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SLIDE-SPARK ELECTRODE SYSTEM

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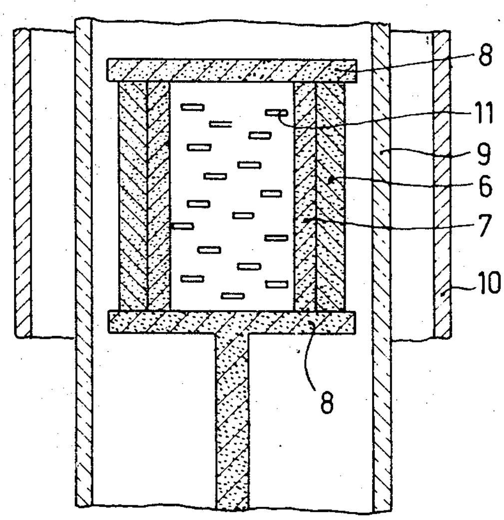

FIG. 2

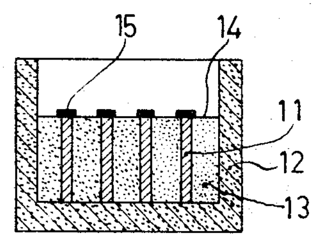

FIG. 3

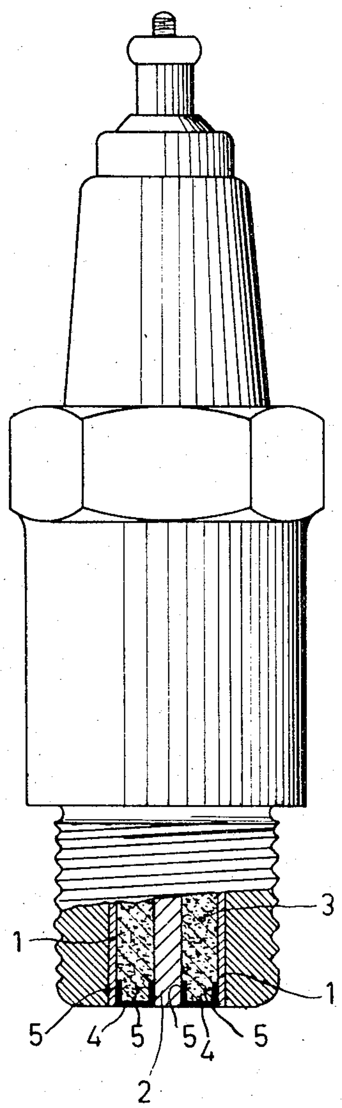

FIG. 1

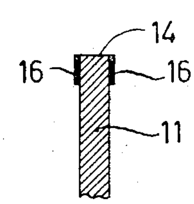

FIG. 4

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SLIDE-SPARK ELECTRODE SYSTEM

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U.S. Cl. 313—131 6 Claims

ABSTRACT OF THE DISCLOSURE

The slide-spark type spark plug has the space between the electrodes filled with a semiconductive material which allow a chain of small sparks across the surface. The semiconductive material is silicon carbide with the surface doped to permit current to flow.

This invention relates to slide-spark electrode systems, more particularly slide-spark plugs.

The term "slide-spark electrode system" is to be understood in this specification to mean a device having electrodes which are separated by an insulating or semiconductor body, wherein a slide spark can be produced across the surface of the separating body by applying a voltage between the electrodes, for example, by means of a capacitor discharge. In this device either the electrodes may be arranged with some spacing between them or one electrode may co-axially surround the other. It is also possible that more than two electrodes are present.

As compared with ordinary spark plugs which have no separating body at the area of the formation of the spark, the device above referred to affords the advantage of operating at lower voltages. Furthermore they are much less sensitive to contamination such as may occur, for example, in uses where liquid fuels are employed in the form of fuel drops or from which carbon deposits may be formed in operation.

A device of this kind having an insulating separating body between the electrodes is known, for example, from Dutch Pat. No. 46,114. In this device use is made of the fact that deposition of fuel drops and soot on the insulating separating body makes the formation of slide sparks possible.

However, since the deposition cannot be regulated and a certain conduction at the surface of the separating body is necessary for producing slide sparks, use has also been made, as described in Dutch Pat. No. 54,723, of insulating separating bodies which have been covered with thin conductive layers of carbon or metal, for example platinum layers applied by burning. Such layers which naturally must have a high electrical resistance and therefore must be very thin are found to be badly damaged, however, after a short period of use so that a reliable operation of the device is not obtained by this step.

This is the case indeed when using separating bodies consisting wholly of sintered products of a mixture of conductive and non-conductive substances, such as specified in Dutch Pat. No. 62,644. However, to inhibit troublesome leakage currents between the electrodes through such a separating body it is then necessary, as has been described in Dutch Pat. No. 90,047, to insulate the electrodes through a great length and to allow electric contact with the electrodes only at the surface of the separating body. Such an additional precaution is little interesting, since it complicates the manufacture of the device.

All of the above-mentioned separating bodies have the disadvantage of being not particularly resistant against

the action of the sparks. In view thereof it has previously been suggested to manufacture the separating bodies of heat-proof and chemically resistant materials, such as silicon carbide and boron carbide. According to German Pat. No. 898,325, for this purpose the separating body is formed of said substances, possibly with an addition of ceramic materials and carbon, and exposed to temperatures of 1500° C. for comparatively a long period. Preferably the resulting high-ohmic sintered product is then covered by vapour deposition within a thin metal layer. A radical solution is thus not obtained. If the resistance of the body is very high, the regular occurrence of slide sparks is ensured only if a metal layer has been applied. However, this metal layer is not particularly durable in operation. On the other hand, if the material forming the separating body has so low a resistance that slide sparks can be obtained, an additional insulation of the electrodes will be necessary as has been described in Dutch Pat. No. 90,047.

The last-mentioned disadvantage also exists when using semiconductor separating bodies on the basis of silicon carbide and silicon nitride, such as have been described in French Pat. No. 1,247,883.

An object of the invention is to obviate the described disadvantages inherent in known devices.

The present invention relates to a slide-spark electrode system, more particularly a slide-spark plug, which has a separating body between the electrodes, and it is characterized in that the separating body consists of compact pure high-ohmic silicon carbide, one surface layer of which has been made conductive, possibly in a given pattern, by diffusion of donors or acceptors in such manner that for a given distance between the electrodes a slide-spark discharge between the electrodes may be established through the said surface layer.

Such a separating body not only has a high resistivity to slide-spark discharge so that a long life-length is ensured, but also any additional insulation of the electrodes for preventing leakage currents can be omitted.

Preferably a kind of conduction of the surface layer is brought about which varies little with temperature, in order that the resistance in operation does not become so high or so low that a slide-spark discharge is made impossible. For example, a surface layer having a weakly positive temperature coefficient of the resistance may be obtained by diffusing nitrogen into, whereas a layer having an acceptable negative temperature coefficient is obtained by diffusion with boron or aluminum in a small dosage.

The separating body may comprise a piece of monocrystalline pure silicon carbide which, as is well-known, may be obtained, for example, by condensation and/or crystallisation in a space bounded by SiC in an inert atmosphere, by crystallisation from a solution in chromium, or the like. Sintered bodies of such pure silicon carbide can be used as well.

As is well-known, a very compact polycrystalline silicon carbide of high resistivity may further be obtained by pyrolytic deposition from vapour of compounds containing silicon and carbon on a carbon core, possibly in an atmosphere of hydrogen. The use of this silicon carbide for the separating body is preferred in the invention, since it can readily be obtained and at low cost.

For satisfactory operation of the device it is important that the electrodes should make good electric contact with the conductive layer of the separating body.

For this purpose use may be made of, if necessary, of alloys of gold and tantalum, preferably gold containing 5% by weight of tantalum, which, as is well-known, can provide a very well adhering contact on silicon carbide by alloying.

To prevent the formation of rectifying contacts with p-conductive layers obtained, for example, by diffusion of boron or aluminum, it is possible to add an acceptor, for example boron or aluminum, to the gold-tantalum. Such a step is not necessary for n-conductive surface layers such as obtained, for example, by diffusion of nitrogen.

In order that the invention may be readily carried into effect it will now be described in detail, by way of example, with reference to the accompanying diagrammatic drawing.

FIG. 1 is a diagrammatic view, in elevation and in part section, of one embodiment of a spark plug according to the invention.

Two co-axial electrodes, indicated by **1** and **2**, are separated by a body **3** of high-ohmic silicon carbide. A surface layer **4** of the body **3** has been made conductive by diffusion of substances acting as acceptors or donors. The layer **4** is in electric contact with the electrodes **2** and **3** through alloyed layers **5** of a gold-tantalum alloy.

For the separating body use may be made of large plate-shaped crystals of pure silicon carbide, such as may be obtained by the method described in U.S. Pat. 2,854,-364. In this method pure crystals of silicon carbide each having a surface area of 1 sq. cm. and a thickness of 1 mm. may be obtained within 5 hours by recrystallisation and/or condensation in an atmosphere of argon in a space bounded by silicon carbide at a temperature of approximately 2500° C.

For the formation of the crystals a device can be used as shown in section in FIG. 2. This figure shows a graphite cylinder **6** in which a cylinder **7** obtained by sintering pure powdered silicon carbide is placed. The silicon carbide may be manufactured by pyrolysis of methylchlorosilane ($SiHCl_2CH_3$) in hydrogen. The cylinder is closed at its ends by graphite plates **8**. The whole is placed in a quartz envelope **9** in which an atmosphere of argon is maintained. By means of an inductance coil **10** there is heated to 2450° C., during which process the plate-shaped pure siliconcarbide crystals are deposited approximately at right angles to the wall of the cylinder.

A number of these crystals **11**, after having been ground to size, as shown in FIG. 3, is placed in a graphite crucible **12**, the crystals being kept apart by means of powdered silicon carbide **13**. Subsequently a plate **15** of sintered boron carbide is placed on the surface **14** of each crystal and heated in argon to 2000° C. A thin boron-doped p-conductive layer is thus formed on each of the surfaces **14** by diffusion. The conductive surface **14** of each crystal is provided with ohmic contacts by alloying on it layers **16** consisting of an alloy of gold with 5% by weight of tantalum and 5% by weight of aluminum, as shown in section in FIG. 4. The resulting crystals may be used as separating bodies for two juxtaposed electrodes of a slide-spark plug.

If a silicon-carbide cavity as shown in FIG. 2 is covered by a graphite plate and a temperature of 2600° C. is maintained in it, then only few crystals are formed on the wall but a thick layer of compact pure hexagonal silicon carbide is deposited on the graphite plate. This coarse polycrystalline plate is made n-conductive at its surface by heating for two hours at 2500° C. in an atmosphere of nitrogen. By removing the graphite substrate and then sawing into small blocks it is possible to obtain separating bodies for slide-spark plugs. Contacts can in this case be formed, if desired, by allowing on said bodies an alloy of gold with 5% by weight of tantalum.

Compact cylindrical separating bodies for slide-spark plugs having co-axial electrodes as shown in FIG. 1 may be manufactured, for example, as follows:

A carbon rod of 3 mm. in diameter and a length of 30 cm. is heated by passage of current at a temperature of 1500° C. in a flow of very pure hydrogen containing 2% of methylchlorosilane. If the gas flow is led through at a rate of 5 litres/min. a compact layer of pure polycrystalline silicon carbide of 1.5 mm. thick is deposited on the carbon rod within 2 hours. Cylindrical parts of silicon carbide are obtained by dividing the rod into pieces of 5 mm. each and removing the carbon core by burning. In the manner as has been described with reference to FIG. 3, the surface at one of the end faces is made conductive by diffusion of boron, whereafter the conductive surface is provided with contacts on the inner and outer sides of the cylinder by alloying on it an alloy of gold with 5% by weight of tantalum and 5% by weight of aluminum.

It is also possible to obtain such cylindrical separating bodies in the desired dimensions by sintering mouldings made of fine-granular pure silicon carbide.

What is claimed is:

1. A slide-spark electrode system comprising electrodes and a separating body between the electrodes, said separating body having a spark surface layer along which a slide-spark discharge may be established when a voltage is applied across said electrodes, said separating body consisting essentially of compact pure high-resistivity silicon carbide having a conductive surface layer due to the presence in a surface layer of the silicon carbide of diffused donors or acceptors in a concentration gradient diminishing from the surface into the body, and means effecting electrical connection between the electrodes and the conductive surface layer.

2. A slide-spark electrode system as set forth in claim **1** wherein the conductive surface layer has a content of acceptors and donors such that its temperature coefficient of resistance is close to zero.

3. A slide-spark electrode system as set forth in claim **2** wherein the donors and acceptors are nitrogen, boron or aluminum.

4. A slide-spark electrode system as set forth in claim **1** wherein the separating body is of polycrystalline silicon carbide obtained by pyrolytic vapor deposition from silicon- and carbon-containing compounds onto a carbon core.

5. A slide-spark electrode system as set forth in claim **1** wherein the electrical connection means comprises an alloy of gold and tantalum fused to the electrodes and to the surface layer.

6. A slide-spark electrode system as set forth in claim **5** wherein the surface layer is p-type conductive and the alloy also contains acceptors.

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