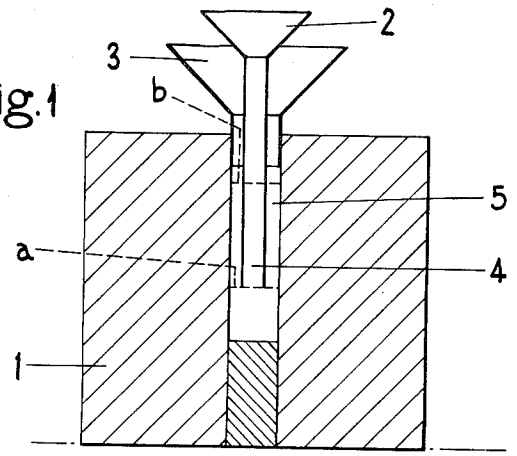
Jan. 25, 1966 D. J. JONES ETAL 3,231,332

ELECTRODES FOR ELECTRIC DISCHARGE APPARATUS

Filed July 31, 1962

Fig.1



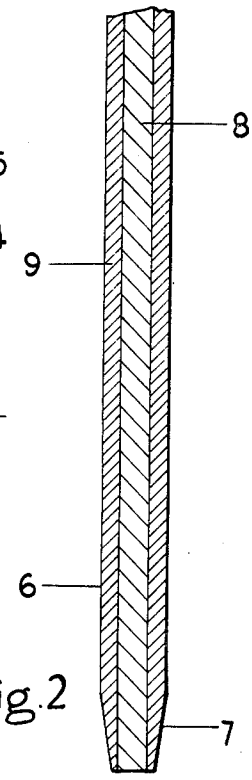


Fig.2

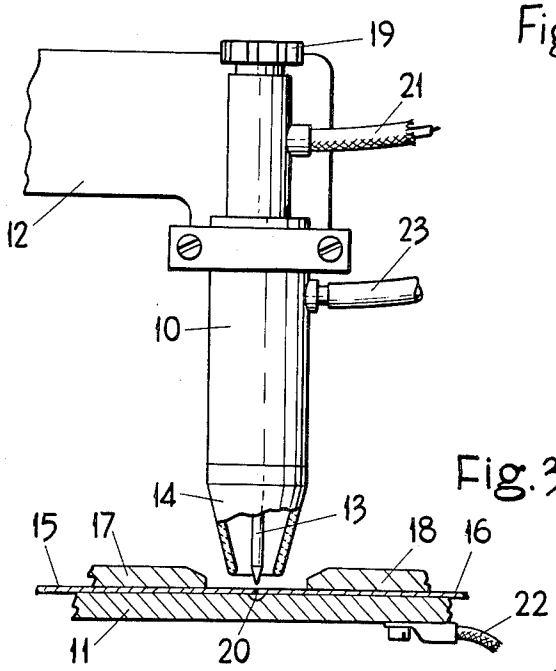


Fig.3

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United States Patent Office 3,231,332 Patented Jan. 25, 1966

3,231,332

ELECTRODES FOR ELECTRIC DISCHARGE APPARATUS

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Filed July 31, 1962, Ser. No. 213,727
11 Claims. (Cl. 29—182.2)

This invention relates to electrodes for use in electric discharge apparatus, and is more particularly concerned with electrodes of the kind comprising an electron emissive part consisting mainly of tungsten, which, usually in the form of rods, find use, for example, in arc welding and spark cutting apparatus and as cathodes in electric discharge lamps. The invention also relates to electric discharge apparatus in which one or more electrodes of the kind described is or are incorporated.

It has already been proposed to incorporate electron emissive materials of relatively low work function, such as thoria and zirconia, in tungsten electrodes for use in electric discharge devices, since the presence of the low work function material promotes rapid starting of the discharge at a relatively low temperature and low voltage. For some applications, thoria is a particularly useful additive, on account of its high electron emissivity, which enables an electrode incorporating thoria to be operated over a wide range of values of electric current; moreover thoriated tungsten is less affected than pure tungsten by metal vapour pickup during operation of the electrode. The incorporation of oxides such as thoria in tungsten, however, renders the material difficult to work, the workability decreasing and the brittleness of the material increasing with increasing oxide content. For some applications it is desirable to employ tungsten electrodes containing a high proportion of electron emissive material; for example for arc welding at low pressures a thoria content of up to 15% may be required to give adequate electron emission; tungsten containing such high proportions of thoria is very brittle, so that the working of material of such composition, to form electrodes of desired shapes, becomes extremely difficult.

It is an object of the present invention to provide an improved form of electrode for use in electric discharge devices, a particular object being the provision of an electrode which is composed mainly of tungsten treated with electron emissive, low work function material, and which can be more easily formed by working the said treated tungsten than has hitherto been the case. Another particular object of the invention is the provision of an improved form of electrode for use in arc welding and spark cutting apparatus, especially for inert gas shielded tungsten arc welding.

According to the invention, in an electron emissive electrode for use in electric discharge apparatus the electron emissive part consists of a core of tungsten containing a dispersion of electron emissive material and, substantially surrounding the core and integral therewith, an outer layer consisting essentially of tungsten and substantially free from such electron emissive material, the material of the core having an appreciably lower work function than that of the material of the said outer layer.

The outer layer may consist of pure tungsten, or may consist of tungsten containing one or more additives of the kind which are not electron emissive but which influence the crystal structure of the tungsten, especially additives of the kind which promote the growth of large elongated crystals, for example alumina and potassium silicate.

The outer layer of pure tungsten, or of tungsten containing a large crystal growth-promoting additive, is relatively ductile and hence, since it substantially surrounds the more brittle core, renders the composite body more readily workable than the core material alone would be. Thus the composite body may be worked, for example by swaging and rolling, to a suitable shape and size of an electrode for use in arc welding or cutting, or spark cutting apparatus, or of a cathode for an electric discharge lamp; usually the worked body will be in the form of a rod. If desired, the final shaping of the electrode may be effected by a machining operation, for example grinding.

It will be appreciated that for most applications, it will be necessary for a small part of the core to be exposed at the surface of the electrode, to provide a surface capable of emitting electrons immediately on the application of a voltage to the electrode, and it is to be understood that the phrase "substantially surrounding the core," employed above in connection with the outer layer, includes the case where such small part of the core is exposed. For arc welding or spark cutting applications, or for use as a cathode in an electric discharge lamp, the electrode is usually in the form of a rod consisting of a core containing the electron emissive material, surrounded longitudinally by said outer layer, the end surface of the core being exposed at least at one end of the rod. For these applications, in which the electric discharge emanates from an end surface of the electrode, arising from the direct emission of electrons from the core, the thickness of the outer layer relative to the diameter of the core may be varied as desired according to the relative requirements of current carrying capacity, which is determined by the thickness of the outer layer, and rate of emission, which is determined by the exposed surface area of the core: the ratio of the thickness of the outer layer to the diameter of the core is suitably in the range of 7:1 to 1:7. The electrode may be in the form of a straight rod of constant diameter throughout its length, or if desired, especially in the cases of arc welding or spark cutting electrodes, the end at which the discharge is to be formed, that is to say the end at which the core is exposed, may be tapered.

An electrode in accordance with the invention, when employed for any of the above-mentioned applications in which the discharge is produced at an exposed surface of the electrode, possesses the additional advantage that control of the discharge is improved by the presence of the surrounding outer, non-emissive layer. Thus the discharge area is confined to the exposed area of the core, wandering of the discharge away from the exposed surface of the core being restricted by the presence of the outer layer: this feature is of importance, for example, in arc welding electrodes and in electrodes for compact source discharge lamps.

If desired, for some applications, the electron emissive core of the electrode may be wholly surrounded by the outer layer of tungsten, or of tungsten containing an additive as aforesaid, provided that at least a part of the said outer layer is sufficiently thin to permit the activating atoms from the core to diffuse through it.

The electron emissive material employed in the core of an electrode according to the invention may be any material known to be suitable for this purpose, and capable of giving a core having an appreciably lower work function than that of the material employed for the outer layer, whether this is pure tungsten or tungsten containing one or more additives as aforesaid. Suitable electron emissive materials are, for example, thoria, zirconia, and the oxides of yttrim, lanthanum and the rare earth metals. As is well known, in the operation of an elec-

trode containing one of these oxides, the oxide is first reduced to the metal and electrons are emitted from the metal atoms as they reach the surface of the electrode by diffusion, the steps of reduction, diffusion and emission taking place continuously during operation of the electrode. Hence the proportion of emissive material incorporated in the core need only be sufficient to keep the surface from which emission is required to take place (that is to say, the exposed area of the core or, if none of the core is exposed, the whole of the emitting surface of the cathode) saturated with the electron-emitting atoms, for maintaining continuous emission at a suitable concentration. The amount of emissive material required may vary according to operation conditions: for example, if thoria is employed as the emissive material, a thoria content in the range of 0.5 to 5% by weight of the total weight of the core is usually sufficient, but if the electrode is to be operated in an atmosphere at low pressure, a considerably larger proportion of thoria, for example 10 to 15%, may be required to maintain emission at the desired rate.

In some cases where the outer layer contains additive material as aforesaid, it is not objectionable, and may even be desirable, to include in the core material, in addition to the electron emissive material, the same additive as that incorporated in the outer layer, preferably in a proportion not greater than that in the outer layer.

An electrode in accordance with the invention may be manufactured by preparing a powder consisting mainly of tungsten and containing, dispersed throughout the powder, a suitable proportion of electron emissive material of low work function, placing a mass of this powder in contact with, so as to be substantially surrounded by, a second mass of powder consisting either of pure tungsten or of tungsten containing one or more additives as aforesaid, pressing the assembly of powders to form a composite compact, heating the compact in a reducing atmosphere to expel volatile additive material, if present, and to sinter the compact, and subjecting the sintered composite body to the required working operations for forming an electrode of the desired shape and size. Usually the worked body will be in the form of a rod of considerable length, and may be cut to suitable lengths for forming a number of electrodes. In some cases it may be desirable, in forming the composite body, to surround the core completely with the outer layer material, for ease of working; then a portion of the outer layer may be subsequently removed by grinding if required, either to expose a part of the core or to reduce the thickness of the outer layer.

The two powder masses may conveniently be arranged in contact with one another in a mould of suitable shape, divided into compartments by means of one or more suitable spacers, for the introduction of the powders into the mould.

The powdered materials to be used for forming the core and the outer layer respectively may each be prepared in known manner, the electron emissive material, and other additives if used, being introduced into the respective masses of tungsten powder by known methods, for example by treating tungsten or tungsten oxide powders with solutions of suitable salts and heating the mixtures under reducing conditions to bring about decomposition of the salts to the required additives and reduction of the tungsten oxide, if present, to tungsten. The methods employed for preparing the two powders are preferably such that the powders obtained are of the same order of particle size and have a similar degree of porosity after being subjected to the same compression load: these precautions will ensure that the respective parts of the composite body formed from the powders will sinter at substantially the same rate and shrink to substantially the same extent during sintering, so that cracking of one part or the other during sintering is avoided.

Usually tungsten oxide is used as the starting material in the production of both masses of powder, and since the particle size of the product is strongly influenced by the conditions under which the reduction of the tungsten oxide to tungsten is carried out, these conditions should be so arranged, for the respective reduction processes, that the two powders finally obtained are as closely matched as possible in respect of particle size and porosity. For example, it is well known that when thoria is dispersed in tungsten a very fine tungsten powder usually results so that if thoria is employed as the electron emissive material, the reduction step in the preparation of the core material is preferably carried out under conditions which tend to produce larger particles, that is to say in a moist atmosphere, at relatively high temperatures, and with a low flow rate of the reducing gas. On the other hand, since the types of tungsten powder to be used for the outer layer in accordance with the invention tend to be formed in larger particles, the reduction step in the preparation of this powder is preferably carried out under conditions tending to produce small particles, that is to say at relatively low temperatures, in an atmosphere as dry as possible, and with a high flow rate of the reducing gas.

In some cases it may be desirable, for the production of the core material, first to prepare a powdered master mixture of tungsten and the electron emissive material containing a relatively high proportion, for example 15% by weight, of the electron emissive material, and then to mix this powder with some of the powder to be employed for the outer layer, to give a final powder containing the desired proportion, for example 1 to 5% by weight, of the electron emissive material. This method of preparing the core powder is advantageous in giving a more uniform distribution of the electron emissive material throughout the core.

One specific method of manufacturing an electrode in accordance with the invention will now be described by way of example.

In the method of the example, a batch of the material for the core of the composite body from which the electrode is to be formed is prepared by thoroughly mixing 5 kilograms of tungstic oxide (WO_3) powder with 525 mls. of an aqueous solution of thorium nitrate containing 100 gms. of $Th(NO_3)_4$ per litre of solution. The resulting slurry is heated gently to drive off most of the water, and the mixture is crushed and then heated in hydrogen to reduce the tungstic oxide to tungsten and to decompose the thorium nitrate to thoria: for the reduction process, the powder is contained in boats, in batches of 100 gms. in each boat, and the boats are passed through a long furnace tube comprising four zones successively held at temperatures of approximately 550° C., 750° C., 850° C., and 900° C., the boats being introduced into the furnace tube at 12-minute intervals, and the time taken for each boat to pass through the four temperature zones being three hours. The atmosphere in the furnace tube is kept moist by the expulsion of residual water from the powder, and hydrogen is arranged to flow through the tube at the rate of 25 to 30 cubic feet per hour. The product of the reduction consists of tungsten powder containing a substantially uniform, finely divided dispersion of thoria (ThO_2) in the proportion of 0.7% by weight of the weight of tungsten.

For the outer layer of the composite body, in accordance with the example, silicated tungsten powder is employed. This powder is prepared by mixing powdered tungsten oxide with aqueous solutions of potassium silicate and sodium chloride, in the proportions of 34 mls. of a 5% solution of sodium chloride and 50 mls. of a 5% solution of potassium silicate to each kilogram of the oxide. The slurry is heated to remove as much water as possible, and the dried material is crushed and subjected to a reduction process. In this case the reduction is carried out in two stages: for the first stage,

the powder, which is yellow in colour, is passed through four temperature zones in a furnace tube, in 100-gram batches contained in boats introduced into the furnace at 12-minute intervals, while a flow of dry hydrogen is maintained through the tube at the rate of 60 cubic feet per hour, the four successive zones being maintained at temperatures of approximately 550° C., 640° C., 660° C. and 740° C. At the end of the first stage the material is only partially reduced to a brown oxide but is thoroughly dry; for the second stage of the reduction the product of the first stage is mixed with an equal amount of the initial yellow oxide powder, and this mixture is again passed through the furnace tube at the same rate and with the same rate of hydrogen flow as in the first stage, the four successive temperature zones being maintained at approximately 550° C., 750° C., 800° C., and 850° C. The product of the second stage consists substantially of tungsten powder containing a uniform dispersion of silica, with small amounts of potassium oxide and sodium oxide, the total proportion of additive material being approximately 1% of the weight of tungsten.

The particle sizes and porosities of both of the powders prepared as described above have been determined by means of the apparatus known as the "Fisher Sub Sieve Sizer" and described in United States patent specification No. 2,261,802. When subjected to a compression load of 400 lbs./sq. in. in this apparatus, the thoriated tungsten powder was found to have a particle size range of up to 5 microns, with an average particle size of 1.45 microns and the silicated tungsten powder was found to have a particle size range up to 5 microns, with an average particle size of 3.39 microns, and the porosity figures obtained were 0.732 for the thoriated tungsten and 0.734 for the silicated tungsten.

The mould employed for forming the composite mass of powders is shown diagrammatically, in sectional elevation, in FIGURE 1 of the accompanying drawings. The mould comprises a steel container **1** having a cavity of length corresponding to the desired length of the pressed composite bar, of width corresponding to the desired width of the pressed bar, and of depth about four times the width. A trough-shaped double filling funnel is fitted into the open top of the mould cavity, the outer funnel **3** being made of brass and having a short stem, fitting closely within the wall of the mould cavity, and the inner funnel **2** which is made of thin tin plate, having a long stem arranged coaxially with that of the outer funnel, the width of which stem can be varied according to the desired width of the core of the composite bar.

Suitable dimensions of a mould for the manufacture of a plurality of electrodes in accordance with the example are as follows; the mould cavity is 60 cm. long, 1.4 cm. wide and 5.6 cm. deep, the stem of the inner funnel is adjusted to an internal width of 7 mm., and the inner funnel is arranged so that its stem extends downwards into the mould cavity for 4.2 cm. To form the composite bar, using a mould of these dimensions, 380 grams of silicated tungsten powder, prepared as described above, are first introduced into the mould cavity, filling it up to the level *a* indicated in the drawing. The double funnel is then placed in the position shown, and 140 grams of the thoriated tungsten powder, prepared as described above, are introduced into the central compartment **4** of the mould cavity through the inner funnel **2**, filling this compartment up to the level *b*. The outer compartments **5, 5** of the mould cavity are then filled up to slightly above the level *b* by introducing 250 grams of silicated tungsten powder through each side channel formed between the inner and outer funnels. The double funnel is then carefully removed, avoiding disturbance of the powder, and 280 grams of silicated tungsten powder are added, to fill the remaining space in the mould cavity above the level *b*: the object of slightly overfilling the outer compartments **5, 5** is to ensure that none of the core material can flow outwards on removal of the inner funnel.

The composite mass of powders so formed is subjected to a pressure of approximately 15 tons/sq. in.; if desired, to facilitate pressing, 0.5% by weight of camphor may be added, in ether solution, to each of the tungsten powders before they are introduced into the mould.

The pressed compact is removed and heated slowly in a hydrogen atmosphere to a temperature above 1000° C. to remove the camphor, if present, and to strengthen the compact for facilitating subsequent handling. The compact is then raised rapidly, in approximately 4 to 6 minutes, to the sintering temperature by the passage of an electric current through the bar, the current being increased in that time to a value corresponding to 90–93% of the current required to melt the tungsten; the current is held at this final value for 12 minutes, the temperature being approximately 2950° C. The sintering is carried out in an atmosphere of hydrogen.

The sintered composite bar thus produced is worked down to a rod of the desired dimensions, by hot-rolling and/or swaging in known manner, and is then cut into the desired shorter lengths to form electrodes for arc welding or spark-cutting apparatus, or to form cathodes for electric discharge lamps. Each rod produced in the manner described above will have a core of diameter approximately half the total diameter of the rod itself. If desired, the total diameter, and thickness of the outer layer, may be further reduced by grinding; also if desired, the rods may be tapered at one end by machining or by rolling, care being taken to ensure that a coating of silicated tungsten is retained around the core over the whole of the tapered portion.

One particular form of inert gas shielded tugnsten arc duced by the method of the example is shown diagrammatically, in section, and greatly enlarged in diameter, in FIGURE 2 of the accompanying drawings. This electrode is suitable for use in inert gas shielded tungsten arc welding apparatus operated on direct current, and in form consists of a straight rod **6** of diameter, for example, 1 to 3 mm., tapered at the end **7** at which the arc is to be produced. The rod is composed of a core **8** of tungsten containing 0.7% by weight of thoria, and an outer layer **9** of silicated tungsten: the diameter of the core is approximately half the total diameter of the main body, that is to say the non-tapered part, of the rod; the end is tapered by grinding, so that the outer layer is reduced in thickness at this end, while the diameter of the core is constant throughout the length of the rod.

One particular form of inert gas shielded tungsten arc welding apparatus in which an electrode of the above-described form can be employed is shown diagrammatically in FIGURE 3 of the accompanying drawings. The apparatus comprises a welding torch **10** of known general type, supported vertically above a metal work table **11** by means of an arm **12**, which is arranged to be movable (by means not shown in the drawing) to cause the torch to traverse the work table in a horizontal direction. The electrode **13** is held in a vertical position at the lower end of the torch, and a nozzle **14** of refractory ceramic material is screwed on to the main body of the torch so as to substantially enclose the electrode, leaving only the tip of the electrode exposed: the nozzle is shown partly broken away to expose part of the electrode to view.

The apparatus is shown, by way of example, set up for a seam welding operation, the work pieces to be welded together being two metal strips **15, 16** which are held in position on the work table by clamping means **17, 18**. A means, shown diagrammatically as an adjusting screw **19**, is provided for adjusting the distance between the tip of the electrode and the junction **20** between the work pieces where the weld is to be formed.

Cables **21, 22** for connection to an electrical supply are connected respectively to the electrode, passing through the wall of the torch body, and to the work table. An

inlet pipe **23** is provided for admitting a flow of inert gas into the torch, so that in operation the gas will fill the space around the electrode within the torch body and will flow out through the nozzle **14** so as to surround the tip of the electrode and form an inert atmosphere in the region of the arc formed and the metal surfaces to be welded together.

Apparatus of the form shown in FIGURE 3, including an electrode of the form described above with reference to FIGURE 2, is suitable for operation from an open circuit direct current electrical supply of 2 to 600 amperes and 45 to 85 volts, giving an arc voltage of 9 to 14 volts. The inert gas employed may be, for example, argon, helium, or a mixture of argon and helium.

We claim:

1. An electron emissive electrode for use in an electric discharge device, wherein the electron emissive part is formed of a one-piece, composite sintered-powder-mass and worked body composed mainly of tungsten and consisting of a core of tungsten containing a dispersion of electron emissive material and, integral with the core and covering at least the whole of the major surface of the core, which surface is subjected to direct mechanical action during working, an outer layer of higher ductility than the core and consisting essentially of tungsten and free from such electron emissive material, the electron emissive material included in the core being such that the core has an appreciably lower work function than that of the said outer layer.

2. An electron emissive electrode according to claim **1**, wherein the electron emissive material included in the said core consists of at least one oxide selected from the group consisting of thorium oxide, zirconium oxide, yttrium oxide, lanthanum oxide and the rare earth oxides.

3. An electron emissive electrode according to claim **1**, wherein the electron emissive material included in the said core consists of thorium oxide, in a proportion in the range of 0.5% to 15% by weight of the total weight of the core.

4. An electron emissive electrode according to claim **1**, wherein the said outer layer consists of pure tungsten.

5. An electron emissive electrode according to claim **1**, wherein the said outer layer consists of tungsten containing a non-electron emissive additive material incorporated in the tungsten for influencing the crystal structure thereof.

6. An electron emissive electrode according to claim **1**, which is in the form of a rod, wherein the whole of the lateral surface of the core is covered by the said outer layer and the end surface of the core is exposed at least at one end of the rod, and wherein the ratio of the thickness of the said outer layer to the diameter of the core is in the range of 7:1 to 1:7.

7. An electron emissive electrode according to claim **5**, wherein the said additive material consists of alumina.

8. An electron emissive electrode according to claim **5**, wherein the said additive material consists of potassium silicate.

9. An electron emissive electrode according to claim **5**, wherein the core also contains the same non-electron emissive additive material as that incorporated in the outer layer, in a proportion not greater than that in the outer layer.

10. An electron emissive electrode for use in an electric discharge device, wherein the electron emissive part is in the form of a one-piece composite rod formed by working a sintered-powder-mass body and consisting of a core formed from tungsten powder containing a substantially uniform dispersion of thoria in the proportion of 0.7% by weight of the weight of tungsten and, integral with the core and covering the whole of the lateral surface thereof, an outer layer formed from tungsten powder containing 1% of its weight of crystallization-controlling, non-electron emissive, additive material consisting of silica, potassium oxide and sodium oxide, the end surface of the core being exposed at one end of the rod and the said end of the rod being tapered, and the diameter of the core being half the total diameter of the non-tapered part of the rod.

11. An electron emissive electrode in the form of a one-piece composite rod formed by working a sintered-powder-mass body composed mainly of tungsten and consisting of a core of tungsten containing a dispersion of electron emissive material and, integral with the core and covering the whole of the lateral surface thereof, an outer layer of higher ductility than the core and consisting essentially of tungsten and free from such electron emissive material, the electron emissive material included in the core being such that the core has an appreciably lower work function than that of the said outer layer, the ratio of the thickness of the said outer layer to the diameter of the core being in the range of 7:1 to 1:7, and the end surface of the core being exposed at least at one end of the rod.

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