Nov. 4, 1947. P. L. SPENCER 2,430,309

ELECTRONIC DISCHARGE DEVICE

Original Filed Sept. 30, 1941 2 Sheets-Sheet 1

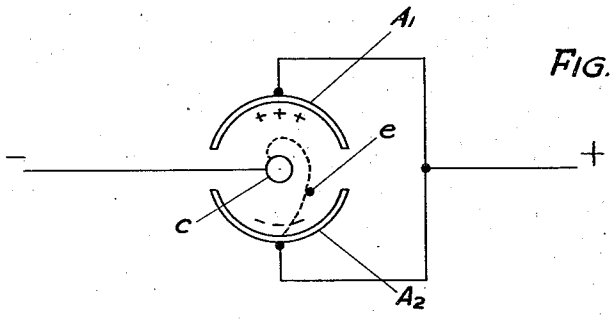


FIG. 1

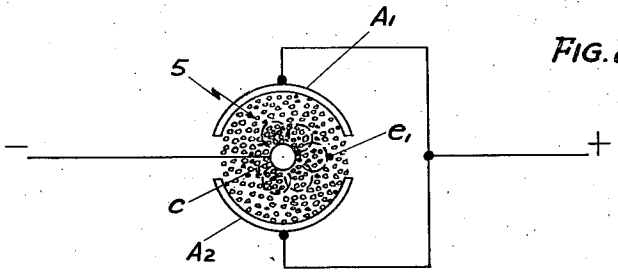


FIG. 2

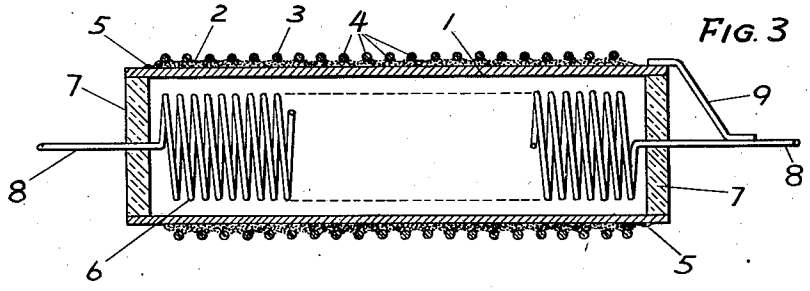


FIG. 3

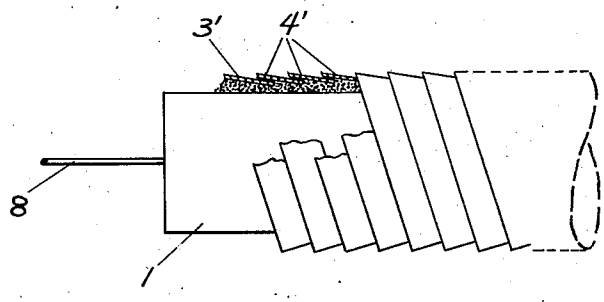


FIG. 4

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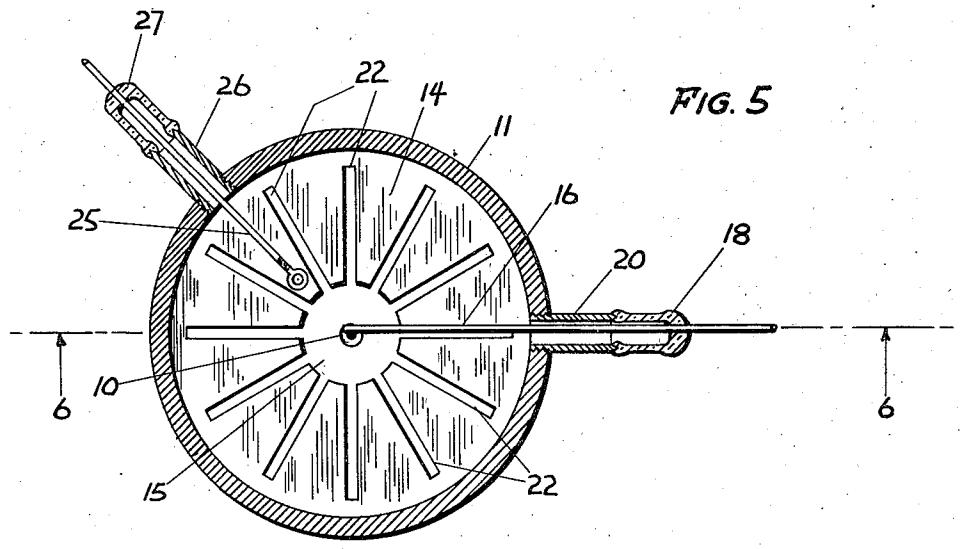


FIG. 5

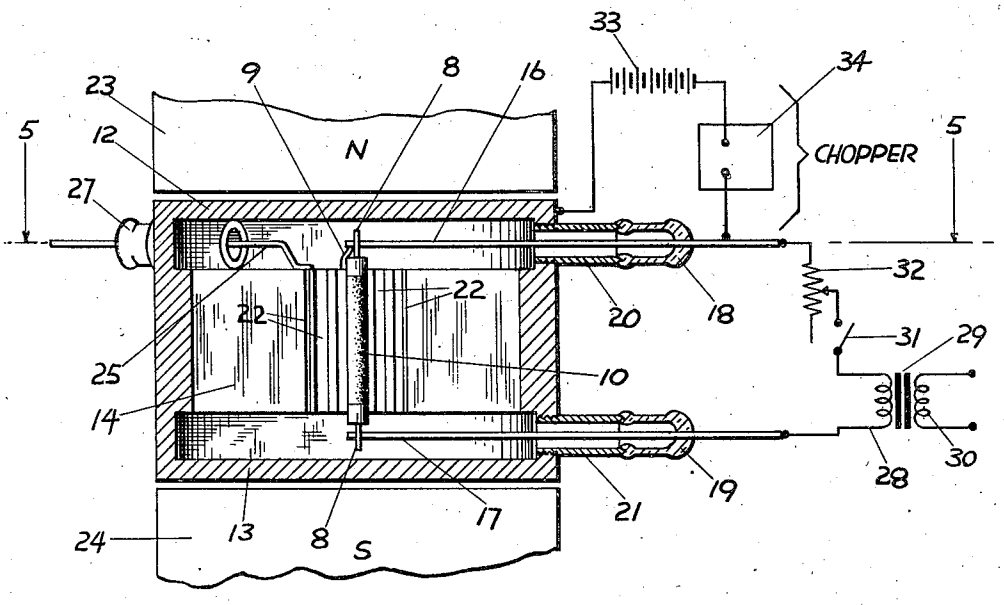


FIG. 6

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Patented Nov. 4, 1947 2,430,309

UNITED STATES PATENT OFFICE

2,430,309

ELECTRONIC DISCHARGE DEVICE

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Original application September 30, 1941, Serial No. 412,993. Divided and this application June 5, 1946, Serial No. 674,453

1 Claim. (Cl. 250—27.5)

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This is a division of my copending application, Serial No. 412,993, filed September 30, 1941, entitled Electronic discharge device.

This invention relates to an electronic discharge device, particularly of the magnetron type, and to a cathode for such a device capable of supplying large peak values of current.

In electronic discharge devices particularly of the magnetron type which are called upon to supply relatively large peak values of current, various difficulties have heretofore existed. The cathodes of such devices have been heated to relatively high temperatures in an attempt to supply sufficient thermionic emission to carry such peak values of current. Such cathodes have had an unusually short life due to the fact that the emissive coating with which the cathodes are normally coated was rapidly driven off from the cathode. This effect was increased by the fact that the load current through the tube tended to overheat and burn out the cathode. The art has resorted to the use of complicated regulating and protective devices in order to protect the cathodes of such magnetrons from being burned out. However, such protective and regulating devices did not substantially affect the loss of coating due to high operating temperatures of the cathode which resulted in short life for such cathodes.

An object of this invention is to produce an electron discharge device of the type which supplies high peak values of current with its cathode normally operating at a temperature substantially below that necessary to cause such peak values of current to be emitted thermionically.

Another object is to accomplish the above in a magnetron type of discharge device.

Another object is to cause such peak values of current to be supplied largely by secondary emission.

A further object is to devise a cathode in such a device which will emit large numbers of secondary electrons without substantial time delay, and which will have a long life.

A further object is to devise a magnetron which does not need special regulating and protecting devices to prevent the cathode from being burned out.

A still further object is to devise such a magnetron which is capable of supplying much larger amounts of power than have heretofore been possible.

The foregoing and other objects of this invention will be best understood from the following description of exemplifications thereof, reference

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being had to the accompanying drawings, wherein:

Figs. 1 and 2 are diagrammatic representations of a magnetron illustrating certain principles of operation of my invention;

Fig. 3 is a cross-sectional view of one embodiment of my novel cathode;

Fig. 4 is a fragmentary view partly in section of another embodiment of my novel cathode;

Fig. 5 is an illustration of one type of magnetron incorporating my invention, the view in Fig. 5 being taken along line 5—5 in Fig. 6; and

Fig. 6 is a cross-section of the magnetron in Fig. 5 taken along line 6—6 of Fig. 5, together with a diagrammatic representation of a circuit with which said magnetron may be used.

In Fig. 1 A_1 and A_2 represent two anodes of a split anode magnetron. C is the centrally located cathode thereof. As is usual in this type of device, a longitudinal magnetic field is impressed thereon in a direction at right angles to the plane of illustration in Fig. 1. The cathode C is connected to a negative potential while the anodes A_1 and A_2 are connected together to a positive potential. Devices of this kind are evacuated to high vacuum conditions in which the gaseous atmosphere plays substantially no part in the discharge. This type of magnetron when energized sets up high frequency oscillations, creating an oscillating electrostatic field between the anode A_1 and A_2. At one instant of time the anode A_1 may be more positive than the anode A_2. Under these conditions an electron *e* emitted from the cathode C is accelerated toward the anode A_1 by the potential thereof. However, the magnetic field causes the electron *e* to travel in a curved path which deflects the electron to such an extent that it misses the anode A_1 and falls upon the anode A_2. This imparts a negative characteristic to the device, and causes it to operate as an oscillator.

Under the conditions of operation which I contemplate in my invention, in addition to the action described in connection with Fig. 1, another action, as exemplified by Fig. 2, also takes place. The electron emission from C causes a swarm S of electrons in the space surrounding C. An electron *e'*, which otherwise might follow the path as described in Fig. 1, however encounters interference from the other electrons in the swarm S, and thus never reaches the anodes A_1 or A_2, but falls back onto the cathode. The interaction between the electrons in the swarm S may impart considerable energy to the electron *e'* by collision or otherwise by the time it reaches the cathode C.

Assuming the tube to be oscillating, the electrons e' also may receive a considerable amount of energy directly from the oscillating field between the two anodes A_1 and A_2. The magnetic field tends to give to the electron e' a definite orbital period in its travel around C, which period is substantially equal to the period of oscillation of the voltage appearing between the anodes A_1 and A_2. This condition permits said oscillating field to exert its accelerating force upon the electron e' in the proper phase and at the proper time to successively impart energy to said electron.

Due to the above effects, electrons of the e' type can be made to fall upon the cathode C with considerable speed and energy, which may be substantially above 100 volts. If the cathode C is made so as to be a good secondary electron emitter, then such impinging electron may give rise to the emission of several additional electrons. The current due to secondary emission may be made several times the current due to simple thermionic emission at the operating temperature of the cathode. In addition, when the tube is called upon to supply greatly increased peaks of current, then the secondary electron emission can be made to increase enormously to carry such peak currents without substantial time delay. In other words, such a device can be made to operate as an electron multiplying arrangement in which the normal thermionically-emitted electrons are multiplied to give an increased supply of electrons which in turn are again multiplied by a similar process.

In accordance with my invention I utilize such secondary emission to supply a large part of the peak currents which such a device may be called upon to supply. For this purpose I prefer to construct the cathode of the discharge device in a special form, as shown for example in Fig. 3. The cathode illustrated consists of a sleeve 1 made of some suitable material, such as tantalum or nickel. In one example of this cathode the cylinder was about six millimeters in diameter and about fifteen millimeters long. The sleeve is coated, except for the end portions thereof, with a layer 2 of a mixture of barium and strontium carbonates in a nitrocellulose-amylacetate binder. In some instances I prefer to add from one to one and one-half per cent. of borax in order to decrease the evaporation rate of the coating material during operation. The sleeve so coated is baked in air at a temperature of about 400° F. Thereupon a winding 3, preferably of tantalum wire, is wound over said coating. In the embodiment mentioned above, this wire has consisted of tantalum .004 inch in diameter, spaced .003 inch between adjacent turns. In order to retain the winding upon the cathode and to insure good electrical contact with the underlying sleeve, the ends 5 of the wire 3 may be welded directly to the sleeve 1. After the wire 3 has been wound upon the cathode, the cathode is again coated with the coating material described above and again baked in air at a temperature of about 400° F. Thereupon the coating is scraped off the outside of the cathode structure, leaving the top surfaces 4 of the wire 3 bare. The baking of the carbonate coatings in air not only drives off the binder material, but also largely converts the carbonates into the oxides. A heater coil 6, preferably of tungsten, the turns of which are coated with insulating material, is inserted within the sleeve 1 for the purpose of enabling the cathode to be raised to a temperature of thermionic emission. The ends

of the sleeve 1 are closed by insulating plugs 7—7, preferably of alumina. The ends of the heater coil 6 extend through said plugs so that heating current may be supplied thereto. An electrical connector tab 9 has one end thereof welded to the sleeve 1 and the other end welded to one of the heater ends 8, so that electrical connection may be established to the emitting surface of the cathode.

Instead of making the cathode as illustrated in Fig. 3, it can take a variety of other forms, one of which is illustrated in Fig. 4. In this figure, instead of using round wire, the sleeve 1 is wound with a flat ribbon 3', also preferably of tantalum. This ribbon, for example, may be .0005 inch thick and .050 to .100 inch wide. Such a ribbon may be initially coated with emitting materials, as described above, and wound upon the sleeve 1 with about half of each turn of the ribbon overlapping the preceding turn. Here again the coating may be baked in air as described above, and the coating scraped from the outside of the cathode structure, leaving the top surfaces 4' of the ribbon material 3' bare.

The cathode structures as described above possess the property of being excellent secondary electron emitters, particularly from the scraped tantalum surfaces, as well as good thermionic emitters from the exposed oxide surfaces. The tantalum has a tendency to reduce the barium oxide, liberating small amounts of barium on the surface of the coating which tends to give excellent electron emission. Also the barium so liberated tends to coat the bare surfaces of the tantalum, making it an excellent secondary electron emitter. Even without any barium coating, tantalum in itself is a good secondary emitter.

Cathodes of the type as illustrated in Figs. 3 and 4 may be incorporated, for example, in a magnetron of the type as illustrated in Figs. 5 and 6. The magnetron therein illustrated comprises an envelope 11 which is preferably made of a block of conducting material, such as copper. This block forms the anode structure of the magnetron. Said block has hollow end sections which are covered by end caps 12 and 13, likewise of conducting material, such as copper. Between the hollow end sections of the block 11 is a central bridging portion 14. The portion 14 is provided with a central bore 15 within which is supported substantially at the center thereof a cathode 10 which, as pointed out above, is preferably of the type as illustrated in Figs. 3 and 4. The cathode 10 is supported by a pair of lead-in conductors 16 and 17 fastened respectively to the ends 8 of the cathode structure, and sealed through glass seals 18 and 19 mounted at the outer ends of pipes 20 and 21 hermetically fastened within the walls of the block 11 adjacent the upper and lower hollow end sections. A plurality of slots 22 extend radially from the central bore 15 to within a short distance of the outer wall of the block 11.

When such a magnetron is placed between suitable magnetic poles 23 and 24 to create a longitudinal magnetic field and the device is energized, oscillations are set up whose frequency and consequently whose wave length are determined primarily by the dimensions of each of the slots 22. It is also desirable that the value of the magnetic field is such as to impart to the electrons travelling around the cathode an orbital frequency substantially equal to the frequency of said oscillations. Moreover the voltage applied to the anode structure should be of the proper

value to cause such oscillations to occur and for the desired peak value of current to flow between the cathode and anode structure. The oscillations produced in the slots 22 reinforce each other and may be led out from the tube by means of a coupling conductor 25 fastened to the central bridge portion 14 in the central bore 15 between two of the slots 22. The coupling conductor 25 leads out from the magnetron through a glass seal 27 at the outer end of a pipe 26 likewise hermetically fastened through the wall of the envelope 11 adjacent the upper hollow portion thereof.

The magnetron may be connected in any suitable circuit, one of which is shown diagrammatically in Fig. 6. In this circuit the cathode is supplied with heating current from the secondary winding 28 of a heating transformer 29 whose primary winding 30 is adapted to be connected to a suitable source of alternating current. Interposed in the circuit of a secondary winding 28 is a switch 31 and a current-regulating resistance 32. A source of potential 33, which in a practical embodiment may be of the order of 12,500 volts, is connected between the envelope 11, constituting the anode, and the lead-in wire 16 for the cathode 10. Interposed in the circuit for the source 33 is an interrupter or "chopper" 34 which interrupts the circuit so that the magnetron generates short pulses of high intensity high frequency oscillations. The frequency of interruption may be of the order of two thousand times a second. The duration of each energization of the tube may be of the order of a half a micro-second.

I have constructed a considerable number of devices substantially as shown in Figs. 5 and 6 and embodying a cathode as illustrated in Fig. 3, as well as the various parameters recited herein. Tubes of this kind were designed to produce oscillations of a wavelength of about three centimeters. In such a tube I have found that during each half micro-second during which the device was energized, the anode current rose substantially instantaneously to a value of about twelve amperes and continued throughout at this value for substantially each period of energization. The average anode current throughout the entire time was of the order of about fourteen milliamperes.

In starting the operation of such a device, the cathode was raised to a temperature at which enough thermionic emission occurred to initiate the operation of the device, such emission being of the order of milliamperes and being much less than that required to supply peak currents of the order of amperes. However, as pointed out above, when operation started, peak currents of the order of amperes were supplied. Furthermore, after the operation of the device had begun, it was possible to open the heating circuit by the switch 31, and the device continued in operation with no discernible difference, the tube continuing to generate oscillations in the same way and to substantially the same degree as before the opening of said circuit. Also under these conditions, when the pole pieces 23 and 24 were deenergized so as to remove the magnetic field on the device, the current to the anode structure fell to zero and the operation of the device ceased. This is in strong contrast to the usual magnetron device in which if during operation the magnetic field is deenergized, the current between the cathode and the anode structure rises rapidly.

As pointed out above, the heater 6 is supplied with heating energy so as to initially raise the cathode to a temperature at which some thermionic emission occurs. This thermionic emission may emanate largely from the oxide coating which is exposed to the discharge area through the spaces between the coiled winding on the outside of the cathode. Some of this thermionic emission may occur from the surface of the coiled winding itself, particularly if the metal thereof has a thin film of barium coated upon it. However, during operation the electrons which fall upon the cathode largely impinge upon the bare metal surface of the coiled external winding, and liberate the secondary electrons therefrom. The oxide coating between the turns of this winding is largely shielded from such electron bombardment, and thus forms very little, if any, tendency for such bombardment to drive any of the oxide coating from the cathode. However, such coating is always available to supply barium for the initial electron emission as well as barium which tends to increase the secondary electron-emitting qualities of the metal surface of the external winding. An additional advantage of the construction which I have illustrated is that the surfaces from which the secondary electrons are emitted are directly electrically connected to the sleeve 1 by having the ends 5 welded thereto. In this way the current can flow through a direct low resistance metallic path to the very surface at which the electrons are being liberated. This is in contrast to the usual oxide-coated cathode in which the current must flow through the relatively high resistance oxide coating before it reaches the emitting surface. In this way the present cathode structure is much more effective and efficient.

By my present invention I have been enabled to construct practical magnetron devices which have generated enormous peak quantities of micro-wave length power entirely outside of the range of anything which has heretofore been practicable with such devices.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will suggest themselves to those skilled in the art. For example, it may be possible to incorporate certain fundamental features of this invention in other devices which are called upon to supply high peak values of current, particularly in connection with micro-wave generators.

What is claimed is:

An electron discharge device system comprising a cathode and an anode, said cathode during normal operation being at an elevated temperature and provided with an active surface which at said temperature is an appreciable but relatively poor thermionic emitter with thermionic emission which is substantially smaller than that required to carry the normal load current of said device and also a good secondary electron emitter, and an oscillatory circuit connected to said cathode and anode for producing a cloud of electrons and for oscillating said cloud of electrons with sufficient energy to cause electrons thereof to collide with said cathode to liberate sufficient secondary electrons therefrom to produce a total electron emission capable of carrying said normal load current, the space between said cloud of electrons and said cathode being unimpeded to cause said collisions to occur freely.

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