ELECTRIC GRILL WITH A THIN-FILM HEATING ELEMENT

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Filing Date: Sept. 16, 1970
Application Number: 72,600

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ABSTRACT
A metallic thin film resistance heating element comprises an electrically and thermally insulating sub-stratum, a thin film resistor deposited in a plurality of sprayed layers superposed upon the sub-stratum in the form of parallel, uniform strips, interconnectors for adjacent strips, electrode terminals at the ends of the resistor, and preferably an inert, abrasion-resistant coating covering the resistor upon the outer surface of the assembled heating element. A method of constructing such a heating element includes providing a thermally insulating sub-stratum, depositing thereon by spraying in a plurality of layers a thin film resistor in a pattern of parallel uniform strips, providing series interconnectors for the strips and take-off terminals, and preferably applying an abrasion resistant coating covering the resistor upon the outer surface of the heating element.

4 Claims, 17 Drawing Figures
ELECTRIC GRILL WITH A THIN-FILM HEATING ELEMENT

BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

This invention relates to electrical heating elements of particular utility in the cooking of food through surface contact heating.

Electrical heating elements in present use for cooking devices are inefficient as to both the time and energy expended, with the basic reasons for these inefficiencies stemming from the type of heating element used, as well as the technique of heat transfer employed. Generally, the heating element utilizes a resistance element of large mass, thereby requiring a substantial time to attain operating temperature. Also, the technique used to transfer heat from the heating element to the food to be heated or cooked is likewise inefficient. For example, in frying bacon in an electric skillet, a long time is needed to heat the large masses of the skillet and resistance heating element to operating temperature, and much heat energy is lost, primarily through convection from the surfaces of the skillet, with some heat also lost by radiation. This same task could be accomplished with greater speed and efficiency by use of a low mass heating element having good energy transfer characteristics.

It is therefore the major purpose of this invention to provide an electrical heating element characterized by a short rise time and efficient energy transfer characteristics. It is an additional purpose of this invention to provide a method for constructing the heating element by means of a series of steps readily adapted to high-speed construction procedures.

In order to accomplish the objective of an efficient heating element with a short rise time to operating temperature, the invention utilizes a thin film metallic resistor deposited by means such as flame spraying onto an insulating substratum. The thin film metallic resistor is preferably utilized in a rectangular heating element comprised of parallel strips of metal film deposit with the ends of the strips appropriately interconnected to produce a convoluted series resistance configuration. The insulating substratum quite efficiently prevents heat loss through the rear of the heating element. While several types of insulating substratum could be used, some materials and combinations of materials are preferred as is further discussed below.

Some uses of the heating element will call for a protective covering over the resistor, terminals, substratum combination. For example, if the heating element is to be used as a grill, a smooth, inert, abrasion-resistant coating, such as porcelain, could be used.

A heating element formed in accordance with the present invention exhibits several advantages over existing heating elements. In general the deposited thin film forms a more durable resistor, having a higher resistance per unit mass. Additionally, the resistor being deposited onto an insulating substratum provides efficient transfer of heat, particularly by means of surface contact.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a heating element comprising as a substratum alternating layers of asbestos millboard and aluminum reflecting sheets, a thin-film resistor deposited on the upper surface of the top layer of millboard, and a protective coating applied over the heating element, with part of the protective coating cut away for illustration.

FIG. 2a is a cross-sectional view in frontal elevation of the heating element in FIG. 1, taken along line 2a–2a, with an electrode leadoff utilizing a threaded shank and nut;

FIG. 2b is an enlarged view of the electrode leadoff in FIG. 2a.

FIG. 2c is a similar view of 2b with an electrode leadoff utilizing a spring loaded contact;

FIG. 2d is a similar view of 2a and 2b with an electrode leadoff comprised of a rivet;

FIG. 3 is a plan view of a portion of another heating element using interconnectors and electrode terminals in the form of a staple.

FIG. 4 is a perspective of an interconnector in FIG. 3;

FIG. 5 is a perspective view of the electrode terminal in FIG. 3;

FIG. 6 is a plan view of another heating element;

FIG. 7 is a view in frontal elevation of the heating element in FIG. 6;

FIG. 8 is a view in frontal elevation of an interconnector used in FIG. 6;

FIG. 9 is a view in side elevation of the interconnector in FIG. 8;

FIG. 10 is a view in side elevation of an electrode terminal in FIG. 6;

FIG. 11 is a perspective view of a grill incorporating a pair of heating elements, such as those of FIG. 1.

FIG. 12 is a cross-sectional view in frontal elevation of the grill in FIG. 11, taken along line 12–12;

FIG. 13 is an electrical diagram of the grill in FIG. 11.

FIG. 14 is an oblique, shortened view of a heating element in the form of an extended strip.

DETAILED DESCRIPTION OF THE INVENTION

The heating element of the present invention is comprised of an electrically and thermally insulating substratum, a thin film metallic resistor deposited by spraying in a plurality of superposed layers, preferably in parallel, interconnected strips onto the substratum, and electrode terminals and electrode lead-offs at the ends of the resistor. Preferably, the heating element also contains a protective coating covering the exposed upper surfaces of the resistor, interconnectors, electrode terminals and electrode lead-offs. Also in accordance with the invention, a grill suitable for rapid and efficient cooking incorporates one or a pair of heating elements, in conjunction with appropriate thermostatic control, timing control, base insulation, and exterior covers.

The thin film resistor is deposited in several, superposed layers onto the substratum by flame spraying, arc spraying, plasma spraying or the like.

By spraying the thin film in several passes, it is possible to achieve superior uniformity, as compared with a film of like thickness sprayed in a single pass. Although each single pass does not leave a uniform layer, by the random nature of spray application each succeeding, superposed pass tends to increase the uniformity of the film. It has been found, unexpectedly, that thin film resistors of the present invention have a resistance substantially greater than the resistance of the same metal as a solid of like dimensions.
Through such techniques, the metal can be deposited in generally any desired configuration or depth. Since the resistance of the thin film is determined by its dimensions, i.e. resistance varies directly with the length of the strip and inversely with its cross-sectional area, a wide range of resistance values in a variety of configurations can be produced. While the preferred embodiment utilized Nichrome V (T.M., a composition of 80% Ni and 20% Cr) as the resistor alloy metal, a number of other metals, for example, high resistivity alloys such as stainless steel, copper, aluminum alloys, or other alloys of nickel and chromium, could be used.

A heating element utilizing such a thin film resistor exhibits several advantages over a comparable heating element incorporating a solid resistor: a better bond can be achieved between the resistor and substrate; the thin film resistor has better thermal expansion characteristics; since the thin film resistor can be deposited onto the substrate by superposed passes of spray, any desired thickness and resistance can be readily obtained; the thin film resistor exhibits a higher resistance per cross-sectional area and per unit mass, than that of a comparable solid resistor.

The insulating substrate must have good thermal and electrical insulating properties and provide both structural support and a base for efficient bonding to the thin film resistor. Although several types of material would accept such a bond, many of them, for example glass and ceramics, have a high thermal conductivity. High density asbestos sheet, known in the trade as millboard, has properties particularly well suited for this use. Not only does millboard provide an extremely good bond and a low thermal conductivity, it is also readily available in thin sheets, enabling the addition of thin reflecting sheets, such as thin aluminum, behind millboard layers, with the combination of the layers of reflector and millboard having superior insulating and structural properties. Resin bonded carbonbrumex exhibits properties similar in these respects to millboard and is also suitable in this use.

Care must be taken in depositing the thin film resistor to insure a deposit of sufficiently uniform thickness to avoid burnouts resulting from current density irregularities. Millboard has a smooth, calendered surface with a slight grain running along it, providing adequate smoothness for a thin film deposit of at least 0.002 inch. It has been discovered, however, that a thin film deposited along the grain has a different resistance than that deposited across the grain; this characteristic of the millboard can be utilized to enable a production choice between, for example, two values of resistance with a minimum of production line changes. In addition, it might be that for a given resistance value of thin film, a better bond to the substrate is obtained when the metal is deposited in a particular direction relative to the grain of the millboard.

The thin film can be deposited in a number of configurations on the substrate, with the basic limitation that of current density burnout. While the preferred embodiment incorporates strips of thin film running parallel to one another, interconnected into a series resistor, other configurations are apparent. For example, the same strips of thin film in the preferred embodiment could be connected into a parallel configuration. Alternatively, strips could be parallel connected, with these parallel resistors connected in series. As further example, the thin film could be deposited in an outwardly spiraling strip, as in an electric range burner, or deposited in a long strip to be used as a baseboard heater. Of course in these cases interconnectors may not be necessary. In any case, the considerations of current density burnout, temperature expansions, and energy efficiencies are always present and the preferred embodiment serves to present one illustration in accordance with the teachings of this invention.

In the preferred embodiment, the strips of thin film are connected into a convoluted series resistance pattern by use of high conductivity interconnectors at the appropriate ends of the strips of thin film. These interconnectors must be of a sufficiently high conductivity and must run substantially along the widths of the strips of thin film to avoid current density burnout where the current "turns the corner" at the ends of the strips.

One method of forming the interconnectors is to deposit an appropriate material onto the substrate by means such as flame spraying, with the thin film subsequently deposited. Not only must the material used for the interconnectors be of a high conductivity, but also the bonding between the substrate and the interconnector, and between the interconnector and the thin film resistor, must be adequate to withstand the expansions involved in the heating of the configuration during production and use.

Another form of interconnector consists of a strip of high conductivity material secured onto the ends of the substrate, so as to run substantially along the widths of the strips to be incorporated. One embodiment of this terminal consists of a long clip of such material, which is crimped over the end of the substrate with the thin film deposited subsequently. Another embodiment consists of a staple, which has a body long enough to run substantially along the widths of the strips to be incorporated. The arms of the staple penetrate into the substrate, securing the body of the staple onto the substrate, with the thin film deposited subsequently. In these instances also, the thermal expansions encountered can be limiting factors in use.

The electrode terminals positioned at, and running substantially along, the width of the ends of the convoluted series resistor serve to collect the current and conduct it to the electrode lead-off without danger of thin film burnout. Since they perform the same basic function of current collection as do the interconnectors, the same considerations as to conductivity, bonding, and thermal expansions are involved. The solutions are also basically the same, with one embodiment comprised of a deposit of a high conductivity material onto the substrate with the thin film subsequently deposited, another embodiment comprised of a clip of a high conductivity material to be crimped over the substrate with the thin film subsequently deposited, and another embodiment in the form of a staple, with the arms of the staple driven into the substrate, securing the body of the clip to the surface of the substrate with the thin film subsequently deposited.

Lead-offs in electrical contact with the electrode terminals provide means for connecting the thin film resistor to a source of electrical power. The lead-offs must be of a high conductivity, and must be able to maintain contact with the electrode terminals throughout the temperature expansion cycles. Several embodiments of the lead-offs will be described below with reference to the drawings.
The protective coating applied as a final step in construction of the heating element is preferred, depending upon the utilization of the heating element. This protective coating provides an inert, durable, smooth, abrasion-resistant surface of particular utility in certain food preparation techniques, such as in grilling. Since the protective coating is deposited superposed over the various layers of interconnectors, thin film resistor, electrode terminals, and electrode take-offs, it must be capable of withstanding the temperature expansions encountered during production and use. Two materials exhibiting the necessary characteristics for use in the protective coating are porcelain and fluorocarbon resins such as polytetrafluoroethylene, e.g. Teflon (T.M.). In some cases, such as when polytetrafluoroethylene resin is used, a prime coat should be first applied to the thin film in order to produce the required smoothness in the final protective coating.

With reference to FIGS. 1 and 2a, a preferred heating element is comprised of an insulating substratum 10, a thin film metallic resistor 12 deposited as five superposed strips onto the substratum, interconnectors 14, electrode terminals 16, electrode lead-offs 18 and a protective coating 20 covering the above configuration.

As seen in FIG. 2a, the insulating substratum 10 of the preferred embodiment utilizes a layered configuration of thin asbestos millboard 22 interspersed with thin aluminum reflecting layers 24. Although any number of layers of millboard with reflectors could be employed, the preferred embodiment illustrates a four layered substratum consisting of a 0.002-inch aluminum reflector 24 below each sheet of 0.064-inch asbestos millboard 22. While other configurations of insulating substratums, other types, and other dimensions could be used, the illustrated substratum 10 has proved highly satisfactory in providing the basic structural, insulating and bonding qualities needed for the thin film resistor 12.

The thin film resistor 12 in FIG. 1 is comprised of five superposed strips of Nichrome V, each strip 9.5-inches long, 1-inch wide, and 0.002–0.005-inches thick, formed by flame spraying 4–5 passes back and forth, and connected into a series resistance pattern through the use of the interconnectors 14. As an example of the higher resistance per cross-sectional area and per unit mass attained by the flame sprayed resistor 12, the illustrated resistor 12 has a resistance of 4.36 ohms, and with a thickness of 0.003 inches weighs less than 5 grams. By contrast, solid Nichrome V of the same pattern would have a resistance of about 0.65 ohms, and solid Nichrome V of equivalent resistance would weigh approximately 21 grams. This increased resistance per unit 0.003 inches weighs less than 5 grams. By contrast, solid Nichrome V of the same pattern and like dimensions would have a resistance of about 0.65 ohms, and solid Nichrome V of identical cross sectional dimensions and equivalent resistance would require a much greater total length and would weigh approximately 21 grams. This increased resistance per unit weight or dimension of a thin film resistor, formed in several passes by flame spraying, achieves significant benefits. For example, the smaller electrode mass of the thin film enables a faster rise time to operating temperature in comparison with solid metal.

As noted before, the smooth millboard 22 used in the substratum 10 provides adequate smoothness to ensure against burnout of the 0.002–0.005 inch thin film 12; also, the resistance of the thin film 12 can be altered somewhat by varying the direction of deposit relative to the millboard 22. In the embodiment of FIG. 1, the resistance of the 0.003 inch thin film 12 can be doubled, to 8.7 ohms, by depositing the film 12 in strips across the substratum 10, a 90° change in direction of the strips.

The interconnectors 14 in FIG. 1 are formed of copper, 0.010 inch thick, deposited by flame spraying onto the substratum 10 prior to the depositing of the thin film resistor 12. The bonds between the copper interconnectors 14 and the substratum 10 and between the copper interconnectors 14 and the Nichrome 12 are sufficient to withstand the thermal expansion of temperatures up to 1,150°F.

When the deposited interconnectors 14 are used on the layered substratum 10, means must be provided for fastening the layers of millboard 22 and aluminum reflector 24 together. As seen in FIG. 1, preferred means for fastening comprises staples 26, extending into the substratum 10, with the staples 26 positioned around a one-fourth inch border of the substratum 10 left clear for this purpose.

Another form of interconnector to be used in the embodiment similar to that illustrated in FIG. 1 is illustrated in FIGS. 3–5 and has the form of a brass staple 28 0.010 inch thick, with a broad, flat head 30 and arms 32. The staple interconnector 28 is driven into the substratum 10, so that the head 30 is secured to the substratum and positioned similar to the deposited copper interconnector 14, with the head 30 running substantially across the width of the strip 12 of thin film. When this type of interconnector 28 is used, the aluminum reflector 24 must be cut away to avoid electrical contact with the arms 32 of the staple.

The electrode terminals 16, positioned at, and running substantially along the width of the ends of the convoluted series resistor, serve to collect the current and feed it to the electrode lead-offs 18 without danger of current density burnout. They must therefore be of appreciably higher conductivity than that of the thin film resistor 12. In the embodiment in FIG. 1, the electrode terminals 16 are formed of copper deposited onto the thin film 12. The electrode terminal 34, for use in the element shown in FIG. 3, is illustrated in FIG. 5 and is comprised of a brass staple, similar to the staple interconnector 28, with a hole 36 for the electrode take-off drilled prior to securing the terminal 34 to the substratum 10.

The electrode lead-offs 18 provides the means of connecting the thin film resistor 12 to a source of electrical power. FIGS. 2b, 2c, and 2d illustrate methods of accomplishing a good electrical contact between the electrode terminal 16 and the electrode lead-off 18 and are suitable for use with either the copper deposited terminal 16 (FIG. 1) or the staple terminal 34 (FIG. 5). The lead-off 18 illustrated in FIG. 2b is a brass stud 38 comprised of a head 40 a threaded shank 42, used in conjunction with a washer 44 and a hex nut 46. The head of the stud 40 is forced into good electrical contact with the terminal 16 through pressure exerted by the hex nut 46. A wire crimp cavity 48 is provided at the bottom of the shank 42. The thin film resistor 12 is deposited over the substratum 10, interconnecting terminal 14, electrode terminal 16, and electrode lead-off 18 combination.
FIG. 2c illustrates an alternative lead-off 50, again constructed of a brass stud with its head 52 forced into good electrical contact with the terminal 16, through pressure exerted by a push-on nut 54. Again a washer 56 is utilized, and a wire crimp cavity 58 is provided.

FIG. 2d illustrates another alternative lead-off 60, comprised of a copper rivet, utilized in a manner similar to those lead-offs in FIG. 2a and FIG. 2b. When the leadoffs in FIGS. 2b, 2c, and 2d are used with copper deposited interconnectors, the aluminum sheets 24 used in the substratum 10 must be cut away in order to avoid contact with the leadoffs.

As noted in the figures, the thin film 12 is deposited over the interconnectors 14, the electrode terminals 16 and electrode lead-offs 18. Care must be taken that the bondings between these elements are sufficient to withstand the temperatures encountered; as example, where Nichrome is deposited onto brass, a better bond can be obtained if a layer of copper is first deposited onto the brass, with the Nichrome deposited subsequently.

Other interconnectors 62, electrode terminals 64 and electrode take-offs 66 are illustrated in FIGS. 6–10. The interconnector 62 is comprised of a phosphor bronze clip, thereby providing the required high conductivity, is crimped at the appropriate positions on the edges of the substratum 10 and runs substantially along the widths of the strips 12, which strips 12 are deposited subsequently. The bottom layer of the aluminum reflecting strip 24 must be cut away to avoid electrical contact with the clip 62, as seen in FIG. 7.

The electrode terminal 64 is similarly comprised of a phosphor bronze clip, crimped at the ends of the resistor 12 with a take-off arm 66 extending therefrom, and a hole 68 drilled in the take-off arm 66 for external connection.

The thin film 12 is, as in the prior cases, deposited over the phosphor bronze clips 62 and 64, in order to obtain adequate electrical contact.

The protective coating 20 is applied as a final step. Some coatings, such as polytetrafluoroethylene resin, will need a smoothing undercoat 70 as seen in FIG. 2b.

Choice of take-off and terminal method is dictated somewhat by the choice of protective coating: if, for example, porcelain is chosen as the protective coating, the relatively high bakeout temperature of 1,150°F might dictate a take-off such as those in FIGS. 2b or 2c, since these provide less chance of damage by thermal expansion. However, the take-off illustrated in FIG. 2d is quite adequate for the 700°F bake-off temperature needed for a polytetrafluoroethylene resin. The staple interconnector 28 and electrode terminal 34 enable bonds particularly resistant to damage by thermal expansions, due to the positive gripping by the arms 32 of the staple. The clips 62 and 64, however, are more suitable for lower temperature uses, such as with a polytetrafluoroethylene resin.

The preferred embodiment of the heating element in FIG. 3 is, for purposes of illustration, incorporated into a grilling device illustrated in FIGS. 11–13. The heating element 72, as described above in reference to FIG. 3, has a resistance of 4.36 ohms. As seen in FIG. 11, two of these heating elements 72 are connected in series, used in conjunction with a thermostatic control 74, a time control 76, and a source connection 78.

The cutaway view in FIG. 12 illustrates the internal configuration, somewhat blown-up for purposes of illustration, comprised of a heating element 72, two layers of 0.064-inch asbestos millboard 80 and 0.002-inch aluminum 82, and two layers of one-fourth-inch air cell asbestos 84 with aluminum reflecting foil on one side, all enclosed in an aluminum outer casing 86.

The thermostat 74 is positioned between the layers of millboard 80.

In the configuration shown, with the two 4.36 ohm heating elements 72 connected in series across a 120V driving potential, the heating elements will attain their 500°F operating temperature in less than 8 seconds.

The outer casing 86 will get no higher than 150°F. This is an extremely short time rise to operating temperature and provides extremely fast cooking; for example, bacon can be prepared on the embodiment in FIG. 11 in 25 seconds. The embodiment is extremely efficient due both to the short time rise to operating temperature and to the efficient insulating configuration.

Other embodiments of the invention could include, for example, a configuration such as in FIG. 11 with a reflecting element taking the place of one of the heating elements, and an 8.72 ohm heating element opposed.

While the embodiments discussed so far have been concerned with means for heating through surface contact, the heating element is by no means limited to this use. For example, the heating element could be used as a radiation heater featuring a fast rise time and narrow dimensions, ideal for use as a baseboard heater. Such a heater is illustrated in FIG. 14, where the heating element 88 is comprised of a thin film resistor 90, flame spray deposited as superposed layers onto the substratum 92, with terminals 94 bonded to the substratum 92 and the thin film resistor 90, and extending substantially the width of each end thereof.

I claim:

1. In an electric grill for cooking food including at least one heating element, thermal and time control means, and an outer casing having two hinge-connected shells enclosing the at least one heating element and control means, an improvement wherein the heating element includes a thermally and electrically insulating substratum, a thin film nickel and chromium alloy metal resistor, 0.002 to 0.005 inches thick, spray deposited onto the substratum in a plurality of superposed integral layers in direct contact, the film having a resistance ranging from 7 to 9 ohms and having a weight of approximately 10 grams to permit the resistor to reach an operating temperature from 500°F to 600°F in approximately 8 seconds, at least one thin reflecting sheet adjacent the other side of the substratum, at least one layer of air cell asbestos adjacent said sheet, the substratum, the sheet, and the air cell asbestos adapted to inhibit the temperature of the casing from exceeding a temperature of 150°F, an inert protective coating deposited upon the metal film to permit the film to come substantially into direct contact with the food, the film being positioned on the substratum as a plurality ity of parallel strips, a sprayed deposit of highly conductive metal deposited along the end of the strips of metal film so as to interconnect the strips electrically and a pair of terminals connected to the ends of the inter connected strips.

2. The grill according to claim 1 wherein a pair of the heating elements are provided, each being mounted to one of the shells.

3. The grill according to claim 1 wherein the substratum is a thin asbestos millboard.

4. The grill according to claim 1 wherein the substratum is a thin resin-bonded carbonborundum.