May 3, 1960 R. FORMAN 2,935,624

ELECTROSTATICALLY-CONTROLLED RESISTANCE TUBE

Filed Aug. 26. 1955

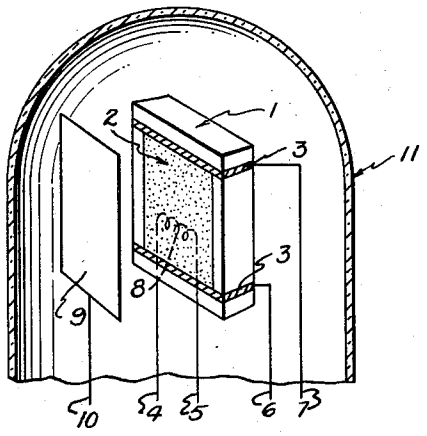


Fig. 1

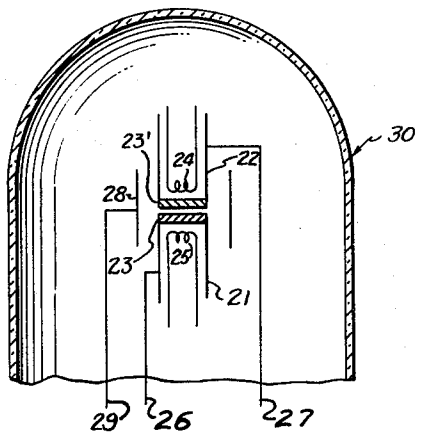


Fig. 2

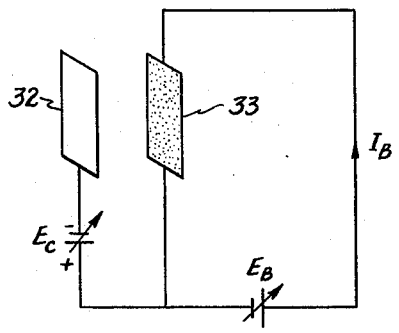


Fig. 3

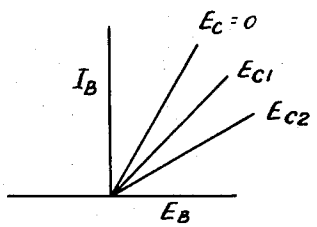


Fig. 4

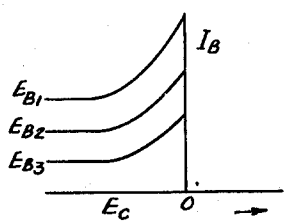


Fig. 5

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United States Patent Office 2,935,624 Patented May 3, 1960

2,935,624

ELECTROSTATICALLY-CONTROLLED RESISTANCE TUBE

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Application August 26, 1955, Serial No. 530,915

1 Claim. (Cl. 307—88.5)

This invention relates to a variable resistance tube and more particularly to a tube employing a porous semiconductor, the resistance of which may be electrostatically controlled by an electric potential applied to an element surrounding or adjacent to the semiconductor.

The present invention is a continuation-in-part of an application Serial Number 460,778 for a Magnetoresistive Device filed October 6, 1954 by Ralph Forman and Robert G. Breckenridge which has now matured into U.S. Patent No. 2,828,396.

It is well known that porous oxide coatings on various metals act as good electron emitters and have been used successfully as cathode material for many types of electron tubes.

The present invention is directed to the fact that these coatings exhibit a marked change in resistance when subjected to a variation in applied electrostatic field.

One object of this invention is to provide an electrostatic variable resistance.

Another object of this invention is to provide a variable resistance controllable by the influence of an electrostatic field.

A further object of this invention is to provide an electrostatically-controlled variable resistance tube.

Still another object of this invention is to provide an improved electrostatic amplifier.

Other uses and advantages of the invention will become apparent upon reference to the specification and drawings in which,

Fig. 1 shows one embodiment of an electrostatically-controlled resistance tube of the present invention;

Fig. 2 shows another embodiment in modified form of an electrostatically-controlled resistance tube of the present invention;

Fig. 3 shows the tube of either Fig. 1 or Fig. 2 arranged in a circuit to form an amplifier;

Figs. 4 and 5 show transfer characteristics derived from the circuit of Fig. 3.

Referring to the drawings, in Fig. 1 is shown a high temperature ceramic base 1 composed of insulating material such as MgO on which is deposited an oxide cathode coating 2. Base 1 is hollow and a filament 8 shown in dotted lines is placed inside with external lead wires 4 and 5 coupling filament 8 out of base 1. Metal-ceramic contacts 3 provide electrical coupling to the cathode coating 2. Electric current is passed through coating 2 by means of leads 6 and 7. A metallic plate 9 supplied by lead 10 is positioned adjacent to coating 2 and serves to establish an electrostatic potential in the region of the coating. An evacuated glass envelope 11 completely surrounds the tube structure.

Fig. 2 shows a second embodiment of the present invention. Numerals 23 and 23' refer to oxide coatings corresponding to the coating 2 of Fig. 1. Coatings 23 and 23' are deposited around the ends of nickel cylinders 21 and 22, respectively. As shown, the two coatings are separated by a small air gap, but, if desired, cylinders 21 and 22 may be butted together so that coatings 23 and 23' are in contact with each other. The coatings are heated by means of filaments 24 and 25. Electric current is supplied to coatings 23 and 23' through leads 26 and 27. Surrounding the coatings is an electrostatic metallic element 28 which is connected to a suitable potential source (not shown) by way of lead 29. An evacuated glass envelope 30 surrounds the entire structure.

Fig. 3 shows a circuit arrangement in which the resistance tube of the present invention is connected in the form of an amplifier. The oxide coating shown as 33 is supplied a "plate" current I_b by a source of voltage E_b. A negative voltage or retarding potential in the manner of an amplifier grid voltage is applied to metallic element 32 (in Fig. 3) adjacent or surrounding element 33, by variable source E_c. The characteristic curves for the device are shown in Figs. 4 and 5. The curves in Fig. 5 are very similar to those showing variation of plate current with grid voltage of an ordinary triode. The equivalent g_m of this tube, variation of I_b with a variation in E_c, is in the order of a few hundred micromhos, and this tube can be used as a voltage amplifier or power amplifier. The advantages of this device are that it has a very high impedance input, because of the negative voltages applied to element 32 in Fig. 3, and the output impedance can be made very low if the resistance of the material 33 is decreased by changing its dimensions.

Fig. 4 is a plot of the current I_b through coating 33 of Fig. 3 as a function of the series voltage source E_b for three different values of electrostatic supply voltage E_c, while Fig. 5 is a plot of I_b as a function of E_c for three different values of voltage source E_b.

The principle of operation of this device is based on the theory developed for porous semiconductors (oxide cathodes) which are good thermionic emitters. At high temperatures, for example, ranging from 700° K. to 1100° K., electrical conduction in the oxide cathode takes place because an electron gas exists in the porous structure of the material. This mechanism assumes that electrons, thermionically emitted from the crystals, form an electron gas in the pores of the oxide cathode, and, at sufficiently high temperatures, current through the oxide cathode is predominately due to current flow through the electron gas. The electrical conductivity of the oxide cathode is then found to be functionally dependent on the space charge distribution of the electron gas in the pores. If an electrostatic potential is applied to an element adjacent to or surrounding the cathode material, which does not necessarily draw any current from the emitting material, the space charge distribution in the pores changes and alters the electrical conductivity of the oxide cathode. A change in electrical conductivity causes I_b in Fig. 3 to change for a constant applied voltage E_b.

The device has been built with the oxide cathode as the porous semiconducting material, but any other material having porous semiconductor properties would be equally applicable.

It has been found, as can be seen from Figs. 4 and 5, that a negative charge on element 32 of Fig. 3 produces an increase in the resistance of the coating 33. In Fig. 4, for example, when the voltage E_c equals zero, the "plate" current I_b is quite large. However, as the charge-producing potential E_c increases negatively as represented by E_{c1} and E_{c2}, the "plate" current decreases. This shows that the current flowing through coating 33 for a constant applied voltage is proportional to the strength of the electrostatic field to which the coating is subjected. Obviously any means for changing the magnitude of this field will have a corresponding effect on the resistance of coating 33.

A similar, though less pronounced change in resistance is noted if a charged bar is placed near element 32. If

negatively charged, the bar will cause the resistance of coating **33** to increase as the bar approaches element **32**, and the resistance will subsequently decrease to its original value as the negatively charged bar is drawn away.

Source E_c provides a permanent stationary substitute for such a bar. The increase and decrease in negative charge on element **32** produces the same effect as a negatively charged bar moving toward and away from the element.

The theory by which the resistance of coating **33** changes resistance is thought to involve the electron space charge in the pores of the coating. When a negatively charged bar is brought near metallic element **32** it induces a corresponding positive charge on the outer surface of element **32**. This positive charge is brought about by a rush of electrons from the outer surface of the metallic element **32** to the inner surface of the element, resulting in a negative charge on its inner surface adjacent coating **33**. This nearby negative charge drives electrons around the constantly emitting coating **33** into the pores of the coating, thereby increasing the negative electron space charge in the pores of the coating. With an increased space charge in the pores fewer electrons accelerated by "plate" source E_b are able to flow across the pores and hence a smaller current I_b flows for an equal voltage E_b. A decreased "plate" current for equivalent "plate" voltage represents an increase in effective resistance of coating **33**.

With variable voltage source E_c in place of a charged bar the theory of operation remains the same. The source E_c "pushes" a surplus of electrons from its negative terminal onto element **32**, the electrons being distributed on both surfaces of the element. The negative charge on the inner surface of element **32** increases the space charge of electrons in the coating pores effectively increasing the resistance of the coating. Removal of the electrons from the nearby inner surface of element **32** restores the original space charge distribution in the pores of coating **33**, thus restoring its resistance to the original value.

The advantages of this device over conventional amplifiers are as follows:

(*a*) The device is an amplifier with a very high impedance input (retarding fields are applied by control electrode, element **32** in Fig. 3, therefore the currents to the control electrode are very low).

(*b*) The output impedance of the device can be varied over a wide range of values by controlling the resistance of the device. The resistance of the device can be controlled by its linear dimensions. In other words, very low output impedances (in the order of 10–100 ohms) can be obtained.

(*c*) By eliminating the usual type of grid element used in vacuum tubes, the structure of this device is capable of being much more rigid than the conventional tube.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claim.

What is claimed is:

An electrostatic variable resistance tube comprising a hollow insulated base, a porous semiconductive coating on said base, filament means within said base for heating said coating to a temperature above 700° K., means for passing an electric current through said coating, metallic means adjacent said coating, and means for applying a variable electric potential to said metallic means.

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