Feb. 22, 1949. J. A. VICTOREEN 2,462,441

VACUUM TUBE WITH FILAMENTARY CATHODE

Filed Feb. 12, 1947

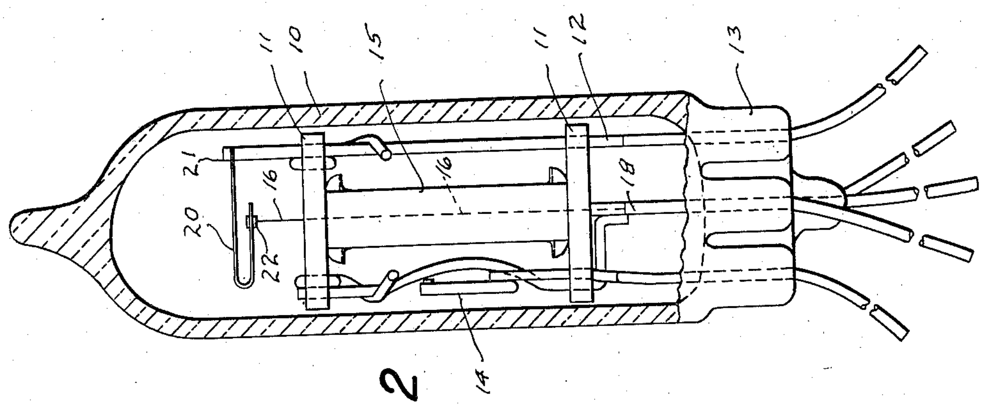

FIG. 2

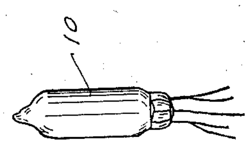

FIG. 1

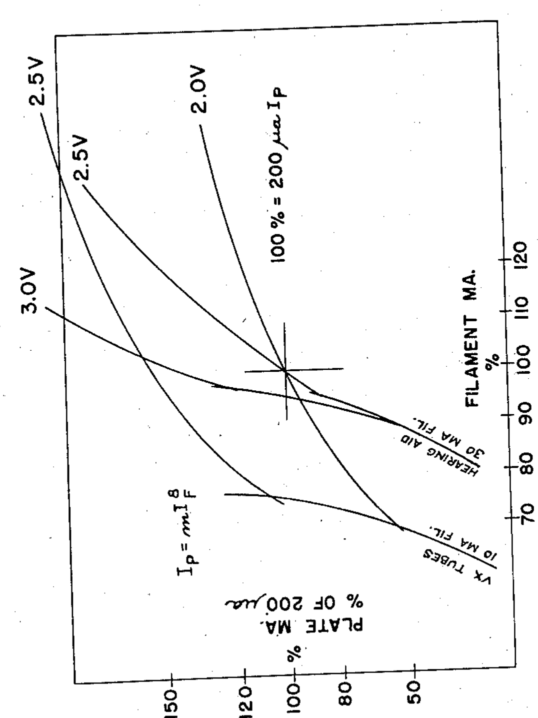

FIG. 3

INVENTOR.
JOHN A. VICTOREEN

BY J. W. Douglass

Patented Feb. 22, 1949

2,462,441

UNITED STATES PATENT OFFICE

2,462,441

VACUUM TUBE WITH FILAMENTARY CATHODE

John A. Victoreen, Cleveland, Ohio

Application February 12, 1947, Serial No. 728,109

3 Claims. (Cl. 250—27.5)

1

This invention relates to improvements in thermionic tubes and more particularly to an improved filamentary cathode for a vacuum tube and the method of making the same. See my copending application Number 642,446.

Heretofore, many problems have arisen in connection with the manufacture of vacuum tubes, not the least of which were those arising in conjunction with the construction and operation of the filament. Among other things, the size of the filament was one of the controlling factors in the construction. In large tubes this did not involve too much of a problem, but in small tubes, the limitations as to the size of the filament has a definite bearing in its construction. This will be better appreciated when it is understood that in a vacuum tube it is desirable to heat the filament with some conventional voltage source, and that the temperature of the filament and its resistance is usually a function of its length and circular mil area as well as the specific resistance of the material.

In the smaller type tubes, the filaments are very often heated by 1.4 or 1.5 volt voltage sources, such as a dry, wet, or so-called "Mallory" cell. In order for a filament to be heated to the desired emitting temperature by a 1.4 or 1.5 volt cell, it was necessary to provide one of a certain length. The length was also determined by the specific resistance of the filament, and since the current necessary to heat the filament to an emitting temperature varied with the diameter, it was desirable to draw the wire to a diameter as small as possible. In order to use prior materials, the filament had to be longer which made it necessary to fold the filament in order to get it into a small space. The folded filament, although taking up less longitudinal space, took a greater transverse space, thus placing limitations on the spacing of the tube elements. Furthermore, the folded or the long filament had a tendency to vibrate when shocked which resulted in microphonic operation, as well as instability thereof. The filament, being long and of small diameter, had less strength and there was, therefore, a tendency for it to sag, causing short circuits. It also had many other disadvantages, including that of complicating the manner of its support. Small diameter filaments also had a greater tendency toward hot spots due to unequalities in diameter which occurred during the drawing process.

Another disadvantage of the previous filaments was the variation of the resistance of the material upon heating. Normally, all prior

2

known filaments had a high temperature coefficient of resistance which resulted in a low resistance when cold, and which resistance greatly increased upon heating. This variation in the temperature coefficient of resistance in nickel, for instance, is of the order of 400% from hot to cold. This increase in resistance or change in resistance after the filament is heated is very undesirable because it is the direct cause of circuit instabilities. The fact that the voltage source which is used to heat the filament varied during its life, being maximum when new and dropping off after use, caused very apparent changes in the tube performance and resultant changes in circuit performance due to the inability of the current in the filament to follow proportionate changes in voltage. Such instabilities were such that in certain instances the utility of the tube was greatly limited.

Furthermore, in these prior filaments, and tungsten in particular, when first heated, had a low resistance; but this resistance increased as the heating was prolonged. Thus, the resistance did not keep pace with the heating, causing the filament to glow brightly at first and then gradually decrease in brightness to its normal color. This "flashing" effect had a tendency to decrease the life and stability of the filament. Furthermore, changes in ambient temperature were sufficient to cause resistance changes resulting in changes in the emission current. These changes were especially undesirable when the tubes were used in conjunction with a direct current amplifier, because in a direct current amplifier the absolute values of emission determines what happens in the circuit, as distinguished from an alternating current amplifier where only incremental changes are of interest. This effect may be utilized in certain places, such as a bolometer where a high temperature coefficient is necessary to its operation, but has no place in a vacuum tube, and more particularly, is extremely undesirable when the tubes are used for instrumentation as in nuclear physics, where exceptional static emission stability and circuit resistance stability is desired.

By my present invention I have discovered an improved filament material which has a high specific resistance as compared with previously known filament. This enables a much shorter filament to be used than heretofore. By the use of a short filament, longitudinal and transverse space in the tube are economized. This enables a very small tube to be made. It enables the filament to be heated by conventional voltage sources, such as 1.5 volt cell, instead of a fraction thereof, thus greatly enhancing its use. The manner of supporting the filament is simplified, allowing a more sturdy support, causing the filament to be more rigid and eliminating all the disadvantages of the long flexible filament. The filament is freely suspended at its ends without having contact with any other part of the assembly. Thus there is no thermal contact with other parts of the tube which would cause the plate current to assume different values due to mechanical disturbances.

Furthermore, the filament of my discovery has a low temperature coefficient of resistance being of the order of 5 percent from hot to cold. Still another advantage of the filament of my invention is that in my filament, which has low thermal conductivity, a greater efficiency of the filament in operation is realized, because the filament heats more evenly throughout its length and heats to the desired temperature closer to its support and there is less heat lost throughout the support. This, as distinguished from the conventional tungsten or nickel filament which has its highest temperature at the places most removed from its support and which is quite cool at its points of support due to its high thermal conductivity.

To better illustrate certain aspects of the invention, reference will be had to the accompanying drawing wherein;

Fig. 1 is a full sized elevational view of a tube embodying the filament of my invention;

Fig. 2 is an enlarged vertical medial section thereof;

Fig. 3 is a graph depicting the operation of the tube of my invention as compared with a commercial hearing aid tube.

The filament of the present invention is particularly useful in the so-called miniature tubes, such as is shown in Fig. 1. In the tube, the overall length is approximately 1¼ inches, and the space inside the envelope which houses the tube element is ⅞ inch long. The diameter of the tube is approximately 11/32 inch, and the inside diameter is approximately .275 inch. The actual useful portion of the filament is 15/32 inch long while the diameter is .0004 inch and is provided with a coating of oxides which is .0002 inch thick, bringing the diameter of the complete filament with its oxide coating to .0008 inch.

The construction of such a tube is shown in detail in the greatly enlarged sectional view in Fig. 2. Here the glass envelope which houses the elements is shown at **10**. A pair of ceramic members are provided at **11** spaced from the top and bottom of the tube and held in position by supports **12** which extend through the press **13** at the base. One of the supports is adapted to support a getter **14** and the anode **15** is supported between the two ceramic members. The filament **16** has its lower end secured in the lead **18** preferably by insertion in the hollow end of the lead which is then pressed and welded. The upper end of the filament is supported by a spring wire **20** of U shape conformation, one leg of which is welded to the flattened end **21** of the support **12** and the other end of which has a flag **22** of thin metal to which the filament is welded.

The preferred filament material of my invention comprised a binary alloy of a chromium and nickel which has a specific resistance of 600 ohms or more per circular mil foot. I also contemplate the use of ternary alloy, however, wherein other elements than nickel and chromium are present, such as cobalt. This filament has a high tensil strength at normal emitting temperature.

A chromium-nickel alloy having 500 ohms per circular mil foot will also be satisfactory. So far as I am aware, the more commonly accepted material for filaments is tungsten or nickel. I have discovered, however, that nickel and chromium provide a material having a high specific resistance, as well as a low temperature coefficient of resistance.

This material may be drawn down to a diameter of approximately .0004 inch, which seems to be the practical limit of minimum diameter to which it may be drawn.

It also has a temperature coefficient of resistance such that it only changes in resistance approximately 5 percent from cold to hot, as compared with nickel or tungsten which varies over 400 percent from cold to hot. Because the resistance is high, it permits a filament of larger diameter to be used and of shorter length for a given filament current and voltage. This allows the manufacture of tubes of extremely small size having a straight filament, and which tubes are characterized by their extreme static stability as compared with prior small tubes. As a matter of fact, prior to this invention, a severe limitation on the use of these tubes was apparent because of the inconsistencies of results in operation due to the structure. These tubes may be operated singly or in parallel with a single voltage source, and the behavior of the filament provides such consistent results that it becomes particularly useful in D. C. amplifier circuits, such as are used in electronic instrumentation, due to the fact that between tubes a close tolerance of characteristics is attained. This feature is of particular importance in D. C. amplifiers or electrometer circuits where the absolute value of current is of interest rather than the incremental value such as is used in A. C. circuits. In such a circuit the control element may have an input leakage resistance of the order of 10^{16} ohms and a current of 10^{-15} amperes and, very often in such circuits, it is desirable to have the filament become a part of the resistance network. In such cases, if the filament has a high temperature coefficient of resistance, it becomes a non-linear component which makes it impossible to properly balance the circuit. The filament maintains a relatively constant emission under conditions of varying filament current, thus decreasing the tendency to drift.

It will be noted that the coating of oxides used on my filament is extremely thin as compared with previous coatings.

The oxides may comprise the usual barium and strontium compounds which are preferably deposited on the filament by cataphoresis in the form of barium and strontium carbonate crystals. I have found that it is desirable that these crystals provide the best result if they are not too small and preferably are of the largest size which will successfully cataphorize and still adhere properly to the filament.

The coating after being applied to the filament is converted to oxides during the activating stage of manufacture.

A family of curves, plotting plate current against filament current show that this tube has characteristics more nearly to the ideal curves desired by the industry but which have never been attained and particularly in miniature tubes. Fig. 3 illustrates the curves for a tube of my invention and in comparison therewith a similar curve for a socalled "hearing aid" tube. These curves show the change in emission with cathode heating current which, although often ignored in alternating current amplifier design, becomes of major importance in a direct current instrument. The curve designated "VX tube" is one made from a tube having the filament of my invention, and the curve "hearing aid" is that of a commercial tube available on the market. The "hearing aid" is presumed to have a nickel filament. In each instance, the grids and plates of the tubes were connected together to make a diode and the values were reduced to common ordinates giving the emission as 100% at 200 m. a. plate current, and at rated cathode current to make the curves comparable. The relative constancy of plate conductance of the "VX" tube is apparent. The operating range is wider, and the change in emission current is considerably less.

It will also be noted that the "VX" tube cathode produces a nearly constant difference over a wide range either side of rated operating cathode current. The hearing aid tube does not have a well defined saturation point and the conductance varies greatly with cathode current.

It has been found by graphical analysis that the plate current, in the region in which the tube is emission limited, varies exponentially; that is, it follows the expression $I_p=MI_f^n$. As a specific instance, the tube shown in Fig. 3 follows the expression $I_p=MI_f^8$, where M is a constant depending on the geometry of the tube and power input to the tube.

By the use of a filament of my discovery, I am able to make tubes for the purpose intended which have heretofore been impractical of construction. These tubes have a definite and important use in connection with the instrumentation of nuclear physics, allowing simple and rugged instruments to be made and provide consistent and long life operation.

Having thus described my invention, I claim:

1. A miniature tube for control purposes including an evacuated envelope, electrodes disposed in the envelope and including at least an

anode and an electron emitting cathode, said cathode being capable of stable operation with changes in heating potential and comprising a single short wire of under three-quarters of an inch in length and between .0008 and .0004 inch in diameter, means to support said filament comprising a lead in wire extending through a press in said envelope and a support extending spaced from the filament, spring means on the end of the support connected to said other end of the filament to hold it taut, said filament being formed of an alloy of nickel, chromium and cobalt in such proportions as to provide a high specific resistance and low temperature resistance coefficient and low thermal conductivity.

2. A vacuum tube for control purposes for controlling small currents, including an evacuated envelope, electrodes disposed therein and including an electron emitting cathode capable of stable operation with changes in heater potential comprising an alloy of chromium, nickel and cobalt having a length of between ⅝ and ¾ inch and a diameter of between .0004 and .0008 inch and of high tensile strength, and spring means to hold the filament taut.

3. A sub-miniature tube for control purposes including an evacuated envelope, electrodes disposed in the envelope and including an electron emitting cathode capable of stable operation with changes in heating potential comprising a single short length of wire formed of an alloy of nickel, chromium and cobalt in such proportion as to provide high specific resistance, a low temperature resistance coefficient and having low thermal conductivity.

JOHN A. VICTOREEN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,803,467	Driver et al.	May 5, 1931
1,812,103	MacRae	June 30, 1931
1,839,899	Slepian	Jan. 5, 1932