operation.

One object of this invention is to provide an improved phototube. Other objects are to provide a photomultiplier tube using stable silver magnesium dynodes, and to provide a method for increasing the gain and cathode sensitivity of such tubes. Other objects will be apparent from the following specification together with the drawings in which:

Fig. 1 is a side view of a phototube with parts, such as the glass wall, broken away to show the dynodes there within and certain of the dynodes also broken away to show the interior thereof, together with a heating coil wound about the envelope of the tube as used in one step during manufacture of the tube; and

Fig. 2 is a side view of the phototube, again with parts of the glass wall broken away to reveal the interior thereof, the view being at a different angle from that of Fig. 1, together with modified or alternative heating elements adjacent the envelope.

The invention is not limited by mechanical features of the phototube but is directed toward chemical or physical aspects of materials used therein.

After the bulb 11 has been evacuated a coil 33 (or a pair of such coils) is brought into position adjacent the wall of the bulb in a region near receptacles 31 and 32 and radio-frequency energy is supplied to the coil to heat the receptacles and thereby volatilize the cesium pellets so as to fill the bulb 11 with cesium vapor. This vapor reacts with the previously deposited antimony on the face-plate portion of the bulb to form the second layer of the photocathode 13. It is only to form this required cesium antimony photo-emissive second layer that the cesium vapor is introduced into the tube. Unfortunately, the vapor condenses not only on the photocathode area but also on the dynode structure 14 and on the silver magnesium coated surfaces of the dynodes. For instance, in Fig. 1 droplets 34 of cesium are shown on the silver magnesium layer 36 as a result of condensation. Similar cesium droplets collect on corresponding surfaces of other dynodes, where their presence adversely affects operation. These droplets are not removed by baking the phototube in an oven because heating merely re-evaporates the cesium droplets (both those shown as having condensed on the dynode surface as well as the relatively innocuous droplets 37 which have collected on the inner wall of bulb 11) and, when the phototube has cooled, droplets of cesium again condense on the silver magnesium surfaces of the dynode structure 14.

In order to remove the droplets 34 from the dynode structure and prevent their returning, the present invention includes the step of heating the phototube differentially to create more heat on the dynode structure 14 than on the wall of bulb 11. The cesium droplets 34 then evaporate and condense out on the cooler wall of bulb 11 or, preferably on the photocathode layer 13.

Any droplets 34 which may condense on the wall of bulb 11 will not have a deleterious effect on the gain of
the dynodes 16—25; and any droplets which condense on the photocathode 13 add more cesium thereon and sensi-
tize.

This differential heating may be improved by cooling the faceplate 12 as much as possible so that there is a
greater tendency for the cesium to condense on the photo-
cathode 13 than on other parts of the wall of bulb 11.

The differential heating may be carried out by induc-
tion heating from radio-frequency energy supplied to a
coil 38 surrounding the phototube, or by heating the coil
38 by electrical direct current and heating the dynode
structure 14 by infra-red radiations. In either case, the
metallic dynode structure 14 is heated more than the glass
wall of bulb 11.

Another alternative is shown in Fig. 2 where an infra-
red lamp 39 is shown to provide heat to the dynode
structure 14. An air blast may be used to cool
the faceplate 12, and following the differential heating
process, the tube may be baked sufficiently to fix the
cesium in position wherever it may have condensed.

By this improved heating process it is common to in-
crease the overall gain of the dynode structure by a factor
of three; from a gain of about 80,000 times to a gain of
about 250,000 times. Simultaneously, and as a desirable
byproduct, the sensitivity of photocathode 13 may be
raised from 40 microamperes per lumen to 55 micro-
amperes per lumen, which is equivalent to raising the
overall output of the tube by a factor of more than 3:1.
It may be necessary to repeat the differential heating pro-
cess more than once to achieve the gain and photocathode
sensitivity of which the phototube is capable.

Although this invention has been described with refer-
ce to a specific embodiment, others will be apparent to
those skilled in the art and the method may be used in
the manufacture of other electron discharge devices.

What is claimed is:

1. In the manufacture of a phototube comprising a bulb
having a glass wall, a silver magnesium dynode structure,
and a source of cesium, the method consisting in the steps
of heating said source to create cesium vapor within said
bulb; heating said dynode structure to a temperature
greater than that of the wall of said bulb whereby cesium
on said dynode structure is evaporated and condensed on
said wall.

2. In the manufacture of a phototube comprising a bulb
having a glass wall, a photocathode layer on a portion of
the wall, a silver magnesium dynode structure, and a
source of cesium, the method consisting in the steps of
heating said source to create cesium vapor within said
bulb; cooling said photocathode layer; differentially heating
said phototube to allow said vapor to settle on said photocathode layer, and differentially heating said phototube so that said dynode structure is at a tem-
perature greater than that of the wall of said bulb where-

by cesium which has settled on said dynode structure is
evaporated and condensed on said wall.

3. In the manufacture of a photomultiplier tube com-
prising a bulb having a glass wall, a photocathode layer
on a portion of the wall, a silver magnesium dynode struc-
ture, and a source of cesium, the method consisting in the
steps of heating said source to create cesium vapor within
said bulb; cooling said phototube to allow said vapor to settle on said photocathode layer; differentially heating said phototube so that said dynode structure is at a tem-
perature greater than that of the wall of said bulb whereby
cesium which has settled on said dynode structure is evap-
orated again; and maintaining the temperature of said
silk photocathode layer relatively cool to keep the cesium
evaporated from said dynode structure to condense on
said photocathode layer.

4. In the manufacture of a photomultiplier tube com-
prising a bulb having a glass wall, a combined photo-
cathode layer composed of manganese layer on a portion
of the wall of said bulb and a cesium antimony layer on
said manganese layer, a dynode structure having silver
magnesium photomultiplier surfaces and a cesium pellet
attached to said dynode structure, the method consisting
in the steps of heating said pellet to create cesium vapor
within said bulb; forcing said vapor to settle on said
photocathode layer; differentially heating said phototube
so that said dynode structure is at a temperature greater
than that of the wall of said bulb whereby cesium which
has settled on said dynode structure is evaporated again;
and maintaining the temperature of said photocathode
layer relatively cool to allow the cesium evaporated from
said dynode structure to settle on said photocathode layer;
and baking said phototube to stabilize said cesium.

5. In the process of manufacturing photomultiplier
tubes having silver magnesium secondary emissive surfaces
on the dynodes and a cesium antimony photo-emissive
surface on the faceplate, and including the step of vaporiz-
ing cesium to form the photo-emissive surface whereby
some cesium inadvertently condenses on the silver mag-
nesium dynode surfaces and adversely affects the opera-
tion thereof, the improvement comprising the additional
step of heating said dynodes to a temperature high enough
to evaporate said cesium from said dynodes while simul-
aneously cooling said faceplate to encourage said evap-
orated cesium to condense thereon.

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