

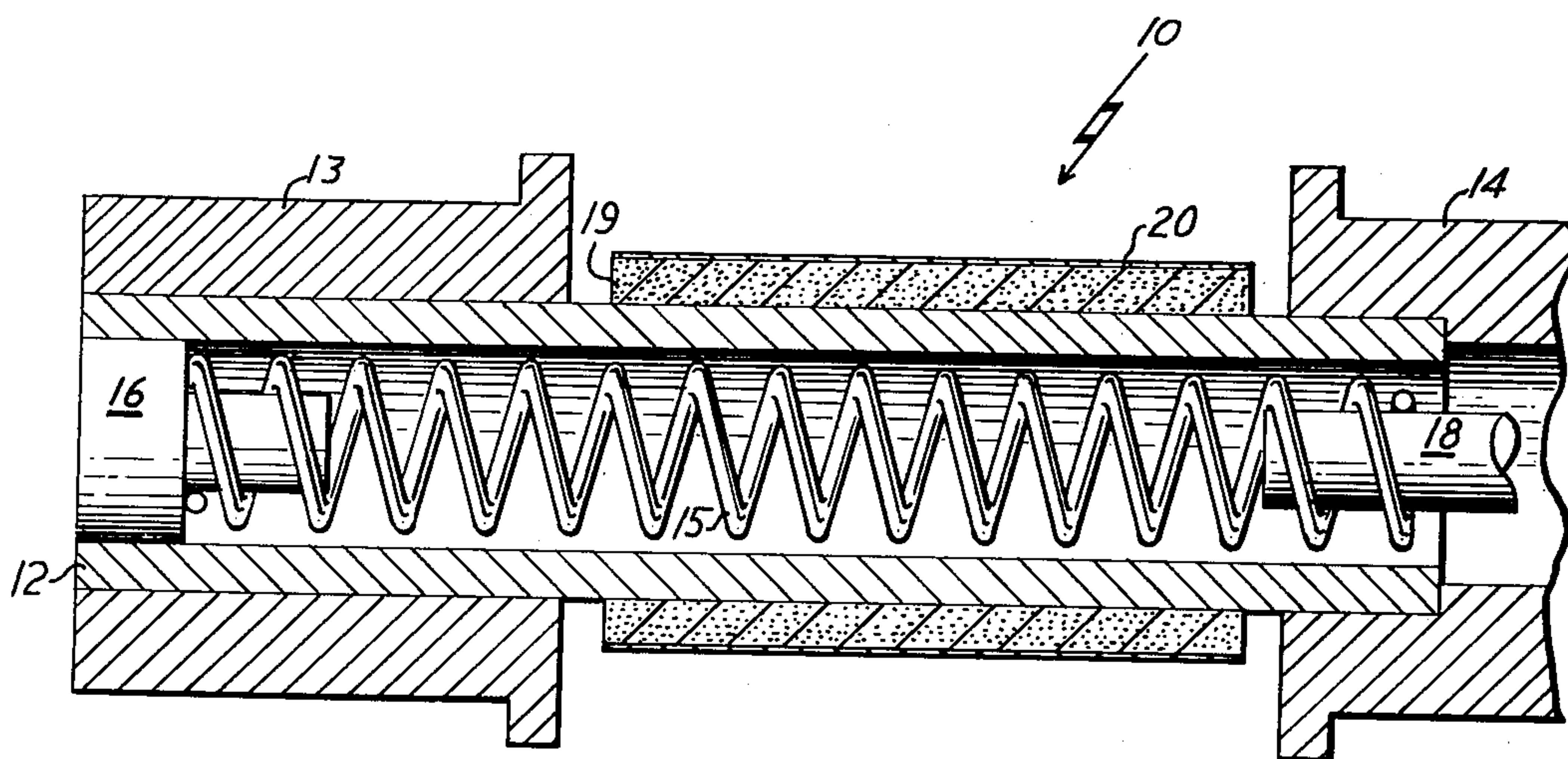
Aug. 8, 1961

J. H. APELBAUM ET AL

2,995,674

IMPREGNATED CATHODES

Filed Feb. 27, 1959



INVENTORS  
JOSEPH H. APLEBAUM  
KENNETH W. DUDLEY  
BY *H. Vincent Harsha*  
ATTORNEY



1

2,995,674

## IMPREGNATED CATHODES

Joseph H. Apfelbaum, Waban, and Kenneth W. Dudley,  
South Sudbury, Mass., assignors to Raytheon Com-  
pany, a corporation of Delaware

Filed Feb. 27, 1959, Ser. No. 796,109

12 Claims. (Cl. 313-346)

This invention relates to a cathode for electron discharge devices, and more specifically, to a tungsten cathode impregnated with a mixture of one or more alkaline earth oxides and chromic oxide.

An object of this invention is to produce an impregnated cathode which is characterized by relatively high thermionic emission and which is capable of withstanding relatively high operating temperatures of the order of 1100° C.

In accordance with this invention, a sintered porous tungsten body or matrix is impregnated with an electron-emissive impregnant made of a fused mixture of chromic oxide and one or more of the group known as alkaline earth oxides, including barium oxide. The impregnant preferably consists of barium oxide and chromic oxide, although satisfactory operation has been obtained when either calcium oxide or strontium oxide is added to the barium oxide. Such cathodes, unlike many other oxide cathodes, are capable of satisfactory operation at temperatures of the order of 1100° C. with reasonably high electron emission densities.

The cathodes according to the invention are made by firing a tungsten compact at a high temperature until the compact attains sufficient strength and the desired porosity. A suspension of chromic oxide and one or more alkaline earth oxides—one of which is barium oxide—is applied to the surface of the fired tungsten compact. The coated tungsten compact is next fired to a temperature well above the melting point of the impregnating compound, until the latter becomes dispersed substantially uniformly throughout the porous mass of the tungsten body. During operation of the electron discharge device in which the cathode is placed, a reaction occurs between the impregnant and the tungsten body such that some free barium is formed which diffuses out onto the surface of the tungsten body in a very thin layer—preferably less than one molecular layer thick—at a rate determined by such factors as the porosity of the tungsten body, cathode operating temperature, and the composition of the impregnant. The chromic oxide has been found to slow down the rate of formation of the barium and thereby extends the life of the cathode. The electron-emissive surface is replenished by gradual diffusion of the electron-emitting material toward the surface of the tungsten body. In those cases where alkaline earth oxides, such as calcium oxide and strontium oxide, are added to the barium oxide, a composite emissive layer is formed at the surface of the tungsten body which, like the emissive layer formed with barium oxide and chromic oxide alone, is replenished at a rate dependent upon the factors above-mentioned.

The single figure of the drawing shows in cross section one form of cathode assembly embodying the present invention.

The cathode assembly 10 includes a metal supporting sleeve 12 which preferably is made of a refractory metal, such as molybdenum or tungsten, capable of withstanding relatively high cathode operating temperatures. End shield members 13 and 14 may be attached to the supporting sleeve 12 adjacent both ends thereof to prevent emission of the cathode material in a direction parallel to the longitudinal axis of the cathode assembly. An elongated heater coil 15 is included within the central bore of supporting sleeve 12. One end of heater coil 15

2

may be attached to an electrically conductive member 16, which, in turn, is secured to the inner periphery of the supporting sleeve 12 at one end thereof. The other end of the heater 15 is attached to a heater lead-in conductor 18 which passes through the central aperture in the end shield member 14 and then external to the evacuated envelope of the electron discharge device, not shown, in which the cathode assembly 10 is to be mounted. For a description of a typical electron discharge device of the magnetron type in which a cathode according to the invention may be incorporated, attention is directed to the United States Patent No. 2,542,908 of Palmer P. Derby, issued February 20, 1951. The electron-emissive portion of the cathode assembly 10 includes a tubular cathode body 19 of porous tungsten whose surface, during actual tube operation, is coated with a very thin layer 20 of emissive material diffused from the pores of the tungsten body 19. In practice, this layer is slightly less than one molecular layer in thickness and is greatly exaggerated in the drawing for the sake of clarity.

A mass of tungsten powder is compressed in a mold to produce a tungsten compact which conforms generally to the desired shape and size of the finished cathode body. The tungsten compact should be somewhat oversize, since subsequent firing steps cause some shrinkage. In one instance, the tungsten powder was subjected to a pressure of fourteen tons per square inch. This pressure will depend partly on the size of the tungsten particles and upon the desired porosity of the tungsten compact.

The tungsten compact next is fired at an elevated temperature in a furnace containing a vacuum or non-oxidizing atmosphere, such as helium or hydrogen.

It has been found that firing at a temperature of approximately 2350° C. for about twenty minutes produces a cathode of the necessary structural strength and porosity. The strength, as well as the porosity of the tungsten body is a function of both firing time and firing temperature. If the firing temperature is reduced, the firing time must be increased, and vice versa. The porosity of the tungsten compact partially determines the diffusion rate, that is, the rate at which the emissive material diffuses out of the pores of the tungsten body onto the surface thereof. If the tungsten body is too porous, the emissive material will escape too rapidly from the tungsten body and the cathode life will be limited. Similarly, if the tungsten body is too dense, the emissive material will not diffuse out to the surface rapidly enough to provide proper emission. Moreover, the porosity will determine the amount of impregnant that can be made to penetrate initially into the tungsten body; the higher the porosity of the tungsten body, the greater will be the initial supply of emissive material available in the tungsten body. For a given cathode operating temperature, an equilibrium condition is desired such that optimum coverage of the surface of the tungsten body is attained, since the surface coverage depends upon the amount of electron-emissive material which diffuses out of the tungsten pores onto the surface of the tungsten body. This optimum surface coverage is usually slightly less than a monomolecular layer of the electron-emissive material. If the diffusion rate is lowered, because of decreased porosity of the tungsten body, it is necessary to resort to higher cathode operating temperatures to produce the same emission current density.

A mixture including barium oxide (BaO) and chromic oxide (Cr<sub>2</sub>O<sub>3</sub>), suspended in a suitable binder such as methyl alcohol which evaporates readily during the firing process, is applied to one or both surfaces of the tubular tungsten body 19, as by painting or spraying. The coated tungsten body 19 is then fired at a temperature well in excess of the melting point of the comminuted mixture in



a furnace containing a vacuum or a nonoxidizing atmosphere, such as hydrogen.

In a preferred embodiment of the invention, the impregnant composition included three parts of barium oxide by weight to one part chromic oxide by weight. Another impregnant composition may include four parts of barium oxide by weight to one part of chromic oxide by weight. Another composition may include approximately 70 percent barium oxide by weight, 18 percent chromic oxide by weight and 12 percent strontium oxide by weight, corresponding substantially to four moles of BaO, one mole of Cr<sub>2</sub>O<sub>3</sub> and one mole of SrO. Still another composition may consist of approximately 75 percent barium oxide by weight, 18 percent chromic oxide by weight, and 7 percent calcium oxide by weight, corresponding substantially to four moles of BaO, one mole of Cr<sub>2</sub>O<sub>3</sub>, and one mole of CaO. The impregnant-coated tungsten body may be fired at a temperature of the order of 1800° C. for about one minute. The firing time must not be too long lest excessive emitting material evaporate out of the tungsten matrix during firing. During the firing process, the impregnant melts and flows into the pores of the tungsten body by capillary action. The impregnated cathode, after cooling, is now ready for insertion in an electron discharge device, such as a magnetron. When the cathode heater is energized such that the cathode operating temperature is of the proper value, the impregnant reacts with the tungsten in the cathode body to form barium (in the case of barium oxide and chromic oxide) or barium and either strontium or calcium (when the impregnant contains either strontium oxide or calcium oxide in addition to the barium oxide).

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A cathode comprising a porous body of tungsten and a mixture comprising chromic oxide and an alkaline earth oxide disposed within said body.

2. A cathode comprising a body of tungsten of porous construction and a supply of electron-emissive material disposed within said porous body which comprises a mixture of chromic oxide and an alkaline earth oxide including barium oxide.

3. A cathode comprising a porous body of tungsten and a mixture comprising chromic oxide and barium oxide disposed within said body.

4. A cathode comprising a porous sintered body of tungsten and a supply of electron-emissive material disposed within said porous body which comprises one part

of chromic oxide by weight and three parts of barium oxide by weight.

5. A cathode comprising a porous sintered body of tungsten and a supply of electron-emissive material disposed within said porous body which comprises a mixture of one part of chromic oxide by weight and four parts of barium oxide by weight.

6. A cathode comprising a body of tungsten of porous construction and a supply of electron-emissive material disposed within said porous body which comprises a mixture of chromic oxide, barium oxide, and calcium oxide.

7. A cathode comprising a body of tungsten of porous construction and a supply of electron-emissive material disposed within said porous body which comprises a mixture of chromic oxide, barium oxide, and strontium oxide.

8. A cathode comprising a porous sintered body of a refractory metal and a mixture containing chromic oxide and an alkaline earth oxide including barium oxide disposed within the pores of said body.

9. A cathode comprising a porous sintered body of refractory metal tungsten and a supply of electron-emissive material disposed within said porous body which comprises a mixture of approximately 18 percent of chromic oxide by weight, approximately 75 percent of barium oxide by weight, and approximately 7 percent of calcium oxide by weight.

10. A cathode comprising a porous sintered body of refractory metal tungsten and a supply of electron-emissive material disposed within said porous body which comprises a mixture of approximately 18 percent of chromic oxide by weight, approximately 70 percent of barium oxide by weight, and approximately 12 percent of strontium oxide by weight.

11. A cathode comprising a porous sintered body of refractory metal tungsten and a supply of electron-emissive material disposed within said porous body which comprises a mixture of approximately 18 percent of chromic oxide by weight, and the remainder of at least one alkaline earth oxide.

12. A cathode comprising a porous sintered body of refractory metal tungsten and a supply of electron-emissive material disposed within said porous body which comprises a mixture of approximately 18 percent of chromic oxide by weight, and the remainder of barium oxide.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

2,488,727	Klasens et al. ....	Nov. 22, 1949
2,700,000	Levi .....	Jan. 18, 1955

##### FOREIGN PATENTS

185,472	Austria .....	May 11, 1956
194,994	Austria .....	Jan. 25, 1958