Jan. 5, 1932. J. SLEPIAN 1,839,899

SPACE CURRENT DEVICE

Filed Oct. 15, 1923

Fig. 1.

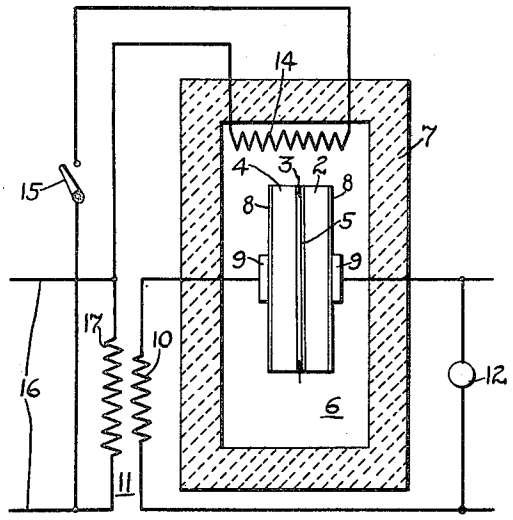


Fig. 2.

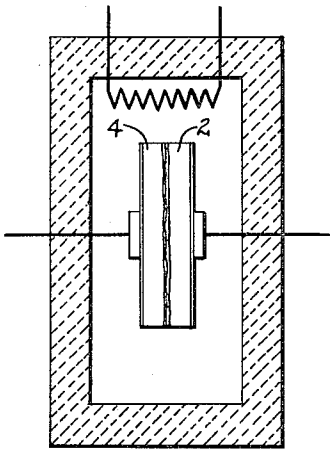


Fig. 3.

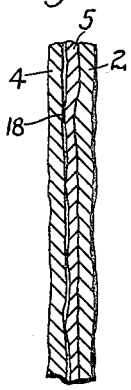
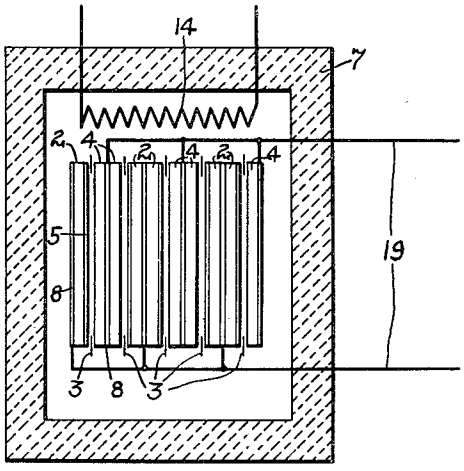


Fig. 4.



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UNITED STATES PATENT OFFICE

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SPACE CURRENT DEVICE

Application filed October 15, 1923. Serial No. 668,553.

My invention relates to space-current devices and it has particular relation to devices for rectifying alternating currents.

The principal object of my invention is to provide a simple and efficient space-current device which may be manufactured at a small cost and operated in a reliable manner.

A more specific object of my invention is to provide a space-current device having an anode and a thermionically active cathode which are spaced from each other by a minute gap.

A further object of my invention is to provide a device of the above character which does not require a highly evacuated vessel for its operation.

In carrying out my invention, I find that by providing a sufficiently close spacing between the anode and the cathode, the space charge effect encountered in devices of the above character may be reduced to a very small value. The close spacing is made possible by utilizing a cathode having a surface adapted to emit electrons at relatively low temperatures and by raising the temperature of the entire device to the required operating temperature. The small space charge effect obtained by the close spacing further permits the operation of such devices in gases of relatively high pressure, of the order of the atmospheric pressure, for instance, permitting the use of constructions which are not limited by the exacting requirements of high vacuum or low pressure devices.

With the foregoing and other objects in view, my invention consists in the arrangements and details of construction hereinafter described and claimed and illustrated in the accompanying drawings, wherein

Figure 1 is a diagrammatic view of a single-cell rectifier embodying my invention;

Fig. 2 is a view similar to Fig. 1 showing a modification of my invention;

Fig. 3 is an enlarged view of portions of the two electrodes shown in Fig. 2 and the gap therebetween, and

Fig. 4 is a diagrammatic view of a multicell rectifier embodying my invention.

In Fig. 1 is shown a rectifier comprising a flat cathode 2 which is spaced, by means of thin spacers 3 of insulating material, such as mica strips, from a flat anode 4. The cathode preferably consists of a material having relatively high specific resistance of the order of 1 ohm per cubic centimeter or more. I may employ materials like carborundum, high-resistance oxides or composite resistance materials.

In my preferred construction, I employ a cathode consisting of a mixture of kaolin, carborundum and lampblack which is molded in the form of slabs and baked at a high temperature. The particular kind of material used for the cathode is, however, not absolutely essential to my invention in its broad aspects and I may likewise employ metallic electrodes such as nickel.

The anode 4 may consist either of the same material as the cathode or I may employ a metal such as molybdenum or nickel.

The active surface 5 of the cathode is coated with oxides giving a relatively high electron emission at low temperatures. A mixture of oxides of barium and strontium provides a very good coating for the surface of the cathode. I may also employ a cathode consisting of a composite material having the electron emitting oxides as component parts thereof, for instance, a mixture of kaolin, carborundum, lampblack and oxides of barium and strontium. Such cathodes and, in general, electrodes of composite material may be used to great advantage in other space current devices, since the resistivity of the electrodes may be easily adjusted to suit the particular applications. The two electrodes 2 and 4 are placed in a preferably gas-tight chamber 6 having heat insulating walls 7 of refractory material. The back sides 8 of the electrodes are in intimate electrical contact with contact members 9 provided within the chamber 6 and connected, through a secondary winding 10 of a supply transformer 11, to a direct-current load 12. In order to insure good electrical contact, I may plate or spray the reverse sides 8 of the electrodes with a metallic or other highly conducting material which forms the contact surface for the contact members 9.

A heating coil 14, which is provided with-

in the heating chamber 6, may be energized by means of a connecting switch 15 from an alternating current supply line 16 that constitutes also the source of supply for the primary winding 17 of the transformer 11. The chamber is preferably filled with a gas at approximately atmospheric pressure, which does not react with the oxides of the electrodes. I prefer to employ such gases as hydrogen, helium or nitrogen for reasons explained more fully hereinafter.

To operate the rectifier, the heating coil is energized and the temperature of the electrodes within the chamber 6 is initially raised to about 700° or 800° centigrade. At this temperature, the cathode emits electrons in copious amounts and current flows from the anode to the cathode. In the reverse direction, the device acts as an open circuit by reason of the relatively negligible number of electrons emitted by the anode at the above temperature. After the operation has once started it may be possible to open the heating circuit, either intermittently or permanently, relying upon the internal heating of the rectifier to maintain the necessary temperature.

In Fig. 2 is shown a modification of my invention, wherein the mica spacer 3 is entirely avoided and the cathode plate is placed in apparently direct contact with the surface of the anode. I find that the direct contact between the two electrodes is actually restricted to a small number of points 18 of relatively small conducting area as seen in the enlarged view in Fig. 3, the larger part of the surfaces of the two electrodes being spaced from each other by a minute gap. By using electrodes of sufficiently high resistivity, the points of actual contact will have a very high resistance and act like insulating spacers.

I will now discuss certain characteristic features of my device and set forth the theory of operation thereof as I understand it at present, although I do not wish to be altogether limited to any particular theory or form of construction.

The electrons emitted from the cathode surface move toward the anode under the action of the electromotive force applied to the electrodes. During their travel, the electrons may combine with an uncharged gas molecule to form negative ions. The conduction of the currents between the two electrodes depends upon the presence of electrons or negative ions in the space between the electrodes and thus it depends upon the action of the cathode in continually creating a new supply of electrons or ions.

It may be shown that the following relation exists between the distance x between the parallel electrodes, the current i per unit area, the potential v necessary to overcome the space-charge effect caused by the flow of the ions constituting the current i, and the mobility k of the ions in cm. per sec. per unit of potential gradient:

$$V=\frac{2}{3}\sqrt{\frac{8\pi}{K}}I^{\frac{1}{2}}X^{\frac{3}{2}},$$

in the electrostatic system of units, or

$$v=3.1\ 10^{6}k^{-\frac{1}{2}}i^{\frac{1}{2}}x^{\frac{3}{2}},$$

in the practical or ordinary system of units.

In the above equation, the potential v is proportional to the three halves power of the distance x. Assuming a current i of 10 milliamperes per cm.^{2} and assuming the mobility k equal to 1 cm. per sec, per volt per cm., we find for the distance x,

$x=10^{-6}$ cm.; $v=0.00031$ volts,
$x=10^{-4}$ cm.; $v=0.31$ volts, and
$x=10^{-2}$ cm.; $v=310$ volts.

Although the assumed value for the mobility is rather low, the potential across the electrodes for a close spacing such as is employed in my invention is of the order of 1 volt. Gases like hydrogen or helium have, however, a mobility of the order of 6 cm. per sec. and in other gases like argon or nitrogen, the mobility of the negative carriers is much higher still, the negative carrier in such gases being probably, in part at least, free electrons. Consequently, the potential across the electrodes operating in such gases will be still lower than the value computed above, or what amounts to the same, larger spacings may be employed without an increase in the potential across the electrodes.

The particular arrangement of my rectifier makes the operation at atmospheric pressure possible, provided that the maximum rectifier voltage is not more than the minimum sparking potential for the gas used, which is of the order of several hundred volts.

Difficulties may be encountered in providing a sufficiently small spacing between the electrodes. It is in order to avoid such difficulties that I employ electrodes made from a material having a relatively high resistivity, so that a slight contact at a few points will not constitute a short circuit. A similar effect may, however, be secured by providing purely metallic electrodes and making the oxide coating upon the cathode sufficiently thick and of sufficient resistivity to prevent a perfect electrical contact at a point of accidental contact between the two electrodes.

The employment of electrodes having a relatively high resistance is also beneficial on account of the balancing effect of the resistance tending to keep the current well distributed over the entire electrode surface and counteracting a possible tendency to develop an arc between the two electrodes.

The temperature of operation is prefer-

ably kept just high enough to supply the requisite thermionic emission in order to avoid the danger of an arc-over by reason of excessive emission from one point of the electrode. As noted above, the current carried per square centimeter of the electrode surface is relatively low. The simple construction of my rectifier permits, however, the use of a very large electrode surface by the provision of a plurality of parallel-connected rectifying cells. Such a construction is shown in Fig. 4, wherein a plurality of cathodes 2 are assembled in pairs with their corresponding anodes 4 with spacers 3 therebetween in the same manner as in Fig. 1. The cathodes and anodes are connected in parallel to two conductors 19 serving as terminals of the rectifier.

The above arrangement shown in Fig. 4 presents a very simple construction which entirely avoids the use of evacuated vessels and glass envelopes and is adapted for the construction of rectifiers of large capacity. For rectification of high voltages I may utilize a plurality of rectifiers connected in series.

Various modifications in the details of construction and operation of my invention may be made by those skilled in the art without departing from the spirit thereof and it is my desire that only such limitations shall be placed thereon as are indicated in the appended claims or are required by the prior art.

I claim as my invention:

1. A space-current device comprising two bodies in gas at a pressure of the order of one atmosphere having contact surfaces separated by a gap of not over 10^{-2} centimeters length, one of said surfaces constituting themmionically active means.

2. A space-current device comprising two bodies in gas at a pressure of the order of one atmosphere having contact surfaces separated by a gap so minute as to carry a space current of at least 10^{-2} amperes per square centimeter across said gap at voltages lower than is necessary to maintain an arc, one of said bodies being adapted to emit electrons freely.

3. A unidirectional-current conducting device comprising two bodies, a surface of one body being in contact with a surface of the other body in a plurality of points, said points of contact being of relatively high resistance, the surface of said one body being coated with a thermionically active material.

4. A unidirectional-current conducting device comprising two conducting bodies having contact surfaces separated from each other by a gap of not over 10^{-2} centimeters, said gap being filled with a gas at approximately atmospheric pressure, and means for rendering one of said contact surfaces thermionically active.

5. A unidirectional-current conducting device comprising two conducting bodies having contact surfaces separated from each other by a minute gap, and means for controlling the temperature of said bodies, the contact surface of one of said bodies being thermionically more active than that of the other.

6. A unidirectional-current conducting device comprising a body having a surface adapted to emit electrons, a second body having a surface adapted to emit substantially no electrons disposed in contiguity to said first body, one of said surfaces being of a material having a resistance of the order of one ohm per centimeter cube.

7. A unidirectional-current conducting device comprising an electrode member having a surface layer of material having a resistance of about one ohm per centimeter cube and another electrode member having a surface in close juxtaposition to the first said electrode member, said electrodes being in gas at a substantial pressure, and one of said electrodes being adapted to emit electrons more freely than the other.

8. A unidirectional-current conducting device comprising a cathode member having a surface layer adapted to emit electrons freely, an anode member having a surface placed in close proximity to said cathode member, said members being insulated from each other and at least one of them having a resistivity of the order of one ohm per centimeter cube, means providing an enclosure for said members, and a gas filling said enclosure.

9. A unidirectional-current conducting device comprising a cathode member having a surface layer adapted to emit electrons at a temperature above 700° centigrade, an anode member having a surface placed in close proximity to said cathode without making substantial electric contact with the same and means for causing said members to operate substantially at said temperature in a gas at a pressure of the order of one atmosphere.

10. A unidirectional-current conducting device comprising a plurality of plate-shape cathodes having substantially plane surfaces, means for rendering said surfaces thermionically active, a plurality of plate-shape anodes having substantially plane surfaces mounted in close proximity to said cathode surfaces, and insulating means for providing minute gaps between each pair of cathode and anode surfaces.

11. A unidirectional-current conducting device comprising a plurality of plate-shape cathodes and anodes stacked in close juxtaposition, substantially plane surfaces upon said cathodes and anodes, means for rendering said cathode surfaces thermionically active at an elevated temperature, means providing a heat insulating casing around said cathodes and anodes, and means for raising the temperature within said casing.

12. An electrode for an electron discharge device including an electrode of a composite material comprising a mixture of kaoline, carborundum and carbonaceous material.

13. An electron discharge device comprising a plate-shaped cathode of a high-resistance composite material including, at least in the surface thereof, substances of high electron emissivity, and a plate-shaped anode spaced therefrom a distance of the order of a few microns.

14. The combination of means providing a cathode surface in gas at a pressure of the order of one atmosphere, said surface being electron emissive at a temperature above 700 degrees centigrade, and means providing an anode surface in close proximity to said cathode surface but separated therefrom by a minute distance, said distance being so small that the electrons emitted from said cathode surface produce a negligibly small space-charge effect.

In testimony whereof, I have hereunto subscribed my name this 9th day of October 1923.

JOSEPH SLEPIAN.