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Brzuszek et al.

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[54] **ELECTRICAL HEATING DEVICE AND METHOD**

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[52] **U.S. Cl.**...................... **219/553,** 29/195, 75/148, 148/33, 219/540, 338/22 SD, 338/330

[51] **Int. Cl.** **H05b 3/10**

[58] **Field of Search**.................... 219/523, 213, 530, 219/540, 553, 462; 338/223, 22 SD, 330, 331; 13/25; 23/23.5; 29/195; 75/148; 148/33, 33.5

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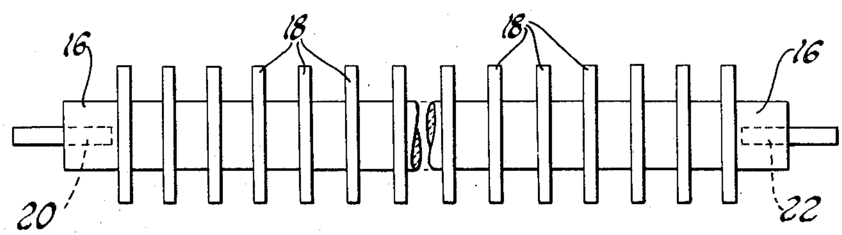
[57] **ABSTRACT**

In accordance with the invention there is provided an electrical heating device comprising a semiconductor body having bidirectional electric current conducting characteristics and having ohmic electrical contacts secured thereto at spaced points thereon for passing an electric current through at least a portion of said body, said body containing at least 99 percent by weight silicon and at least one other element uniformly dispersed therethrough.

2 Claims, 4 Drawing Figures



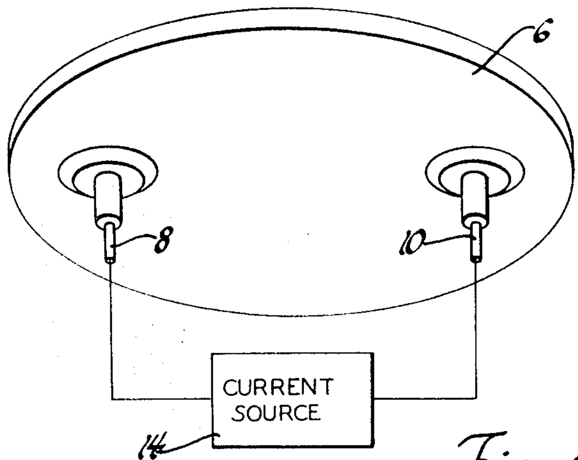


Fig. 1

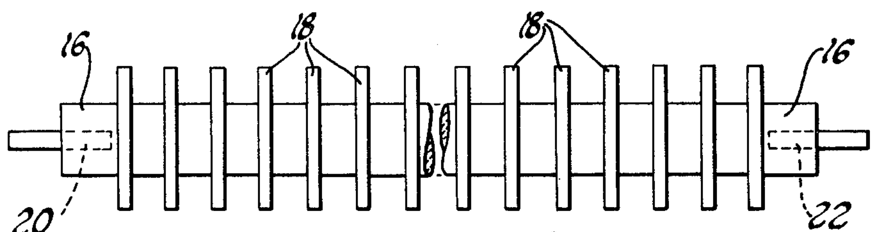


Fig. 2

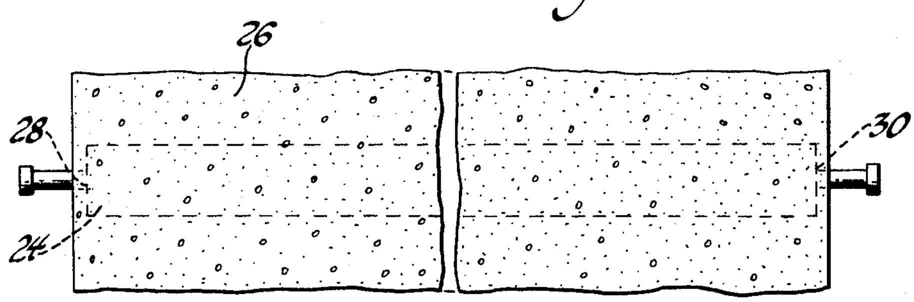


Fig. 3

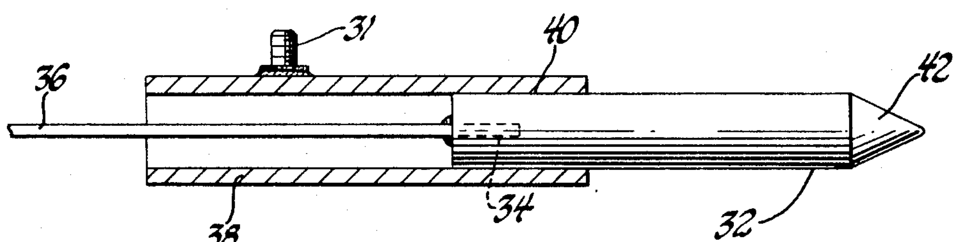


Fig. 4

ELECTRICAL HEATING DEVICE AND METHOD

This invention relates to a new and improved electrical heating device and method and has as its principal object the provision of an electrical resistance type heating device which is extremely efficient, inexpensive, and wherein the body functioning as the heating element has very high thermal conductivity such that heat generated by passing electric current through one portion of the body is rapidly transferred throughout the body.

Briefly, what we have discovered is that if a body containing at least 99 percent by weight silicon and at least one other element uniformly dispersed therethrough and having bidirectional electric current conducting characteristics is provided with spaced ohmic electrical connections and electric current is then passed through said body between said connections, the body functions as an extremely efficient electrical heating element, the high thermal conductivity of the silicon assuring rapid transfer of the generated heat to all surfaces of the body.

The body, as described, which functions as the heating element can take any of various shapes depending upon the particular application to be made of the heating device and examples of such shapes are shown in the drawings wherein:

FIG. 1 is a perspective view of an electrical heating device embodying the invention;

FIG. 2 is a side view showing another embodiment of the invention;

FIG. 3 is a top view, with parts broken away, of another embodiment of the invention; and

FIG. 4 is a side view, with parts broken away, of still another embodiment of the invention.

Silicon is classified as a nonmetal, but with various metallic properties. It is sometimes referred to as a metalloid. Absolutely pure silicon is specified to have a high dielectric constant and hence to be an electrical insulative material. However, it is well known in the art that a silicon body doped with any of certain other elements, and with the concentration of the other element varying from one surface of the body to another, displays semiconductive properties. Hence, it is common practice to provide such a body with a rectifying electrical contact, the body demonstrating unidirectional electric current conducting characteristics thereby to provide a rectifier. Such doped silicon bodies as are used in rectifiers are quite expensive and have no practical use as electrical heating elements not only by reason of the expense but also by reason of the unidirectional current conducting characteristics.

In accordance with the present invention the heating element for the electrical heating device is a body containing at least about **99%** by weight silicon and at least one other element, the other element or elements being uniformly dispersed through the body and the body having bilateral electric current characteristics. The element or elements other than silicon uniformly dispersed through the body are effective to provide a conductivity in the body higher than the conductivity of pure silicon. Electric current is passed through the body through spaced ohmic electrical contacts on the body. By "ohmic contact" is meant an electrical contact wherein there is substantially no current rectification. By reason of the semiconductive properties imparted to the body by the uniformly dispersed small

amount of another element or other elements, the body serves as an extremely efficient electrical resistance heating element. Further, because of the very high thermal conductivity of silicon, the heat generated is very rapidly conducted to all surfaces of the body, this being highly advantageous in the efficient utilization of the heat generated by the body.

The silicon containing the one or more other elements uniformly dispersed therethrough, such elements generally always being themselves electrically conductive (specifically, metals believed to be alloyed with the silicon) is commerically available on the market in the form of commerically pure silicon containing at least about 99 percent by weight silicon, and the remainder "impurities", and is used as silicon additive for the manufacture of iron, aluminum, or other alloys containing silicon. Commerically pure silicon of the type described is inherently polycrystalline in structure. Preparation of this polycrystalline, commerically pure silicon for use in semiconductor devices such as transistors centers on refinement of the silicon to remove the impurities and transformation of such refined silicon to single crystal form by means of a crystal growing process. The following is a table of such commerically pure silicon materials, all of which serve well, when fabricated to the desired shape, as the electrical heating element for the practice of the present invention.

Silicon	Iron	Calcium	Aluminum	Manganese	Chromium
99.03	.24	.13	.28	.03	.04
99.20	.42	.01	.07		
99.00	.34	.04	.55		
99.00	.33	.03	.36		

The best manner of farbicating the heating element from such commercially pure silicon will, of course, depend upon the precise shape desired for the heating element. In some cases this involves a casting operation, in others, machining operations and in still others extrusion or drawing operations.

The ohmic electrical contacts can be provided by a brazing operation wherein the electrical leads are brazed, as by means of a silver brazing composition, to the heating element, or they can be accomplished simply by very tightly clamping the metal contact members to the heating element. The metal used for forming the ohmic contact with the heating element should, of course, have a melting point higher than that of silicon, which is about 1410°C, or at least higher than the maximum temperature to be generated within the heating element during operation thereof. One manner we have found quite successful for providing the ohmic electrical connections with the heating element is to form, for each of the connections, a blind hole in the heating element, as by a drilling operation, and then driving a short rod of hard electrical conductive material, for example tungsten carbide, stainless steel or other hard metal, into the blind hole so as to provide an interference fit. Also, a silver brazing material can be used between the rod of the hard electrical conductive material and the walls of the opening in the heating element so as to attain a bond.

FIG. 1 shows an embodiment of the invention wherein the electrical heating device is for use as the heating element for a household electric range. In this embodiment the heating element 6 is a circular plate, about 5 inches diameter and three-eighths inches thickness, and is cast of molten silicon containing at least about 99 percent by weight silicon together with very small amounts of other metals uniformly dispersed therein — for example, any of the materials set forth in the above table. The ohmic electrical contacts are shown at **8** and **10**, these contacts being connected by suitable metal wires from integral projections on the bottom of the cast plate to a source of direct or alternating current, preferably the former, diagrammatically shown at **14**. Upon passage of current through the element **8**, heat is generated in the portion of the element between the electrical contacts, and this heat is very rapidly conducted throughout the heating element and hence relatively uniformly over the entire upper area of the element. With the contacts spaced about 3 inches and using a DC source of about 5 volts and 4 amps, a plate temperature of 1000°F can be attained — with the temperature being relatively uniform across the plate. Of course by reducing the current, there can be controlled lower plate temperatures.

FIG. **2** shows an embodiment wherein the heating element, of the composition described, is in the form of a rod **16** having integral spaced parallel disc shaped fins **18** extending radially therefrom. Upon passage of current through the rod, by way of the ohmic electrical contacts **20** and **22** heat is generated within the rod and this heat is very rapidly conducted to the fins. By circulating air between the fins the air becomes heated and this embodiment can be effectively used, therefore, as a space heater for heating dwellings.

In the FIG. **3** embodiment, the heating element **24**, of the composition described, is in the form of a sheet or slab embedded in and slightly below the surface of a concrete sidewalk, driveway or other surface. When current is passed through the heating element, by way of the electrical contacts **28** and **30** at the ends of the heating element, the heat generated within the rod is conducted to the surface of the concrete thereby to melt snow or ice or prevent the formation of accumulation thereof. For the FIG. **2** and **3** embodiments, it will generally be desired to generate temperatures only on the order of about 200° to 250°F, and it will be understood, of course, that the amount of current used will depend on the length of the heating element and the precise temperature desired to be generated.

The FIG. **4** embodiment shows a soldering iron, partially in section, incorporating an electrical heating element made in accordance with the present invention. That is, the heating element **32** is a rod of the silicon containing another element or elements uniformly dispersed therethrough, as aforesaid, the electrical connections being shown at **40** and **34**. An insulated wire **36** extends from the contact back through a handle (not shown) which is secured to a metal casing **38** to which the contact **40** is secured. Hence, the second of the ohmic contacts (the first of the ohmic controls being shown at **34**) is actually the contact between the heating element **32** and the metal casing **38** at the location shown at **40**. Despite the short current path through the heating element, between the contacts **34** and **40**, the tapered end **42** of the heating element very rapidly becomes heated because of the extremely high thermal conductivity of the silicon. Using a heating element of about 2½ inches length and ¾ inches diameter and a DC source similar to that described with reference to FIG. **1**, temperatures of about **1000**°F can be rapidly generated at the tapered end of the heating element. In connection with this particular embodiment, the invention has an additional advantage in that conventional soldering materials do not adhere to the silicon heating element thereby simplifying soldering operations.

Of course the amount of heat generated is dependent upon the electrical current passed through the heating element, and it will be manifest that in no instance should the amount of current applied be such as to generate a temperature within the heating element in excess of the melting temperature of the heating element and, to be on the safe side, it is preferable that the temperature generated not exceed about 1000°C. Such a temperature is more than ample for an extremely wide range of end-uses for the heating device.

It will be understood that while the invention has been described with reference to certain embodiments thereof, various changes and modifications may be made all within the full and intended scope of the claims which follow.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An electrical heating device comprising a polycrystalline semiconductor body having a bilateral current conducting characteristic and having ohmic electrical terminal contacts directly secured thereto at spaced points thereon for passing an electric current through at least a portion of said body, said body containing at least about 99 percent by weight silicon and containing metal uniformly dispersed therethrough and alloyed with the silicon, said metal comprising at least about 0.5 percent by weight of said body thereby being effective to provide a conductivity in said body higher than the conductivity of pure silicon.

2. A method for generating heat at a rate on the order of about 20 watts or greater comprising passing an electric current through a solid body having bilateral current conducting characteristics thereby to cause the generation of heat in said body, said body containing at least about 99 percent by weight polycrystalline silicon and containing metal uniformly dispersed therethrough and alloyed with the silicon, said metal comprising at least about 0.5 percent by weight of said body thereby being effective to provide a conductivity in said body higher than the conductivity of pure silicon.

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