Inventors:

INVENTOR.
JACOB W. DE RUITER
ANTON WILLEMSTEIN

INVENTOR.
JACOB W. DE RUITER
ANTON WILLEMSTEIN
BY

Frank R. Jofani
AGENT
METHODS AND ARRANGEMENTS FOR MELTING MATERIAL WHICH MELTS ONLY WITH DIFFICULTY

Jacob Willem de Ruiter and Anton Willemsen, Emma-
singer, Eindhoven, Netherlands, assignors to North
American Philips Company, Inc., New York, N.Y., a
 corporacion of Delaware

Filed Nov. 17, 1965, Ser. No. 508,271
Claims priority, application Netherlands, Dec. 23, 1964,
6,414,964

Int. Cl. H05b 11/00, 7/18

It is known to heat materials melting only with difficultly in electric furnaces in which an arc discharge is operative between two electrodes or a gas discharge is maintained by a high-frequency induction field, while the required starting substance is processed in pulverulent form. Metal powder in compressed and sintered form is used as a lighting electrode of an electric arc discharge, but the pulverulent starting substance is likewise supplied to the discharge arc in pulverulent state, in which event it falls down through the flame. The melted material is collected on the lower side in a cooled crucible.

The latter method has the advantage that it is not necessary to start first with the manufacture of compressed and sintered electrodes. It may also be used for non-metallic materials. On the other hand it can be assessed that when the pulverulent material is supplied to the discharge arc, the conversion into melted material is not complete, since the absorption of a quantity of heat sufficient for melting is dependent upon the temperature and the particle size. The temperatures in the discharge arc are different from place to place and decrease especially from the centre towards the outside so that only part of the discharge volume has the correct temperature at which material particles of a given size melt. Furthermore, it is very time-consuming to pulverize material to particles of substantially equal size. In order to obtain optimum results, attempts can be made to limit the supply of pulverulent material to a given region within the discharge volume, but due to whirlings gas flows the power will be scattered and partly excessively heated and be burned or it will be insufficiently heated and it will be collected as such together with the melted material in the crucible.

The invention has for its object to avoid this disadvantage and relates to a method and an arrangement for melting pulverulent material which melts only with difficulty by means of an electric gas discharge inside a sheath of high melting-point material, for example, of quartz glass, the gas discharge being operative in the induction field of a high-frequency coil which surrounds the sheath and is connected to a high-frequency generator. According to the invention, the pulverulent material is fed to the working space while the sheath is rotating, as a result of which the powder spreads along the circumference of the sheath and constitutes a wall layer and said layer is heated on the inner side to the melting temperature of the material by the heat developed in the gas discharge.

The method in accordance with the invention may be used for melting pulverulent material and conducting away the melted material. In a specific embodiment for this purpose of an arrangement for carrying out the method in accordance with the invention, the rotatable sheath is arranged vertically and provided with a transverse wall having a small aperture and constituting the lowermost boundary of the gas discharge volume. The pulverulent material is collected immediately above this transverse wall. On the wall of the sheath, which may be cooled on the outer side, the material remains in the pulverulent state, but between the pulverulent material and the melted material a material is formed which is sintered. Contamination of the melted material by particles of material which have not melted is thus avoided. A continuous supply of powder may take place on the upper side of the working space so that the melted material flows away continuously through the aperture in the transverse wall.

In case of melting substances which are electrically conducting or which are electrically conductive when heated to a high temperature, it must be considered that the formation of an electrically conducting path within the field of the high-frequency coil, for example, owing to the fact that the material is sintered, results in that the induction field of the high-frequency is screened for a major part so that an insufficient or at least smaller quantity of high-frequency energy is available for the gas discharge. On the inner side of the sheath wall, provision may be made of receding ribs or thickened parts which prevent the formation of an uninterrupted coating of pulverulent material. In order to prevent the thickened parts from melting, they are made of high melting-point material and moreover a satisfactory drainage of heat may be ensured in that channels are provided on the inner side for a circulating coolant, for example, gas or liquid. In order to maintain the dynamic equilibrium, at least two thickened parts should be provided diametrically opposed to each other.

The diameter of the aperture in the transverse wall is dependent upon the material to be melted, in which case surface stress, specific weight and similar material properties must be taken into account.

The arrangement provides the possibility of manufacturing wire or thin rods of high melting-point metals, oxides or carbides. For the manufacture of tubes, provision is made in the transverse wall at the centre of the aperture of a mandril of refractory material which is connected at a plurality of points by narrow radial strips with the transverse wall. The mandril preferably consists of a material of satisfactory thermal conductivity and having a high melting point, so that the temperature is substantially the same at all places as a result of a satisfactory heat distribution. As a matter of course, the radial strips must have a sufficient strength to resist the pressure of materials having a comparatively low flow capacity. This pressure may be considerable if the flow of the material must be forced and a high pressure of, for example, a few atmospheres, is maintained in the discharge space. It is also possible to exhaust the space beneath the transverse wall to a low pressure. Since the liquid mass of material fills the aperture, a pressure difference may be maintained without a substantial loss of material being involved.

A particular advantage exists if the gas in the discharge space has a low pressure. In this case, the material to be melted may be degased simultaneously, as a result of which the formation of gas bubbles in the melted material is counteracted. With the use of the high-frequency gas discharge satisfactory results can be obtained in the pressure range of 10⁻² to 10⁻⁶ torr, although the flows of whirlings gas which are associated with the rotation of the sheath and which maintain the stabilization of the discharge have become less important due to the low pressure. In this pressure range, the lengths of the free paths of the electrically charged gas particles are sufficient for the absence of magnetic stabilization with the aid of a comparatively low magnetic field of constant strength the lines of force of which are parallel to the axis of the sheath. Under the influence of this field, the charged particles may cover circular paths and particles having outwardly directed speeds are conducted back into the discharge volume.

The method in accordance with the invention is of particular importance for the manufacture of granular material. When the sheath rotates at a sufficient speed, the coherence of the material flowing out of the aperture in the transverse wall is broken up, as a result of which
the material spreads from the aperture in separate drops the size of which is dependent upon the flow capacity and the surface stress of the material and upon the speed of rotation of the sheath. At a constant speed of rotation, grains of material of equal size will be obtained which have a substantially spherical shape.

Alternatively, the method in accordance with the invention may be used for manufacturing high melting-point alloys. When the starting substances required for an alloy are supplied separately in pulverulent state to the space situated inside the sheath and above the working space, these substances are mixed as a result of the whirling caused by the rotation. The powder particles of the more readily meltable starting substance will melt more rapidly and wet the grains melting only with difficulty, whereupon the melting of these grains is continued and the melted alloy is formed.

High melting-point materials for the manufacture of fuel elements of reactors may be manufactured in the same manner. It is known to use uranium carbide or plutonium carbide as mixed with other carbides, such as zirconium carbide, niobium carbide, tantalum carbide and thorium carbide, in which event the desired composition can be obtained by melting in the high-frequency gas discharge instead of carrying out the time-consuming sintering process at high temperature.

The materials obtained in successive melting phases have a high density while the starting materials are distributed over the composed matrix in a uniform manner.

An embodiment of an arrangement for carrying out the method in accordance with the invention will now be described with reference to the drawing.

Such an arrangement consists of a rotating gas discharge burner comprising the tubular sheath 1 which is made of high-melting point material, for example, of quartz glass. The sheath 1 is provided at both ends with ball-bearings 2 and 3 which are arranged in flat plates 4 and 5. These plates are connected to each other by rods 6 and 7. The sheath is vertically arranged and covered on the upper side with a hood 8 secured to the flat plate 4. Two tubes 9 and 10 for supplying one or more gases suitable for producing an electric discharge are provided in the hood. Together with an electrically insulated through-connection 11 consisting, for example, of a vitreous enamel, two current conductors 12 and 13 are passed through the hood 8 into the sheath, the ends of these conductors located inside the sheath being spaced apart by a short distance and constituting electrodes 14 and 15 between which an arc discharge can be produced by the application of an electric voltage thereto. With the aid of such an auxiliary discharge, the gas discharge inside the sheath 1 can be ignited. For this purpose, it is required that the high-frequency coil 16 which surrounds the sheath 1 and which is disposed in the current circuit of a high-frequency generator, for example, a magnetron oscillator, produces a magnetic induction field in the proximity of the auxiliary discharge. The position of the high-frequency coil 16 in which the gas discharge is located is indicated with dotted lines. It is therefore rendered possible to relatively displace the coil and the sheath, in the embodiment the sheath 1 being displaceable along the supports 17 and 18.

Approximately at the center of the sheath 1, provision is made of a transverse wall 19 comprising an aperture 20.

A crucible 21 is mounted below this transverse wall and has a rod-shaped support 22 by which the crucible 21 bears on a transverse plate 23. This plate is secured by means of a ring 24 to the lower flat plate 8. The ring is provided with an aperture 25 which serves for drawing off gas and which may communicate with a vacuum pump for reducing the pressure in the lower portion of the sheath 1. The ball-bearings 2 and 3 are closed by means of locking rings 26 and 27 of a resilient material. The crucible 21 may be artificially cooled by a cooling liquid for which an inlet and an outlet 28 and 29 are indicated on the lower side of the transverse plate 23.

The inner ring of the lower ball-bearing 3 has secured to it a rotary disc 30 which is provided with a groove for a rope establishing the transmission required for the rotation of the sheath 1 with a driving gear.

After the ignition of the gas discharge the discharge is limited by an inductive field of the rotation of the sheath and of the intensity of the gas supply to a volume inside the sheath 1 of a cross-section such that the wall of the sheath is not damaged by the developed heat. When the sheath 1 is displaced upwards along the supports 17 and 19, the transverse wall 19 approaches the gas discharge. At the same time, the starting substance to be melted is introduced into the working space through a tube 32 which projects outwards through the hood 8 and which is provided with a filling funnel 33. Under the influence of the rotation, the powder is scattered along the wall of the sheath 1 and is at the same time moved downwards so that an accumulation 34 is formed in the proximity of the transverse wall 19. When the flow of gas is gradually reduced until the supply of gas is stopped completely or substantially completely, the gas discharge volume may be adjusted by the control of the speed of rotation of the sheath so that the powder particles constituting the inner surface of the collected pulverulent mass melt. A kind of crucible is then formed in the sheath which protects the sheath from excessive heating. The heat penetrating into the powder brings about sintering of the powder under the melting layer and consequently constitutes a sufficient thermal resistance. The sheath may be cooled on the outer side. No difficulties are involved in adjusting the supply of the pulverulent starting substance so that an equal quantity of material is conducted away by melting, which material is collected in the crucible 21.

What is claimed is:

1. A method of melting materials which melt only at relatively high temperatures comprising supplying gases suitable for producing an electric discharge in a working space surrounded by a sheath of high melting point material, maintaining said gas discharge in said sheath by the induction field of a high frequency coil, rotating said sheath while said melting materials are supplied to said working space in a pulverulent state, the speed or rotation being such that the material powder spreads along the inner side of said sheath to form a wall layer, and heating said wall layer to its melting temperature by the heat developed by said gas discharge.

2. A method of melting materials which melt only at relatively high temperatures as claimed in claim 1 further conducting away the melted material through an aperture in a transverse wall provided in said sheath.

3. A method of melting materials which melt only at relatively high temperatures as claimed in claim 2 wherein the speed of rotation of said sheath is such that the material passing through said aperture is scattered in the form of drops.

4. A method of melting materials which melt only at relatively high temperatures as claimed in claim 2 wherein at the outlet side of said transverse wall the pressure is lower than in the working space of said sheath.

5. A method of melting materials which melt only at relatively high temperatures as claimed in claim 4 wherein the gas pressure in the working space is 1-10⁻³ torr.

6. A method of melting materials which melt only at relatively high temperatures as claimed in claim 1 wherein at least two powders of different starting substances are simultaneously applied to the working space of said sheath.

7. An apparatus for melting materials which melt only at relatively high temperatures comprising an electric gas discharge burner which is provided with a sheath of high melting point material, means for rotating said sheath about its axis, a high frequency coil surrounding said sheath, and second means for displacing said sheath along
3,436,465

5

the longitudinal axis thereof relative to said high frequency
coil.

8. An apparatus for melting materials which melt only
at relatively high temperatures as claimed in claim 7
wherein said sheath is provided with at least two partitions
of thickened parts extending radially from the inner cir-
cumference of said sheath.

9. An apparatus for melting materials which melt only
at relatively high temperatures as claimed in claim 8
wherein said thickened parts are hollow tubes of high
melting point, non-conducting material, said tubes being
cooled by a coolant conducted through said tubes.

6

References Cited

UNITED STATES PATENTS

3,124,633 3/1964  Van Run 13-1
3,250,842 5/1966  Hikido 13-1 X

BERNARD A. GILHEANY, Primary Examiner.
R. N. ENVALL, Jr., Assistant Examiner.

U.S. Cl. X.R.

75-5