SECONDARY EMISSION SUPPRESSION IN ELECTRON BEAM TUBES

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This invention relates to improved electric discharge devices of the beam type, particularly with respect to freedom from the detrimental effects of unwanted secondary emission during operation.

In high frequency electron beam tubes, operation depends upon the passage of an elongated electron beam in energy-exchanging relation with respect to a conducive structure. In one type of velocity modulation discharge device, the beam passes across one or more gaps, each defined by aperture parts providing parts of the opposed walls of a cavity resonator. Where more than one resonator and associated gap is employed at spaced points along the path of the beam, the beam path is usually enclosed by a drift tube defining a field-free drift space. At various points in the tube and particularly in the region immediately surrounding the gaps, substantial high frequency fields exist and the bombardment of these parts by the beam upon passing through the apertures produces secondary electrons. If the material of the parts defining these gaps emits secondary electrons as a result of the impact of primary electrons and particularly if the emission ratio is greater than one, there is a tendency for a large number of secondary electrons to be liberated in the gap region. Under certain operating conditions, this phenomenon builds up to the point where the overdriven efficiency deteriorates to the point where the tube becomes useless. In another type of high frequency beam device known as a traveling wave tube, the beam interacts with a conducting slow wave structure which is often in the form of a spiral. Electrons emitted due to the impact of primary electrons thereon may result in a build-up of secondary electrons which are not in proper phase relation with respect to the high frequency field on the spiral, with a resultant loading of the structure and loss of gain and efficiency. Beam collimating axial magnetic fields are usually used with both types of discharge devices mentioned above and this field tends to collimate the secondary electrons as well as the primary electrons so that the problems resulting from secondary electrons are further aggravated in discharge devices of these types.

I have found that many of the operating difficulties experienced in tubes of this type which may be termed severe operating conditions with respect to the formation of secondary electrons, are in fact due to the secondary electrons and the resultant loading of the associated circuits. I have also found that these difficulties may be avoided by adequately minimizing the production of secondary electrons. Severely operating conditions are encountered in high frequency, high power, and high voltage tubes, for example. This invention relates particularly to the provision of surfaces having improved characteristics with respect to the emission of secondary electrons under operating conditions at those points along the beam path where such characteristics are most likely to be produced and where due to the combination of fields existing are most apt to build up into a runaway or cumulative phenomenon. Specifically, I provide a clean metallic titanium surface on those parts defining the beam path which are subjected to substantial high frequency fields during operation of the device.

It is accordingly an important object of this invention to provide an improved electron beam discharge device having improved operating characteristics and exhibiting substantial freedom from the detrimental effects of secondary emission.

It is a further object of my invention to provide an improved electron discharge device of the beam type having those parts along the beam path which are subjected to conditions favorable to the formation of secondary electrons of improved surface characteristics with respect to the emission of secondary electrons.

Further objects and advantages of this invention will become apparent as the following description proceeds, reference being had to the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is an elevational view in section of an electron discharge device of a type to which my invention may be applied with particular success. Fig. 2 illustrates a portion of the device of Fig. 1 showing more clearly the surfaces which are provided with improved characteristic with respect to the emission of secondary electrons in accordance with this invention.

In the drawing my invention is illustrated in connection with an electron beam tube of the klystron type. The discharge device is of the three cavity type including an input cavity 1, an output cavity 2 and an intermediate floating or stabilizing cavity 3. These cavities are spaced along a beam path and separated by drift tubes 4 and 5. At the input end of the tube is provided a source of electrons in the form of a hemispherical cathode 6 forming a part of an electron gun reservoir 7. The gun structure is supported from the input cavity by means of a beam passage defining tube 7 and is insulated therefrom by means of a suitable cylindrical ceramic insulator 8. The cathode is adapted to be maintained at an emitting temperature by means of a heater element 9 illustrated schematically as having a terminal connection with the cathode supporting sleeve 10 and the other end bonded to a conductor 11 which is sealed through the end of the envelope in insulated relation with respect thereto.

A generally conical collecting electrode 12 is supported from the output cavity 2 at the other end of the discharge device in insulated relation with respect thereon by a seal construction illustrated generally by the numeral 13 and including an annular ceramic member 14 bonded to thin metal flanges 15.

The three cavities are in general of similar construction and are hollow cylinders in shape. Each cavity is provided with a tuning member terminating in a ring-like portion 16, movable in the interaction gap of the cavity. The ring is movable from the exterior of the tube by means of a suitable bellows arrangement 17. The input cavity is provided with a concentric line input connection 18 terminating in an input loop 19. The output cavity is provided with a waveguide output 20 communicating with the output cavity 2 through a dielectric window 21. The rigidity of the assembly including the three cavities is enhanced by means of supporting bolts 22 and secured to flanges on the three cavities, only one of which is illustrated in the drawing. In order to facilitate the fabrication and assembly of the tube, it is made sectional and the drift tubes, drift disks, for example, are made in two parts 2a and 2b which are screwed together and then hermetically sealed by means of flanges 23 which are welded together at their outer edges. These flanges are previously bonded to the drift tube sections 2a and 2b in such a position that they come essentially into contact as these parts of the drift tube are screwed together.
In the operation of the device described above as an amplifier, the electron beam emanates from the cathode and is accelerated by a suitable apertured accelerating anode located in a space between the cathode and the beam path defining tube 7. This electrode is not visible in the drawing but is well understood by those skilled in the art. The accelerated beam passes across the gap in the input cavity and is modulated in accordance with an input signal coupled to the cavity by the coupling loop 19. The modulated beam then traverses the essentially field-free drift space defined by the drift tube 5 and enters the floating or stabilizing cavity 3 where the electron bunches resulting from the modulation and drift space are accentuated and these bunches then pass through a further drift space defined by the tube 4 and across the gap of the output cavity to excite high frequency voltages across that gap and provide for the supply of modulated and amplified waves in the output waveguide 20. The electrons of the beam are collected on the inner wall of the conical electrode 12. In operation, the cavities, the drift tubes, and also the collector, if desired, may all be operated at a high positive potential with respect to the cathode. It is common practice to operate the structure at ground potential with the cathode at a high negative potential. As is well understood, an axial magnetic field for collimating the electron beam is provided. This field may be produced by suitable permanent magnets or electromagnet means which, for the interests of simplifying the drawing, have not been illustrated.

In the operation of devices of this character under certain combinations of high voltage and high power conditions, particularly at high frequencies, there is a tendency for power conversion efficiency to fall off seriously. I have found that actually this decrease in efficiency is due to loading of the cavity resulting from the emission of secondary electrons particularly from the areas surrounding the gaps in each of the cavities where high frequency fields of high strength exist. When these surfaces are bombarded by the electrons of the forward electron beam they tend to liberate secondary electrons and some of these are liberated in proper phase relation with respect to the high frequency fields to travel back to the other side of the gap where more secondaries are released. This initiates a cumulative action resulting in a large number of secondary electrons improperly phased with respect to the desired function of the gap with resultant loss in efficiency and output of the device. As previously mentioned, this condition is aggravated by the presence of the axial magnetic field used for collimating the primary electrons. I have found that this undesirable condition may be eliminated by coating the parts of the interior of the tube, particularly those regions surrounding the gaps, which are subjected to high fields with a material which not only has the property of exhibiting a low yield of secondaries when in its clean state, but also a material which may be readily maintained in a clean state under operating conditions in an electric discharge device. I have found that the operation may be materially improved by providing a surface of clean titanium. Titanium has the property of absorbing gases at high temperatures and in this way tends to keep itself clean by absorbing any gases or oxides which tend to be present on its surface. Fig. 1 shows an enlarged view of a subassembly of the device of Fig. 1, including the input cavity and portion 5b of the drift tube. This is a suitable subassembly of the device to subject to a coating treatment in accordance with the present invention. The coating with titanium may to advantage be accomplished in a vacuum by heating a filament of titanium wire positioned in the region between the tuner element 16 and the end of the tube 7, in other words, in the gap of cavity 1 across the electron travel. This is the region of high field during operation of the device. The filament may be heated by passage of electric current there-through to a temperature in the order of 1400-1600° C. and at these temperatures in vacuum evaporation readily takes place and the clean titanium deposits on the parts defining the gap and to a lesser extent on the surrounding parts of the discharge device. The coating process is carried on until at least the parts defining the gap are covered with a continuous layer of titanium. Additional titanium does no harm, it being essential, however, that a rather continuous surface be provided at the gaps. After the coating has been accomplished the tube component is baked out, preferably in vacuum, to burn up the surface and dispose of any material which may have been formed. The temperature and time of this heating operation are related and as the temperature is increased the time decreases. For example, the bakeout of 400° C. would require around eight hours, whereas an 800° C. baking out might be accomplished in a few minutes. Actually a temperature of around 900° C. for a period of 1 or 2 hours is very desirable. It will be understood that the interior of the other cavities, in particular the gap regions thereof, are treated in a similar manner. Having once been treated in this manner, the tube may be let down to air since it may be readily cleaned up again as it is evacuated and baked out at a subsequent time.

While I have described my invention as applied to a klystron type of device to which it is particularly suited, it may also be applied to other discharge devices of the high frequency beam type where a large field exists between rather closely spaced metal parts. For example, it may be applied to the adjacent turns of the helix or other slow wave structure of a traveling wave tube.

It is also possible to make these parts of titanium rather than providing the surface by cladding or coating a base metal. However, large bodies of titanium are expensive and, in addition, the evaporated coating provides the bright surface which is desired when applied in a good vacuum.

It is a particular advantage resulting from the use of an evaporated coating of titanium that it may be applied after the tube is largely assembled and the parts free of contaminants. This facilitates obtaining an uncontaminated layer of titanium on the finished tube.

It should be pointed out that not all materials which yield a low number of secondaries upon bombardment with primary electrons are suitable for this operation. For example, aluminum, which would appear to be well suited for such an application, does not work. Apparently, it is not commercially possible to obtain an aluminum surface on the parts which remains sufficiently clean metal to exhibit the properties usually attributed to aluminum as far as secondary electrons are concerned.

In the foregoing description, titanium alone has been mentioned as the surface material employed in accordance with the present invention. It should be noted that zirconium may be substituted in whole or in part for the titanium and that in general these materials are effective in absorbing gases at lower temperatures than the titanium alone.

While I have shown and described particular embodiments of my invention, it will be apparent to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects and I aim, therefore, to include in the appended claims all such changes and modifications as come within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A high frequency electric discharge device comprising means providing an electron beam having a predetermined path, means providing a collimating magnetic field along said path, a conducting structure surrounding the path of the beam including spaced parts
5 across which a high frequency field is produced during operation of the device for interaction with the beam, and means for improving the efficiency of said device by minimizing secondary emission electrons from said spaced parts comprising a surface of clean titanium metal on said spaced parts.

2. A high frequency electric discharge device of the beam type including means producing an electron beam having a predetermined path, electrode means positioned along said path including means defining a plurality of interaction gaps and a plurality of field-free drift spaces therebetween, the parts defining said gaps being subjected to high frequency fields during operation of said device and means for minimizing beam loading due to secondary electrons during operation of said device comprising a surface of clean titanium metal on said parts.

3. A high frequency electric discharge device of the beam type including means producing an electron beam having a predetermined path, means providing a collimating magnetic field along said path, electrode means positioned along said path including means defining a plurality of interaction gaps and a plurality of field-free drift spaces therebetween, the parts defining said gaps being subjected to high frequency fields during operation of said device and means for minimizing beam loading due to secondary electrons during operation of said device comprising a surface of clean titanium metal on said parts.

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