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Eilenberger

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[54] **ELECTRIC GRILL WITH A THIN-FILM HEATING ELEMENT**

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[21] Appl. No.: **72,600**

[52] **U.S. Cl.** ....**219/525**, 29/620, 174/68 C, 99/390, 99/447, 219/345, 219/464, 219/543, 338/308

[51] **Int. Cl.** **H05b 3/06**

[58] **Field of Search** ....219/543, 549, 345, 219/524–525, 212–213, 528–529, 464, 530, 527; 338/211–212–214, 308–309, 288–289; 99/390, 447; 339/17 T, 19, 218; 174/68 C; 117/105, 217, 227, 229; 29/620

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[57] **ABSTRACT**

A metallic thin film resistance heating element comprises an electrically and thermally insulating substratum, a thin film resistor deposited in a plurality of sprayed layers superposed upon the substratum 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 substratum, 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

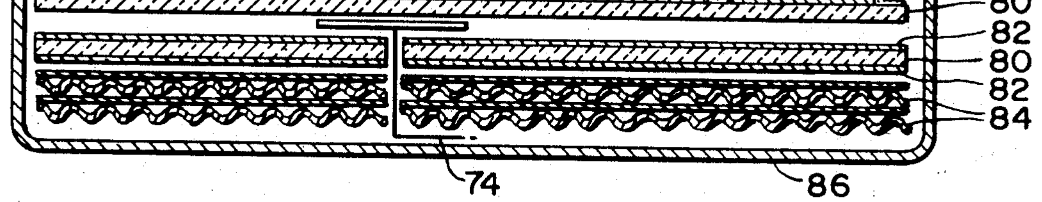
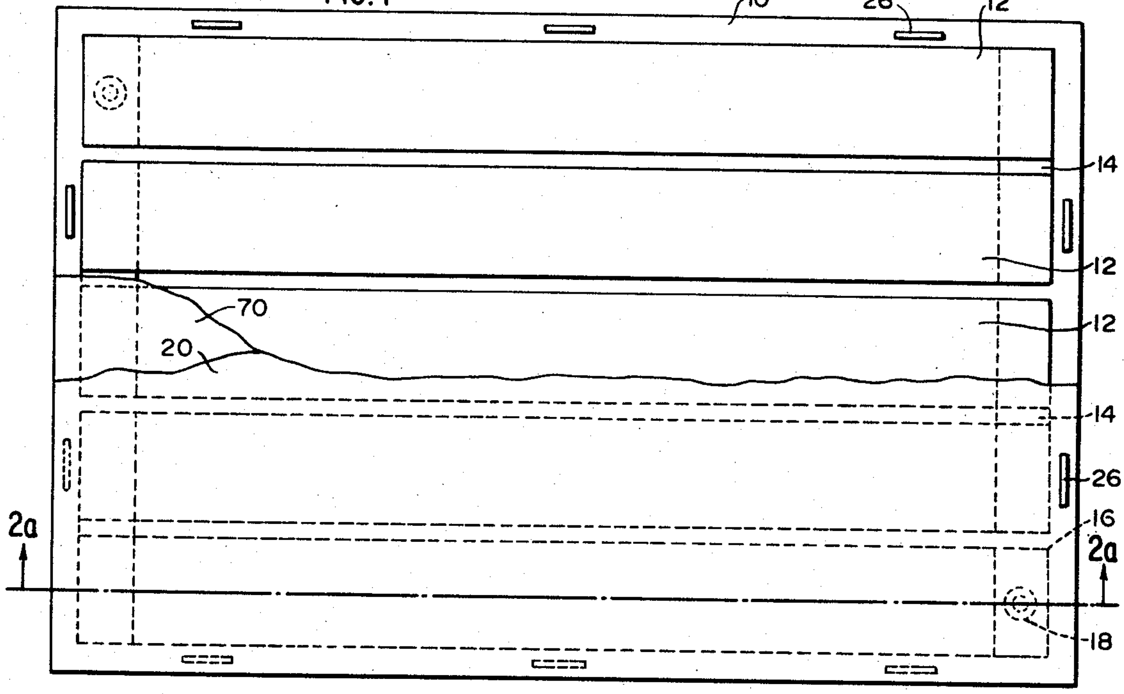


FIG. 1



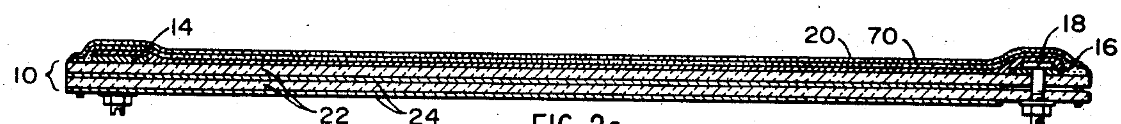


FIG. 2a

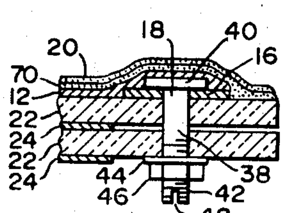


FIG. 2b

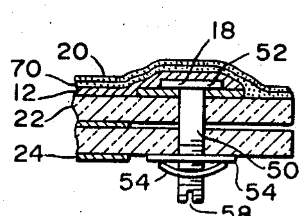


FIG. 2c

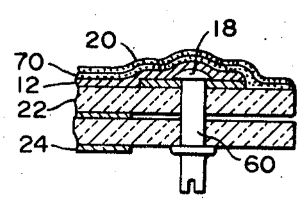
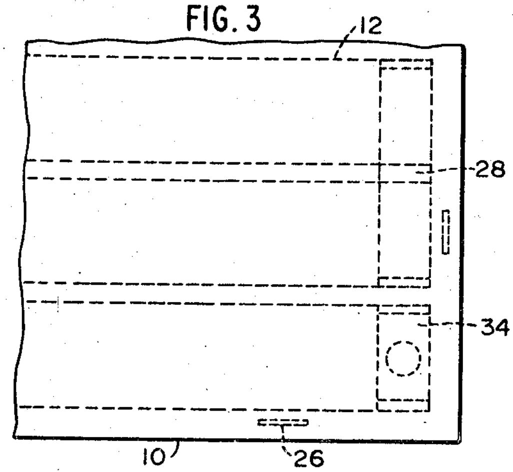


FIG. 2d

FIG. 3



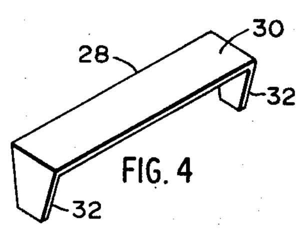


FIG. 4

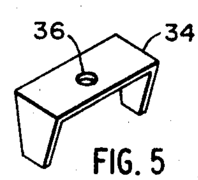


FIG. 5

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FIG. 6

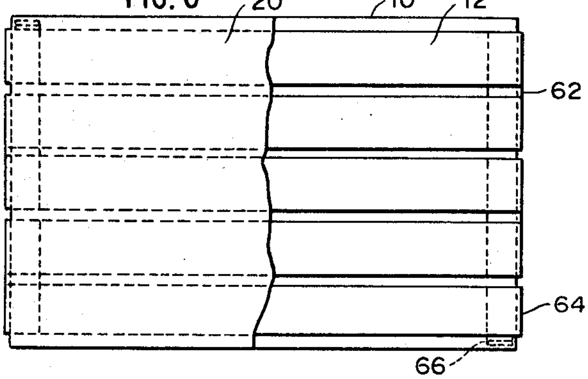
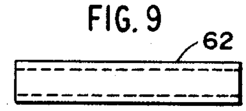


FIG. 8

FIG. 9



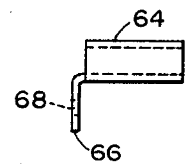


FIG. 10

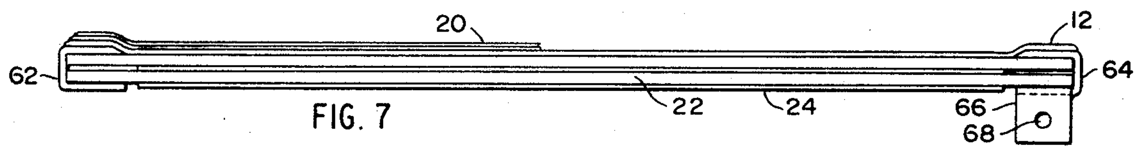


FIG. 7

FIG. 11

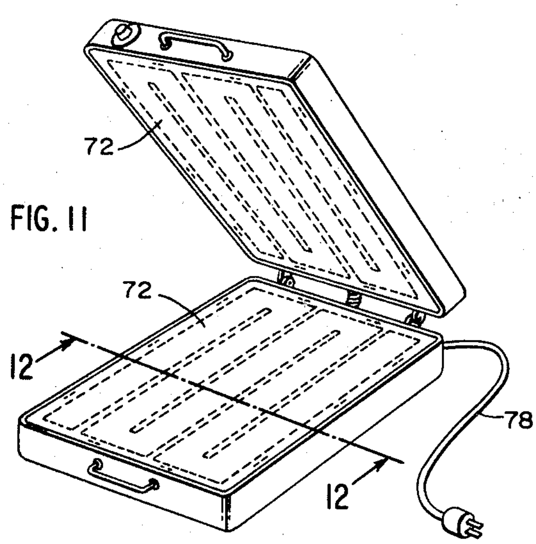


FIG. 13

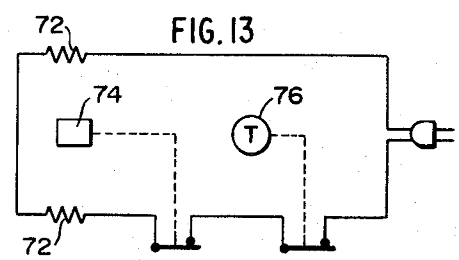
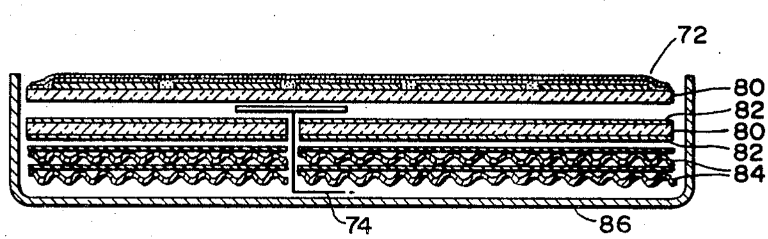


FIG. 12



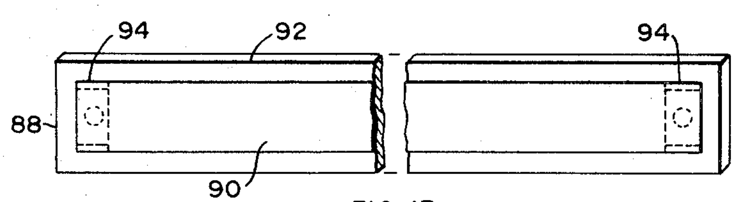


FIG. 13

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

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

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

FIG. 2*d* is a similar view of 2*a* and 2*b* 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, some 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 substratum; the thin film resistor has better thermal expansion characteristics; since the thin film resistor can be deposited onto the substratum 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 substratum 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 carborundum 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 substratum 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 substratum, 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, or alternate adjacent 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 substratum 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 substratum 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 substratum, 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 substratum 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 substratum, securing the body of the staple onto the substratum, 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 substratum with the thin film subsequently deposited, another embodiment comprised of a clip of a high conductivity material to be crimped over the substratum with the thin film subsequently deposited, and another embodiment in the form of a staple, with the arms of the staple driven into the substratum, securing the body of the clip to the surface of the substratum 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 5 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 upto at least 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 leadoffs **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 **32**. 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 phospher 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 phospher 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 phospher 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 polytetrafluorethylene 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 power 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 hotter than about 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 restricted 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 bonded between 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° 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 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 interconnected 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 carborundum.

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