F. SCHRÖTER.

METHOD OF AND APPARATUS FOR SECURING CONSTANCY IN THE LIGHT OF VACUUM TUBES.

APPLICATION FILED APR. 3, 1913.

1,172,568.

Patented Feb. 22, 1916.

2 SHEETS—SHEET 1.

Fig. 1.

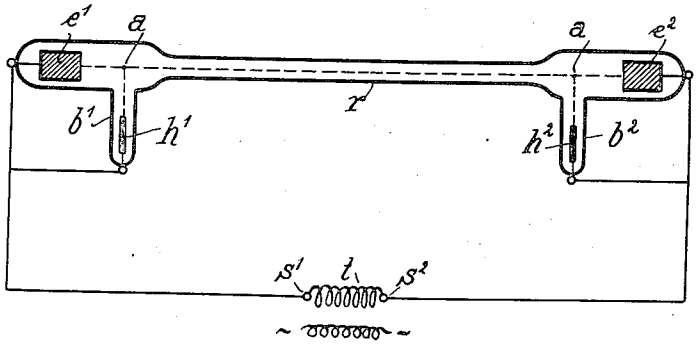
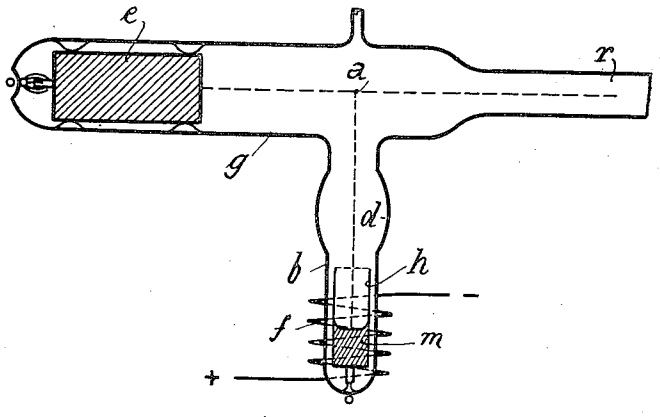


Fig. 2.



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2 SHEETS—SHEET 2.

Fig. 3.

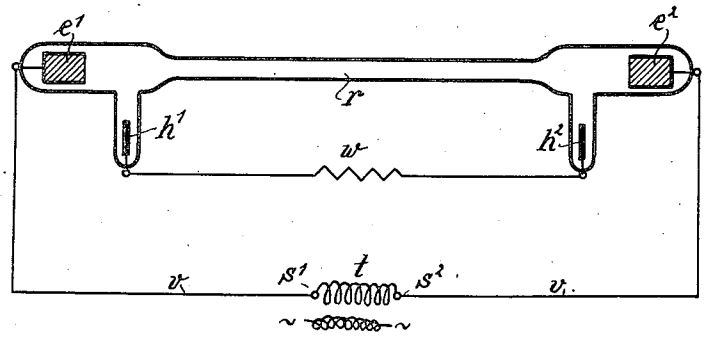
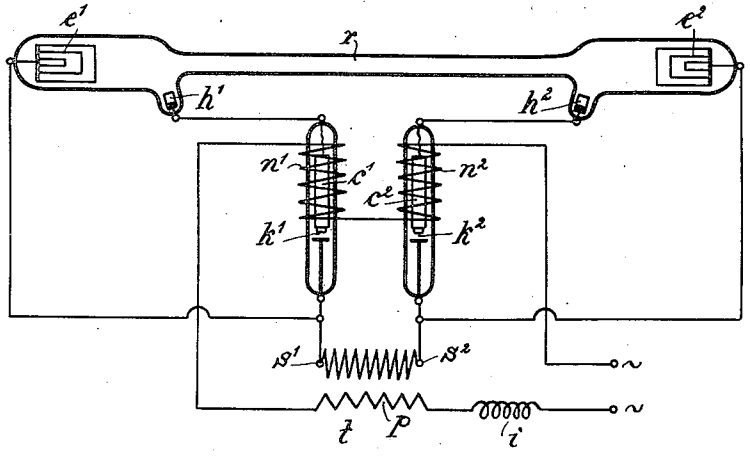


Fig. 4.



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UNITED STATES PATENT OFFICE.

FRITZ SCHRÖTER, OF BERLIN-WILMERSDORF, GERMANY.

METHOD OF AND APPARATUS FOR SECURING CONSTANCY IN THE LIGHT OF VACUUM-TUBES.

1,172,568. Specification of Letters Patent. Patented Feb. 22, 1916.

Application filed April 3, 1913. Serial No. 758,527.

To all whom it may concern:

Be it known that I, Dr. FRITZ SCHRÖTER, a subject of the King of Prussia, in the German Empire, residing at Berlin-Wilmersdorf, in the Kingdom of Prussia, German Empire, have invented certain new and useful Improvements in the Method of and Apparatus for Securing Constancy in the Light of Vacuum-Tubes, of which the following is a specification.

My invention relates to improvements in the method of and apparatus for securing constancy in the light of vacuum tubes.

The change of color of the light of a vacuum tube during discharge is essentially due to three causes: (1) the electrodes and the wall of the tube may give off gaseous impurities which cause an increase in the pressure of the gas, and cause the light-giving gas—*e. g.*, helium or neon—to behave in a remarkable manner, its characteristic light being extinguished by the presence of small quantities of foreign gases; (2) an absorption of the light-giving gas accompanied by a diminution of pressure may take place owing to the vaporization or pulverization of the electrodes, whereby a change in the color of the light is produced—*e. g.*, in the case of nitrogen from yellow to pink, in the case of carbon di-oxid from white to bluish, and in the case of helium from ytllow to green; and (3) gaseous impurities may have been left behind by incomplete exhaustion of the tube before it was filled with the desired light-giving gas, a small percentage of these impurities changing the color of the light of discharge—*e. g.*, the presence of air causing nitrogen to give a white light and the presence of water vapor causing neon to give a bluish light, the characteristic colors given by these gases in their pure state being yellow and orange respectively. In order to produce and maintain the characteristic color, in these cases, purification of the light-giving gas is necessary in the first and third cases, and its regeneration in the second case.

It has already been proposed to purify the light-giving gas by highly-colored wood charcoal or certain chemical substances which are so placed in the tube as to be heated by the heat of the discharge and are thus made to become active. Further for the regeneration, valves on the outside of the light tube are employed, which automatically admit gas into the tube when a change in the resistance of the tube takes place. These means, however, operate in a one-sided and incomplete manner.

The present invention has for object to provide a method and an apparatus for affecting vacuum-light tubes in such a manner that the above mentioned different causes of the changes in the color of the light can be removed at the same time. For this purpose, auxiliary electrodes are used in the tube, which come into operation under certain circumstances, and, by the pulverization or vaporization of the cathode of these auxiliary electrodes under the influence of the heat of discharge, cause the taking up of the light-changing impurities, and so render them ineffective, or give up the heat they receive from the heat of discharge to gas evolving substances, which by evolving gas prevent the increase of the terminal potential difference and the consequent change of color of the light. Such auxiliary electrodes have already been used in Röntgen tubes for preventing the hardening of the tube, the arrangement being such that whenever the vacuum becomes too high, the discharge leaps upon an auxiliary electrode, which, owing to the heating effect of the heat of discharge, evolves a certain quantity of gas and thus regenerates the tube. This arrangement, however, works intermittently, since it is only in operation during certain periods. The auxiliary electrodes in vacuum tubes according to this invention, however, act continuously, since the change of the seat of discharge in consequence of the peculiar properties of the small vacuum takes place continually.

In the drawings, are shown diagrammatically some examples of methods of carrying out the invention for several cases in which internal electrodes are used. In a similar manner, however, external electrodes can be employed.

In said drawings Figure 1, is a longitudinal section of the tube, Fig. 2, is a similar section of one end of a modification of the tube showing a subsidiary electrode of a different construction, and Figs. 3 and 4 are longitudinal sections of further modifications of the tube.

The arrangement according to Fig. 1 shows a light tube, which contains in its ex-

panded portions at its ends the two main electrodes e^1 and e^2. In lateral extensions b^1 and b^2 of the tube auxiliary electrodes h^1 and h^2 are arranged. Each auxiliary electrode is electrically connected with the corresponding main electrode. The main electrodes are connected by wires in the usual manner with the secondary terminals s^1 and s^2 of an electrical generator or transformer t.

The ratio of the distances of the main and auxiliary electrodes from the points a may be chosen as desired, according to the circumstances at the time being. If the distances $a\ h^1$ and $a\ h^2$ are greater than the distances $a\ e^1$ and $a\ e^2$ and the auxiliary electrodes have not normally a substantially smaller cathode drop, the discharge takes place between the main electrodes. As soon, however, as those main electrodes give off impurities which immediately increase the cathode drop of the main electrodes, the discharge is transferred to the auxiliary electrodes, and establishes itself between them since it is provided for that the cathode drop of the auxiliary electrodes cannot increase, the impurities immediately vanishing there. For this purpose the auxiliary electrodes are made of a metal which is sufficiently pulverizable or sufficiently vaporizable by the discharge proceeding therefrom to cause an absorption (occlusion) or a chemical combination of the impurities to take place at the electrodes themselves or in the metallic sublimate which they produce on the vessel wall.

The property of metallic vapors to combine with gases under the influence of the electric discharge is well known. During electrical discharge in vacuum tubes, the metallic electrodes generally volatilize and emit vapors into the gas, which becomes combined therewith to form a solid substance. All gases do not so combine with equal ease. For instance, if rare gases contain traces of other gases such as nitrogen or carbon di-oxid, and electric discharge takes place between volatilizing aluminium electrodes in an atmosphere of such gases, only the gaseous impurities are removed, while the rare gas in question is purified. Similarly the purification of gases, by heating and so vaporizing therein a suitable metal, and at the same time subjecting the gases to the electric discharge is known.

According to this invention the vaporization or pulverization produced by the electrical discharge is used with the object of purifying the light-giving gas from traces of foreign gases, but without the disadvantage of causing the darkening of the light by prolonged maintenance therein of the pulverization or vaporization and the consequent deposition of the metallic sublimate on the wall of the tube. This darkening would take place for example, if either the main electrodes were so arranged that they were sufficiently pulverizable or volatile to purify the gas sufficiently quickly and thoroughly, or if during the electric discharge in the light tube, a metal were caused to undergo prolonged vaporization by a separate and moreover inconvenient heating device. In both cases the volatilization process would proceed during the whole of the period of illumination of the tube, and the effect would be a rapid deposition on the whole of the inner wall of the tube which would thus lose its transparency. Besides this there would be introduced the danger that the light-giving gas might soon become combined with the too rich deposit.

According to this invention the process of pulverization or vaporization is intended to take place at the auxiliary electrodes only, and very strongly at these electrodes in order to effect a rapid purification of the gas and so to maintain the light at a constant color. These auxiliary electrodes come automatically into operation only in cases of need,—*i. e.*, only when the color of the light tends to change and a purification by volatilization of metal is required. If the cause of the change of color of the light ceases to operate, the auxiliary electrodes automatically become inoperative, and the danger of the darkening of the whole of the light tube by prolonged volatilization and sublimation of metal is avoided.

Metals which, on the vaporization of cathodes made thereof, are well adapted to fix such impurities as hydrogen, gases containing carbon, water vapor, and nitrogen, are, for example, the alkali metals. Further the alkaline earth metals, magnesium, zinc, nickel, aluminium, and generally all metals which chemically combine with hydrogen or easily take it up in their pores, such as platinum or palladium, are suitable. The alkali metals are suitable for the object in question only after heating *in vacuo* for a long time, when they give off impurities themselves. The other metals give off completely their small gaseous contents, when they are subjected for some time at high current density to a glow discharge. This is easily effected by allowing the discharge to travel solely between the auxiliary electrodes. While the other metals can be employed as desired in the form of wires or thin plates of desired form with the purpose of increasing the current density to the utmost degree and so producing the greatest heating effect, the alkali metals are employed preferably in a form which is represented in Fig. 2, which shows only one end of the tube.

In the expanded portion g at the end of the light tube r is situated the main electrode e. The lateral extension b, which

preferably bulges out at d, contains an iron electrode h which serves as a receptacle, in which some potassium or other alkali metal m is melted. On vaporization, a mirror of potassium is deposited on the wall of the dilated portion d. For the heating of the potassium either an electrical heating spiral f may be wound on the outside, or the electrode may be arranged for internal electrical heating. The heating may be effected externally by other means such as, for example, a heating bath or a flame. External electrical heating, however, has the same effect.

The mode of operation of the apparatus according to Figs. 1 and 2 is the following. The light tube is exhausted and some of the light-giving gas, for example neon, is then admitted. The discharge first travels through the shorter path—from e^1 to e^2. As soon as these electrodes become warm the impurities are expelled and on account of the accompanying increase of potential drop of e^1 and e^2, the discharge is transferred to h^1 and h^2. Immediately there are evolved at these auxiliary electrodes, vapors which absorb the impurities, whereby the pure orange color of the neon is restored, and at the same time the discharge returns to e^1 and e^2, because the potential drop there is again lowered owing to purification of the gas. This action is repeated automatically until the electrodes give off no more gaseous impurities, and all other impurities coming from the wall of the vessel or gases which remained behind on the exhaustion of the tube are removed. Neon is in this process not appreciably absorbed. In this way, by the alternating action of the main and auxiliary electrodes, every impurity is removed and the light of the tube is maintained constant. As soon as impurities can no more appear in the tube, the discharge takes place permanently between e^1 and e^2, and the auxiliary electrodes automatically go out of action. In spite of the initial prolonged alternation of the seat of discharge, the light of the light tube proper r remains unchanged. The transference of the discharge to the auxiliary electrodes in the case of an evolution of gas on the part of the main electrodes can be facilitated by artificial warming of the auxiliary electrodes.

If the same arrangement is to be used for the purpose of the regeneration of the tube, the heat appearing at the secondary electrodes on transference of the discharge is used for the purpose of heating these substances which on warming slowly evolve the light-giving gas until a small quantity of the gas is evolved, whereby the original color of the light is restored, so that since the apparatus works in a continuous manner, the slightest fluctuations in the color of the light are immediately counteracted. If, for example, the light tube is filled with carbon di-oxid which, at the normal terminal potential difference, gives a white light, any consumption of gas at the electrodes would have the effect of causing the terminal potential difference to rise in consequence of the diminution of the pressure of the gas, so that the light of the tube would tend to become bluish. As soon, however, as the terminal potential difference is slightly increased, the auxiliary electrodes come into action, and the substance provided there, in this case advantageously a pure bicarbonate, gives off some carbon di-oxid which immediately cuts off the discharge at the auxiliary electrodes and then spreads itself throughout the tube, the normal color of the light and the normal voltage being simultaneously restored. In the case of tubes filled with nitrogen, a suitable compound of a metal with nitrogen, as magnesium nitrid, or better lithium nitrid mixed with powdered quartz, or a nitrid of an alkali metal mixed with some metal powder, is employed. For helium tubes eleveite mixed with some metal powder—for example, calcium,—can be used. The tube must possess in all these cases extensions with quickly acting drying agents.

In Fig. 3 another mode of connection of the tube is represented. In this case the auxiliary electrodes h^1 and h^2 are not directly connected with the source of current, but are connected together by a metallic connection w. This connection can be either a simple wire or a suitable resistance device such as liquid or wire resistance, vacuum tube, spark-gap, or self-induction. The simple wire connection is only employed initially and is removed later. It allows the discharge to travel in the following path; from terminal s^1 to e^1, thence directly to h^1, through the wire w to h^2, thence to e^2 and to the terminal s^2. An alternating current flows alternately in this and the opposite direction. The discharge goes this way only when the surface of the auxiliary electrode is not too small—*i. e.*, when the cathode potential drop of the auxiliary electrodes is not too great. With this arrangement the main electrodes are caused to be rapidly and thoroughly freed from gas owing to the fact that the path of the current through the tube is shorter and closer to the main electrodes; on the other hand the auxiliary electrodes pulverize very strongly and purify the whole of the contents of the tube by fixation of the impurities by the existing deposit on the wall. Frequently one observes between the electrodes a constant alternation between the glowing phase and arc phase of the discharge in consequence of the alternate heating and cooling of the auxiliary electrodes. When the main electrodes are freed from gaseous impurities, the aux-

iliary electrodes are for some time switched out, and the discharge is allowed to travel through the whole length of the tube in order to free the vessel wall from gaseous and all other impurities. The auxiliary electrodes are again connected together and the accumulated impurities are removed by the discharge of the auxiliary electrodes, whereupon the tube finally shows a light of a constant color, and the connecting wire of the auxiliary electrodes may be permanently removed, whereupon the auxiliary electrodes go out of action. In other cases the auxiliary electrodes h^1 and h^2 are connected by a resistance w, which is so adjusted that the resistance to transference at the auxiliary electrodes plus the resistance of the connection is greater than the resistance possessed by the portion of the light tube between the auxiliary electrodes, when it contains completely pure gas giving of its characteristic color. Consequently a portion or the whole of the discharge goes through the resistance w which connects the auxiliary electrodes. These auxiliary electrodes thus come into operation—*i. e.*, they purify the gas on account of their pulverization—and the gas on restoration of the normal resistance and the consequent reëstablishment of the discharge between the main electrodes, again gives its correctly colored light. The resistance connecting the auxiliary electrodes need not be removed but may remain during the whole life of the light tube, since the auxiliary electrodes h^1 and h^2 come into operation only when the resistance of the tube is increased by impurities. The same arrangement can be used for regulating the light which changes color through an increase of terminal potential difference which is due to a diminution in the pressure of the light-giving gas. For instance, when a vacuum whose pressure is below the point of maximum conductivity is increased, the potential drop along the light-giving column of gas becomes greater and the light consequently varies. In this case, therefore the discharge would pass through the external resistance w, whereupon suitable substances provided at the auxiliary electrodes h^1 and h^2 would give off sufficient gas to decrease the drop of potential along the light-giving column of gas to such an extent as to cause the light to regain its normal color.

Fig. 4 shows an arrangement corresponding to Fig. 1, whereby, however, the necessary connection and disconnection of the auxiliary electrodes is effected when required (for instance, as long as opportunity for the production of impurities in the gaseous contents of the light tube exists), not by the operation within the tube itself—*i. e.*, in the secondary circuit, but by operations in the primary circuit. In this case there are again in the light tube r the main electrodes e^1 and e^2 and the auxiliary electrodes h^1 and h^2. The electrodes e^1 and e^2 are permanently connected with the secondary element of the source of current, for example, the secondary coil of the transformer t, at s^1 and s^2. The path between h^1 and h^2 is shorter than that between e^1 and e^2 so that in the case of impure gas the discharge travels along the shorter path. When the discharge travels from h^1 to h^2, however, the current in the tube rises on account of the purifying effect of the auxiliary electrodes. With this increase of the secondary current there is connected an increase of the primary current, which flows through the two solenoids n^1 and n^2 besides flowing; through the choking coil i and the primary winding p of the transformer. Owing to the increase of the strength of the primary current, the iron cores c^1 and c^2, situated in suitably constructed high tension interrupters, are so attracted into the solenoids as to cause the disconnection of the auxiliary electrodes from the source of current at contacts k^1 and k^2, which previously secured the connection between s^1 and h^1 (through k^1, c^1, and o^1) and between s^2 and h^2 (through k^2, c^2 and o^2). The auxiliary electrodes being disconnected from the source of current, the discharge takes place through the light tube between e^1 and e^2. As soon, however, as impurities are again evolved, the primary current falls in consequence of the decrease in strength of the secondary current and the auxiliary electrodes are again connected with the source of current at k^1 and k^2 by the falling of the iron cores c^1 and c^2—*i. e.*, they again act as purifiers, until they are again disconnected by the increase of the current on the removal of the impurities. This arrangement, unlike the arrangements shown in Figs. 1 to 3, enables the tube to give not only a light of constant color, but also of constant luminosity, since on the occurrence of a stronger current the path of discharge is increased and vice versa. The apparatus tends to keep the light column proper at constant current strength. The contacts k^1 and k^2, owing to the high voltage employed, lie preferably in a good insulating liquid. Obviously the solenoids n^1 and n^2 may be traversed by the secondary current instead of by the primary current so that the switching in and out will be effected directly by the strength of the current of the discharge circuit. Further, it will be clear that the auxiliary electrodes may be permanently in circuit, and the main electrodes switched in or out, after the manner described with reference to the auxiliary electrodes, according to the condition of the gas in the tube.

The apparatus can also be used for the regeneration of the tube. Gas evolving sub-

stances are used at the auxiliary electrodes which are switched in on a diminution in current strength, and cause an evolution of gas, and the consequent restoration of the normal pressure in the tube. Obviously, the apparatus may be adapted to the simultaneous switching out of one set of electrodes and switching in of the other set, and vice versa, so that always only one set of electrodes, either the main electrodes only or the auxiliary electrodes only, will be switched in. Again the distance between the auxiliary electrodes can be made greater than the distance between the main electrodes.

I claim herein as my invention:

1. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in temporarily establishing a subsidiary discharge within the tube and causing the same to atomize a material which is adapted to render the said impurities inactive.

2. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in temporarily establishing a subsidiary discharge within the tube and causing the same to atomize a material which is different from the electrode of the subsidiary discharge and is adapted when heated to give off a gas which prevents an increase of the voltage at the terminals and a change of the color of the light of the tube which would be caused by such an increase.

3. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in temporarily establishing a subsidiary discharge within the tube and causing the same to atomize a material which is adapted to render the said impurities inactive, and simultaneously heating the said material by an external source of heat.

4. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in providing within the tube apart from the main electrode a subsidiary electrode of suitable material susceptible of giving off a vapor capable of rendering the said impurities inactive, and causing atomization of the said subsidiary electrode by means of an electrical discharge therefrom.

5. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in providing within the tube apart from the main electrodes a subsidiary electrode of suitable material susceptible of giving off a vapor capable of rendering the said impurities inactive, causing atomization of the said subsidiary electrode by means of an electrical discharge therefrom, and heating by means of the discharge from the subsidiary electrode a substance which is adapted when being thus heated to give off a gas which prevents an increase of the voltage and a change of the color of the light of the tube which is caused by an increase of the voltage.

6. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in providing within the tube apart from the main electrodes a subsidiary electrode of suitable material susceptible of giving off a vapor capable of rendering the said impurities inactive, and causing atomization of the said subsidiary electrode by means of an electrical discharge therefrom while heating the same.

7. The herein described method of rendering inactive the impurities in the light giving gas which when present change the light of a vacuum tube, which consists in providing within the tube apart from the main electrodes a subsidiary electrode of suitable material susceptible of giving off a vapor capable of rendering the said impurities inactive, causing atomization of the said subsidiary electrode by means of an electrical discharge therefrom while heating the same, and heating by means of the discharge from the subsidiary electrode a substance which is adapted when being thus heated to give off a gas which prevents an increase of the voltage and a change of the color of the light of the tube which is caused by an increase of the voltage.

8. A vacuum tube comprising a pair of main electrodes, and at least one subsidiary electrode which is mounted in the tube and normally inoperative and means for rendering said subsidiary electrode operative upon a change of the resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrode, when operating, atomizing a substance which is adapted when atomized to render the said impurities inactive.

9. A vacuum tube comprising a pair of main electrodes, and at least one subsidiary electrode which is mounted in the tube and normally inoperative and means for rendering said subsidiary electrode operative upon a change of the resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrode, when operating atomizing a substance which is adapted to give off a gas which prevents an increase of the voltage and a change of the color of the light of the tube which is caused by an increase of the voltage.

10. A vacuum tube comprising a pair of main electrodes, at least one subsidiary electrode which is mounted in the tube and normally inoperative and means for rendering said subsidiary electrode operative upon a change of the resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrode, when operating, atomizing a substance which is adapted when atomized to render the said impurities inactive, and special heating means for said substance.

11. A vacuum tube comprising a pair of main electrodes, and at least one subsidiary electrode which is mounted in the tube and normally inoperative and means for rendering said subsidiary electrode operative upon a change of the resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrode consisting of a material which is adapted to be atomized by an electrical discharge and when atomized to render the said impurities inactive.

12. A vacuum tube having a main chamber and at least one subsidiary chamber and comprising a pair of main electrodes within the main chamber, and at least one subsidiary electrode located within the subsidiary chamber and which is normally inoperative and means for rendering said subsidiary electrode operative upon a change of the resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrode, when operating, atomizing a substance which is adapted when atomized to render the said impurities inactive.

13. A vacuum tube comprising a pair of main electrodes, and a pair of subsidiary electrodes which are mounted in the tube and normally inoperative; means for rendering said subsidiary electrodes operative upon a change of a resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrodes, when operating, atomizing a substance which is adapted when atomized to render the said impurities inactive.

14. A vacuum tube having a main chamber and a pair of subsidiary chambers and comprising a pair of main electrodes within said main chamber, and a pair of subsidiary electrodes located one within each subsidiary chamber and which are normally inoperative; means for rendering said subsidiary electrodes operative upon a change of the resistance of the tube caused by impurities of the gas within the tube; said subsidiary electrodes, when operating, atomizing a substance which is adapted when atomized to render the said impurities inactive.

In testimony whereof I affix my signature in presence of two witnesses.

DR. FRITZ SCHRÖTER.

Witnesses:

HENRY HASPER,

WOLDEMAR HAUPT.