United States Patent

[11] 3,597,591

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[54] **BONDED FLEXIBLE HEATER STRUCTURE WITH AN ELECTRIC SEMICONDUCTIVE LAYER SEALED THEREIN**
1 Claim, 8 Drawing Figs.

[52] **U.S. Cl.** **219/528,** 117/47, 156/310, 219/535, 219/541, 219/544
[51] **Int. Cl.** **H05b 3/36**
[50] **Field of Search** .... 219/528—9, 345, 543—549, 535, 211; 156/179, 310; 338/211—12, 308; 117/47

[56] **References Cited**

UNITED STATES PATENTS

2,783,358	2/1957	Wolf	219/529
2,789,063	4/1957	Purvis et al.	117/47
2,809,130	10/1957	Rappaport	156/310
2,952,761	9/1960	Smith-Johannsen	219/541
3,031,739	5/1962	Boggs	219/345 X
3,277,419	10/1966	Butz	338/212 X
3,344,385	9/1967	Bartos et al.	219/528 X
3,359,525	12/1967	Hubbuch	338/308
3,387,248	6/1968	Rees	219/549 X
3,422,244	1/1969	Lauck	219/212
3,423,574	1/1969	Shomphe et al.	219/528

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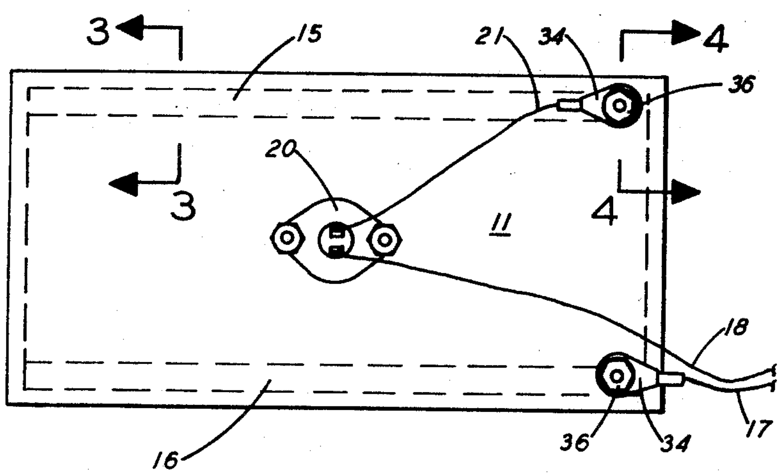
ABSTRACT: A bonded aluminum-semiconductive heater structure and process for preparing the same wherein a flexible, planar, semiconductive heating element, enclosed within chemically etched insulating layers of a perfluorocarbon copolymer, is bonded to the surface of an aluminum article through a similar copolymer film both surfaces of which have been rendered adherable by exposure to the action of an electrical discharge.



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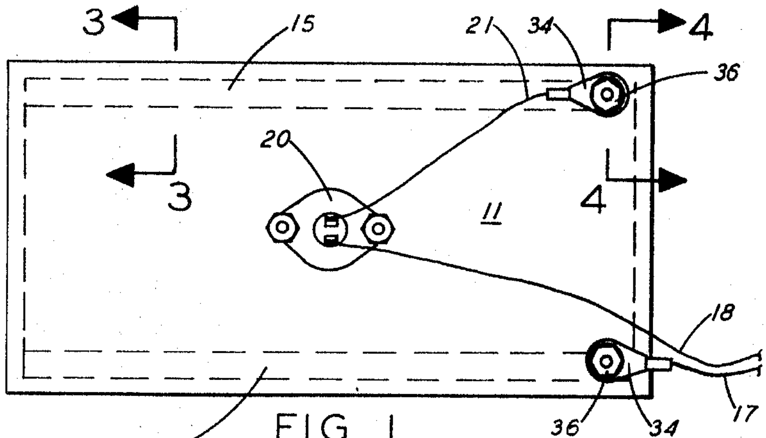

FIG. 1

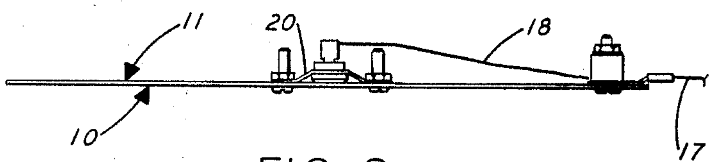

FIG. 2

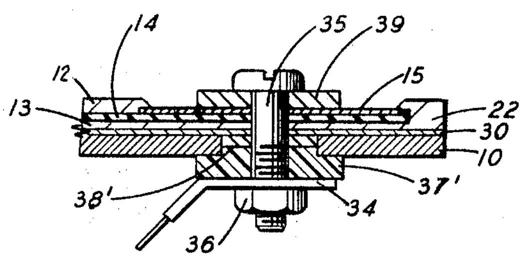

FIG. 5

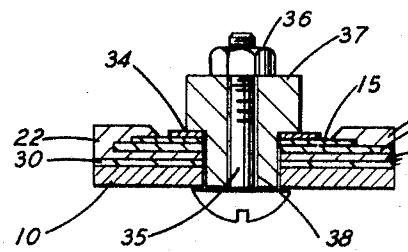

FIG. 4

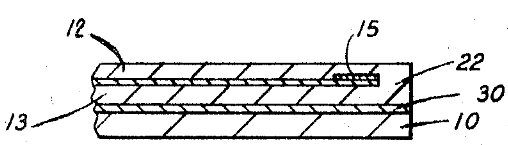

FIG. 3

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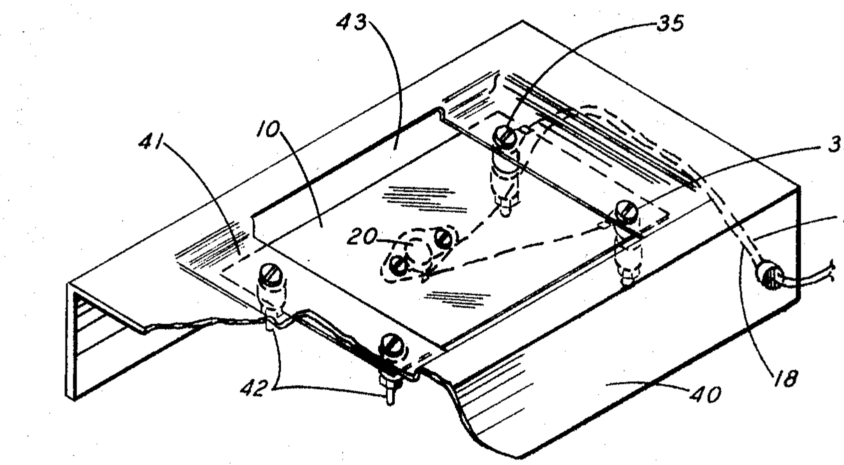

FIG. 6

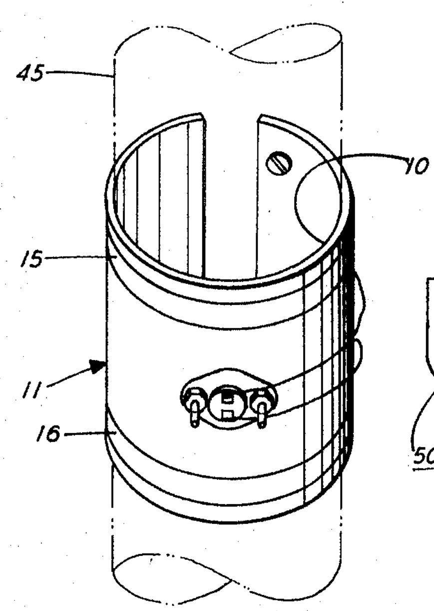

FIG. 7

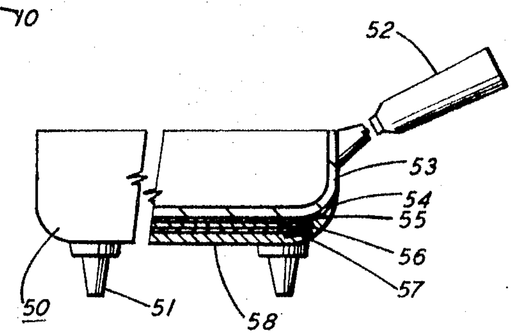

FIG. 8

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BONDED FLEXIBLE HEATER STRUCTURE WITH AN ELECTRIC SEMICONDUCTIVE LAYER SEALED THEREIN

SUMMARY OF THE INVENTION

The present invention relates to a new and useful heating device made up of an aluminum article which is bonded along a face thereof to a flexible, planar, semiconductive heating unit, said bond being effected through a layer or film of a copolymer of tetrafluoroethylene and hexafluoropropene both surfaces of which have been rendered adherable by exposure to the action of an electrical discharge. For the sake of simplicity and clarity of expression, such copolymers, apart from the nature of their surface treatment, are herein referred to as perfluorocarbon copolymers.

The heating unit which is bonded to the aluminum surface is one of the flexible, planar type having a semiconductive heating element forming a core layer which, together with the spaced bus elements provided on the surface thereof to receive electrical current, is sandwiched between electrically insulating perfluorocarbon copolymer sheets or films wherein the surfaces adjoining the core layer have been given a chemical etch by treatment with a sodium compound. The latter materials are firmly bonded (over the buses) to the semiconductive core layer by the application of heat and pressure.

The core layer of the heating unit is one having characteristics which enable it to conduct electrical current passed therethrough between the spaced bus elements with resultant production of heat. A preferred material of this type comprises a polyimide web reinforced by Fiberglas cloth and containing a substantial amount of finely divided carbon particles, as described in U.S. Pat. No. 3,359,525 to Hubbuch, though other useful semiconductive materials of a flexible character are also taught in the art as, for example, in U.S. Pat. No. 2,952,761 to Smith-Johannsen.

The insulating panels which enclose the inner, semiconductive core layer of the heating unit are sheets of a perfluorocarbon copolymer material (e.g., Teflon films) which have been chemically etched on the side placed adjacent said inner layer by a sodium treatment of the type described in U.S. Pat. Nos. 2,789,063 to Purvis et al., and 2,809,130 to Rappaport. This etching treatment serves to convert the material of the etched side to a form in which it can be fused to the adjacent semiconductive layer either with or without the use of adhesives. In the preferred practice of this invention, no adhesive is employed and the chemically etched copolymer layers can be bonded to the intervening semiconductive layer (as well as to one another where they extend beyond the margins of said layer) as the assembly is maintained for a short interval in a press at temperatures of from about 500° to 650° F. and at pressures of at least about 30 p.s.i. Particularly good results are obtained when this bonding is effected at pressures of from about 100 to 300 p.s.i. and at temperatures of from about 500° to 550° F. for periods ranging from several seconds to 5 or more minutes.

Reference is hereby made to the foregoing patents for a more complete disclosure of exemplary methods and materials to be employed in preparing flexible, planar heating units of the type employed in the present invention for bonding to a surface of the aluminum member of the heater structure.

The heating unit of the type described above, comprising the bus-bearing semiconductive layer bonded between facing, electrically insulating perfluorocarbon copolymer layers, is securely bonded to a face of the aluminum member which forms a part of the present structure by means of an intervening sheet or film of a perfluorocarbon copolymer both surfaces of which have been rendered adherent by the application thereto of an electrical discharge. In carrying out this operation the surfaces of the perfluorocarbon copolymer film are exposed to the action of a electrical discharge at substantially atmospheric pressure between spaced electrodes. This electrical discharge is one having an average energy level below 15 electron volts and the operation is carried out in an atmosphere containing less than about 5 percent by volume of the vapor of an organic compound having a vapor pressure of at least 0.25 mm. of mercury at 60° C. in a gaseous carrier medium which will sustain the electrical discharge. This process, and the perfluorocarbon copolymer materials produced thereby, are fully described in U.S. Pat. No. 3,296,011 to McBride et al., to which reference is made for a more complete disclosure of said methods and materials. For convenience of description, this bonding layer, both sides of which are adherent, will hereinafter be referred to as a "-doubly adherent" perfluorocarbon copolymer sheet or film.

The flexible, planar heating unit is secured to the aluminum surface by interposing a sheet of the aforesaid, doubly adherent perfluorocarbon copolymer between the aluminum and the nonetched perfluorocarbon copolymer surfaces to be bonded to one another, and by then pressing the assembly together at elevated temperatures and pressures for a relatively short period of time. Temperatures of from about 470° to 550° F. and pressure of the order of about 100 to 500 p.s.i. can be employed with good results in this bonding step, with the article being maintained in the press under these conditions for periods ranging from a few seconds to one of several minutes, if desired. Once the assembly is brought to the proper temperature and pressure, the bonding step proceeds very rapidly. In carrying out this bonding step, one can employ either a preformed heating unit of the type wherein the semiconductive core layer is already bonded between the insulating face panels, or the latter unit can be formed at the same time that said unit is bonded to the aluminum provided the conditions employed fall within the ranges described herein as suitable for bonding the heating unit to the aluminum surface. In carrying out this latter method, the laminate placed in the press is one made up successively of aluminum, the doubly adherent layer, an electrically insulating layer, the semiconductive layer and, finally, the other electrically insulating layer, the etched face of said insulating layers being placed next to the semiconductive layer. Following the practice of either bonding method, the bonded article may be allowed to cool in the press or it can be removed and allowed to cool under nominal pressures. Good results can also be obtained in some instances by removing the hot laminate from the press and quenching it in cold water.

Heat is generated in the structure of the present invention as electrical current is supplied to the bus elements carried on the semiconductive core member. These elements are spaced from and essentially parallel one another. They can be fabricated of any conductive material such as aluminum or copper in sheet, foil, paint, powder or other form, and they can be affixed to the core member either mechanically or by adhesives. These bus elements can be connected to electrical leads by any one of several methods. However, it forms a feature of the present invention in one embodiment thereof to employ for this purpose a pair of connecting posts each of which is made up of a metal bolt provided with an insulated bushing arranged to be secured within an aperture cut into each of the respective bus elements and extending through the entire aluminum-heating unit structure. In using this structure the outer electrically insulating layer of the heating unit is cut away from the bus in the vicinity of each aperture to permit the electrical connector to make contact with the bus either directly or through the metal bolt. The bushing which fits about the bolt has a shoulder portion which fits against one or another of the surfaces exteriorly of the aperture and a shank portion of smaller diameter which is adapted to fit within the opening for contact with the aluminum walls thereof so as to keep the bolt from contacting the aluminum member. This prevents current applied to the bus elements from shorting across the aluminum surface between the respective bus terminals. These insulated bolt members can be used not only to secure the electrical connectors to the unit but also to mount the assembly to an associated structure. Similarly insulated posts, not connected with electrical leads, can also be employed without in any way impairing the operation of the apparatus.

To the extent permitted by the shape and thickness of the aluminum member, the article of the present invention may be repeatedly flexed or bent from a flat to a cylindrical or other shape without impairing the bond between the aluminum surface and that of the heater unit. Moreover, the aluminum surface to which the heater unit is applied need not be a perfectly flat one. Thus, the heating unit may be bonded to arcuate and other rounded aluminum surfaces by the use of molds having faces of the appropriate shape and contour.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The objects and advantages of this invention will become apparent from the description that follows when read in conjunction with the accompanying drawings wherein:

FIG. 1 is a plan view of a heating apparatus embodying features of this invention;

FIG. 2 is a view in elevation of the apparatus of FIG. 1;

FIG. 3 is an enlarged sectional view taken along the line 3–3 of FIG. 1;

FIG. 4 is an enlarged sectional view taken along the line 4–4 of FIG. 1;

FIG. 5 is a sectional view generally similar to that of FIG. 4, but showing another embodiment of an insulated electrical connecting post;

FIG. 6 is a view in perspective of an electrical stove wherein the bonded aluminum-heating unit structure is mounted in a vessel-supporting position below an aperture in the top of the stove;

FIG. 7 is another view in perspective showing the heating apparatus of FIG. 1 bent into a cylindrical shape and adapted to supply heat to an enclosed vessel or the like; and

FIG. 8 is a view of an aluminum cooking utensil, shown partially in section, wherein the heating unit is bonded to the undersurface of the vessel.

Referring now more particularly to FIGS. 1 to 4 of the drawings, there is shown a flat, rectangular heating apparatus incorporating a base plate **10** to which is bonded the flexible, planar, heating unit shown generally at **11**. The latter comprises upper and lower, chemically etched Teflon layers **12** and **13**, each having a thickness of approximately 5 mils, bonded to a semiconductive core layer **14** made up of Fiberglas impregnated with a polyimide resin having a substantial content of finely divided carbon particles. Aluminum bus strips **15** and **16** are bonded in position on opposite sides of the said semiconductive member in spaced, parallel relationship, the member **16** being connected to an electrical lead **17** while the other lead **18** leads to a thermostat device **20** and from thence to the bus member **15** via line **21**. In the form of apparatus shown in FIGS. 1 to 4 and in FIG. 7 (the latter being the device of FIG. 1 as bent into a generally cylindrical shape) the insulating layers **12** and **13** are shown as being bonded to one another outwardly of the semiconductive layer **14** about the periphery of the article as indicated at **22**, thereby minimizing the possibility of the current short circuiting from the layer **14** to the aluminum support **10**. Shown at **30** is a doubly adhesive Teflon bonding layer which bonds the surface of the aluminum member **10** to the adjacent surface of the electrical insulating layer **13**, the bonding layer **30** illustrated having a thickness of approximately 2 mils. The material employed for this purpose is designated by the manufacturer, E.I. du Pont de Nemours & Company, as Teflon FEP film, Type C-20, surface modified, both sides. The electrical insulating layers **12** and **13** are products of the same manufacturer and are designated as Teflon FEP film, Type 500*e*. All the films in the apparatus are perfluorocarbon copolymers.

Referring particularly to FIG. 4, there is shown a post for connecting the source of current to the respective bus elements **15** and **16** of the apparatus. Said post comprises a bolt **35** fitted with nut **36** and an insulating bushing having a shoulder portion **37** and a somewhat smaller shank portion **38**, the latter portion being adapted to fit within an opening provided through the structure in the region of the bus elements thereon. In connecting the post to the electrical connector **34**, provision is made to expose a portion of the bus element adjacent the opening for contact with the connector. The latter can then be held tightly against the underlying bus element as the shank of the bushing fits into the opening over the bolt and the bushing shoulder is pressed tightly against the connector by tightening the nut **36**. This insulating bushing structure serves to hold the bolt **35** well away from contact with the sidewalls of the aperture and therefore prevents current supplied to the bus from passing to the aluminum member **10** rather than through the semiconductive layer **14**.

In the alternative embodiment of a connecting post structure illustrated in FIG. **5**, the direction in which the bolt is inserted into the opening is reversed and current is supplied from connecting member **34** through bolt **35** and washer **39** to the bus member **15**. In this structure the bolt **35** is maintained away from contact with the aluminum member by means of an insulating bushing having a shoulder **37'** which seats against the aluminum surface and a shank portion **38'** which fits within the aperture thereby maintaining the bolt in the center of the hole and away from the aluminum.

FIG. 6 illustrates one manner in which the structure of the present invention may be used, the composite of FIG. 1 here being secured to a stove having a frame **40** and a depressed central portion **41** in which is cut the relatively large aperture **43** adapted to receive a pan or other utensil which can then seat against the aluminum surface of the composite aluminum-heating unit structure. The latter is secured in a spaced position below the depressed stove surface by means of the connecting posts as shown in FIG. 4 and by means of members **42** which are similar to those indicated at **35** except that no electrical leads are employed. It will be noted that the aperture cut in the stove allows air to circulate upwardly between the aluminum heater surface and that of the stove, thereby maintaining the temperature of the latter at a relatively low level.

In the structure shown in FIG. 7, the generally flat, rectangular form of composite unit illustrated in FIG. 1 is shown as being wrapped into cylindrical shape to enclose a drum, pipe, or other member **45** to which heat is to be supplied. The heater can readily be sprung into or away from this position of contact.

FIG. 8 illustrates somewhat schematically the manner in which the composite structure is utilized in connection with an electric frypan indicated generally at **50**, as provided with legs **51** and a handle **52**. Here the outer and particularly the bottom portion of the pan, as indicated at **53**, represents the aluminum portion of the composite. The heating unit is bonded thereto through the doubly adherent Teflon layer **54**, with the inner insulating layer being indicated at **55**, the semiconductor layer at **56**, the bus strip at **57**, and the outer insulating layer at **58**. Conventional brazing or other means may be employed to connect electrical leads (not shown) to the buses, and the bottom of the structure may be protected against tearing or other damage by the use of a protective cover structures (not shown).

In the operation of the present device, general control of temperature can be provided by varying the amount of current passes to the heating unit. However, temperature can also be controlled by means of a thermostat as shown at **20**. The latter interrupts the current as temperatures rise to a given level and then reengages the circuit as the temperature falls in some predetermined measure, thereby reinstituting the heating process. The present structure is adapted to be operated either intermittently or continuously for long periods of time at temperatures as high as 450° F. It is also capable of being maintained at temperatures of about 500° F. for short periods of time, the limiting factor here being the temperature at which the Teflon layers employed begin to melt.

While this invention has been described in conjunction with preferred embodiments thereof, it is obvious that modifications and changes thereof can be made therein by those skilled in the art without departing from the spirit of the invention, the scope of which is measured by the claims.

I claim:

1. A bonded heater structure comprising a flexible, planar, semiconductive heater made up of a semiconductive core layer carrying spaced bus elements arranged for connection to a source of electrical current and bonded between electrically insulating layers of a polyfluorocarbon copolymer wherein the sides facing the core layer have been given a chemical etching treatment, a flexible, planar, aluminum member bonded through a layer of doubly adherent perfluorocarbon copolymer, as formed by treatment of the layer with an electric discharge, to one of the electrically insulating layers of said semiconductive heater, said semiconductive core layer comprising Fiberglas impregnated with a polyimide resin and carbon particles, electrical connector posts extending through apertures in the heater structure in the area of the bus elements and electrically connected thereto, and electrically nonconductive bushings insulating said connector posts from the aluminum member, said bus elements being freed of any covering insulating layer in the area adjacent said apertures.