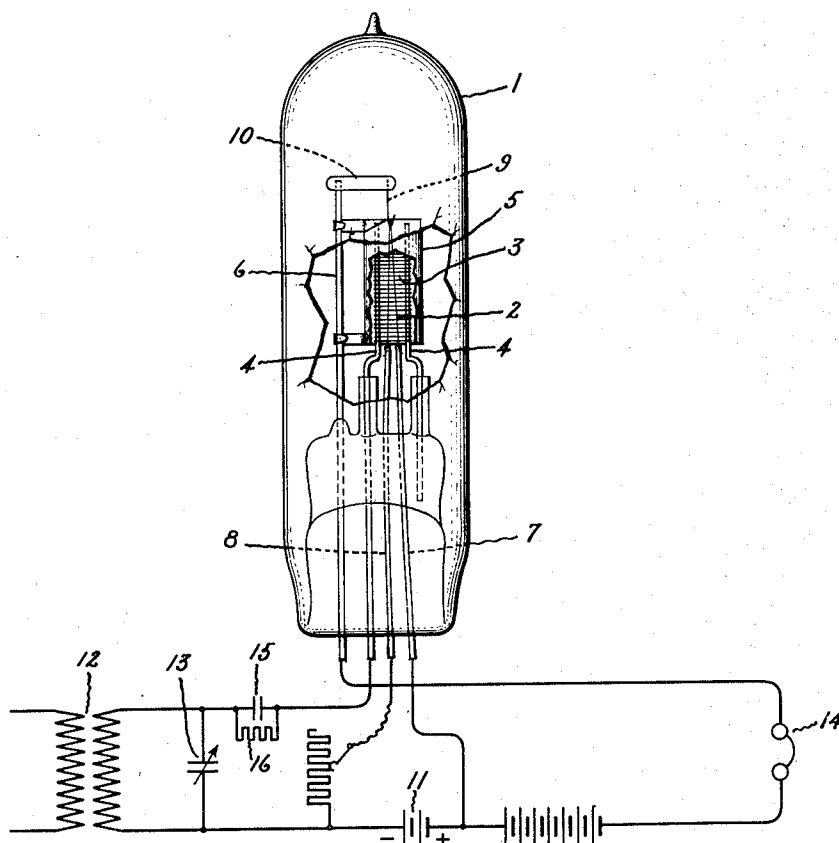


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ELECTRON DISCHARGE APPARATUS
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ELECTRON-DISCHARGE APPARATUS

Application filed July 17, 1924. Serial No. 726,639.

My present invention relates to thermionic discharge devices and more particularly to devices which are particularly adapted for service as detectors of high frequency signals.

5 One of the objects of my invention is to provide a form of thermionic device which is particularly adapted for detection purposes, which will be stable in its operation and which will not be critical to changes in cathode temperature or impressed voltages on the electrodes.

15 Electron discharge devices of the thermionic type containing carefully regulated amounts of a suitable gas have been used in the past for the detection of high frequency signals. Such devices have been more sensitive for this purpose than devices which were so highly evacuated that the gas present was too small in amount to play any appreciable part in their operation. In devices containing gases, there has been a formation of positive ions due to collision of electrons with atoms of the gas, and these ions have reduced the negative space charge in the space between the cathode and anode thereby permitting a larger change in electron current to the anode per unit change in grid voltage, than takes place in a highly evacuated device. To be effective in reducing the electron space charge around the cathode and thus increasing the effectiveness of the grid control, positive ions must be present in the zone between the filament and the grid.

25 The optimum number of positive ions in such a device depends upon its geometry and the electron emission of the filament. A device which depends upon positive ions produced in this way is quite critical of adjustment. A slight change in the composition and pressure of the gas and also fluctuations in the cathode temperature and plate voltage may produce very abrupt changes in the number of and position of the positive ions formed and a resultant change in the detector action of the tube.

30 A more specific object of my invention is to provide a device which will be more effective as a detector than the usual gas device and which will not be so critical to changes in

cathode temperature, gas pressure and plate voltage.

This object may be attained by the introduction into the device of certain alkali metals and by a proper correlation between the metal used, the cathode material and temperature and the geometry of the device. The number of positive ions required to produce the most sensitive detector action in a device of the type described is somewhat critical. In order to have a device which will be comparatively stable and non-critical in its action, therefore, the conditions must be so determined that the number of positive ions will not change materially with changes in the cathode temperature and in the potential applied to the electrodes.

It has been found that under certain conditions if an alkali metal is introduced into a thermionic device, one electrode of which is heated above a predetermined critical temperature, positive ions will be emitted from that electrode. For example, if a pure tungsten electrode is heated above 1000 to 1200° C. in a device containing caesium, positive ions will be emitted from that electrode and the emission will be substantially independent of the electrode temperature as long as the temperature is maintained above this critical value.

The theory of operation of such a device is fully set forth and a device in which this phenomenon is utilized is described and claimed in the co-pending application of Kingdom and Langmuir, Serial No. 608,918, filed December 21, 1922.

Without going in great detail into the theory of operation whereby positive ions are emitted in such a device it will be sufficient to state that their emission depends upon the "electron affinity" or, as it is sometimes termed, the "work function" of the emitting surface and the ionizing potential of the alkali metal. This work function may be expressed in volts and for pure tungsten its value has been determined as 4.52 volts. The ionizing potential of caesium is about 3.9 volts and when a caesium atom strikes a hot positively charged tungsten surface with an electron affinity of 4.52 volts it loses an electron to

the tungsten and leaves the heated surface in the form of a positive ion.

By the production of positive ions by emission in contra-distinction to their production by collision between electrons and atoms a much more stable operation may be obtained. The number of positive ions produced in this way in addition to being substantially independent of the temperature of the heated electrode is also substantially independent of the voltage applied to the anode. Positive ions in sufficient number to produce good detector action may be obtained in this way with vapor pressures so low that ionization by collision is absent to such an extent that it plays no appreciable part in the operation of the device.

The desired number of positive ions may be produced in various ways. An extra electrode may be employed whose sole function is to emit positive ions, this electrode being maintained at a suitable positive potential with respect to the grid. It is more convenient, however, to utilize a portion of the cathode for the emission of positive ions. This may be brought about by maintaining the grid at a suitable negative potential with respect to a portion of the cathode. The value of the negative grid potential required for best operation will vary somewhat with the cathode material, the particular alkali metal used and the geometry of the electrodes. For example, in one case with a thoriated cathode in a device containing cesium and with a voltage drop of about two and one-half volts along the cathode, satisfactory operation could be obtained if the grid was maintained at a negative potential of about two volts with respect to the negative end of the cathode. In this case it is likely that positive ions were effectively emitted from about one-half of the cathode while electrons only were emitted from the other half of the cathode which was at a positive potential with respect to the grid of about three volts and less.

The portion of the cathode which emits positive ions should, preferably, be as close as possible to the portion which emits electrons to secure most effective reduction of the space charge around the cathode. The permissible difference of potential between the positive ion emitting portion of the cathode and the grid will also be limited by the negative potential which may be applied to the grid and still obtain the desired grid control.

The number of positive ions emitted from a given surface depends upon the geometry of the electrodes, the particular alkali metal employed, the nature of the emitting surface and the pressure of the vapor which in turn depends upon the temperature at which the device is operated. With a pure tungsten cathode cesium gives the largest positive ion

emission and sodium the smallest of the alkali metals. As before stated, the number of positive ions required to produce a sensitive non-critical detector action is fairly definite. If this definite number is greatly exceeded the action of the device becomes much more critical. If sodium is used with a pure tungsten cathode with a device operated at room temperature and with a device having suitable geometry of electrodes and proper grid potential to secure good detector action, the number of positive ions produced is somewhat below the optimum value and hence the device must be operated at somewhat above room temperature in order to secure the best results. This elevation in temperature may be secured by external heating or by supplying more energy to the cathode than would be necessary to obtain the required electron emission. On the other hand when cesium is used with a pure tungsten cathode the number of positive ions produced at room temperature will, except in very special cases, be materially greater than the optimum number, hence such a device operates best when the temperature is maintained below room temperature. The same is also true when rubidium is used although the number of positive ions obtained with rubidium is somewhat less than with cesium.

I have discovered that when a pure tungsten cathode is replaced by a thoriated tungsten cathode such as that described in Langmuir Patent 1,214,216, issued October 23, 1917, the number of positive ions which may be emitted with different alkali metals is materially less than the number which will be emitted by pure tungsten. I have found that when cesium or rubidium is employed with a thoriated tungsten cathode and a suitable form of construction provided, the number of positive ions which may be emitted is of about the optimum value required for good detector action when the device is operating at about room temperature. This combination has the advantage that the required electron emission may be obtained with an expenditure of materially less energy for heating the cathode than in the case of pure tungsten and no external heating of the device is required to cause it to operate to the best advantage.

When, on the other hand, sodium is used with a thoriated cathode the number of positive ions emitted is so small that they have substantially no effect on the detector action when the device is operated at near room temperature and the temperature required for successful operation would be excessively high.

The reason for the marked difference between the positive ion emission from a pure tungsten cathode and one containing thorium is not altogether clear. It appears likely however that the surface of the thoriated cathode

is not entirely coated with thorium. When a caesium atom strikes a portion of the cathode which is coated with thorium the atom will not give up an electron as the work function of thorium is below the ionizing potential of caesium. If, however, a caesium atom strikes a portion of the cathode surface which is not coated with thorium an electron will be abstracted from the atom and it will leave the surface as a positive ion. I have observed that in some cases the positive ion emission from a thoriated cathode is only from one to two percent of that from pure tungsten. This would seem to indicate that all but about one to two percent of the surface of the cathode was covered with a layer of thorium.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention, itself, however, will best be understood by reference to the following description taken in connection with the accompanying drawing in which I have shown a device suitable for carrying out my invention. I have indicated in the drawing an electron discharge device comprising the usual evacuated receptacle 1, containing a cathode 2, a grid 3 of helical form wound around supports 4 surrounding the cathode and a cylindrical anode 5 which is secured to a supporting arm 6, surrounding the grid and cathode. The cathode in this case is in the form of a V and is supplied with current by means of leading-in conductors 7 and 8. The loop of the cathode is supported by a hook 9 which in turn is supported by a member of insulating material 10 secured to the arm 6. The two legs of the V should, preferably, be quite close together. The desired alkali metal may be introduced into the device after evacuation and before sealing off in any suitable way such, for example, as by distillation from a side bulb containing the alkali metal or a compound thereof mixed with a suitable reducing agent which will give the pure metal upon the application of heat.

I have indicated the connections of the device in a circuit for detecting high frequency signals. The grid 3 is connected to the negative terminal of battery 11 which supplies heating current to the cathode 2 and the signals to be detected are impressed upon the grid circuit by means of the coupling transformer 12, the grid circuit being tuned by means of the variable condenser 13. The signal to be detected may be indicated in the usual telephone receivers 14 in the output or plate circuit.

In the construction shown the end of the cathode connected to the positive terminal of battery 11 emits positive ions. These are produced in the space between cathode and grid, and by bringing the two legs of the filament close together they will be produced and distributed as closely as possible to the other

leg of the filament from which the main supply of electrons is emitted and will, therefore, be most effective in reducing the space charge between the filament and the grid.

In the circuit arrangement shown the grid is connected to the negative terminal of battery 11 so that the full potential of the battery is applied between the grid and the positive end of the cathode. The normal negative potential of the grid during operation may be increased to the desired value by suitable selection of the grid condenser 15 and grid leak resistance 16.

While I have shown and described only one embodiment of my invention, it will be apparent that many modifications in the structural features of the device and in the selection of the materials employed, as well as in the circuit connections may be made without departing from the scope of my invention as set forth in the appended claims.

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

1. An electron discharge device containing an alkali metal and comprising an electron emitting cathode, an anode and a grid, said cathode being of a material which when heated is capable of emitting both electrons and positive ions and said cathode being partially covered with a surface film which is substantially incapable of emitting positive ions, means for maintaining the grid at such a negative potential with respect to a portion of said cathode that a sufficient number of positive ions will be emitted to reduce the negative space charge around the cathode to such an extent as to materially improve the detector action of the device.

2. An electron discharge device containing caesium and comprising a thoriated tungsten cathode, an anode and a controlling grid, said cathode being of filamentary form and having its two ends closely adjacent to each other, a source of heating current connected to said cathode and means for maintaining the grid at such a negative potential with respect to the positive end of the cathode that positive ions will be emitted from about one-half of the cathode.

3. An electron discharge device comprising an evacuated receptacle containing an alkali metal which during the normal operation of the device supplies to the evacuated space vapor at a pressure below that at which appreciable ionization by collision will occur, and comprising an electron emitting cathode capable of emitting positive ions in the presence of the alkali metal, an anode and a grid, said cathode being composed of a material having a higher work function than the ionizing potential of the alkali metal and an additional material having a lower work function whereby the capability of positive ion emission of the cathode is reduced, and the electrodes being

so related that the positive ion emission from said cathode during normal operation will be of such value as to permit the device to operate as an efficient detector of high frequency signals.

4. An electron discharge device comprising an evacuated receptacle containing cesium which during the normal operation of the device supplies to the evacuated space vapor at a pressure below that at which appreciable ionization by collision will occur, and comprising an electron emitting cathode capable of emitting positive ions in the presence of cesium, an anode and a grid, said cathode being composed of a material having a higher work function than the ionizing potential of cesium and an additional material having a lower work function whereby the capability of positive ion emission of the cathode is reduced, and the electrodes being so related that the positive ion emission from said cathode during normal operation will be of such value as to permit the device to operate as an efficient detector of high frequency signals.

5. An electron discharge device comprising a bulb containing cesium, a thoriated tungsten cathode, an anode and a controlling grid, said cathode being capable of emitting sufficient positive ions in the presence of cesium to afford efficient detection of high frequency signals when the bulb temperature is so low that the pressure of cesium vapor therein is below that at which appreciable ionization by collision will occur.

6. An electron discharge device comprising a bulb containing cesium, a thoriated tungsten cathode, an anode and a controlling grid, said cathode being of filamentary form and having its two ends closely adjacent to each other, said cathode being capable of emitting sufficient positive ions in the presence of cesium to afford efficient detection of high frequency signals when the bulb temperature is so low that the pressure of cesium vapor therein is below that at which appreciable ionization by collision will occur.

7. The method of operating a three-electrode thermionic device having a thoriated tungsten cathode and containing an alkali metal, which consists in controlling the pressure of the vapor of the alkali metal in the space surrounding the cathode to maintain it at a value below that at which appreciable ionization by collision will occur, producing an emission of positive ions from the cathode and utilizing this emission of positive ions to obtain a sensitive detector action of high frequency signals.

8. The method of operating a three-electrode thermionic device containing an alkali metal and having a thoriated tungsten cathode which consists in controlling the

pressure of the vapor of the alkali metal in the space surrounding the cathode to maintain it at a value below that at which appreciable ionization by collision will occur, producing an emission of positive ions from the cathode and maintaining the grid of the device at a sufficiently negative potential with respect to the cathode to collect the positive ions emitted therefrom and thereby produce an efficient detector action of high frequency signals.

In witness whereof, I have hereunto set my hand this 16th day of July, 1924.

ERNEST E. CHARLTON.

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