A monolithic ceramic resistance igniter of simple configuration is composed essentially of polycrystalline silicon carbide adapted for use in gas and liquid fuel burning systems. As a result of the combination of its sintered silicon carbide composition, its microstructure, controlled density and large cross-sectional area, the igniter possesses an unusually high degree of physical ruggedness. The igniter will attain a temperature of about 1,000°C in well under 20 seconds drawing a maximum of 6 amps at 132 volts, with a room temperature resistivity of 0.10 to 1.70 ohm centimeters and a resistivity at about 1000°C of from 0.06 to 0.26 ohm centimeter. The igniter also has a physical construction such that a high percentage of its hot surface area radiates directly to the environment.

12 Claims, 3 Drawing Figures
SILICON CARBIDE RESISTANCE IGNITER

BACKGROUND OF THE INVENTION

The invention relates to igniters for fuel burning devices such as domestic and industrial liquid fuel and gas burning appliances. More particularly, the invention relates to ceramic resistance igniters for gas burning appliances such as kitchen ranges, furnaces, clothes dryers and the like.

The concept of non-pilot light igniters has been known for years. The earlier type of igniter was the incandescent wire device such as an electrically heated platinum wire coil. These are fragile and, in most applications, require a step-down transformer. Ceramic resistance igniters made their appearance in about 1937. U.S. Pat. No. 2,089,394 describes a total electrical ignition system in which a ceramic resistance igniter composed of “Durty Material” is utilized to ignite a fluid fuel system. Durty is a dense sintered silicon carbide impregnated with silicon. A U-shaped ceramic igniter is disclosed in U.S. Pat. No. 2,095,253 where the igniter is composed of sintered and silicon impregnated silicon carbide. This igniter element is formed by first performing 120 grit (142 microns) and finer silicon carbide material, into rods of suitable length, which are then fired to presinter the silicon carbide. The rods are then cut into the desired length and slotted to form a U-shaped element which is subsequently impregnated with silicon metal. Another basic type of silicon carbide igniter is that described in U.S. Pat. No. 3,052,814. This is a sparkplug type igniter as opposed to the pure resistance type mentioned above and is composed of silicon nitride bonded with silicon carbide. Still another silicon carbide igniter device is described in U.S. Pat. No. 3,282,324 as part of a complete ignition and heat injection system. In this case the silicon carbide is a sintered silicon carbide cylinder having a spiral cut which provides a relatively small percentage of the hot area which radiates directly to the environment.

By nature of their use, resistance igniters must be small in dimension, particularly in terms of their cross-section and overall length. Because of these physical parameter restrictions, prior art silicon carbide igniters are very fragile. As a result, attempts have been made to physically reinforce ceramic resistance igniters by such approaches as that described in U.S. Pat. Nos. 3,372,305 and 3,467,812. Both of these igniters have a spiral configuration which is fabricated of a sintered tube of silicon carbide which is made as dense as possible. The spiral configuration is cut in the sintered silicon carbide tube, which is then supported by an aluminum oxide rod which passes through the opening of the spiral igniter body.

Still another type of resistance igniter is described in U.S. Pat. No. 3,454,345. This igniter is composed of a sintered mixture of silicon carbide and silicon oxynitride wherein the silicon oxynitride functions as a bond for a relatively coarse 10F silicon carbide, i.e., a mixture of particles of 1,340 microns and finer in size with 10 percent by weight of silicon oxynitride. This silicon carbide/silicon oxynitride mixture is one manufactured and sold by the Norton Company, Worcester, Mass., and its foreign affiliates under the trademark CRYS-TOLON 63.

Despite the substantial amount of activity in the ceramic resistance igniter field, the igniters enjoying most widespread use today, for most applications, are still of the pilot light type. In view of the current energy crisis and the result of various surveys which show that pilot lights consume from 10 to 15 percent of the total gas consumed in this country, there is obviously a compelling need for an igniter to replace the presently used pilot light.

It is, therefore, a principal object of the present invention to provide a ceramic resistance igniter for liquid and gas fuel burning devices which is free of the foregoing deficiencies, and which is physically rugged, heats rapidly, survives hundreds of thousands of heating cycles, is simple electrically and structurally, has low susceptibility to premature burn out, and radiates primarily to the environment.

SUMMARY OF THE INVENTION

Compositionaly the ceramic igniter of the present invention consists of 95 to 99.9 percent by weight of alpha silicon carbide, 0.05 to 0.50 percent by weight of aluminum, 0 to 4 percent by weight silica, 0 to 0.25 percent by weight of iron or iron-based compounds, a maximum of 100 parts per million of boron and a minor amount, generally not in excess of 0.25 percent, of miscellaneous impurities. The composition also contains a very small (on the order of 500 ppm) amount of nitrogen which is introduced into the silicon carbide by a doping process which will be described in more detail subsequently. The small amount of aluminum incorporated in the SiC is necessary to raise the high temperature (e.g. 1,000°C) resistivity of the igniter to a level on the order of 0.06 to 0.26 ohm centimeters. The boron content is preferably kept below 50 ppm to maintain reasonably low resistivity at both low and high temperatures, the low resistivity at room temperature being particularly important from the standpoint of heat up time.

The igniter shape is formed by conventional methods which result in said igniter having a controlled density of from about 2.60 to 2.70 grams per cubic centimeter. This controlled density has the advantage of producing a silicon carbide resistor with a higher resistivity than a more dense silicon carbide, thus facilitating the formation of an igniter with the required resistance, but with a relatively short electrical path. The importance of this latter feature relates to the fact that igniters generally are used in very limited spaces, therefore, must be small in size. The high resistivity of the controlled density igniters of the invention greatly facilitates this objective. As a result of the composition, density, and the processing employed, the resulting silicon carbide igniter is ideally suited as a fuel igniter for such devices as gas clothes dryers, in that the stringent requirements for such igniters are easily satisfied by the igniters of the invention. To be acceptable for such end uses, the igniter must have sufficient mechanical strength to resist severe physical forces; the present igniter will withstand a whipping type force of at least 125 g's. Such an igniter must also be able to attain a temperature of about 1,000°C in less than 20 seconds while drawing a maximum of 6 amps at 132 volts, and in less than 60 seconds at an input of 80 volts; the present igniter easily satisfies these requirements by virtue of a room temperature resistivity of 0.10 to 1.70 ohm centimeters, and a resistivity at approximately 1,000°C of 0.06 to 0.26 ohm centimeter. Its overall physical dimensions for gas fired clothes dryers and ranges is from 2.125 to 2.625 inches in length, with an effective cross-section...
of from 0.012 to 0.072 square inch. Finally, the present igniter has an inherent ability to withstand at least 200,000 heat-up and cool-down cycles. This is unexpected in view of the relatively low density of the igniter, but it is believed that this results from a combination of chemical composition, processing conditions involved in the fabrication of said igniter, and the high percentage of the heating area which radiates directly to the environment. By the expression "aera which radiates directly to the environment" we mean hot area that does not "see" other hot areas. Thus the inside surface of a cylindrical heating element would "see" other hot portions of the inside surface (or a hot support element) and would not be considered as "radiating directly to the environment." The "hot" area of the igniter of FIG. 1 is the surface of that part of the element of smallest cross-section, that is the portion of 8a, 8b, 10a, and 10b of minimum cross-section. In FIG. 2, about 55% of the surface of the "hot" area is "outside" surface. To keep the outside surface above 50%, the thickness of the igniter should not be greater than twice the width of the legs. From the design of FIG. 3, the outside area will always be greater than 50%.

The present igniter is monolithic and self-supporting, needing no supporting device such as that required for the successful utilization of the silicon carbide igniter of U.S. Pat. Nos. 3,372,305 and 3,467,812. This results from the relatively great thickness, i.e., cross-sectional area of the present igniters as set forth above. The most desirable configuration is that of a leg having a hairpin shape including terminal connecting ends, because this shape presents at least 50% of the surface area of the hot zone of the igniter to the surrounding environment. With a high percentage of the heating area radiating outward, there is less tendency for hot spots to develop. This characteristic, plus the relatively large cross-section, minimizes premature burn out. It is even more desirable that the igniter be made of two legs of hairpin configuration to maximize the igniter's ability to quickly ignite a fuel exposed thereto.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal view of the largest surface area of the igniter of the present invention.
FIG. 2 is a sectional view of the igniter of FIG. 1.
FIG. 3 is a longitudinal view of the largest surface area of another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred physical configuration of the instant igniter is shown in FIGS. 1 and 2. Referring to FIG. 1 the wing shaped elements 4 and 6 are terminal connecting ends. Coextensive with the terminal connecting ends and with each other are two hairpin shaped legs 8 and 10. The double hairpin configuration is completed by the approximately centrally located slot 12 which traverses from the end of the igniter opposite the terminal connecting ends towards said ends but stopping substantially short thereof; and a slot in each leg 8 and 10 identified as 14 and 16 respectively in FIG. 1. The electrical path begins at the terminal connecting ends 4 and 6 and traverses the legs through a substantial part of their length, forming two elements 8a, 8b and 10a and 10b for each leg. In the slots 14 and 16 at the terminal connecting ends thereof it is desirable, although not absolutely necessary, to include a portion of an electrically insulating cement such as a commercially available aluminia based refractory cement. This is shown as small dabs 18 and 20. Larger quantities of refractory cement may be used if desired. Without the portion of cement so located in slots 14 and 16 there is the danger of shorting out or breaking of the igniter should any force be exerted on the terminal connecting ends 4 and 6 so as to force said ends toward one another. The ends or tips 22 and 24 of legs 8 and 10 respectively have a larger cross-section than the cross-section of their individual elements 8a, 8b, 10a and 10b. This larger cross-sectional area of these ends causes them to remain relatively cool and causes concentration of the hot zone of the igniter in those portions of the two legs in between these ends 22 and 24 and the terminal connecting ends 4 and 6. This configuration exposes, for direct radiation to its environment, at least 50% of the total surface area of the igniters hot zone. In calculating the area of hot zone which radiates directly to the environment in FIGS. 1 and 2 the upper and lower surfaces (those parallel to the plane of the drawing) and the outer boundaries of the element would be considered as the applicable areas. The surfaces of the element defining the slots would not be so considered since they can radiate directly to their hot facing surfaces.

In a preferred form for gas dryers the present igniter is from 2.125 to 2.625 inches in length, with the end 22 and 24 of the legs 8 and 10 each having an essentially rectangular cross-sectional area of from 0.020 to 0.039 square inch. Elements 8a, 8b, 10a and 10b of legs 8 and 10 each preferably have a cross-section of from 0.009 to 0.014 square inch, the slots forming said elements are preferably from 0.033 to 0.080 inch wide. There are many possible variants on the basic configuration of the present igniter, one such being that shown in FIG. 3 which has terminal connecting ends 26 and 28 and a single hairpin shaped leg 30 comprised of elements 30a and 30b, slot 32. Insulating cement 34, is included between the terminal connecting ends 26 and 28. The end 36 has a slightly larger section area than elements 30a and 30b of leg 30.

In one method of forming the present igniters a casting slip is prepared having the preferred composition of 97 to 99.9% by weight of a 50% mixture of high purity 3.0 micron silicon carbide and 100F silicon carbide, and 0.05 to 0.30% by weight of Al2O3. The preparation of the slip, and the casting thereof into plaster molds, is taught in U.S. Pat. No. 2,964,823. The mold cavity has a cross-sectional configuration and dimensions corresponding to the outline of the igniter shown in FIG. 1 or FIG. 3. The length of the mold cavity is 12 inches although obviously said dimension could be longer or shorter if desired. The green billet thus cast is allowed to stand in the mold for 10 to 15 minutes after which it is removed and air dried for 8 to 16 hours at 125° to 150°C. To facilitate slicing of the billet into igniter blanks, the billet is impregnated with a 25% solution in isopropyl alcohol of a mixture of 100 parts by weight of Fapreg P3 and 2 parts by weight of Activator, both materials manufactured and sold by Quaker Oats Company. Other polymerizable organic material may also be used in place of the foregoing. The impregnation is carried out by immersion of the green billet in the solution. The saturated billet is heat treated at about 95°C for at least 12 hours after which temperature is raised.
to about 190°C and held there for 2 hours. The billet is then allowed to cool.

The billet is sliced into igniter blanks preferably about 0.135 inch in thickness. The slicing is best accomplished with a diamond cut-off wheel. The three slots 12, 14 and 16 of FIG. 1 are cut into the blanks, again with a diamond cut-off wheel.

The green igniters are placed in a graphite holder and fired at 2,200° to 2,450°C in a reducing atmosphere for 1/4 to 4 hours. The fired igniters are subjected to a subsequent firing, in nitrogen, at 1,500° to 2,000°C for 15 to 180 minutes, maintaining the nitrogen environment until the temperature in the furnace has dropped to 800°C.

The terminal connecting ends 4 and 6 in FIG. 1 are then coated with a metal, preferably aluminum or an aluminum alloy. This may be accomplished by any known method such as dipping of the ends into molten metal or flame spraying. The ends should also be sandblasted lightly prior to applying the metal coating.

The final step in the fabrication of the present igniter is the placing of the refractory, electrically insulating cement, 18 and 19 in FIG. 1. The cement may be essentially and refractory, electrically insulating cement but the preferred cement is the high alumina type. The quantity of cement required, for the purposes stated above, is small e.g. an amount of cement to fill the slots 14 and 16 of FIG. 1, approximately 1/4 inch in from the far edge of the terminal connecting ends. The slots may be filled further, if desired.

For optimum performance the igniter should be composed of from 97 to 99.9% by weight of polycrystalline silicon carbide, 0.1 to 0.3% by weight of aluminum added as aluminum oxide in the original mixture, less than 50 parts per million of boron, and not more than 0.2% of miscellaneous impurities. It would also appear that an indeterminate amount of nitrogen must be introduced into the structure by subjecting the initial green igniters first to a standard non-oxidizing type of firing step at about 2,200°C or above, followed by firing in a nitrogen atmosphere at 1,500° to 2,000°C. Attempts to combine these two steps into one fail to affect the desired electrical properties in the final igniter. This is believed to be due to the different rates of N₂ diffusion into the SiC crystals at the two different temperatures. When N₂ is present during the initial high temperature firing (2,200° to 2,400°C) it diffuses in sufficient quantities into the body of the SiC so that bulk SiC has a low resistivity both at room and high temperatures thus providing too much current flow at the high temperature (over 6 amps at 132 volts). It is believed that when the igniter is fired in nitrogen at the lower temperature (1,500° to 2,000°C) a small but sufficient amount of nitrogen diffuses into the surface of the fine silicon carbide particles, which bridge the larger particles, to lower the room temperature resistivity of the igniter without significantly affecting the high temperature resistivity. As a result this added N₂ lowers the igniter response time, e.g., the time for the igniter to reach the desired fuel ignition temperature.

Some prior art gas and liquid fuel igniters have the inherent shortcoming of room temperature resistivities that are too high, and elevated temperature resistivities that are too low for the most effective and efficient operation. The igniter of the present invention is free of these problems having a preferred resistivity at room temperature of from 0.15 to 0.5 ohm centimeter and about 1,000°C of at least 0.1 ohm centimeter, resulting in a response time at 80 volts of 10 to 60 seconds to attain approximately 1,000°C.

This unique set of resistivities results primarily from the combination of the introduction of the prescribed amount of aluminum into the crystal lattice of the silicon carbide, and the post-firing nitrogen treatment which introduces a relatively high percentage of nitrogen into the crystal lattice of the finer silicon carbide grains. This same treatment (it is believed) introduces only a very small percentage of nitrogen into the crystal lattice of the larger SiC crystals. The effect of the presence of aluminum is to increase the resistivity of the body, both at room temperature and at elevated temperature; the latter is desirable but the former is not. The nitrogen treatment subsequent to the initial firing reverses or compensates for the undesirable increase in the room temperature resistivity caused by the introduction of the aluminum, i.e., the nitrogen decreases the room temperature resistivity. The resulting igniter thus has a heretofore unknown combination of a relatively high elevated temperature resistivity and a low room temperature resistivity.

The oxygen content of the finished igniter is between about 0.04 to 0.1%. After use the oxygen content will increase substantially due to surface oxidation of the silicon carbide grains. This additional oxygen is not detrimental so long, as it is on the surface of the fired igniter and not between the SiC grains of the igniter where it would introduce a high resistance. In some cases it may be desirable to oxidize the igniters prior to sale or to apply an oxide coating on the finished igniter; these techniques are known in the art.

Where the expression "percent" or "G" is used in the specification and claims it is intended to mean weight percent unless clearly stated to have some other meaning.

What is claimed is:

1. A ceramic resistance igniter, comprised of a pair of terminal connecting ends and a hot-zone extending therefrom and having a composition consisting essentially of from 95 to 99.9% by weight of silicon carbide, 0.05 to 0.50% by weight of aluminum, 0 to 4% by weight of silicon oxide, 0 to 0.25% by weight if iron or compounds thereof, a maximum of 100 parts per million of boron, and up to 0.25% by weight of miscellaneous impurities, said composition having been sintered and then exposed to a nitrogen atmosphere at a temperature of from 1,500°C to 2,000°C for 15 to 180 minutes.

2. The ceramic resistance igniter of claim 1 having electrical characteristics such that said igniter draws a maximum of 6 amps at 132 volts and has an impact resistance of at least 125 g's.

3. The ceramic resistance igniter of claim 2 having a response time at 80 volts of 60 seconds or less to attain 1,000°C and an operational life of at least 200,000 cycles.

4. A monolithic ceramic resistance igniter, comprised of a pair of terminal connecting ends and a hot-zone extending therefrom and having a composition consisting essentially of from 95 to 99.9% by weight of polycrystalline silicon carbide, 0 to 4% by weight of silicon oxide, 0 to 0.25% by weight of iron or compounds thereof, 0 to 50 parts per million of boron, and up to 0.25% by weight of miscellaneous impurities; said silicon carbide containing from 0.05 to 0.50% by weight...
of aluminum in the crystal lattice thereof and nitrogen being introduced into said crystal lattice by subjecting said composition to an atmosphere of nitrogen at a temperature of from 1,500°C to 2,000°C for 15 to 180 minutes.

5. The ceramic resistance igniter of claim 4 having a room temperature resistivity of 0.10 to 1.70 ohm centimeters and a resistivity at 1,000°C of 0.06 to 0.26 ohm centimeter.

6. A sintered ceramic resistance igniter, comprised of a pair of terminal connecting ends and a hot-zone extending therefrom and having a composition consisting essentially of from 97 to 99.9% by weight of polycrystalline silicon carbide, 0.1 to 0.3% by weight of aluminum contained in the crystal lattice of said silicon carbide, 0 to 100 parts per million of boron, and from 0 to 0.2% by weight of miscellaneous impurities, said composition having been doped with nitrogen by heating at 1,500°C to 2,000°C for 15 to 180 minutes; said ceramic igniter having a room temperature resistivity of 0.15 to 0.5 ohm centimeter, a resistivity at 1,800°F of at least 0.1 ohm centimeter, a response time of 10 to 60 seconds to attain 1,000°C, an operational life of at least 200,000 cycles, an impact resistance of at least 125 g's, and the further property that said igniter draws a maximum of 6 amps at 132 volts.

7. A sintered ceramic resistance igniter, comprised of a pair of terminal connecting ends and a hot-zone extending therefrom and having a composition consisting essentially of from 95 to 99.9% by weight of polycrystalline alpha silicon carbide, 0 to 4% by weight of silicon oxide, 0 to 100 parts per million of boron, 0.05 to 0.5% by weight of aluminum, said composition having been preformed and fired at 2,250°C to 2,450°C in an inert atmosphere followed by firing in a nitrogen atmosphere at from 1,500°C to 2,000°C for 15 to 180 minutes; said igniter having a density of 2.60 to 2.70 gms/cc, and having resistivity at room temperature of from 0.10 to 1.70 ohm centimeters and at 1,000°C of from 0.06 to 0.26 ohm centimeter.

8. A sintered ceramic resistance igniter, comprised of a pair of terminal connecting ends and a hot-zone extending therefrom and having a composition consisting essentially of from 95 to 99.9% by weight of polycrystalline alpha silicon carbide, 0 to 4% by weight of silicon oxide, 0 to 100 parts per million of boron, 0.05 to 0.5% by weight of aluminum, said igniter having a density of 2.60 to 2.70 gms/cc, having resistivity at room temperature of from 0.10 to 1.70 ohm centimeters and at 1,000°C of from 0.06 to 0.26 ohm centimeter, and having at least 50% of the surface area of the hot zone of the igniter radiating directly to the environment.

9. A ceramic resistance igniter, comprised of a pair of terminal connecting ends and a hot-zone extending therefrom and having a composition consisting of from 95 to 99.9% by weight of silicon carbide, 0.05 to 0.5% by weight of aluminum, 0.04 to 0.1% by weight of oxygen, 0 to 4% by weight of silicon oxide, 0 to 0.25% by weight of iron or compounds thereof, a maximum of 100 parts per million of boron, said composition having been exposed to a nitrogen atmosphere at a temperature of from 1,500°C to 2,000°C for 15 to 180 minutes.

10. The ceramic resistance igniter of claim 9 wherein said ends having been treated with an aluminum alloy.

11. A monolithic ceramic resistance igniter having a flat elongated configuration essentially rectangular in cross-section, including terminal connecting means at one end, a hot zone extending therefrom comprised of at least one leg having a hairpin shape, where the end of said leg opposite the terminal connecting ends has a greater cross-section than the cross-section of the individual elements making up said hairpin shaped leg, and having at least 50% of the surface area of said hot zone radiating directly to the environment.

12. The monolithic ceramic resistance igniter of claim 11 comprised of polycrystalline silicon carbide and consisting of two interconnected hairpin shaped legs, the overall length of said igniter being from 2.125 to 2.625 inches, the ends of said legs opposite the terminal connecting ends having a cross-sectional area of from 0.013 to 0.049 square inch, the elements of said hairpin shaped legs having a cross-section of from 0.006 to 0.018 square inch, and the width of the slots separating said elements being from 0.012 to 0.080 inch.