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M. M. WACHTEL

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ELECTRON DISCHARGE TUBE STRUCTURE

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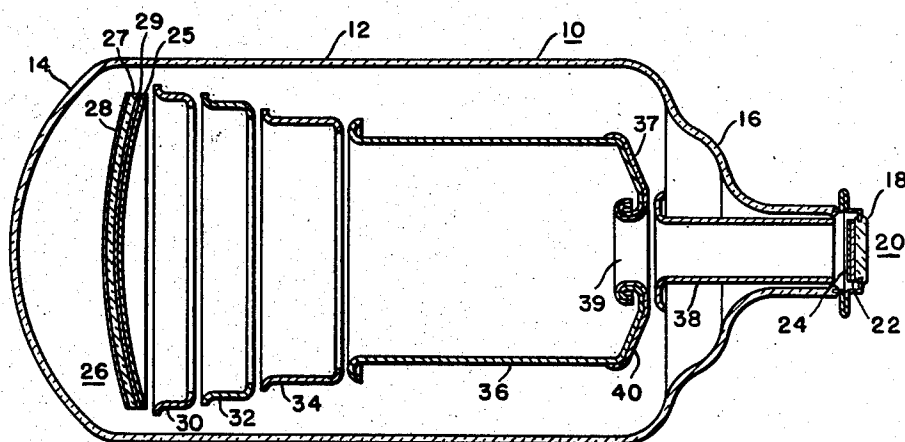


Fig. 1.



Fig. 2.

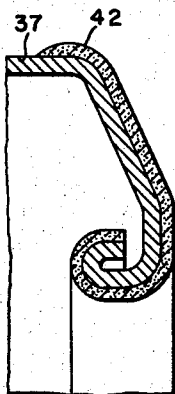


Fig. 3.



Fig. 4.

WITNESSES

Wm. B. Sellers.
Charles F. Ring

INVENTOR

Milton M. Wachtel.

BY

F. E. Snowden
ATTORNEY

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2,879,406

ELECTRON DISCHARGE TUBE STRUCTURE

Milton M. Wachtel, McKeesport, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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4 Claims. (Cl. 250—213)

This invention relates to electron discharge devices and more particularly to structures and methods to reduce field emission from high voltage elements therein. One use of such structures is in image intensifiers of the type described in Mason and Coltman, U.S. Patent 2,523,132 for an X-ray image intensifier. In that arrangement X-rays transmitted through an observed object generate a light image in a fluorescent layer which is positioned in close contiguity to a photoelectric layer and the electron image resulting from the latter is accelerated into impact upon an electron phosphor output screen by means of high voltage electrode lens system to produce an image of highly intensified brightness compared with the original light image. Thus an observer may see on the output screen an accurate reproduction of the X-ray image of the object viewed, enhanced in brightness over a hundredfold.

The amplification and intensity of the output of such image devices is dependent on the acceleration given to the electrons by the electron lens system positioned between the input and the output screen. It has been found in practical embodiments of the device described in the above mentioned patent that the maximum voltages useable for accelerating the electrons is limited by the field emission between members of the electron lens system. The field emission results in spurious electron bombardment of the output screen which gives undesirable background light output.

It is an object of my invention to provide an improved surface to reduce the field emission therefrom.

It is another object to provide a method of reducing the field emission from an irregular surface to increase operating potentials.

It is another object to provide an improved electrode structure for use within high voltage type tubes to increase the operating potentials on such structures.

It is another object to provide an improved surface for elements within an electron lens system such as utilized in an image intensifier to reduce the field emission from the surfaces thereof.

These and other objects are affected by my invention as will be apparent from the following description taken in accordance with the accompanying drawing throughout which like reference characters indicate like parts, and in which:

Figure 1 is a cross-sectional view of a schematic-type showing of an image intensifier embodying the principles of my invention;

Fig. 2 is a detailed view in cross section of the structure of an element of the electron lens system illustrated in Fig. 1;

Fig. 3 is a detailed view showing of another possible modification of an element of the electron lens system illustrated in Fig. 1; and

Fig. 4 is a detailed view of another possible modification of an element of the electron lens system illustrated in Fig. 1.

Referring in detail to Fig. 1 an image intensifier is il-

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lustrated and is comprised of a vacuum tight glass envelope 10 comprised of a cylindrical portion 12 closed at one end by an input face plate 14 and closed at the other end by a tapered neck portion 16 and output window 18. The cylindrical portion 12 is sealed to the neck portion 16 by any suitable means such as welded flanges. Positioned at the end of the restricted portion 16 of the envelope 10 is an output screen 20 which is supported by the glass diaphragm 18. The output screen 20 consists of a phosphor coating 22 such as zinc cadmium sulphide deposited on the interior surface of the support 18 with a thin layer 24 of aluminum deposited on the exposed surface of coating 22. A more complete description of such output screens is described in W. J. Hushley and W. M. Siebert, U.S. Patent 2,533,809, issued December 12, 1950.

Positioned at the opposite end of the envelope 10 is an input screen 26 which is comprised of a thin support member 27 of glass covered on outer side with a phosphor layer 28 of a material such as zinc sulphide. The opposite side of the glass support member 27 is coated with a conductive coating 29 such as tin oxide on which a photo-surface layer 25 of a material such as cesium antimonide is deposited.

A plurality of conductive cylinders 30, 32, 34, 36 and 38 of progressively increasing length and progressively decreasing diameter extend from the input screen 26 longitudinally along the envelope 10 to the output screen 20. The first of these cylinders 30 is insulated from the input screen 26 and each of the other cylinders 32, 34, 36 and 38 is insulated from succeeding and preceding cylinders. Potentials of different magnitude are impressed on the cylinders from a suitable voltage divider system and lead-ins (not shown). The cylinders 30, 32, 34, 36 and 38 function as the electron optical lens system for the electron image emitted by the photo-sensitive surface of the input screen 26 and focused on the output screen 20.

The photo-sensitive layer 25 on the input screen 26 is deposited after the entire tube structure has been assembled and made essentially vacuum tight. This is accomplished by moving an antimony boat by known means through an exhaust port into position near the input screen 26 and heating the boat so that the antimony vapor condenses in a thin layer over the inner surface of the input screen. After the antimony layer is deposited, a cesium container may then be moved into position near the input screen 26 and the antimony layer activated by the evaporating cesium material thereon and thereby form the cesium antimonide layer 25. It has not been found practical to remove all the excess cesium from the envelope 10 and it is believed that this excess cesium is one of the primary causes of field emission from the electron lens system of the tube.

In the image intensifier this field emission may develop between electrodes when the potential difference is of the order of 10,000 volts. This results in a faulty tube that must be rejected. In the specific embodiment shown in Fig. 1, the voltage applied between electrodes of the lens system is of the order of 1,000 volts with the exception of the voltage difference between electrodes 36 and 38. The voltage difference should be of the order of 25,000 volts between electrodes 36 and 38 for minimum acceptable output brightness.

The end of the cylindrical portion of electrode 36 adjacent to the electrode 38 has a bottoming plate member 37 thereon with a central aperture 39 therein through which the electrons pass. The portion of the bottoming plate member 37 surrounding the aperture 39 is adjacent to the electrode 38 and the spacing is of the order of .125 inch. It is the adjacent areas of the electrode 38 and electrode 36 where the highest potential field is

applied and it is in this area that field emission is most likely to occur. It is therefore this area that should be so constructed as to reduce or prevent field emission. It may be desirable to treat the auxiliary lenses in a similar manner as well, since these may also be a source of emission. It has also been found that in a tube in which cesium has been utilized to make a photo-surface, field emission will be further enhanced by the presence of the adsorbed cesium. The cesium, like other free alkali and alkaline earth metals, lowers the work function of the electrode surface. Since the work function of the electrode surface is lowered, the field emission from the base material is enhanced.

In the image intensifiers described above, the electrodes are made of an alloy of iron, chrome and nickel, which is known by the trade mark of Inconel. This material is selected because of the fact that it is non-magnetic, relatively easy to degas and is suitable for electropolishing techniques. It has been found, however, that electropolished Inconel sometimes does not provide a suitable field emission voltage threshold surface for the voltages required within the image intensifier.

It is found that as a result of electropolishing certain materials, projections develop on the surface of the polished material. These projections have their origin in foreign particles or inclusions which are defined for purposes of this explanation as a particle of suspended material in a solid alloy or metal. These inclusions are generally of three main classes; oxides, sulfides and silicates. It is found in electropolishing that these inclusions are not soluble or are only partly soluble in the solutions used. Other types of projections due to the inherent roughness of the Inconel surface may not be removed because of faulty electropolishing techniques. Whatever the origin of these projections, they will have greatly enhanced field strengths surrounding them in comparison to the gross applied field between the two electrodes. Such enhancement is due to the very small size of the projections. Since field emission is dependent on field strength, such projections having high field strengths will experience field emission. Such emission takes place at gross applied fields in which ideally smooth metals should theoretically not field emit.

By placing a suitably smooth glass or vitreous enamel coating 40 having the correct coefficient of expansion upon the lower potential plate 37 of the electrode 36, as illustrated in Fig. 2 to cover the field emissive portion of the electrode 36, a substantial increase in the field emission voltage threshold may be obtained. This glass coating may be applied by any suitable method such as described in a book entitled "Enamels" by A. I. Andrews (chs. 4, 10, 11) and published by Twin City Printing Company of Champaign, Illinois, in 1935. With proper care this process usually results in a surface which is quite smooth and free of projections and which is described as a fire polished surface. If any projections do remain, the coating may then be mechanically polished and refined to obtain the required projection-free surface. The term fire-polished as used in this application is understood to denote a surface which is substantially free of any edges or projections sharp enough to give rise to field emission.

It may actually not be necessary to make such a glass or enamel coating smooth. This is based on the fact that such materials are insulators. Being insulators, their resistance is very high (of the order of 10^{12} ohm-cm.). For example, assume that a projection or irregularity on the insulator surface develops a localized field high enough to cause it to emit. After the projection has emitted a relatively small number of electrons, it becomes positively charged. If it charges up to a high enough positive voltage, the electric field around it will decrease to such an extent that the emission will be reduced to such a low level that it will not interfere with the operation of the device.

The coating applied on the metal electrode support must be of sufficient thickness to entirely cover all projections that might be found on the surface. It is desirable that the glass coating have a thickness of the order of .004 inch in order to prevent field emission from the metallic base through the glass coating.

It may be desirable in some applications to provide a substantially semiconductive smooth glass or vitreous enamel coating 42 as shown in Fig. 3 by loading the glass material with certain materials such as metallic silver and applying it in the same manner as above.

In Fig. 4 a third structure is illustrated in which a smooth glass insulating coating 44 is applied in a manner previously described on the metallic electrode support 37 and then a metallic film 46 is deposited on the glass coating 44 by evaporation or other techniques making electrical contact with the metallic support electrode 37. A suitable metallic coating may be of a material such as silver which has a low vapor pressure.

Still another method of producing a conducting or semiconducting surface on the glass coating is to incorporate silver oxide (Ag_2O) into the glass during the application of the glass coating. On exposing such a material to reducing agents such as ultraviolet light, X-rays or cathode rays in the presence of water vapor, a metallic silver layer develops on the surface of the glass material. This method is described by an article entitled The Spontaneous Growth of Silver Films on Glasses of High Silver Content, by G. E. Rindone, and published in the Transactions of the Society of Glass Technology, volume 37, pages 124-128, 1953. The degree of conductivity may be controlled by the amount of Ag_2O used and the length of exposure to the reducing agent. Suitable electrical content can then be made between this conducting coating and the base metallic side of electrode 36.

In tests conducted with a structure of Inconel of given geometry, the uncoated structure suffered field emission at voltages as low as 14 kilovolts or a gross field strength of 84,000 volts/cm. in the presence of cesium. It was then found that with the same structure but coated with a vitreous enamel surface, that at voltages of 35 kilovolts or a gross field of 210,000 volts/cm. in or out of the presence of cesium, that the electrode did not show any field emission. This was true with both non-conducting and conducting glass enamel coatings.

It should further be pointed out that there is no reason to think that the upper limit or threshold is 210,000 volts per cm. Experimental circumstances made it necessary to limit the field applied to this figure. The threshold may therefore be considerably above this value.

It has therefore been shown that by the utilization of two of the structures illustrated herein that the field emission voltage threshold may be increased to at least three times that normally found with the conventional metallic electrodes. Since the brightness of the electron phosphor varies as a power of the voltage, an increase of amplification of the order of five times is obtained over the non-coated electrode structure in the image intensifier.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various other changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. An image intensifier device comprising an evacuated envelope having at one end thereof a screen which emits light in response to incident electrons and at the other end an input screen which emits electrons in response to incident radiation, an electron lens system positioned between said screens for accelerating said electrons from said input screen to said output screen comprising insulated metallic members having surfaces coated with a smooth semiconductive glass coating.

2. An image intensifier device comprising an evacuated envelope having at one end an output screen which

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emits light in response to incident electrons and an input screen positioned at the opposite end of said envelope which emits electrons in response to incident radiation, and electron lens system positioned between said input and output screen comprising annular metallic support members having field emission reducing coatings thereon comprised of a smooth metallic outer coating and a smooth glass-like intermediate coating.

3. An image intensifier device comprising an evacuated envelope having at one end thereof an output screen which emits light in response to incident electrons and at the other end an input screen which emits electrons in response to incident radiation, an electron lens positioned between said screens for accelerating said electrons from said input screen to said output screen comprising a plurality of metallic lens elements, said lens elements having an insulative glass like coating on portions of the surface of said lens elements to suppress electron emission from said lens element.

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4. An image intensifier device comprising an evacuated envelope having at one end thereof an output screen which emits light in response to incident electrons and at the other end an input screen which emits electrons in response to incident radiation, an electron lens positioned between said screens for accelerating said electrons from said input screen to said output screen comprising a plurality of metallic lens elements, said metallic lens elements provided with an insulative glass like layer adjacent to the surface of said lens elements which are positioned in a high voltage field so that electron emission from said surface is substantially reduced.

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