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THERMIONIC CATHODE HEATER AND
METHOD OF MAKING ITEdward R. Wagenhals, West Orange, N. J., as-
signor to Radio Corporation of America, a cor-
poration of DelawareNo Drawing. Application November 25, 1933,
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2 Claims. (Cl. 250—27.5)

My invention relates to heaters for use in vac-
uum electric devices and more particularly to an
insulated heater element for use in an indirectly
heated thermionic cathode for electron discharge
devices.

A common type of heater for oxide coated
cathodes is a non-inductive reverse wound heli-
cal coil of tungsten wire insulated with a coat-
ing consisting of a mixture of aluminum oxide
and about 2% of talc or silica. Such heaters are
in general satisfactory, but some times the insu-
lation becomes somewhat leaky at high tempera-
tures and allows an appreciable amount of stray
and uncontrollable current to flow between the
cathode sleeve and the heater wire. Tubes con-
taining cathode heaters with leaky insulation are
not desirable and may be noisy.

In one method commonly used for making
cathode heaters a mixture of finely ground alu-
minum oxide and about 2% of talc or silica is
stirred into a solution of nitrocellulose to form a
syrupy suspension, with which a coil of ductile
tungsten wire is coated by spraying the suspension
on the coil with an air pressure spray gun. The
coating is dried and the coated coil heated from
five to ten minutes in a hydrogen furnace to about
1400° C. to 1600° C. At this temperature the coat-
ing hardens on the tungsten wire, which remains
ductile.

It has heretofore seemed necessary, in the com-
mercial manufacture of such cathode heaters, to
mix with the aluminum oxide insulation some talc
or silica or similar material which softens at about
1400° C. in order to obtain a hard firm coating
of insulation at a firing temperature at which the
tungsten wire remains ductile. Aluminum oxide
free from talc or silica sinters and forms a co-
herent layer when fired at temperatures of 1800°
C. or higher, but when the heaters were fired in
the usual hydrogen furnace in the usual way to
the sintering temperature of aluminum oxide the
tungsten heater wire became very brittle and
practically useless.

One of the objects of my invention is to provide
a cathode heater element consisting of a ductile
tungsten wire insulated by a coherent sintered
coating of alumina of the kind usually designated
in commerce as chemically pure aluminum oxide.

Another object is to provide a cathode heater
of ductile tungsten with refractory insulation
such that even at high temperature the electrical
leakage between the heater and cathode is prac-
tically negligible.

A further object is to provide a method by
which a ductile tungsten heater wire can be

coated with a dense coherent coating of chemi-
cally pure aluminum oxide without impairing the
ductility of the wire.

In accordance with my invention the heater
element consists of a tungsten wire which, al-
though covered with a coherent coating of sin-
tered chemically pure aluminum oxide, is practi-
cally as ductile as the tungsten heater wires of
the heaters insulated with a mixture of aluminum
oxide and talc. The heater element is made by
coating a ductile tungsten wire with finely pow-
dered chemically pure aluminum oxide suspended
in a binder, such as a solution of nitrocellulose,
and then fired in an atmosphere of exceedingly
wet hydrogen at about 1800° C., a temperature at
which the chemically pure aluminum oxide sin-
ters into a coherent layer. I have found that
under these conditions the ductile tungsten wire
retains its ductility, although it is covered with
chemically pure aluminum oxide sintered into a
dense adherent coating. Prior to my invention,
heaters with ductile tungsten wire insulated with
aluminum oxide could be had only with aluminum
oxide mixed with talc or silica, as attempts to
insulate ductile tungsten wire by sintering chemi-
cally pure aluminum oxide on it resulted in heat-
ers with wire too brittle to be useful.

One procedure by which, in accordance with my
invention, I have obtained commercially useful
heater elements involves the use of aluminum
oxide containing about .2% or less of impurities.
This oxide, generally made by drying precipitated
aluminum hydroxide, can be obtained commer-
cially in the form of a powder which is usually
sold as chemically pure aluminum oxide. I find
it advantageous to heat this powdered aluminum
oxide to a temperature of about 1600° C. until it
shrinks slightly and increases somewhat in den-
sity, and then to grind it in a ball mill into a fine
powder, of which the average particle size is about
two thousandths of an inch and the maximum
particle size is not more than three times the
average size. I find it desirable to ball-mill the
oxide in a rubber lined mill with pebbles of pure
flint or of mullite, a commercial form of alumina
for about 18 hours. This fine powder of dense
chemically pure aluminum oxide is suspended in
a solution of nitrocellulose or similar decompos-
able carbonaceous binder, preferably of about the
consistency and viscosity of a thin syrup. I pre-
fer to make the suspension with the smallest
amount of solution that will give a smooth even
coating of oxide when the suspension is sprayed
on the tungsten heater wire. A common and use-
ful form of cathode heater is a ductile tungsten

wire, wound into a reverse helix as shown in the United States Patent to Fredenburgh, 1,980,675, November 13, 1934, and assigned to the assignee of my application. The sprayed coating on such a helix may be from 5 mils. to 10 mils. thick, depending on the degree of insulation required.

In accordance with my invention the tungsten wire helix, coated with a smooth uniform coating of chemically pure aluminum oxide and nitrocellulose binder, is dried, preferably by heating it for a short time to about 100° C. to drive off the solvent. The helix with the dried coating can be handled with ordinary care without injury to the coating. After the coated helix is dried, it is fired in an electric furnace in a hydrogen atmosphere to about 1800° C. Ordinarily a firing of 5 to 10 minutes is sufficient. I prefer to fire the coated heater coils by putting them in molybdenum boats which are then passed through the hydrogen furnace in the usual way. In accordance with my invention the hydrogen atmosphere which surrounds the coated heater during the firing in the furnace is kept very wet, practically as wet as possible while the heaters are being fired. The carbon in the binder makes the ductile tungsten wire brittle when fired at 1800° C. in the usual hydrogen atmosphere, but the hydrogen atmosphere saturated with water vapor renders this carbon innocuous to the ductile tungsten. A convenient way of wetting the hydrogen to the desired extent is to bubble it through water kept at a temperature of about 50° to 55° C., whereby the hydrogen is saturated with water vapor and wetted much more than when it is bubbled through water at room temperature. I have found that if the heaters of ductile tungsten wire coated with a suspension of chemically pure aluminum oxide are fired in this very wet or saturated hydrogen atmosphere at about 1800° C., the ductile tungsten wire of the heaters is not affected or rendered brittle by the carbon in the binder, and remains ductile, and the particles of chemically pure aluminum oxide sinter together into a dense coherent coating which adheres to the wire. To the naked eye this coating seems smooth and uniform, with a dull finish. Under the microscope the particles of aluminum oxide appear to be sintered together into a coherent layer. In sintering the particles do not melt and flow together, but soften slightly on the surface and stick together. The sintered aluminum oxide forms on the ductile heater wire an insulating coating which consists of chemically pure aluminum oxide and is of very low electrical conductivity.

Although ductile tungsten is the preferred metal for the heater coils, molybdenum or other ductile metal of high melting point may be used. The pure aluminum oxide may, instead of being

mixed with a nitrocellulose binder and sprayed on the heater wire, be mixed with flour paste and extruded as a rod suitable for use as a core rod for the reverse coiled helix. The extruded rod fired at 1800° C. or higher in very wet hydrogen is strong and is well adapted for use as a core rod for heater coils with chemically pure aluminum oxide insulation. A heater made of a ductile tungsten wire coil mounted on such a core rod and insulated in accordance with my invention is sturdy, and has the advantage that both the core and the coating are of chemically pure aluminum oxide.

The ductile tungsten wire of a heater coil coated with chemically pure sintered aluminum oxide in accordance with my invention retains its pliability to such an extent that a 5 mil. tungsten wire coil of the pitch and diameter of the usual cathode heater coils can be pulled out substantially straight without breaking the wire, although the sintered coating may break. Prior to my invention a heater with a tungsten coil of such pliability could not be made with insulation of chemically pure aluminum oxide.

While I have described a few specific embodiments of my invention, it is to be understood that various changes and modifications are contemplated and that the invention is limited in its scope only by the appended claims.

What is claimed as new is—

1. The method of making an electrically insulated heater for electron discharge tubes which comprises coating a ductile tungsten heater wire with chemically pure aluminum oxide powder of particles of average size of about 2 microns and of maximum size not greater than 6 microns in suspension in a carbonaceous binder and heating said coated ductile tungsten wire to a temperature of approximately 1800° C. in an atmosphere of hydrogen saturated with water vapor until said coating is sintered into a hard dense coherent layer adherent to said wire.

2. The method of making an electrically insulated heater for electron discharge tubes which comprises spraying a ductile tungsten wire with a suspension in a nitrocellulose binder of aluminum oxide containing less than 0.2% of impurities and powdered to particles of maximum size of about 6 microns and average size of about 2 microns to form a coating on said wire, heating said coated wire in an atmosphere of hydrogen substantially saturated with water vapor to about 1800° C. to remove the nitrocellulose binder, and maintain said coated wire ductile and to sinter the aluminum oxide on said wire into a hard dense coherent coating adherent to said wire.

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