TA-AL ALLOY ATTENUATOR FOR TRAVELING WAVE TUBES AND METHOD OF MAKING SAME

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ABSTRACT

The high frequency attenuator in a traveling wave tube and in other devices, in which the attenuator is disadvantageously subject to electron and/or ion bombardment, comprises an alloy coating of tantalum and aluminum. Also described is a process of fabricating such coatings in which the alloy is sputtered from a planar cathode comprising an aluminum plate and a perforated tantalum plate mounted on the aluminum plate.

6 Claims, 3 Drawing Figures
TA-AL ALLOY ATTENUATOR FOR TRAVELING WAVE TUBES AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

This invention relates to radio-frequency attenuation devices, and more particularly to the attenuation of reflected radio-frequency energy in traveling wave tubes.

In a traveling wave tube, an electron beam is projected in close proximity to a slow-wave structure, such as a conductive helix, with interaction taking place between the electron beam and the field of an electromagnetic wave propagating on the helix. With the helix many wavelengths long at the operating frequency, the cumulative interaction between the electron beam and the field of the wave results in a transfer of energy from the beam to the field of the wave, thereby amplifying the wave.

While the advantages of traveling wave tubes are well recognized, and the tubes widely used, it is also recognized that the device can become unstable, and that this instability is often caused by an attenuator film on the helix. The majority of the film failures are due to temperature extremes, and particularly to a phase change of the film.

An early attenuator film for use in traveling wave tubes was a tantalum oxide film. However, the resistivity of tantalum oxide decreases about 700°C, which has caused the film to fail in many instances when the power output of the TWT is high.

SUMMARY OF THE INVENTION

In an illustrative embodiment of our invention, a traveling wave tube comprises an electron gun for projecting a beam of electrons toward a collector. An elongated slowwave structure, such as a wire helix, which extends between the electron gun and the collector, surrounds the beam path and is coupled at its input end to a signal source and at its output end to a load. The tube is provided with a focusing structure for constraining the flow of electrons to a path entirely within the slow-wave structure.

Feedback energy is attenuated by a coating of a film on a portion of the helix. It is well known that the helix loss material should have a low vaporization pressure, high melting point, and high resistivity and should, according to the Anand patent previously mentioned, be capable of extended operation without substantial change of its loss characteristic due to electron and ion bombardment.

Our invention is characterized in that a portion of the slow-wave structure is coated with a film comprising an alloy of tantalum and aluminium for attenuating feedback energy. This alloy possesses a sufficiently high melting point, low vaporization pressure, and high resistivity to meet the above requirements. In addition, a thin film of a tantalum aluminium alloy on the helix and support rods provides the desired loss characteristics without deteriorating substantially as a result of electron and ion bombardment.

More importantly, however, we have found that an attenuator coating of tantalum-aluminium alloy desirably exhibits no phase transition, and hence no abrupt decrease in its resistivity, in the temperature range from 500°C to 900°C. This range covers essentially all film temperatures which would be expected under normal operating conditions of even relatively high power TWTs, and in addition covers the common range of temperatures used in the aforementioned vacuum heat treatment. We have found, moreover, that a near optimum alloy composition includes 60±10 atomic percent aluminium which limits the resistivity changes of the film to ±10 percent over the range 500°C to 900°C. This resistivity range represents a permissible deviation from stability in a commercial TWT.
We have found, in addition, that the tantalum-aluminum alloy attenuator coating is preferably deposited on the helix and support rods by sputtering from a planar cathode which comprises a "Swiss cheese-like" structure; i.e., an aluminum plate affixed to a water cooled mount and a perforated tantalum plate affixed to the aluminum plate. By sputtering at about 4 kV and 150 ma with this type of cathode, we have been able to fabricate reproducibly relatively pure tantalum-aluminum films (less than about 3 atomic percent interstitial impurities and about 2 atomic percent argon) with aluminum compositions of about 40 atomic percent — the near optimum design.

BRIEF DESCRIPTION OF THE DRAWING

Our invention, together with its various features and advantages, can be easily understood from the following more detailed description in conjunction with the accompanying drawing, in which:

FIG. 1 is a partial sectional view of a traveling wave tube employing the principles of our invention;

FIG. 2 is an enlarged section taken along line 2—2 of FIG. 1; and

FIG. 3 is an enlarged view of part of the helix and helix support structure of the traveling wave tube of FIG. 1.

DETAILED DESCRIPTION

Before discussing in detail our invention, it will be helpful to review briefly the operation of a TWT and the role which a high frequency attenuator plays in its operation.

Referring now to FIG. 1, there is shown a traveling wave tube package 10, the purpose of which is to amplify electromagnetic waves which are transmitted to the tube by an input waveguide 11 as shown by the arrow. Located near the opposite end of the device is an output waveguide 12 for extracting amplified electromagnetic waves from the traveling wave tube and transmitting them to an appropriate load as indicated by the other arrow. Extending between the input and output waveguides is a conductive wire helix 13 which surrounds the central axis of the device. An electron beam is formed and projected along the central axis by an electron gun 14 of a well-known type which includes a cathode 15, a beam-forming electrode 16 and an accelerating anode 17. The electron beam is collected by a collector electrode 18 located at the end of the helix 13 opposite the electron gun 14.

The electron beam is projected in close proximity to the conductive helix with interaction taking place between the electron beam and the field of the electromagnetic wave propagating on the helix. With the helix many wavelengths long at the operating frequency, the cumulative interaction between the electron beam and the field of the wave results in a transfer of energy from the beam to the field of the wave, thereby amplifying the wave.

The helix 13 is mounted by three support rods 19 which are shown in more detail in FIGS. 2 and 3. A periodic magnetic structure 20 surrounding both the rods 19 and the helix 13 focuses the beam and constrains it to flow along the central axis to the collector 18. Other known focusing structures can be used, if so desired.

As mentioned previously, the major cause of instability in a traveling wave tube is the tendency of wave energy to be reflected from the output end of the helix 13 back toward the input end and thereby to cause oscillations within the device. The reflected waves are usually suppressed by an attenuation coating or layer 21 along part of the helix 13. It has been common practice to include on part of the helix a lossy material, typically a thin coating of graphite or tantalum, which absorbs and dissipates the reflected wave energy. Such helix loss materials should have a low vaporization pressure, a high melting point, and should preferably be a material having comparatively high resistivity. The resistivities of graphite and tantalum at 20° C., for instance, are 800 micro-ohm cm and 15 micro-ohm cm, respectively. Illustratively the coating is about 0.08 inches long and 500 Angstroms thick depending on its resistivity and the desired resistance.

The manner in which the layer 21 attenuates the reflected energy is best understood by considering a single turn of the helix 13 in the loss region defined by the layer 21. As reflected electromagnetic wave energy travels from the output end of the helix 13 toward the input end, it encounters the turn of the helix and therein produces an electric field. The ends of the turn are electrically connected through the layer 21 on the support rods 19. The electric field produced by the reflected waves in the turn of the helix are effectively shunted through the layer 21 and thereby attenuated. Thus the layer 21 acts as a load to the electric fields in the helix in much the same way that a resistor acts as a load when connected across a battery. Also of importance is the attenuation of surface currents produced in the helix by the reflected energy. Since these currents travel on the helix surface, they are attenuated by the layer 21 on the surface of the helix itself.

It is important that the loss material be very carefully applied so that it effectively acts as a reflectionless absorber of waves traveling toward the input end, while minimally affecting the growing wave traveling toward the output end. To this end, the density of the loss material should be tapered in the direction of the output end so that reflected-backward traveling waves are gradually absorbed. On the other hand, the total length of the loss section should be minimized to give the smallest possible interference with the growing wave.

In accordance with one embodiment of our invention a traveling wave tube is characterized in that the attenuating coating or layer 21 comprises a tantalum-aluminum alloy. As shown in FIG. 3, this layer is deposited along a discrete region of the helix 13 and the support rods 19. In order to maintain adequate stability for commercial operation of a TWT, it is desirable that the resistivity of the attenuation coating not vary by more than about ±10 percent. We have found that tantalum-aluminum alloy coatings having 40± 10 atomic percent aluminum satisfy this requirement over the temperature range from approximately 500° to 900° C.

We have also demonstrated that the aluminum content of such coatings can be systematically and reproducibly varied from about 30 atomic percent aluminum to about 50 atomic percent aluminum by means of a unique sputtering arrangement. This arrangement included a planar "Swiss cheese-like" cathode made up of tantalum and aluminum plates illustratively measuring 17.5 inches wide by 2 inches high. The aluminum plate was affixed to a water cooled copper electrode by aluminum screws and the tantalum plate (about 0.02 inches thick) was attached to the aluminum plate using tantalum screws. Importantly, the tantalum plate was
perforated; i.e., in one embodiment it contained 140 holes each 21/64 inches in diameter and spaced 1/8 inch apart in order to expose about 34 percent of the area of the aluminum plate. The cathode was located in a suitable vacuum chamber and a plurality of helices (including support rods 19), suitably masked to define the loss regions, were rotatably mounted in the chamber facing the perforated tantalum plate. A movable shutter shielded the cathode from the helices.

After evacuating the chamber to a pressure of less than about $5 \times 10^{-6}$ torr, argon was introduced at a flow of approximately 4.0 scm. With the chamber pressure of about $15 - 25 \times 10^{-2}$ torr, presputtering was conducted for approximately 25 minutes before opening the shutter to allow deposition of the attenuator coating. During deposition the helices were each rotated about their (cylindrical) axes at a rate of about 60 rpm.

We have found that relatively pure films (less than 3 atomic percent interstitial impurities and approximately 2 atomic percent argon) with aluminum contents nearly optimum (about 40 atomic percent) can be reproducibly fabricated by sputtering at 4 kV and 150 ma. In addition, we were able to systematically vary the aluminum content between about 45 and 30 atomic percent as the voltage increased from 3.0 to 5.0 kV (all at 150 ma). The corresponding range of resistivity values was between approximately 375 and 297 micro-ohm centimeters as measured on ceramic monitor substrates located in the sputtering chamber.

Subsequent to deposition, the helices were, as mentioned before, subjected to a vacuum heat treatment, typically for 1 hour at 800°C and $5 \times 10^{-2}$ torr in order to stabilize the loss patterns and outgas the helices. Optimum stability, less than $\pm$ 10 percent resistivity change, was obtained for films containing about 40±10 atomic percent aluminum which were deposited by sputtering at 4 kV and 150 ma. The deposition rate under these conditions was approximately 55 Angstroms per minute and the film resistivities were approximately 320 micro-ohm cm as measured on ceramic monitor substrates. In a total of about 25 additional runs at 4 kV and 150 ma the variation in aluminum content was only about $\pm$ 3 atomic percent.

Tubes with helices sputtered as aforesaid with tantalum-aluminum alloy attenuator coatings have been successfully life tested. For example, traveling wave tubes operated under normal conditions, with about 5 watts of power being dissipated in the attenuator, have exhibited no failures for more than 5,000 hours.

It is to be understood that the above-described arrangements are merely illustrative of the many possible specific embodiments which can be devised to represent application of the principles of our invention. Numerous and varied other arrangements can be devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention. In particular, tantalum-aluminum is also useful as a loss material on other slow-wave structures and in fact in any device, such as a magnetron or cross-field amplifier, in which the loss material is subject to sustained particle bombardment and in which stable resistivity is desired.

What is claimed is:

1. A transmission system for propagating energy in a first direction comprising:
   a source of electrons and means for projecting said electrons for interaction with said propagating energy;
   said system tending disadvantageously to reflect energy in a second direction opposite to the first direction; and
   means for absorbing the reflected energy thereby preventing the establishment of oscillations in said transmission system;
   characterized in that said absorbing means comprises an alloy of tantalum and aluminum containing approximately 30 to 50 atomic percent aluminum.

2. The system of claim 1 wherein said alloy contains approximately 40 atomic percent aluminum.

3. The system of claim 1 wherein said transmission system includes a slow-wave structure of a traveling wave tube, said absorbing means being formed on said slow-wave structure.

4. An electron discharge device comprising:
   a source of electrons;
   an electron collector;
   means for projecting electrons in the form of a beam from said source to said collector;
   means for focusing the beam of electrons;
   a slow-wave structure surrounding the beam path and support means therefor;
   said slow-wave structure having input and output ends;
   means for coupling electromagnetic wave energy to the input end of said slow-wave structure;
   means for extracting electromagnetic wave energy from the output end of said slow-wave structure;
   said output end tending disadvantageously to reflect wave energy; and
   means for attenuating the reflected wave energy along a discrete portion of said slow-wave structure;
   characterized in that said attenuating means comprises a thin film alloy of tantalum and aluminum containing about 30 to 50 atomic percent aluminum.

5. The device of claim 4 wherein said alloy contains about 40 atomic percent aluminum.

6. The electron discharge device of claim 4 wherein:
   said slow-wave structure comprises a wire helix;
   said support means comprises a plurality of rods each substantially coextensive with said helix and abutting against said helix; and
   said thin film is deposited onto a portion of said helix and said support rods.