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(54) **Title:** ELECTRICAL HEATER WITH PARTICULAR APPLICATION TO HUMIFICATION AND FLUID WARMING

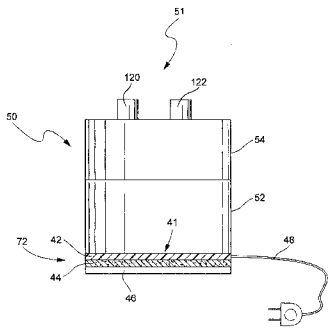

Fig. 5a

(57) **Abstract:** A heater element (41) includes a first polymer film (42) having an electrically conductive circuit. The circuit may include conductive ink (44), a second polymer film (43), and/or resistive or conductive overmolded material (57). The first polymer film (42) is molded into at least one surface of a molded object (46, 50, 51, 150, 250, 350). The molded object may be a humidifier (51) or a component (50, 150, 250, 350) of a humidifier. A method of manufacturing an in-mold heater element (41) includes providing an electrically conductive circuit on a surface of a first polymer film (42); placing the first polymer film including the electrically conductive circuit in a mold such that the non-printed surface of the polymer film is adjacent the mold; and insert molding resin (46) to form a predetermined molded shape such that the first polymer film (42) is incorporated within at least one surface of the molded shape. A method of humidifying a flow of pressurized breathable gas includes passing the flow of pressurized breathable gas over a supply of water (W) contained in a tub (50, 150, 250, 350). The tub is formed of molded resin and a heater comprising a polymer film (42) having a layer of electrically conductive ink (44), a stamped resistive or conductive film (43), and/or resistive or conductive overmolded material (57) on a first surface is molded at least partially within the resin.

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ELECTRICAL HEATER WITH PARTICULAR APPLICATION TO HUMIFICATION AND FLUID WARMING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Australian Provisional Applications 2007902992, filed June 5, 2007, and 2007903599, filed July 4, 2007 and U.S. Provisional Application 60/986,404, filed November 8, 2007, the entire contents of these applications being incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to electrical heaters and particularly to integrated electric heaters for use in heating fluids. More particularly, the present invention relates to in-molded heaters for heating fluids within containers. The electrical heater may be used in a range of devices including, for example, humidification devices, electric jugs, other fluid warming containers, fans and the like. The heater may be used in a respiratory humidification device.

BACKGROUND OF THE INVENTION

[0003] Respiratory apparatus commonly have devices to alter the humidity of the breathable gas in order to reduce drying of the patient's airway and consequent patient discomfort and associated complications. The use of a humidifier placed between the positive airway pressure (PAP) device and the patient mask produces humidified gas that minimizes drying of the nasal mucosa and increases patient airway comfort.

[0004] Many humidifier types have been proposed, including humidifiers that are either integrated with, or configured to be coupled to, the respiratory apparatus. Independent humidifiers have also been proposed. While passive humidifiers can provide some relief, generally a heated humidifier is required to provide sufficient humidity and temperature to the air so that the patient will be comfortable.

[0005] Humidifiers typically comprise a water tub having a capacity of several hundred millilitres, a heating element for heating the water in the tub, a control to enable the level of humidification to be varied, a gas inlet to receive gas from the PAP device, and a gas outlet adapted to be connected to a gas conduit that delivers the humidified, pressurized flow of breathable gas to the patient's mask.

[0006] Commonly, humidifier tubs are attached either directly to a humidifier control base or to a system base, or cradle, that facilitates the correct assembly of the PAP device with the humidifier. Generally, the humidifier control base or the system base, or cradle, comprises a

heating plate that contacts the base of the humidifier tub to facilitate heating of the water within the humidifier tub.

[0007] Fig. 1 depicts a prior art humidifier device 10 with a control base 16, which comprises a heater plate 18. A water tub 12 comprising an air inlet 20, an air outlet 22 and a heat conductive tub base 14, is adapted to sit upon the heater plate 18 of the control base 16. The base systems typically comprise a spring loaded heater plate 18 on to which the water tub 12 is attached. The spring loaded heater plate 18 ensures good thermal contact with the tub base 14 of the water tub 12, although some thermal losses occur between the heater plate 18 and the water tub 12. For example, the Fisher & Paykel HC200™ system and the Respironics RemStar™ heated humidifier have spring loaded heater plates. However, such spring loaded heater plates can provide a friction force against insertion of the water tub, which may make installation of the water tub difficult for some users, especially older or frail users.

[0008] The water in the water tub 12 is heated via thermal conduction between the heater plate 18 and the tub base 14 of the water tub 12. The tub base 14 is commonly formed of aluminium or stainless steel. The tub base 14 is generally formed as a separate component of the water tub 12 and sealingly coupled to the upper portion of the water tub, for example using adhesives or a stamped rolled edge. For example, see Applicant's WO 2007/019626 A1, the entire contents of which are incorporated by reference. This results in multiple components that require assembly during manufacture of the humidifier and increase the size and weight of the device. Furthermore, the assembled construction provides an increased risk of leakage between the sealed components.

[0009] Other forms of heaters are known but have rarely, or not at all, been used in commercially available respiratory humidifiers to date. One example is induction heaters as described in Applicant's WO 2007/101298 A1, the entire contents of which are incorporated by reference. Flexible layered heaters are also known and have been used in a range of applications including defogging mirrors, screens for televisions, video cameras & mobile phones and blanket heaters. For example, printed thick film heating elements that comprise conductive and resistive inks, such as carbon ink or silver ink, have been used. Fig. 2 shows the general construction of a printed thick film heating element 28 comprising a first film substrate layer 30 with a conductive and resistive inks layer 34 printed thereon and then a second film 32. The two films 30, 32 are laminated together with a pressure sensitive adhesive sandwiching the ink layer 34. The films are typically thermoplastic or thermoset polymers such as polyester or polyimide. Such flexible layered heaters may be attached to the required surfaces to provide the required heating function.

[0010] Many products are provided with labels attached to their surfaces. Labels are commonly used to provide decorative designs, branding, texture, instructions, warnings and other

such graphical material to products. There are many different forms of product labels and techniques for attaching such labels to objects. In-mold labeling is a method used to attach the labels to the surface of a molded object wherein the label is attached within the wall of a molded object. In-mold labeling is used with blow molded and injection molded products such as toys, containers for cleaning products, motor oil, beverages and the like. The label is printed onto a film using known printing techniques such as flexography, offset, screen or hot stamping printing. U.S. Patent 6,551,671 (Nishizawa et al.) describes a process for in-mold labeling.

[0011] Fig. 3 illustrates the general construction of an in-mold label 35 where a graphic 38 is printed upon a film 36. The formed printed film 36, 38 is placed and held within an open mold with the film 36 surface adjacent to the mold. The mold is closed and the hot mold resin 40, such as a plastic polymer, is extruded or injected into the mold to form the desired object shape with an integrally molded label. The film 36 is generally comprised of a polypropylene or polyethylene copolymer that comprises a heat-activated adhesive that facilitates attachment of the printed film within the wall of the molded object.

[0012] Conventional humidifiers have the disadvantage of many different components that require assembly and increase weight. The assembly of different components and the use of heater plates and tubs with conductive base plates provides an increased risk of water leakage. The present invention seeks to address one or more of these disadvantages or at least provide a reasonable alternative.

SUMMARY OF THE INVENTION

[0013] An aspect of the invention is directed to a heater element that provides safe and effective heat. Another aspect of the invention provides a heater element that is molded within a container during manufacture. A further aspect relates to an in-mold heater element comprising a polymer film having electrically conductive ink printed upon at least one surface. In another aspect the electrically conductive ink is carbon and/or silver ink. In a further aspect the polymer film is a polyester, polyimide, polycarbonate or polypropylene.

[0014] Another aspect is related to a heater element comprising a polymer film having an electrically conductive ink printed upon at least one surface wherein the polymer film is molded into at last one surface of the molded object. In an additional aspect, the heater element comprises electrical connectors fastened to the electrically conductive ink to provide power and/or control signals. In a further aspect, the heater element comprises sensors such as a temperature sensor for controlling the temperature of the heater element. Yet another aspect includes a thermal fuse to provide a protection system to protect against over heating of the heater element.

[0015] Another aspect of the invention relates to a method for manufacturing an object comprising an in-molded heater element. In a further aspect the object is formed by injection molding. In an alternative aspect the object is formed by extrusion molding.

[0016] Another aspect of the invention relates to a method for manufacturing a humidifier comprising an in-mold heater element. In a further aspect the humidifier has a reduced number of parts and/or simple assembly process.

[0017] Yet another aspect of the invention relates to a respiratory humidifier comprising a heater formed from an in-mold heater element.

[0018] Still another aspect of the invention relates to an electrical heater having simple electrical connections.

[0019] According to one sample embodiment of the invention, a heater element comprises a first polymer film having an electrically conductive circuit provided upon a surface. The first polymer film is electrically insulating and is molded into at least one surface of a molded object.

[0020] According to another sample embodiment of the invention, a method of manufacturing an in-mold heater element comprises i) providing an electrically conductive circuit on a first surface of a first polymer film; ii) placing the first polymer film including the electrically conductive circuit in a mold such that a second surface of the first polymer film opposite the first surface is adjacent the mold; and iii) insert molding resin to form a predetermined molded shape such that the first polymer film is incorporated within at least one surface of the molded shape.

[0021] According to a further sample embodiment of the invention, a humidifier comprises a tub configured to contain a supply of water; and a heater comprising a first polymer film having an electrically conductive circuit provided upon a surface. The first polymer film is electrically insulating and the tub is formed of molded resin and the heater is molded at least partially within the resin.

[0022] According to a still further sample embodiment of the invention, a method of humidifying a flow of pressurized breathable gas comprises passing the flow of pressurized breathable gas over a supply of water contained in a tub, wherein the tub is formed of molded resin and a heater comprising a first polymer film having an electrically conductive circuit on a first surface is molded at least partially within the resin.

[0023] According to yet another sample embodiment of the invention, a molded object comprises a heater element, the heater element comprising a first polymer film having an electrically conductive circuit upon a surface. The first polymer film is molded into at least one surface of the molded object. A control system configured to control a temperature of the heater element.

[0024] Other aspects, features, and advantages of this invention will become apparent from the following detailed description when taken in conjunction with the accompanying drawings, which are a part of this disclosure and which illustrate, by way of example, principles of this invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Sample embodiments of the present invention will be described in relation to the attached drawings, in which:

[0026] Fig. 1 schematically illustrates a prior art humidifier device;

[0027] Fig. 2 schematically illustrates a thick film carbon heater according to the prior art;

[0028] Fig. 3 schematically illustrates an in-mold label according to the prior art;

[0029] Fig. 4a schematically illustrates an in-mold thick film carbon heater according to a sample embodiment of the invention;

[0030] Fig. 4b schematically illustrates an in-mold thick film carbon heater according to a sample embodiment of the invention;

[0031] Fig. 4c schematically illustrates an in-mold thick film carbon heater according to a sample embodiment of the invention;

[0032] Fig. 4d schematically illustrates a sample embodiment of a conductive ink pattern having parallel bands;

[0033] Fig. 4e schematically illustrates a sample embodiment of a conductive ink pattern having a single continuous circuit.

[0034] Fig. 4f schematically illustrates a heater element according to a sample embodiment of the invention;

[0035] Fig. 4g schematically illustrates a heater element according to another sample embodiment of the invention;

[0036] Fig. 4h schematically illustrates a heater element according to another sample embodiment of the invention;

[0037] Fig. 4i schematically illustrates a heater element according to another sample embodiment of the invention;

[0038] Fig. 4j schematically illustrates a heater element according to another sample embodiment of the invention;

[0039] Fig. 4k schematically illustrates a heater element according to another sample embodiment of the invention;

[0040] Fig. 5a schematically illustrates a humidifier according to a sample embodiment of the invention;

[0041] Fig. 5b schematically illustrates a humidifier according to a sample embodiment of the invention;

[0042] Fig. 5c schematically illustrates a humidifier according to a sample embodiment of the invention;

[0043] Fig. 5d schematically illustrates a humidifier according to a sample embodiment of the invention;

[0044] Figs. 6a - 6e schematically illustrate sample electrical connection embodiments of the invention;

[0045] Fig. 7a schematically illustrates an arrangement for providing access for an electrical connection to the heater element molded into a humidifier according to a sample embodiment of the invention;

[0046] Fig. 7b schematically illustrates an arrangement for providing access for electrical connection to the heater element molded into a humidifier according to a sample embodiment of the invention;

[0047] Fig. 8 schematically illustrates a heater element connector construction according to a sample embodiment of the invention;

[0048] Fig. 9a schematically illustrates a sample embodiment of a mating arrangement for the molded heater element connector with a electrical supply unit;

[0049] Fig. 9b schematically illustrates a cross-section through A-A of the mating arrangement of Fig. 9a;

[0050] Fig. 10 schematically illustrates an electrical connector design according to another sample embodiment of the invention;

[0051] Fig. 11 schematically illustrates a heater element and control circuit according to another sample embodiment of the invention;

[0052] Fig. 12 schematically illustrates a heater element and control circuit according to another sample embodiment of the invention;

[0053] Fig. 13 schematically illustrates a heater element and control circuit according to another sample embodiment of the invention;

[0054] Figs. 14 and 15 schematically illustrate a heater element and control circuit for use in a humidifier tub according to another sample embodiment of the invention;

[0055] Figs. 16 and 17 schematically illustrate a heater element and control circuit for use in humidifier tub according to another sample embodiment of the invention;

[0056] Fig. 18 schematically illustrates a heater element and control circuit for use in a humidifier tub according to another sample embodiment of the invention;

[0057] Fig. 19 schematically illustrates a heater element and control circuit for use in a humidifier tub according to another sample embodiment of the invention;

[0058] Fig. 20 schematically illustrates a heater element and control circuit for use in a humidifier tub according to another sample embodiment of the invention; and

[0059] Fig. 21 schematically illustrates a heater element and control circuit for use in a humidifier tub according to another sample embodiment of the invention.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

Heater Element First Embodiment

[0060] Fig. 4a illustrates the general construction of an in-mold heater element 41 formed according a method of the invention. A conductive ink 44, such as carbon ink or silver ink, is printed upon the surface of a film 42. The combined printed film and heater element 72 is then placed within an open mold with the film 42 adjacent the mold. The mold is closed and mold resin 46 is injected or extruded into the closed mold to form the desired object. The resulting molded object has a printed film heater element 72 molded within the wall of the object.

[0061] In one embodiment the film 42 is a thermoplastic or thermoset polymer material such as polyester, polyimide, polycarbonate, polypropylene or other polymers that provide good thermal conductivity together with electrical insulation properties and mechanical protection of the printed ink. The film is thick enough to provide a stable film for the printed ink while still providing sufficient heat transfer. The film may have a thickness between 0.01 mm to 1 mm, for example between 0.05 mm to 0.5 mm.

Heater Element Second Embodiment

[0062] In a further sample embodiment shown in Fig. 4b, a second film 43 may be used to sandwich the conductive ink 44 to provide a protective layer between the conductive ink 44 and the molding resin 46. The second film 43 may also be formed from a thermoplastic or thermoset polymer material. The second film 43 may be electrically insulating, similarly to the film 42. Alternatively, the second film 43 may be resistive or conductive as described in more detail below.

Heater Element Third Embodiment

[0063] In another sample embodiment shown in Fig. 4c, a second layer 45 of protective ink is printed over the conductive ink 44 to provide a protective layer.

[0064] The electrically conductive ink may be carbon ink or silver ink or any other suitably electrically conductive ink. The conductive ink is generally printed in a thickness of about 5 μm to 40 μm, for example about 10 μm to 25 μm. However, larger or smaller conductive ink thicknesses are considered within the scope of the invention. In a sample embodiment, the

electrically conductive ink is printed on to the film using a screen printing process. However, it should be appreciated that other printing processes may be used, for example etching.

[0065] The pattern of the conductive ink affects the distribution of the heat and the resistance in the circuits. The pattern of the electrically conductive ink applied to the film may be adjusted to provide different power densities. The thickness, width, length, and material properties (resistivity/conductivity) of the electrically conductive ink pattern determines the resistance in the circuit. A thicker or wider ink pattern has lower resistance than thinner or narrow ink patterns, whereas the resistance increases with increasing lengths of the conductive ink pattern.

Heater Element Fourth Embodiment

[0066] In a sample embodiment, the ink pattern is designed to provide a given resistance to allow a particular voltage to be applied to the circuit. For example, the electrically conductive ink may be applied in a series of parallel bands linked with a perpendicular band, for example at bands periphery, or the ink may be applied as a single continuous circuit.

[0067] Fig. 4d illustrates an ink pattern having a series of linked parallel bands. The arrows represent the electrical connections that are made to the ends of the circuit. It is to be understood that this is only a sample and other ink patterns are considered within the scope of the invention.

[0068] The conductive ink circuits may include a combination of conductive inks such as carbon and silver ink to provide different resistance properties within the heating element. Carbon ink has a much higher resistance compared to silver ink. For example, carbon ink 47 may be used to form the series of parallel bands, as shown in Fig. 4d, and silver ink 49 may be used to link the carbon ink bands 47 at their periphery.

Heater Element Fifth Embodiment

[0069] Fig. 4e illustrates an ink pattern having a single continuous circuit. As in Fig. 4d, the arrows represent the electrical connections that are made to the ends of the circuit. It is also to be understood that this is only a sample of a continuous circuit and other ink continuous patterns are considered within the scope of the invention.

Heater Element Sixth Embodiment

[0070] In a further sample embodiment, the conductive ink circuit may also include other conductive element components such as metal bands to link a series of conductive ink bands, or for the electrical connections. Fig. 4f shows a heater element 72 comprising a first layer of film 42a having a conductive ink 44 printed thereon and a metal layer 70 laid over the ink 44 on the first layer of film 42a. A second film 42b is laminated to retain the metal layer 70. Any conductive metals or alloys may be used, for example copper, gold and nickel chrome, or any other electrically conductive metal.

Heater Element Seventh Embodiment

[0071] Although various sample heater element embodiments have been described with respect to the use of conductive inks, it should be appreciated that the heater element circuit may be formed of, for example, conductive or resistive polymer film or an overmolded layer instead of, or in addition to, the conductive ink. For example, as shown in Fig. 4g, the heater element 41 may include a circuit formed of a conductive or resistive polymer film 43 that may be stamped to provide the circuit pattern. The conductive or resistive polymer film 43 circuit may be provided on a polymer film 42 to form a stamped film heater element 73.

Heater Element Eighth Embodiment

[0072] As shown in Fig. 4h, the heater element circuit may be formed by overmolding 57 the pattern of the circuit onto the film 42 to form an overmolded film heater element 75. The overmold layer 57 may be formed of a resistive or conductive material.

Heater Element Ninth Embodiment

[0073] Referring to Fig. 4i, heater element 41 and control circuit therefor may be formed by any combination of conductive ink 44, conductive or resistive polymer film 43, and/or overmolding 57. It should be further appreciated that the heater element 41 and control circuit may be used, for example, with the metal layer described above with respect to Fig. 4f. The heater element circuit and/or the control circuit may be formed of multiple layers of conductive ink, conductive or resistive polymer film(s), and/or overmolding to control the thermal properties.

Heater Element Tenth Embodiment

[0074] Referring to Fig. 4j, the heater element circuit may be formed of conductive ink(s) 44, and a film or foil 43 may locate, connect, and/or thermally protect a thermal sensor 90, 94, e.g. a thermistor. The thermal sensor may then be overmolded 57 to control the thermal properties of the sensor, and/or to insulate the sensor from the water of a humidifier tub.

Heater Element Eleventh Embodiment

[0075] As shown in Fig. 4k, the heater element may be either a printed film heater element 72, a stamped film heater element 73, and/or an overmolded heater element 75 and may be formed in a shape, for example a spiral, that is configured to cause differential heating to thereby cause water currents to form. For example, the heater element may be configured to create a swirling flow. As another example, the heater element may be formed with portions causing differential heating in areas of a humidifier where water flow may tend to be reduced, or stagnant, compared to other portions of the humidifier.

[0076] In the embodiments discussed above, any suitable molding resin may be used, including such resins as polycarbonate, polycarbonate ABS blends such as Astaloy™, polyethylene and

polypropylene. The molded object 46 may be formed using extrusion molding or injection molding techniques or any other appropriate molding techniques. The molded object 46 comprising the in-mold heater 41 of the invention, including the printed film heater element 72, the stamped film heater element 73, and/or the overmolded heater element 75, may be made into any desired shape and may be used for a range of heating applications, for example, water baths, heaters, heating racks, syringe heaters, humidifiers, heated containers such as battery heaters and other suitably moldable objects and products.

Humidifier and Humidifier Tub First Embodiment

[0077] In one sample embodiment, the in-molded heater element 41 is formed within a humidifier device, for example in a respiratory humidifier device 51. Fig. 5a shows an embodiment of the in-mold heater element 41 of the invention used in a respiratory humidifier device 51. The conductive ink 44 is printed onto a film 42 and the subsequently formed printed ink film heater element 72 is molded into the base and/or sides of a humidifier tub 50 during the molding of the humidifier tub 50. In this embodiment the humidifier tub 50 comprises an upper portion 54 and a lower portion 52. The lower portion 52 comprises the in-mold heater element 41 at the base of the humidifier tub 50. However, it should be appreciated that the in-mold heater element 41 may be formed in any portion of the humidifier tub 50, for example in the sides, base, top or combinations thereof.

Humidifier and Humidifier Tub Second Embodiment

[0078] In another sample embodiment shown in Fig. 5b, an in-mold printed heater element 41 may be used to heat the air passing through the humidifier to enhance the moisture uptake by the air, or to adjust the temperature of the delivered air.

[0079] The upper portion 54 of the humidifier tub 50 comprises an air inlet 120 and an air outlet 122. However, the air inlet 120 or air outlet 122 or both may be located in the lower portion 52. The upper portion 54 may be formed as a removable lid to allow ease of cleaning and/or filling of the tub with water. Alternatively the upper portion 54 may be permanently fastened to the lower portion 52, for example by welding or gluing or any other techniques known to sealingly fasten components. A seal may be used between the upper portion 54 and the lower portion 52 to reduce the risk of water leakage. The joint between the upper portion 54 and the lower portion 52 may be located above the maximum water fill line of the humidifier tub 50 to reduce the likelihood of water leakages from the humidifier tub 50.

[0080] Electrical connections 48 provide power to the in-mold heater element 41 may be formed as part of the molding process within the humidifier tub, as described in more detail below. In a sample embodiment, the electrical connections 48 are attached to a power source and/or control source and are located above the maximum water fill line of the humidifier tub.

[0081] The molded respiratory humidifier may be configured as a stand-alone humidifier device or designed as an integrated device for attachment to a related product such as a PAP device, for example in a similar manner to the ResMed S8™ PAP device and the HumidAire™ 3i humidifier device. It should be appreciated that the in-mold heater elements may be molded into any appropriately molded object that requires a heater element.

Humidifier Tub Third Embodiment

[0082] A sample humidifier tub embodiment is shown in Fig. 5c, in which the in-mold heater element 41 is not located within the inner surface of the humidifier tub 150 but on an exterior surface of the tub 150. In this embodiment, the in-mold heater element 41 may be molded into the exterior surface of the base of the tub 150 as described above or the heater element 41 may be a printed ink film heater element 72 in the form of a thick film heater that is attached to the base of the tub 150, for example using adhesives. To prevent access to the heater element 41, the tub 150 also comprises a base cover 176 that is attached to the base of the tub 150. In one embodiment the base cover 176 is sealed at contact points 178 to the allow ease of cleaning of the tub, for example in a dishwasher, without disturbing the heater element 41. A cavity 174 is formed between the heater element 41 and the base cover 176 to provide insulation. Insulating material may be inserted into the cavity 174 to prevent the heat transferring to the base cover 176. This embodiment allows easy access to electrical connections as they are provided on the exterior surface of the tub.

Humidifier Tub Fourth Embodiment

[0083] Another sample embodiment for a humidifier tub is shown in Fig. 5d. In this embodiment, the humidifier tub 250 is molded with an open base. A heater element 41 is located in the base of the humidifier tub 250 and a base cover 276 is attached to the base of the humidifier tub 250. The base cover 276 may be attached to the base of the humidifier tub 250 using a clamp 290 around the bottom perimeter. A seal 278 may be located between the humidifier tub 250 and the base cover 276 to prevent water leakage. The clamp 290 may permanently attach the base cover 276 to the humidifier tub 250, for example using an adhesive or rolled edge clamp. Alternatively, the clamp 290 may allow removal of the base cover 276 for cleaning or disinfecting purposes. In this embodiment, the clamp 290 may be in the form of a screw-on or press-fit arrangement or one or more clips. Furthermore, the clamp 290 may be formed as an integral part of the base cover 276, for example in the form of a screw-on base cover (not shown). The heater element 41 may be molded into the base cover 276 as described above or positioned in the base of the humidifier as a laminated heater element 272. The laminated heater element 272 may be attached to the base cover 276, for example using adhesives, or positioned above the base cover 276 to provide a cavity 274 under the laminated

heater element 272. The laminated heater element 272 may provide the internal base of the humidifier tub 250 such that water in the tub cannot flow under the laminated heater element 272. In this embodiment, the cavity 274 under the heater element may provide an insulating layer to protect the base cover 276 from excess heat. Alternatively, the laminated heater element 272 may be positioned within the humidifier tub 250 to allow water to flow on both sides of the heater element 272 allowing heating of water on both sides of the heater element 272.

Electrical Connections

[0084] The in-mold heater element 41 requires electrical connections for operation of the heater element. Access to at least a portion of the in-molded heater element 41 or a connector attached to the heater element 41 is required at a suitable external position of the molded object (e.g. humidifier tub), to enable connection to a power supply unit. The electrical connector construction must establish an electrical connection between the heater element circuit, e.g. conductive ink, conductive or resistive polymer film, and/or overmolding, and an electrical contact.

[0085] In a sample embodiment, the electrical connections are molded into the object together with the heater element during the molding process. The electrical connections may be via a direct contact to the heater circuit or via connection to additional components, such as electrical wire or a metal contact. Figs. 6a - 6e show sample embodiments for the electrical connection. In all embodiments, the film 42 comprising the heater element circuit, e.g. printed conductive ink layer 44 of printed ink film heater element 72, is shown molded into the mold resin 46.

Electrical Connection First Embodiment

[0086] Figs. 6a, 6b and 6c show examples of direct access 60 to the in-mold heater element 41, e.g. to the conductive ink 44, for direct contact to an electrical tab or connector, for example on a base unit or stand unit. The in-mold heater element 41 would be placed upon a complementary shaped tab or connector that may be connected to a power supply unit or electrical plug. In Figs. 6a and 6b, the molded resin 46 is shaped to form the recess 60. In contrast, in Fig. 6c, the film 42 and the conductive ink 44 are exposed in a section of the mold such that no mold resin 46 is formed on a portion of the printed films.

Electrical Connection Second Embodiment

[0087] Figs. 6d and 6e show the use of additional components for the electrical connection. Fig. 6d shows an electrical wire 62 fastened to the conductive ink 44 on the film 42. The electrical wire 62 may be fastened to the conductive ink 44 on the film 42 using techniques for fastening electrical connections, such as crimping or terminal blocks. Alternatively the fastened electrical wire 62 may include a rigid mechanical contact connector, for example a plug and socket type connector, such as a spade or bullet connector, for the connection to the conductive

ink 44 on the film 42. The electrical wire 62 is fastened to the conductive ink 44 on the film 42 prior to the molding step with the mold resin. Thus, the electrical connection and electrical wire 62 is molded into the molded object together with the conductive ink 44 on the film 42. In another sample embodiment, illustrated in Fig. 6e, a conductive material 64, such as a metal contact, is fastened to the conductive ink 44 on the film 42 and the conductive material 64 is exposed on the outer surface of the molded object 46 to provide a direct electrical contact for a complementary electrical contact on a base or stand unit as described above for embodiments shown in Figs. 6a-6c.

Humidifier Tub Fifth Embodiment

[0088] Fig. 7a shows a humidifier tub 350 having a heater element 41 molded into the molded humidifier tub 350. The heater element 41 may be a printed ink film heater element 72 and be formed in the base 351 of the humidifier tub 350 and extend up at least one of the sidewalls 352. The sidewall 352 is molded with the heater element 72 to provide an external access for the electrical power and control connections above and/or away from the water W in the humidifier tub 350. Fig. 7b shows an alternative arrangement for providing access for the electrical connections where the heater element 72 is molded through the humidifier tub sidewall 352. The heater element 72 is shown on the upper surface of the sidewall 352, however it may also be provided on the lower surface.

Electrical Connection Third Embodiment

[0089] The electrical connector for the molded object, e.g. humidifier tub, may be formed using features of the in-molded heater element 41, e.g. a printed ink film heater element 72. Fig. 8 shows an embodiment of a connector region. The connector region comprises a film 42 having the conductive ink layer 44 printed thereon and then having a further layer of metal 70 laid over the conductive ink layer 44. The molded resin 46 is added around the heater element 72 to form the molded object, e.g. humidifier tub. In this design, the molded resin 46 is formed on the internal surface of the object and the heater element 72 is on the external surface. The molded resin 46 provides the structural and physical support for the electrical connection. The molding may also be designed to provide guiding assistance when the heater element connector is engaged with the power supply connector. The metal layer 70 may be exposed on the external surface to provide a conductive contact connector.

Electrical Connection Fourth Embodiment

[0090] Figures 9a and 9b show an example of a mating connector design. The in-mold heater element 41, e.g. a printed ink film heater element 72 as described above, is formed within an exposed surface of the molded object 46. A complementary shaped connector portion is formed in the power supply unit 74. A spring contact 76 on the power supply unit 74 provides electrical

connection to the exposed contact, e.g. metal layer 70, on the heater element 72 in the molded object 46 when the molded object 46 is inserted in direction 78 into the power supply unit 74. Figure 9b shows a cross-section of the contact portions of the molded object. The shape of the molded connector region may be used to provide alignment for the connectors. The alignment portions may be formed in different shapes as indicated by 80 and 82.

Electrical Connection Fifth Embodiment

[0091] Figure 10 shows another sample embodiment for the electrical connector construction to provide an electrical connection between the heater element and an electrical contact. In this embodiment, an electrical connector 81 having a pin-like structure 83 with a head portion 85 that is inserted through the molded object 46 and the in-mold heater element 41, e.g. a printed ink film heater element 72. The pin portion 83 of the electrical connector 81 is inserted from the interior of the molded object 46 until the head portion 85 is positioned against an internal surface of the molded object 46. In one embodiment, the electrical connector 81 is molded into the molded object 46 during manufacture. In an alternative embodiment, the electrical connector 81 is inserted after the molded object 46 is made. The electrical connector 81 contacts the heater element circuit, e.g. conductive ink layer 44, as it passes through the wall of the molded object 46. The molded object 46 may also be designed to expose the film 42 on the outer surface such that a portion of the conductive ink 44 is exposed on the external surface. A securement unit 84 is attached to the pin portion 83 of the electrical connector 81 to provide an increased electrical conductive interface 42a and to secure the electrical connector 81 in position. The securement unit 84 may be in the form of a screwed, riveted or glued adaptor, or the like. Seals 86 may be provided to ensure a secure and safe connection. The electrical connector may be above the water level in a humidifier tub.

Control System First Embodiment

[0092] The level of heating by the in-mold heater elements may be controlled using a temperature sensor such as a thermistor or thermocouple. In a sample embodiment shown in Fig. 11, the in-mold heater 72 includes one or more thermistors 90, 92 electrically in series with the power supply and the printed conductive ink 44 on the film 42. Depending upon the application, a positive temperature coefficient (PTC) thermistor or a negative temperature coefficient (NTC) thermistor may be used to control the level of heating. For example, a PTC thermistor operates to decrease the heating power to the heater element as the temperature increases towards the desired temperature. A PTC thermistor may be used in a respiratory humidifier device.

Control System Second Embodiment

[0093] A temperature sensor 94, or thermistor, or conductive thermoplastic elastomer (PTC-TPE) with PTC electrical properties may be molded into the molded object 46 together with the

heater element circuit, e.g. conductive ink 44, on the film 42, as shown in the sample embodiment depicted in Fig. 12.

Control System Third Embodiment

[0094] In another sample embodiment shown in Fig. 13, a thermal fuse 96 may be incorporated with the conductive ink 44 on the film 42 in a proximity close to the surface of the heater 72 to guard against overheating.

Control System Fourth Embodiment

[0095] Referring to Figs. 14 and 15, a humidifier tub 50 may include an in-mold heater element comprising, for example, a stamped film heater element 73 including a stamped resistive or conductive polymer film 43 and the polymer film 42. The tub 50 may also include an overmold material 57 that separates portions 43a, 43b, 43c of the polymer film 43. When the water level W is above the overmold material 57, the water forms a conductive circuit with the portions 43a, 43b, 43c of the polymer film 43, as shown in Fig. 14. When the water level W is below the overmold material 57, the conductive path between the portions 43a, 43b, 43c is broken. The polymer film 43 may thus be used as a water level sensor. For example, an amp meter may be connected to the polymer film 43. When the water level W falls below the overmold material 57, the conductive path is broken and the amp meter will detect the absence of current. It should be appreciated that the electrically conductive ink may be used instead of, or in addition to, the polymer film 43. It should also be appreciated that the polymer film 43 may be replaced by, for example, a conductive ink foil.

Control System Fifth Embodiment

[0096] According to another sample embodiment shown in Figs. 16 and 17, the humidifier tub 50 may include a printed ink film heater element 72 that comprises a conductive ink 44 and a polymer film 42. The humidifier tub 50 may also include an overmolded material 57 formed over the heater element 72. As shown in Figs. 16 and 17, the overmolded material 57 may include a mound(s), or "volcano(es)", 57a that is formed above the remainder of the overmolded material 57. The mound 57a may include, for example, another heater, including another printed ink film heater 72 or a stamped film heater 73, thermistors 90 or 92, temperature sensors 94 or 98, and/or thermal fuse(s) 96. The additional heater element 72 or 73 may be electrically conductive when the water level W is above the overmolded mound(s) 57a, as shown in Fig. 16, and electrically non-conductive when the water level W is below the mound(s) 57a, as shown in Fig. 17. Thus, the mound(s) 57a may allow the additional heater element 72 or 73 to operate as a water level sensor as described above. Similarly, the thermistors 90 or 92 and/or the temperature sensors 94 or 98 may act as a water level sensor. For example, when the water level falls below

the overmold mound(s) 57a, a large temperature differential may be sensed that indicates the water level has dropped below the mound(s) 57a.

Control System Sixth Embodiment

[0097] In another sample embodiment shown in Fig. 18, a temperature sensor 98 may be positioned adjacent the base of a humidifier tub and may be used to provide an indication of the water level. For example, if the water level is very low the heater element will heat up very rapidly. Other sensors, such as humidity sensors, may also be included within the molded object on the heater element to provide an indication of the level of humidification. Sensors may be loaded on to the heater element in contact with the conductive ink using conductive adhesives and covered with an epoxy for protection. Temperature sensors molded into different portions of a molded object may also provide an indication of the flow rate by detecting the temperature and rate between two temperature sensors.

Control System Seventh Embodiment

[0098] Referring to Fig. 19, a humidifier tub may comprise a lower portion 52 and an upper portion 54. The upper portion 54 may comprise an air inlet 120 and an air outlet 122. The lower portion 52 may comprise a printed film heater element 72, although it should be appreciated that the heater element may be a stamped film heater element or an overmolded film heater element as described above.

[0099] The lower portion 52 may comprise a plurality of temperature sensors 98, 100, 102, 104. As the water level in the lower portion 52 goes down, each sensor 104, 102, 100, 98 will be successively exposed to air flow through the humidifier. The change in the detected temperature, from water to air flow, provides an indication of the water level.

Control System Eighth Embodiment

[00100] Referring to Fig. 20, the heater element 72 may extend along a side wall of the lower portion 52 of the humidifier tub 50 and include a plurality of sensors 98, 100, 102, 104 provided in the heater element to provide an indication of the water level. The heater element 72 will heat up more rapidly in areas not exposed to water in the lower portion 52 and the sensors in the areas of the heater element not exposed to water will indicate higher temperatures. It should also be appreciated that the circuit of the heater element 72 may also include, for example, a thermistor and/or a thermal fuse, as described in relation to other embodiments. It should be further appreciated that the heater element may be a stamped film heater element or overmolded film heater element as also described above.

Control System Ninth Embodiment

[00101] Referring to Fig. 21, the humidifier tub 50 may comprise the upper portion 54 and the lower portion 52. The upper portion may also comprise a thermal sensor, or sensors, 106, 108, 110. The thermal sensor(s) 106, 108, 110 may be placed above the water level, for example a maximum fill level defined in the lower portion 52, to detect a temperature of the air in the upper portion 54. If the air temperature exceeds a predetermined temperature, for example 40°C, the power provided to the heater element 72 may be controlled to lower the air temperature.

[00102] It should be appreciated that the heater element 72 may be provided in a base of the lower portion 52, as shown in Fig. 21, or the heater element 72 may be configured as in Fig. 20. It should further be appreciated that any positive number of temperature sensors 106, 108, 110 may be provided, and temperature sensors may be provided at multiple locations in the upper portion 54 of the humidifier tub 50. For example, a temperature sensor may be provided at the inlet 120 and/or the outlet 122 to provide control of the heater element. As the inlet air temperature changes, the power supplied to the heater element 72 may be controlled to maintain a predetermined temperature at the outlet.

Control System Variants

[00103] The film may also include a water level sensor. For example, a water level sensor including cathodic probes or a thermal gradient using temperature sensors, may be included in the molded object, e.g. humidifier tub. The sensors would rely on the thermal relationship between the heater and the water, and the ability to mold the shape of the molded object to accommodate the mechanical requirements of the humidifier. A humidity sensor(s), either an absolute and/or a relative humidity sensor may be provided in the humidifier to allow for control of the heater element. Such a control system is disclosed in, for example, U.S. Applications 61/034,318 and 61/042,112, filed March 6, 2008 and April 3, 2008, respectively, the entire contents of both being incorporated herein by reference.

[00104] The heaters may also be zoned. For example, the heaters may be provided on the film or overmolded material to include a water heating section and an air heating section. Each heater in each zone may include separate sensing, control, and/or thermal protection elements provided on the film. The zoning may also be horizontal for sensing and heating. Horizontal zoning would allow heating of the surface of the water only to improve warm up time and reduce energy losses.

[00105] In addition to temperature sensors molded into the molded object via the film or overmolded material, an electronic circuit, or circuits, may be provided on the film or overmolded material and molded into the molded object. For example, switching control elements may be provided on the film or overmolded material to recover heat losses that would

normally be dissipated. The recovered heat may be used to heat the water in the humidifier chamber.

Power Supply

[00106] The power supply may be a stand alone power supply unit or incorporated within a supplementary device, such as PAP device that provides the power and electrical control systems for the device comprising the in-mold heater, such as an integrated humidifier device. Alternatively, the power supply unit forms a component of a humidifier device.

Advantages

[00107] The use of in-mold heater elements may provide a number of advantages over conventional heating technologies, including lower cost, ease of manufacture, reduced weight and increased efficiency. For example, the ability to mold the heater element within the molded object results in a reduction in the number of components and the time and complexity of assembly of the complete object. Hot plate and heat conductive plates are no longer required but are combined as the in-mold heater element performs the equivalent function. Such reductions may also lead to a significant cost savings. Furthermore, as the heater element may be included exactly where the heating is required there may be an increase in heating efficiency and response time. Molding the heater elements within the molded object also minimizes the chance of leakage in molded objects designed to hold fluids, such as humidifiers.

[00108] For a respiratory humidifier, the use of an in-mold heater element may have some significant benefits. For example, the humidifier may no longer require a cradle or chassis unit, which conventionally includes the hot plate and the structural features to secure the humidifier tub to ensure good thermal contact between the humidifier tub base and the hot plate. A humidifier tub base seal is no longer required and leakage problems should be reduced, or minimized. These lead to component cost savings and simplified assembly making the humidifier unit less expensive to manufacture. The incorporation of the heater element within the molded humidifier tub can provide enhanced safety and protection against exposure to hot heating elements, especially when the humidifier is in use.

[00109] While the invention has been described in connection with what are presently considered to be the most practical embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the invention. Also, the various embodiments described above may be implemented in conjunction with other embodiments, e.g., aspects of one embodiment may be combined with aspects of another embodiment to realize yet other embodiments. Further, each independent feature or component of any given assembly may constitute an additional embodiment. In addition, while the invention

has been described with particular application to humidification and patients who suffer from OSA, it is to be appreciated that patients who suffer from other illnesses (e.g., congestive heart failure, diabetes, morbid obesity, stroke, bariatric surgery, etc.) can derive benefit from the above teachings. Moreover, the above teachings have applicability with patients and non-patients alike in non-medical applications.

CLAIMS:

1. A heater element comprising a first polymer film having an electrically conductive circuit provided upon a surface, wherein the first polymer film is electrically insulating and is molded into at least one surface of a molded object.

2. A heater element according to claim 1, wherein the electrically conductive circuit comprises at least one of electrically conductive ink, a second polymer film, and a conductive or resistive material that is overmolded on the heater element.

3. A heater element according to claim 2, wherein the electrically conductive ink is printed in a thickness from about 5 μm - 40 μm, for example about 10 μm - 25 μm.

4. A heater element according to claim 2 or claim 3, wherein the electrically conductive ink is carbon ink, silver ink, or a combination thereof.

5. A heater element according to any one of claims 2-4, wherein the electrically conductive ink is etched or screen printed on the first polymer film.

6. A heater element according to any one of claims 1-5, wherein the first polymer film is a thermoplastic or thermoset polymer material.

7. A heater element according to claim 6, wherein the first polymer film is made from polyester, polyimide, polycarbonate or polypropylene.

8. A heater element according to any one of claims 1-7, wherein the first polymer film has a thickness between about 0.01 mm - 1 mm, for example about 0.05 mm – 0.5 mm.

9. A heater element according to any one of claims 2-8, wherein second polymer film sandwiches the electrically conductive ink within the molded object.

10. A heater element according to any one of claims 2-9, wherein the second polymer film is electrically insulating.

11. A heater element according to any one of claims 2-9, wherein the second polymer film is electrically resistive or conductive and is stamped to form at least part of the electrically conductive circuit and is provided on the first polymer film.

12. A heater element according to any one of claims 2-11, further comprising a second layer of ink printed over the electrically conductive ink to provide a protective layer.

13. A heater element according to any one of claims 2-11, further comprising a metal layer over the electrically conductive ink.

14. A heater element according to claim 13, wherein the metal comprises copper, gold, nickel, chrome, or any other electrically conductive metal or alloy.

15. A heater element according to claim 13 or claim 14, wherein the circuit comprises the second polymer film over the metal layer.

16. A heater element according to claim 15, wherein the second polymer film is laminated.

17. A heater element according to any of claims 1-16,wherein the circuit comprises a plurality of parallel bands linked by at least one band perpendicular to the parallel bands.

18. A heater element according to claim 17, wherein the parallel bands are carbon ink and the at least one perpendicular band is silver ink or a metal.

19. A heater element according to any one of claims 1-16, wherein the circuit comprises a single continuous pattern.

20. A heater element according to claim 19, wherein the single continuous pattern is a spiral or helix.

21. A heater element according to any one of claims 1-20, wherein the circuit is configured to provide a predetermined resistance.

22. A heater element according to any one of claims 1-21, further comprising an electrical connector connected to the circuit to provide power and electrical control signals.

23. A heater element according to claim 22, wherein electrical connector comprises an exposed portion of the electrically conductive ink configured to contact an electrical contact of the power supply.

24. A heater element according to claim 22, wherein the electrical connector comprises a wire fastened to the layer of electrically conductive ink and molded partially in the molded object.

25. A heater element according to claim 24, wherein the wire is connected to the electrically conductive ink by an electrical connection, such as crimping or terminal blocks.

26. A heater element according to claim 24, wherein the wire is connected to the electrically conductive ink by a mechanical contact connector, for example a plug and socket type connector, such as a spade or bullet connector.

27. A heater element according to claim 22, wherein the electrical connector comprises a conductive material in contact with the electrically conductive ink and molded partially in the molded object.

28. A heater element according to claim 27, wherein the conductive material is a metal contact.

29. A heater element according to claim 22, wherein the electrical connector comprises a pin-like element extendable through the molded object and the heater element so as to be in contact with the electrically conductive ink.

30. A heater element according to claim 29, wherein the pin-like element comprises a head configured to be on interior surface of the molded object.

31. A heater element according to claim 30, further comprising a seal between the head of the pin-like element and the interior surface.

32. A heater element according to any one of claims 29-31, further comprising a securement unit connected to a pin portion of the pin-like element, wherein the securement unit comprises an electrically conductive interface in contact with the electrically conductive ink.

33. A heater element according to any one of claims 1-32, wherein at least a portion of the heater element is exposed on an interior surface of the molded object.

34. A heater element according to any one of claims 1-32, wherein at least a portion of the heater element is exposed on an exterior surface of the molded object.

35. A heater element according to any one of claims 1-34, wherein at least a portion of the heater element is through a wall of the molded object.

36. A heater element according to any one of claims 1-35, further comprising at least one temperature sensor electrically connected to the electrically conductive circuit.

37. A heater element according to claim 36, wherein the at least one temperature sensor comprises a thermocouple.

38. A heater element according to claim 36, wherein the at least one temperature sensor is a PTC or NTC thermistor.

39. A heater element according to any one of claims 1-38, further comprising a thermal fuse in the electrically conductive circuit to protect against over heating.

40. A heater element according to any one of claims 1-39, wherein the circuit comprises a switching control element.

41. A heater element according to any one of claims 1-40, wherein the molded object is formed via injection molding.

42. A heater element according to any one of claims 1-40, wherein the molded object is formed via extrusion molding.

43. A heater element according to any one of claims 1-42, wherein the molded object is formed of polycarbonate, polycarbonate ABS blends, polyethylene, or polypropylene.

44. A heater element according to any one of claims 1-43, wherein the molded object is a humidifier or a component of a humidifier.

45. A humidifier water tub having incorporated within an internal surface thereof the heater element as claimed in any one of claims 1-43.

46. A method of manufacturing an in-mold heater element, comprising:

i) providing an electrically conductive circuit on a first surface of a first polymer film;

ii) placing the polymer film including the electrically conductive circuit in a mold such that a second surface of the first polymer film opposite the first surface is adjacent the mold; and

iii) insert molding resin to form a predetermined molded shape such that the first polymer film is incorporated within at least one surface of the molded shape.

47. A method according to claim 46, wherein the electrically conductive circuit comprises at least one of an electrically conductive ink, a second polymer film, and a conductive or resistive material that is overmolded on the heater element.

48. A method according to claim 47, wherein the electrically conductive ink is printed in a thickness from about 5 μm - 40 μm, for example about 10 μm – 25 μm.

49. A method according to claim 47 or claim 48, wherein the electrically conductive ink is carbon ink, silver ink, or a combination thereof.

50. A method according to any one of claims 46-49, wherein the first polymer film is a thermoplastic or thermoset polymer material.

51. A method according to claim 50, wherein the first polymer film is made from polyester, polyimide, polycarbonate or polypropylene.

52. A method according to any one of claim 46-51, wherein the first polymer film has a thickness between about 0.01 mm - 1 mm, for example about 0.05 mm – 0.5 mm.

53. A method according to any one of claims 46-53, wherein the predetermined molded shape is a component of a humidifier device.

54. A humidifier, comprising:

a tub configured to contain a supply of water; and

a heater comprising a first polymer film having an electrically conductive circuit provided upon a surface, wherein the first polymer film is electrically insulating and the tub is formed of molded resin and the heater is molded at least partially within the resin.

55. A humidifier according to claim 54, wherein the electrically conductive circuit comprises at least one of electrically conductive ink, a second polymer film, and a conductive or resistive material that is overmolded on the heater element.

56. A humidifier according to claim 54 or claim 55, wherein the first polymer film is a thermoplastic or thermoset polymer.

57. A humidifier according to claim 56, wherein the first polymer film is polyester, polyimide, polycarbonate, or polypropylene.

58. A humidifier according to any one of claims 54-57, wherein the first polymer film has a thickness of about 0.01 mm - 1 mm, for example about 0.05 mm - 0.5 mm.

59. A humidifier according to any one of claims 54-58, wherein the molded resin is polycarbonate, polycarbonate ABS blends, polyethylene, or polypropylene.

60. A humidifier according to any one of claims 54-59, wherein the resin is injection molded.

61. A humidifier according to any one of claims 54-59, wherein the resin is extrusion molded.

62. A humidifier according to any one of claims 55-61, wherein the layer of electrically conductive ink is about 5 μm - 40 μm thick, for example about 10 μm – 25 μm.

63. A humidifier according to any one of claims 55-62, wherein the layer of electrically conductive ink is screen printed on the first polymer film.

64. A humidifier according to any one of claims 55-62, wherein the layer of electrically conductive ink is etched on the first polymer film.

65. A humidifier according to any one of claims 55–64, wherein the layer of electrically conductive ink is carbon ink, silver ink, or a combination thereof.

66. A humidifier according to any one of claims 54-65, wherein the circuit comprises a single continuous pattern.

67. A humidifier according to claim 66, wherein the single continuous pattern comprises a spiral or helix.

68. A humidifier according to any one of claims 54-65, wherein the circuit comprises a plurality of parallel bands linked by at least one band perpendicular to the parallel bands.

69. A humidifier according to claim 68, wherein the parallel bands are carbon ink and the at least one perpendicular band is silver ink or a metal.

70. A humidifier according to any one of claims 54-69, wherein the circuit is configured to provide a predetermined resistance.

71. A humidifier according to any one of claims 55-70, further comprising a layer of protective ink over the layer of electrically conductive ink.

72. A humidifier according to any one of claims 55-70, further comprising a metal layer over the layer of electrically conductive ink.

73. A humidifier according to claim 72, wherein the metal layer comprises copper, gold, nickel, chrome, or any other electrically conductive metal or alloy.

74. A humidifier according to claim 72 or claim 73, further comprising a second polymer film over the metal layer.

75. A humidifier according to claim 74, wherein the second polymer film is laminated.

76. A humidifier according to any one of claims 55-70, further comprising a second polymer film over the layer of electrically conductive ink.

77. A humidifier according to any one of claims 54-76, wherein the tub comprises an upper portion and a lower portion, and the upper portion is removable from the lower portion.

78. A humidifier according to claim 77, wherein the upper portion comprises an inlet and an outlet for a flow of breathable gas.

79. A humidifier according to claim 77, wherein the heater is in the upper portion.

80. A humidifier according to claim 77, wherein the heater is in the lower portion.

81. A humidifier according to any one of claims 54-80, wherein the heater is provided below a maximum water fill line of the tub.

82. A humidifier according to any one of claims 54-81, wherein the tub comprises a base and the heater is at least partially molded into an exterior surface of the base.

83. A humidifier according to claim 82, further comprising a base cover attached to the base.

84. A humidifier according to claim 83, wherein the base cover is sealingly attached to the base.

85. A humidifier according to claim 83 or claim 84, wherein a cavity is formed between the base and the base cover.

86. A humidifier according to claim 85, wherein the cavity is filled with insulating material.

87. A humidifier according to any one of claims 82-87, wherein the base is an open base.

88. A humidifier according to any one of claims 54-87, further comprising an electrical connector configured to connect the heater to a power supply.

89. A humidifier according to claim 88, wherein the electrical connector comprises an exposed portion of the circuit configured to contact an electrical contact of the power supply.

90. A humidifier according to claim 88, wherein the electrical connector comprises a wire connected to the circuit and molded partially in the resin.

91. A humidifier according to claim 90, wherein the wire is connected to the circuit by a fastening electrical connection, such as crimping or terminal blocks.

92. A humidifier according to claim 90, wherein the wire is fastened to the circuit by a mechanical contact connector, for example a plug and socket type connector, such as a spade or bullet connector.

93. A humidifier according to claim 88, wherein the electrical connector comprises a conductive material in contact with the circuit and molded partially in the resin.

94. A humidifier according to claim 93, wherein the conductive material is a metal contact.

95. A humidifier according to claim 88, wherein the electrical connector comprises a pin-like element extending through the molded resin and the heater so as to be in contact with the layer of electrically conductive ink.

96. A humidifier according to claim 95, wherein the pin-like element comprises a head on an interior surface of the tub.

97. A humidifier according to claim 96, further comprising a seal between the head of the pin-like element and the interior surface.

98. A humidifier according to any one of claims 95-97, further comprising a securement unit connected to a pin portion of the pin-like element, wherein the securement unit comprises an electrically conductive interface in contact with the layer of electrically conductive ink.

99. A humidifier according to any one of claims 88 – 98, wherein the power supply is provided in a base or stand unit.

100. A humidifier according to any one of claims 54-99, wherein at least a portion of the heater is exposed on an interior surface of the tub.

101. A humidifier according to any one of claims 54-99, wherein at least a portion of the heater is exposed on an exterior surface of the tub.

102. A humidifier according to any one of claim 54-99, wherein at least a portion of the heater is through a wall of the tub.

103. A humidifier according to any one of claims 54-102, wherein the heater comprises a temperature sensor.

104. A humidifier according to claim 103, wherein the temperature sensor comprises a thermocouple.

105. A humidifier according to claim 103, wherein the temperature sensor comprises a positive thermal coefficient or a negative thermal coefficient thermistor.

106. A humidifier according to any one of claims 54-105, wherein the heater comprises a thermal fuse.

107. A humidifier according to any one of claims 54-106, wherein the heater comprises a humidity sensor.

108. The humidifier according to any one of claims 54-107, wherein the heater comprises a switching control element.

109. A humidifier according to any one of claims 54-108, wherein the heater comprises a water level sensor.

110. A humidifier according to claim 109, wherein the water level sensor comprises a cathodic probe.

111. A humidifier according to claim 109, wherein the water level sensor comprises a thermal gradient.

112. A humidifier according to any one of claims 54-111, wherein the heater comprises zones.

113. A humidifier according to claim 112, wherein some of the zones are configured to heat water contained in the tub and some of the zones are configured to heat air in the tub.

114. A humidifier according to claim 112 or claim 113, wherein each zone comprises a temperature sensor, a humidity sensor, a water level sensor, a thermal fuse, and/or a switching control element.

115. A humidifier according to claim 114, wherein the heater is configured to heat only a zone corresponding to a surface of water contained in the tub.

116. A humidifier according to any one of claims 55-115, wherein the overmolded material is configured to isolate portions of the electrically conductive ink and/or the second polymer film such that at a first water level a conductive path is formed between at least some of the isolated

portions and at a second water level no conductive path is provided between any of the isolated portions.

117. A humidifier according to any one of claims 55-115, wherein the overmolded material includes at least one portion configured to support at least one of a temperature sensor, a fuse or a second heater, such that at a first water level the temperature sensor, the fuse, and/or the second heater is covered by the water and at a second water level the temperature sensor, the fuse, and/or the second heater are not covered by the water.

118. A respiratory apparatus for delivering a flow of breathable gas to a patient comprising a humidifier according to any one of claims 54-117.

119. A method of humidifying a flow of pressurized breathable gas, comprising:

passing the flow of pressurized breathable gas over a supply of water contained in a tub, wherein the tub is formed of molded resin and a heater comprising a first polymer film having an electrically conductive circuit on a first surface is molded at least partially within the resin.

120. A molded object, comprising:

a heater element, the heater element comprising a first polymer film having an electrically conductive circuit upon a surface, wherein the first polymer film is molded into at least one surface of the molded object; and

a control system configured to control a temperature of the heater element.

121. A molded object according to claim 120, wherein the control system comprises a positive thermal coefficient thermistor in series with the electrically conductive ink.

122. A molded object according to claim 121, wherein the thermistor is provided on the first polymer film.

123. A molded object according to claim 121 or claim 122, wherein the thermistor is molded into the at least one surface of the molded object.

124. A molded object according to any one of claims 120-123, wherein the control system comprises a fuse incorporated within the electrically conductive circuit.

125. A molded object according to any one of claims 120-124, wherein the molded object is a tub configured to contain a supply of water.

126. A molded object according to claim 125, wherein the control system comprises a temperature sensor molded into at least one surface of the tub.

127. A molded object according to any one of claims 120-126, further comprising a humidity sensor molded into at least one surface of the molded object.

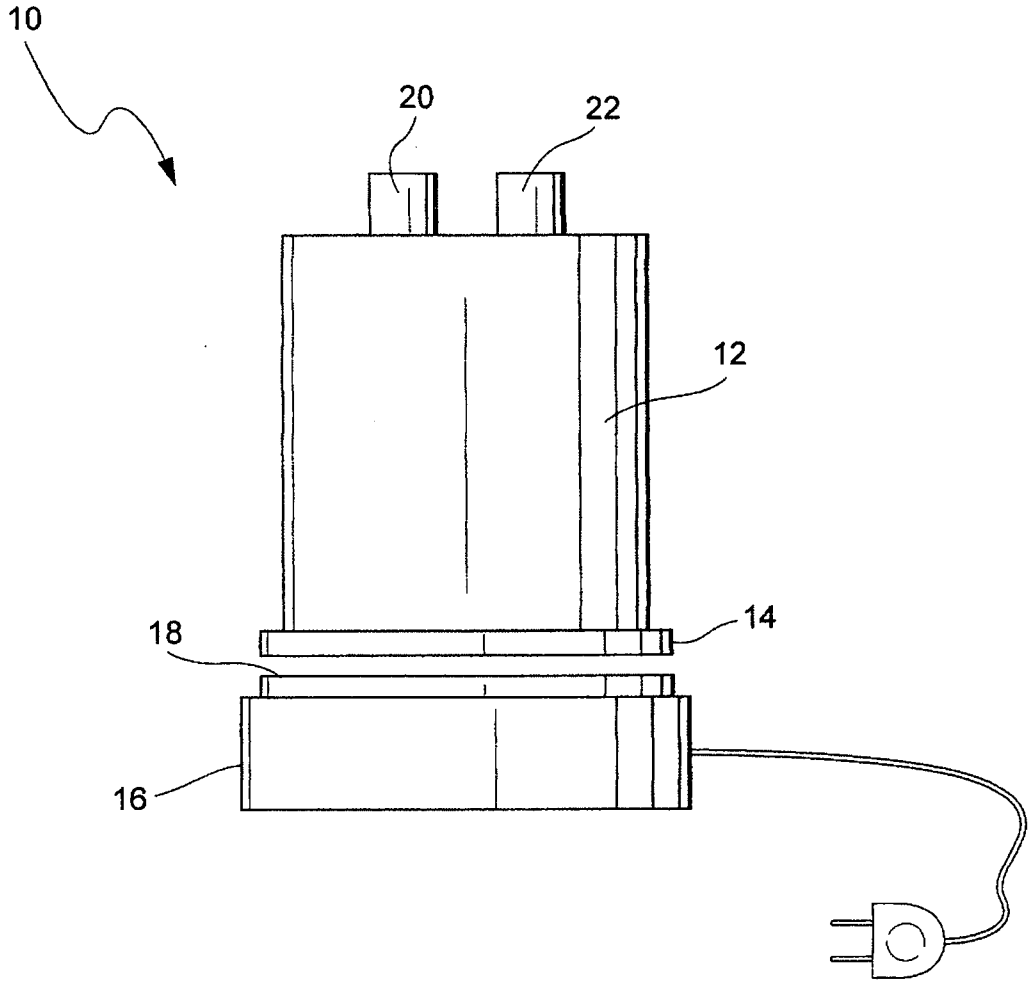


Fig. 1
(Prior Art)

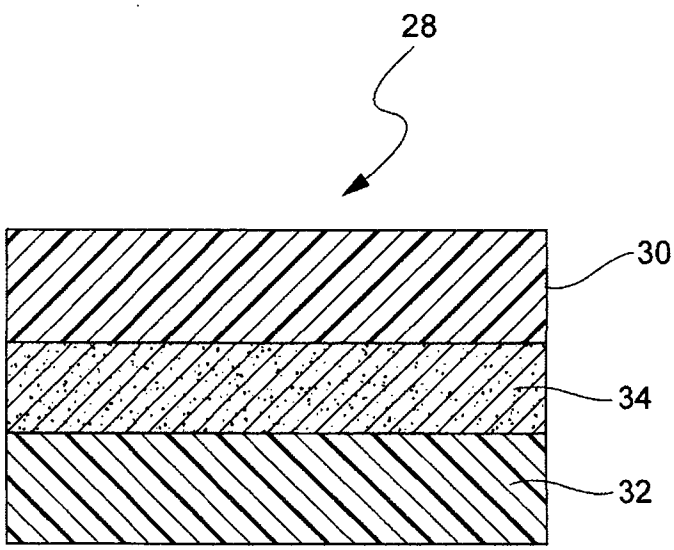


Fig. 2
(Prior Art)

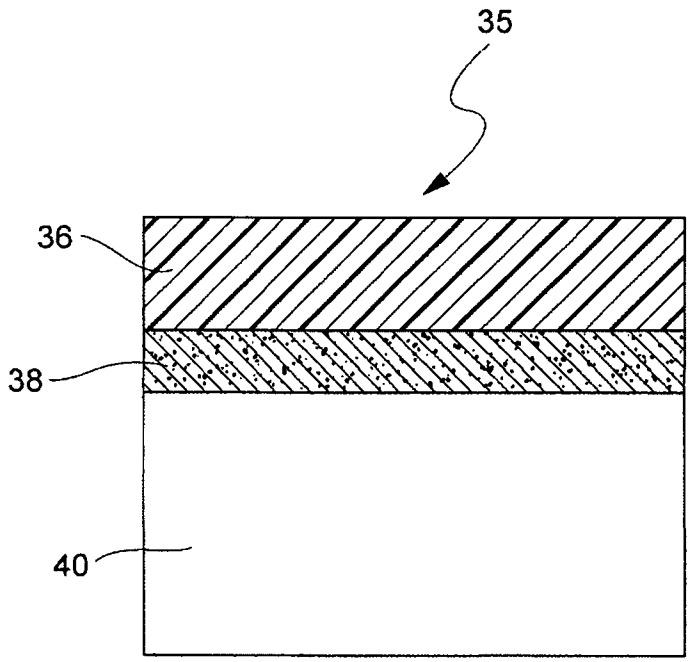


Fig. 3
(Prior Art)

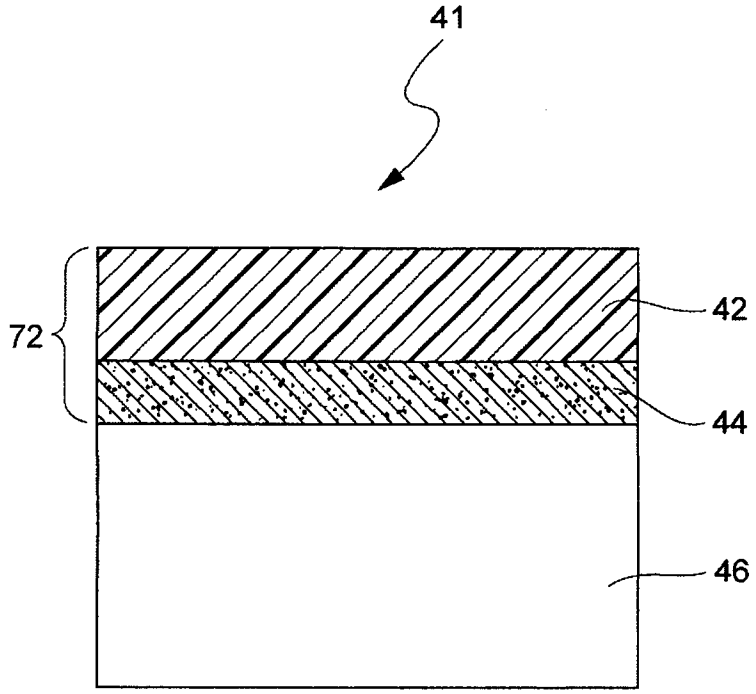


Fig. 4a

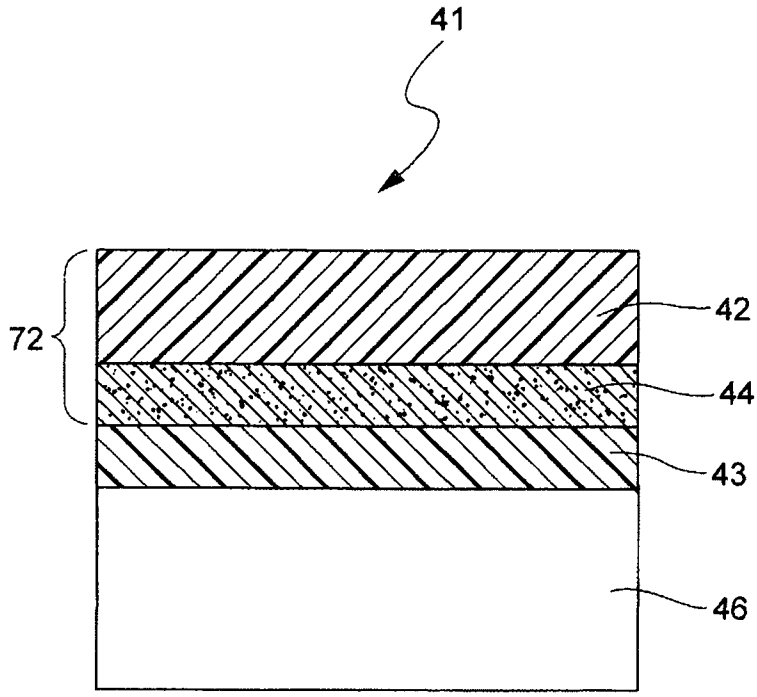


Fig. 4b

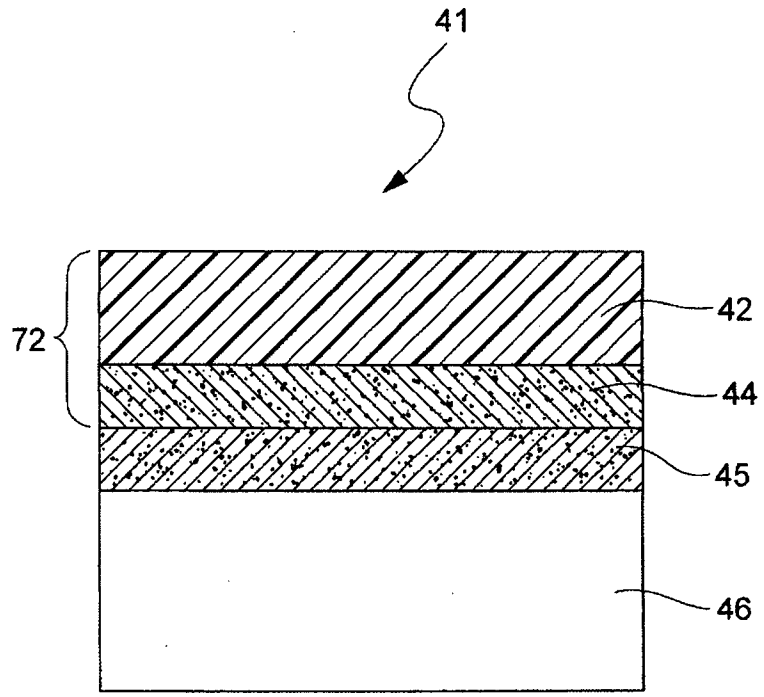


Fig. 4c

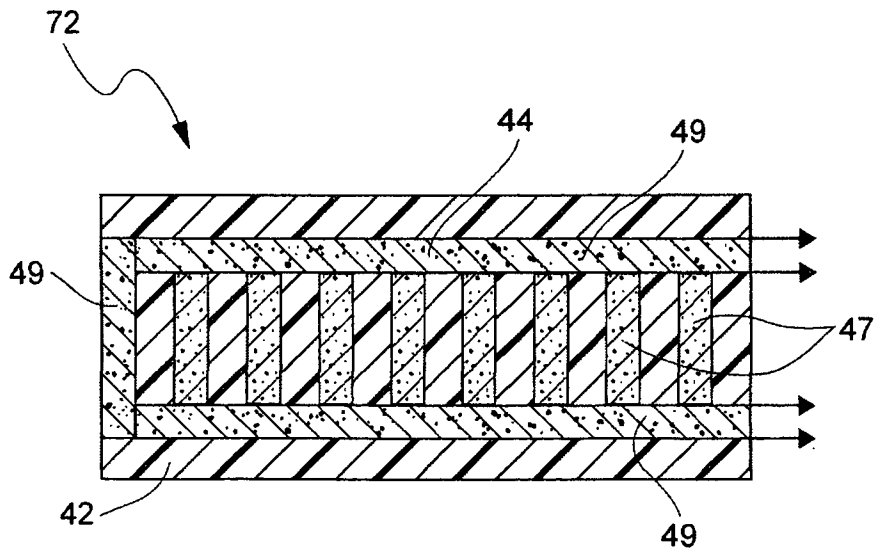


Fig. 4d

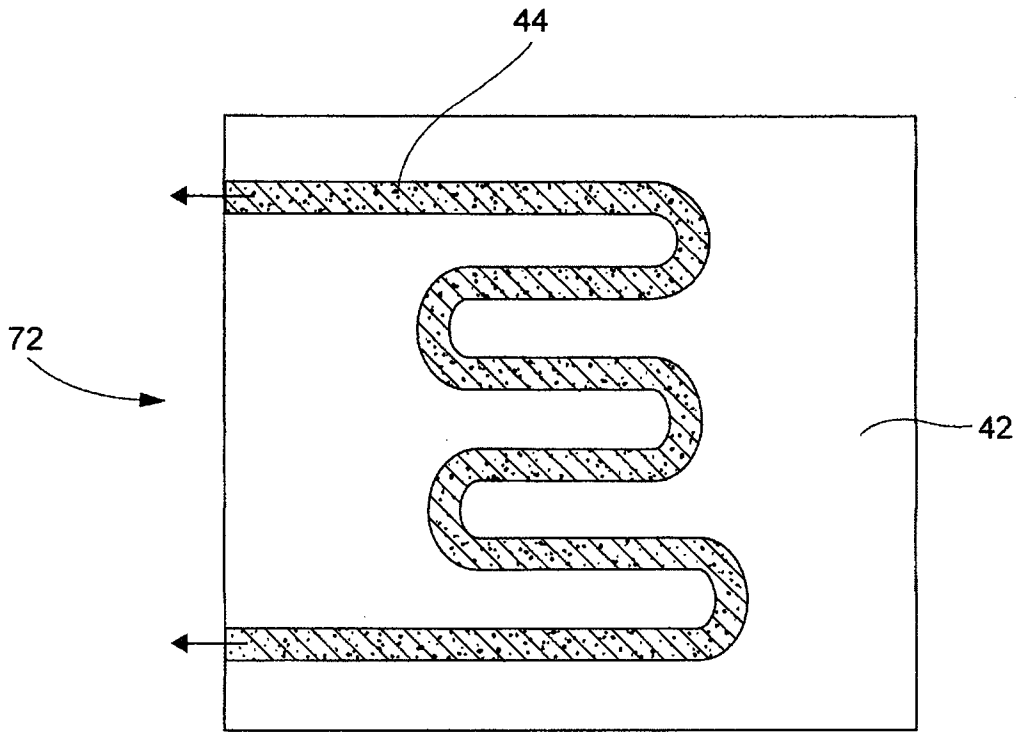


Fig. 4e

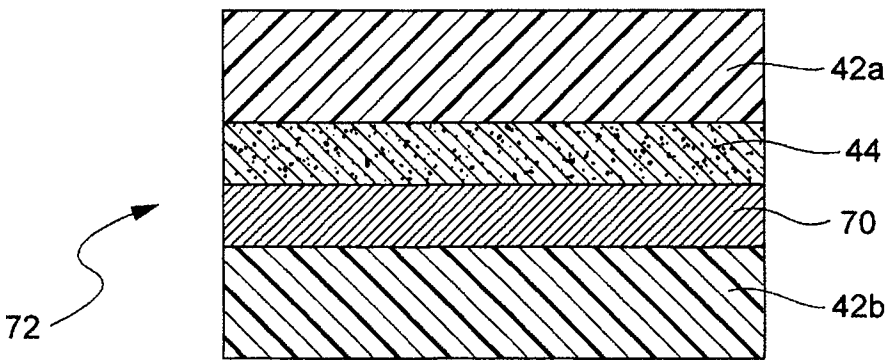


Fig. 4f

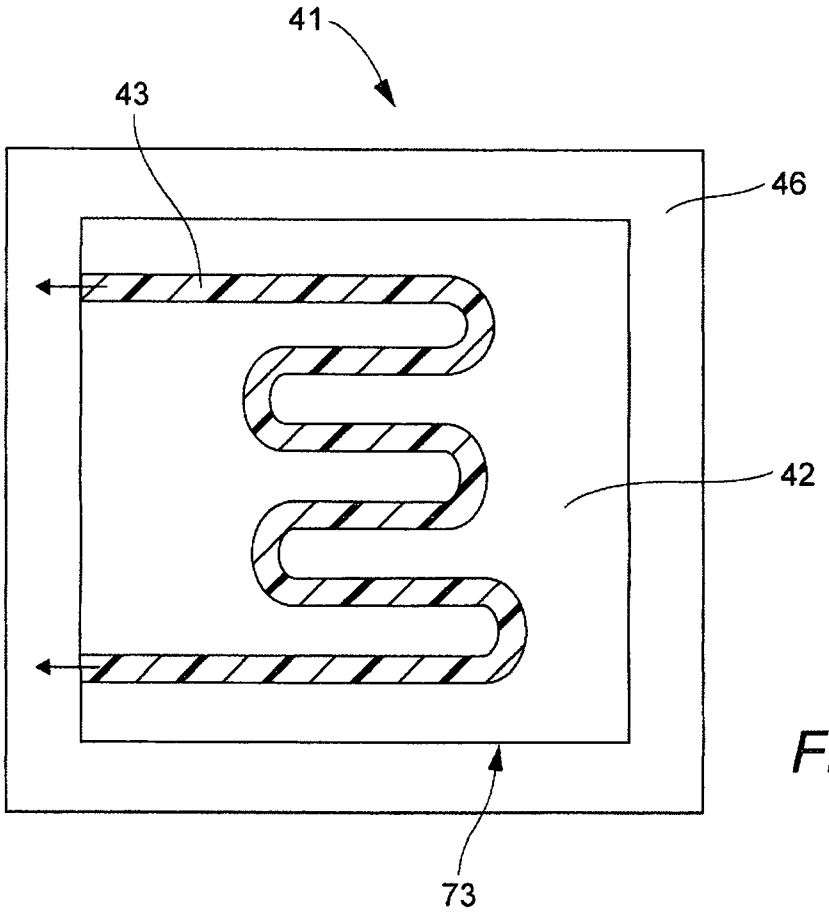


Fig. 4g

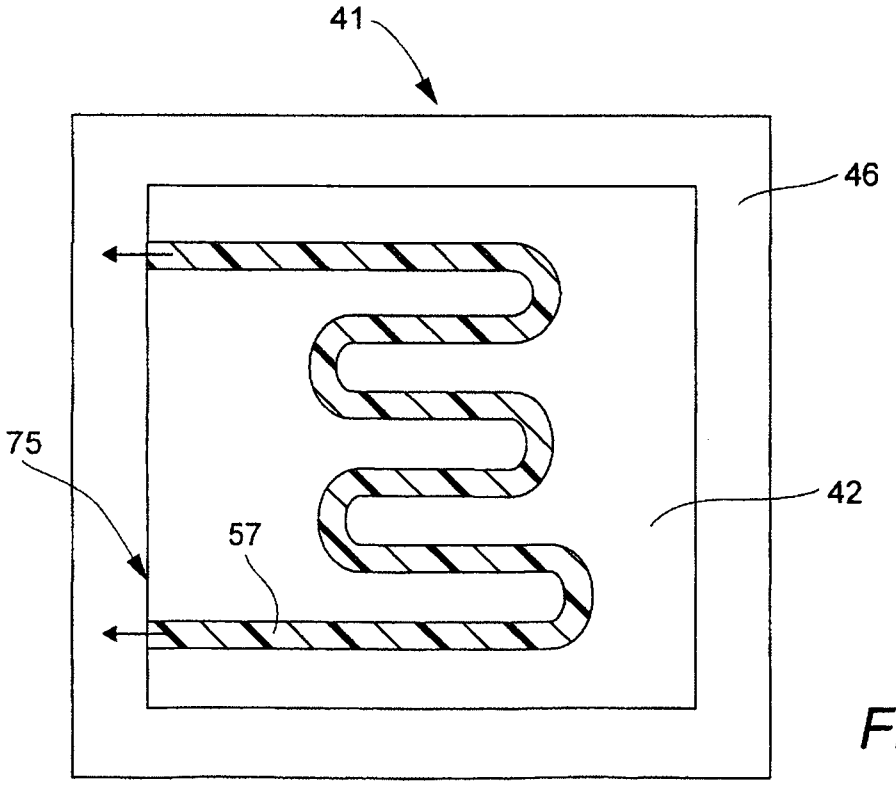


Fig. 4h

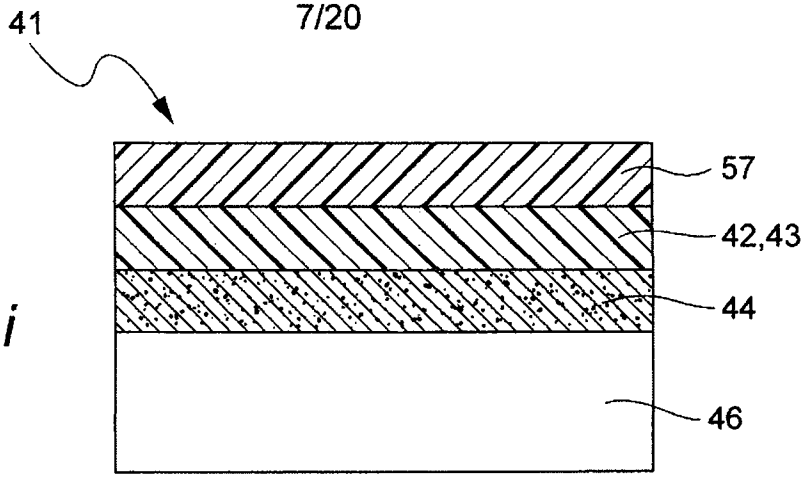


Fig. 4i

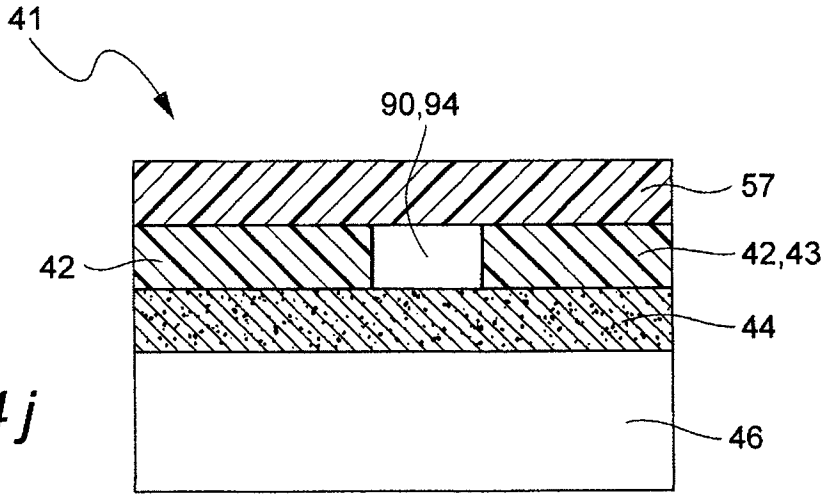


Fig. 4j

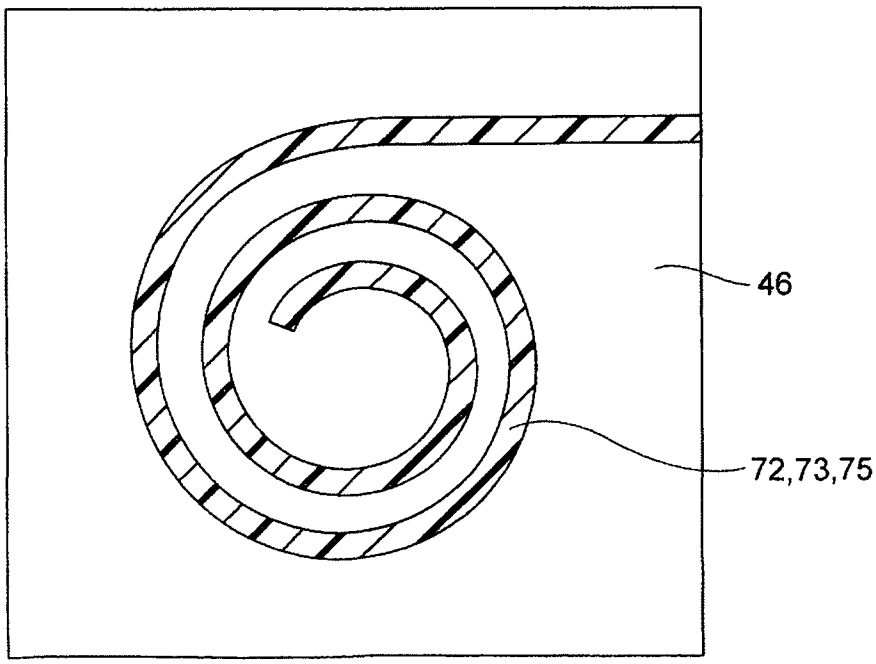


Fig. 4k

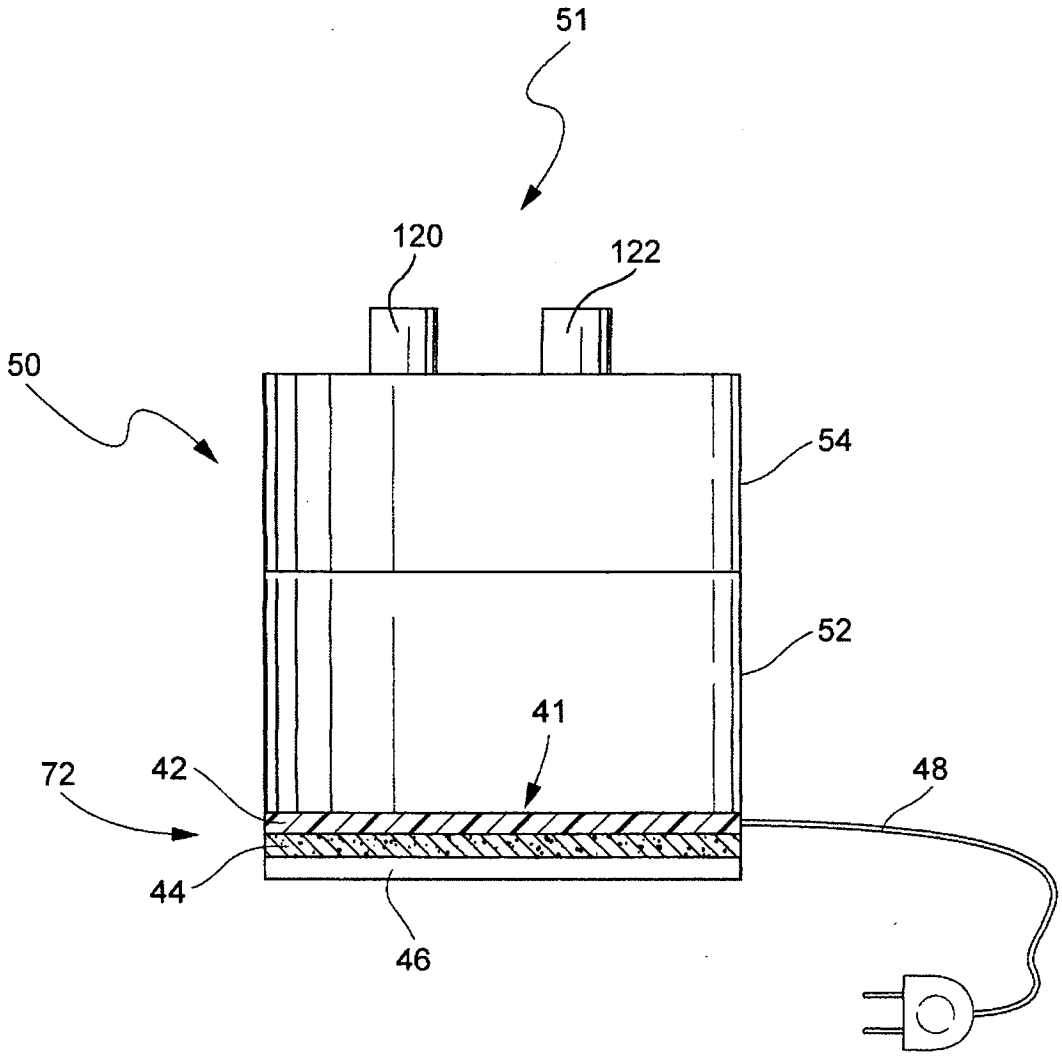


Fig. 5a

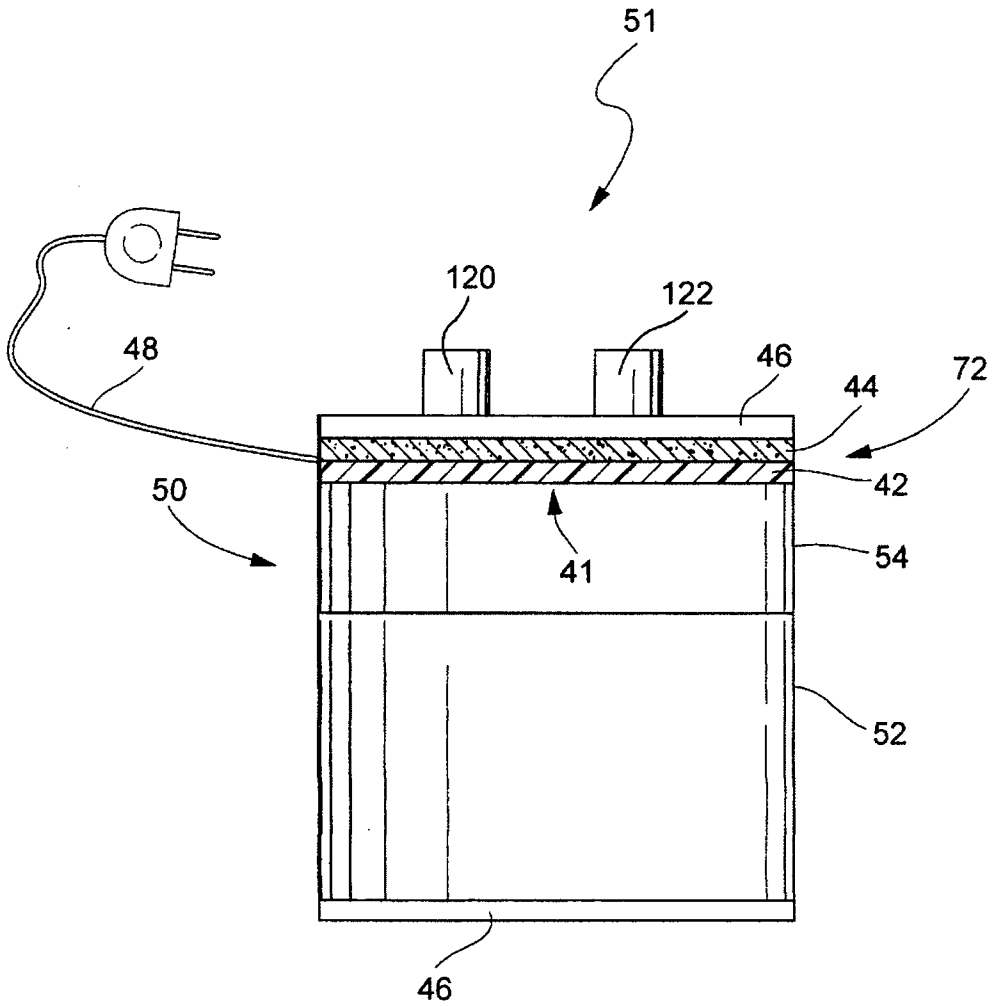


Fig. 5b

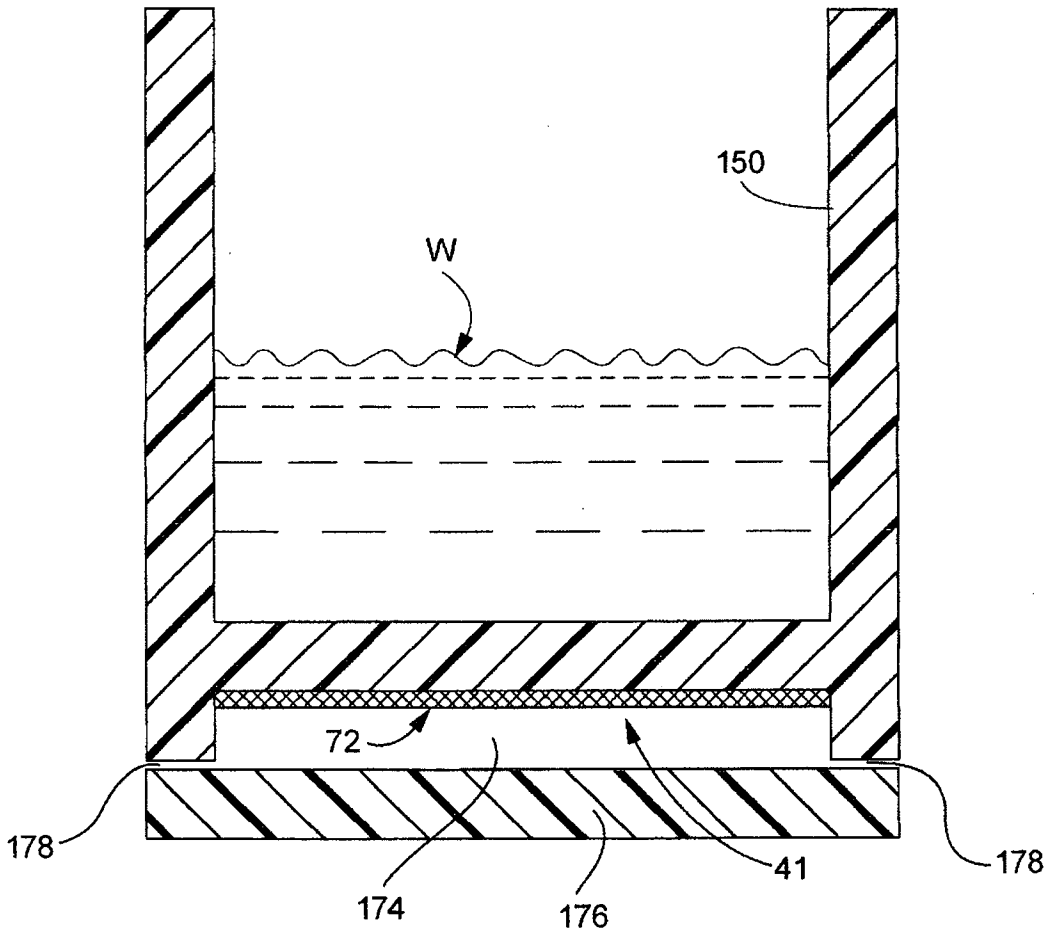


Fig. 5c

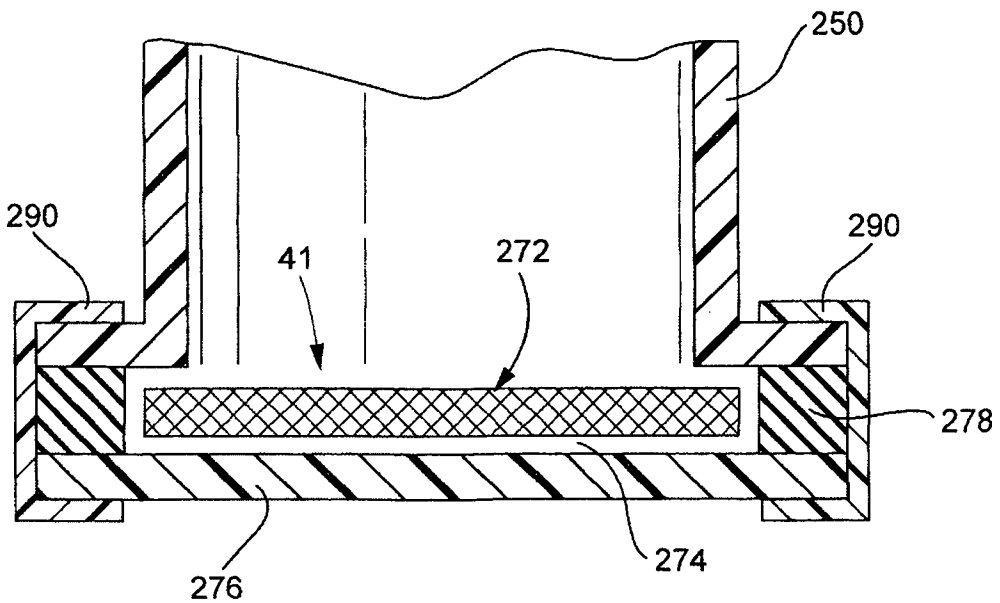


Fig. 5d

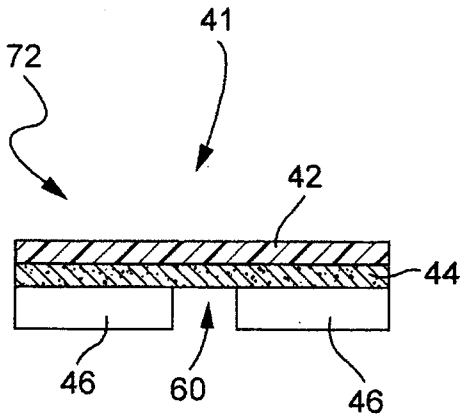


Fig. 6a

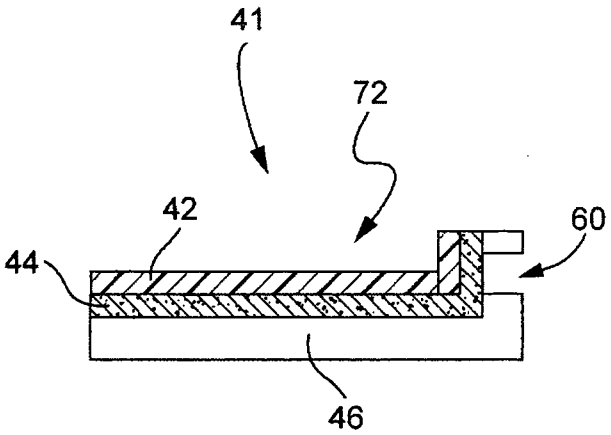


Fig. 6b

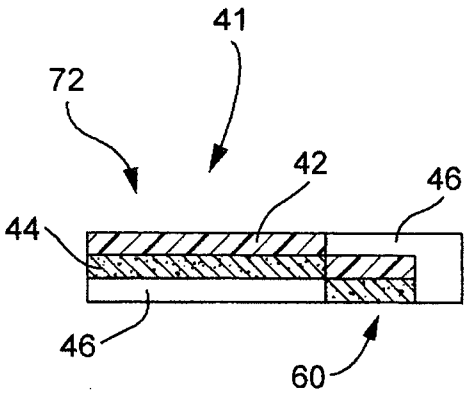


Fig. 6c

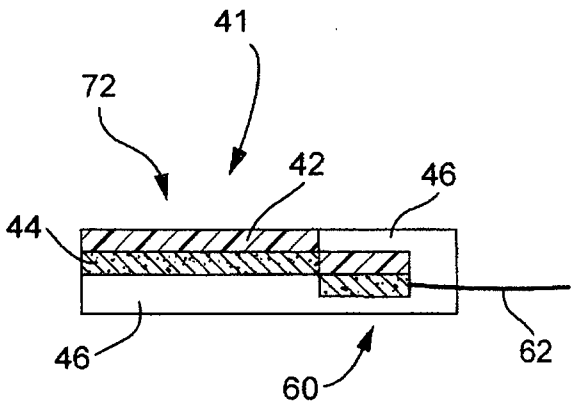


Fig. 6d

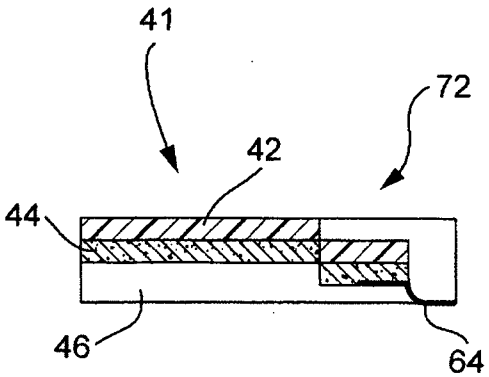


Fig. 6e

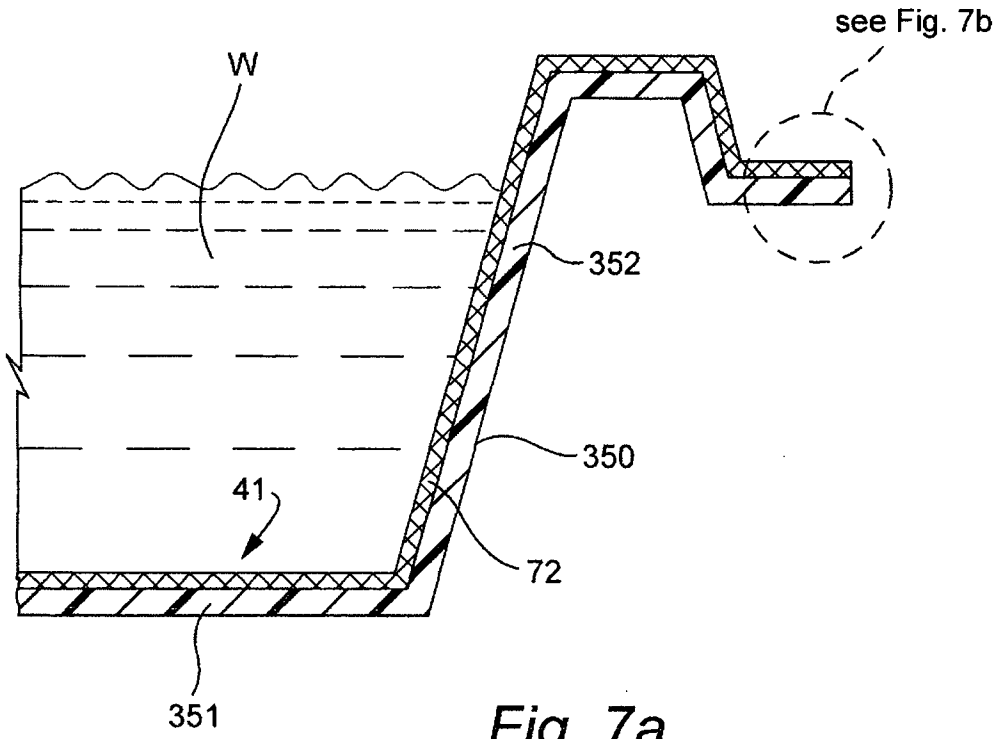


Fig. 7a

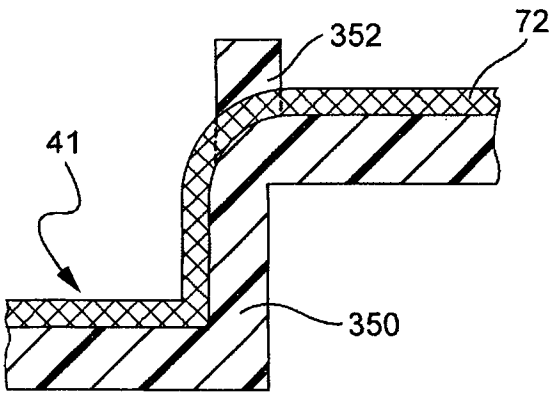


Fig. 7b

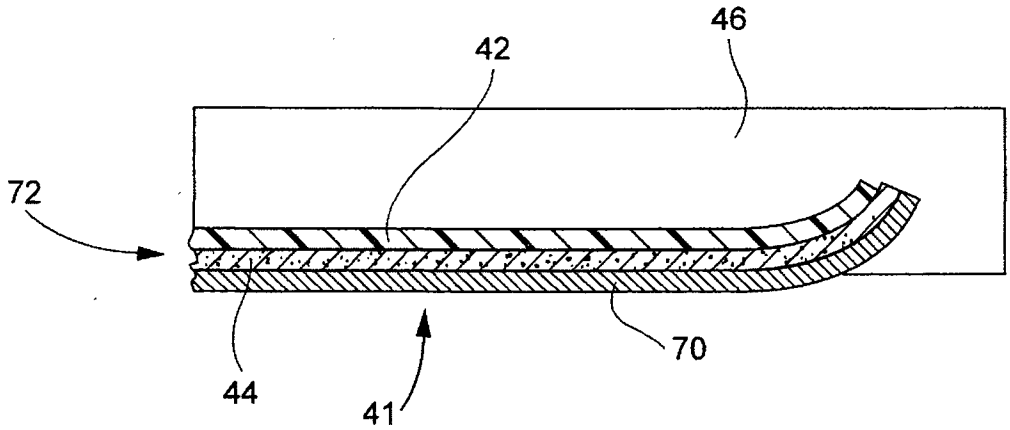


Fig. 8

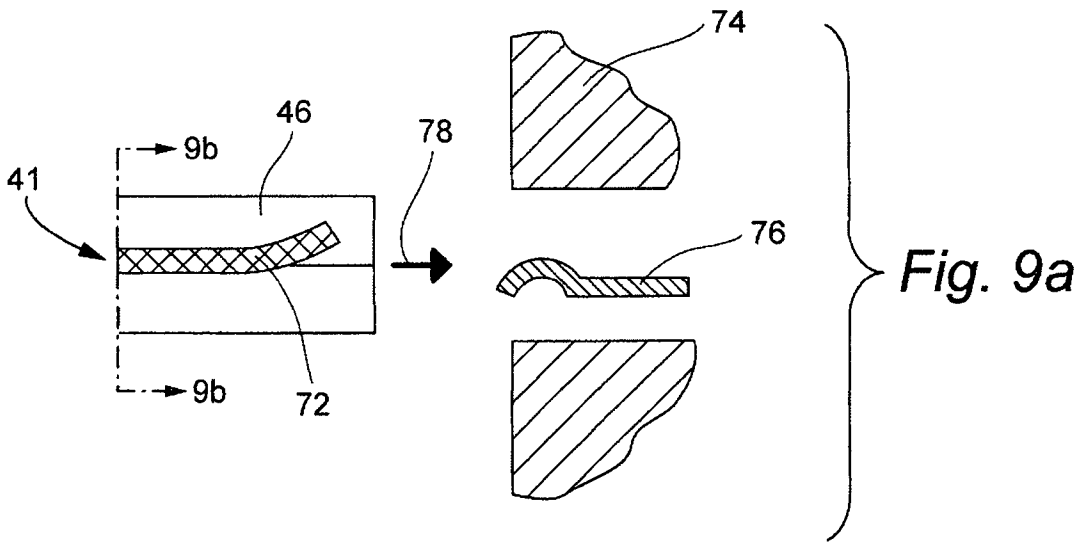


Fig. 9a

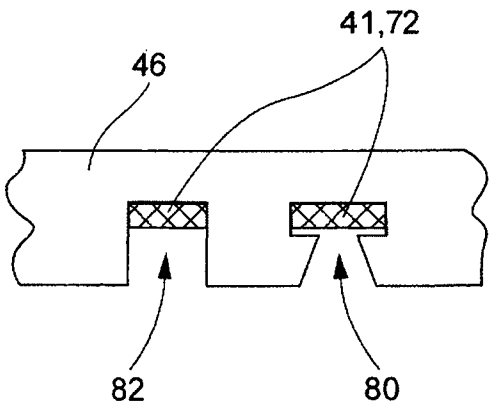
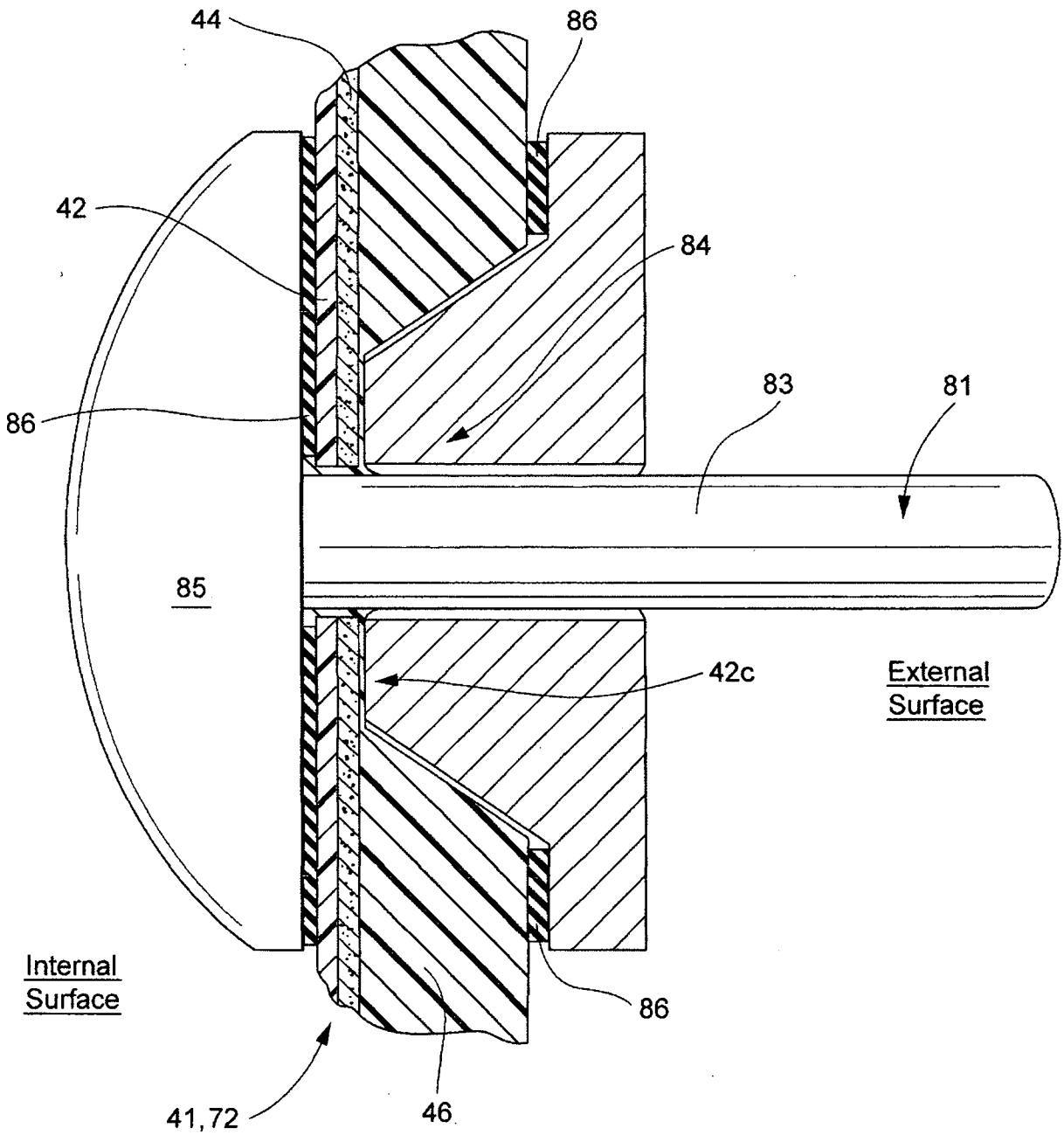


Fig. 9b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External Surface
Internal Surface
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41,72
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Fig. 10

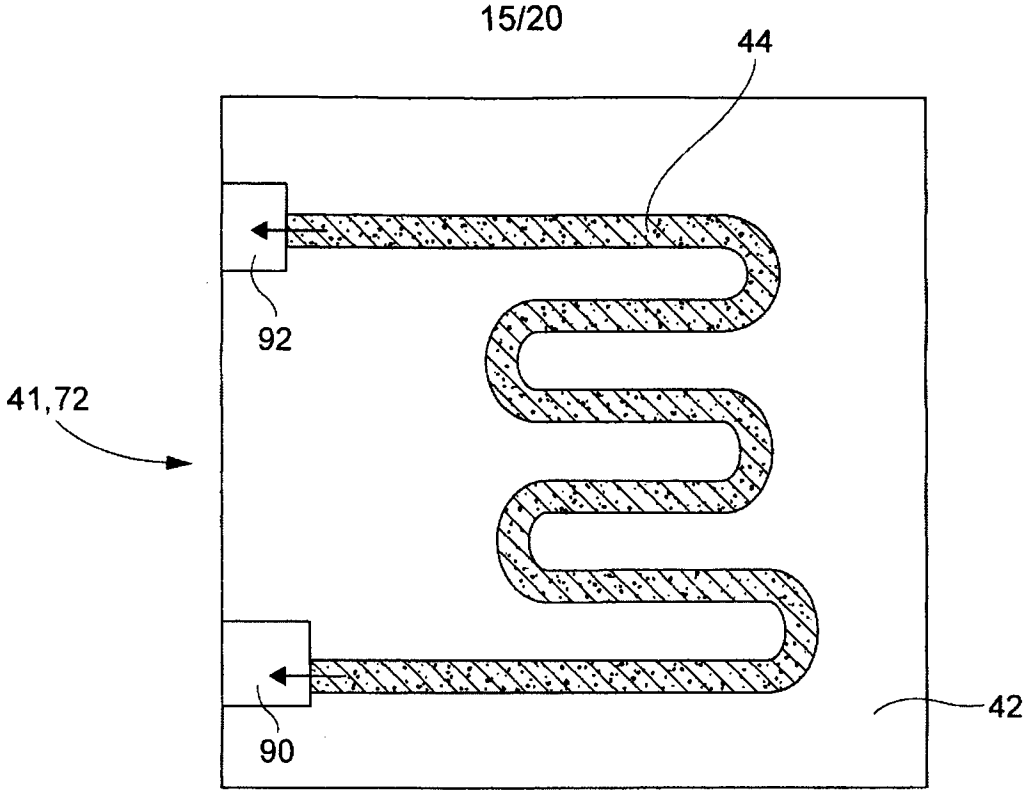

Fig. 11

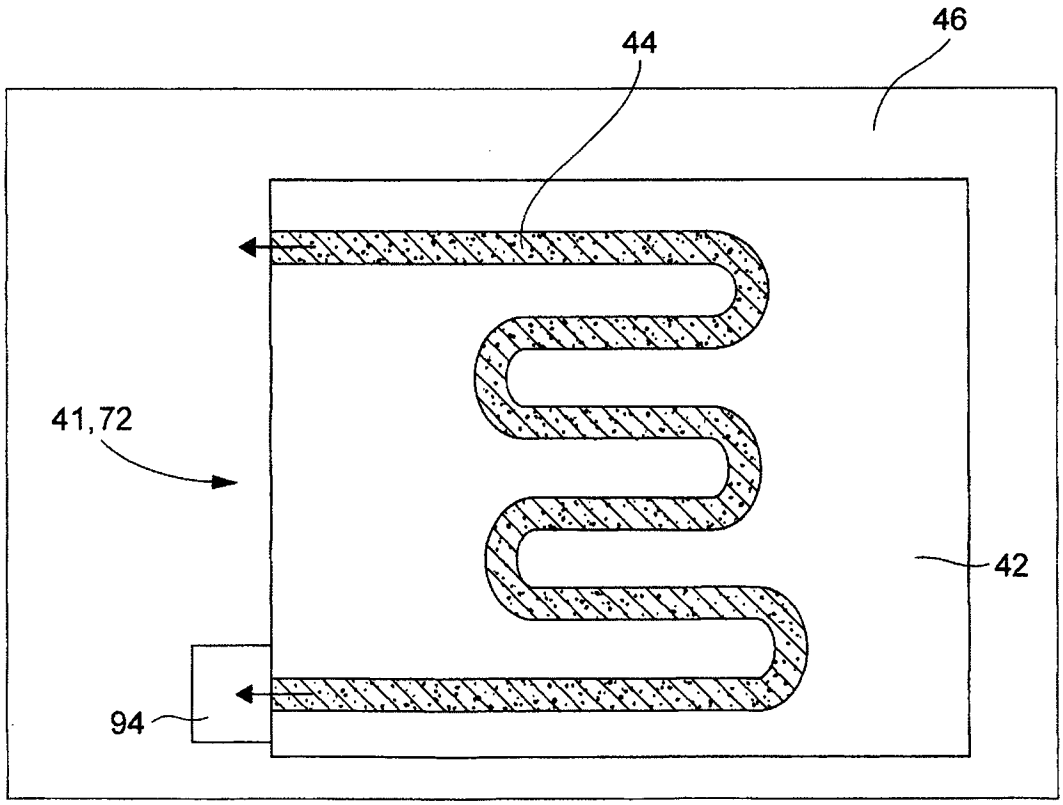

Fig. 12

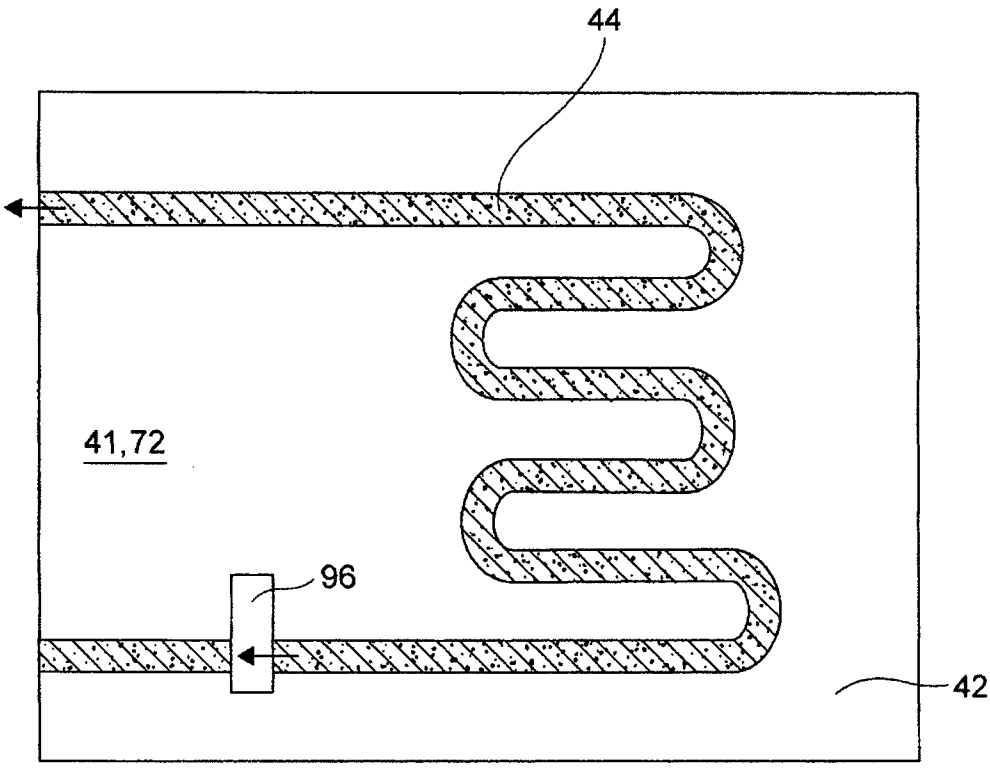

Fig. 13

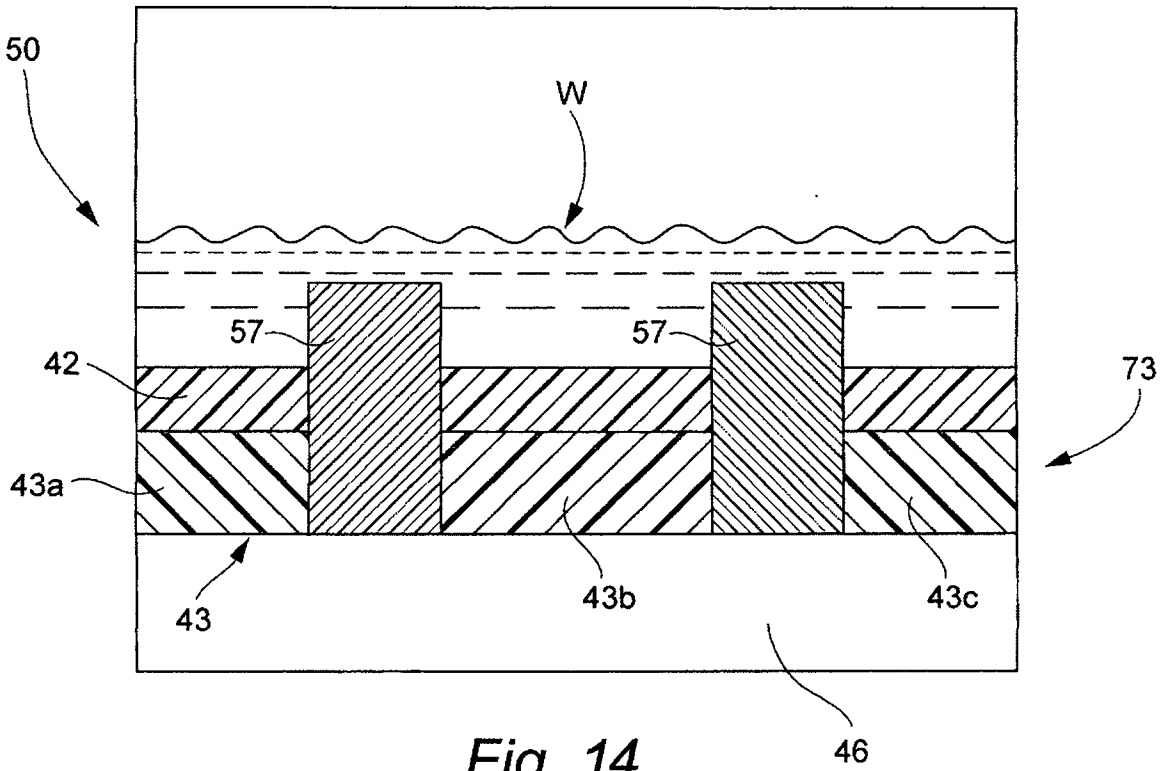

Fig. 14

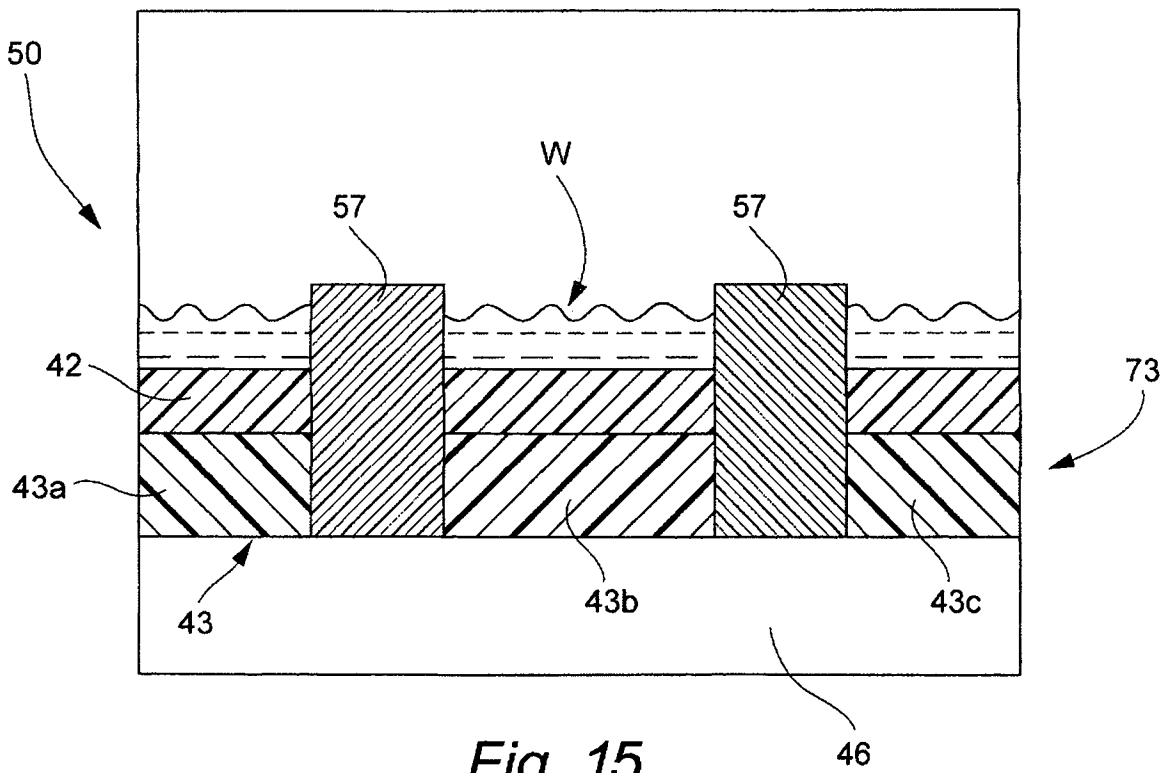

Fig. 15

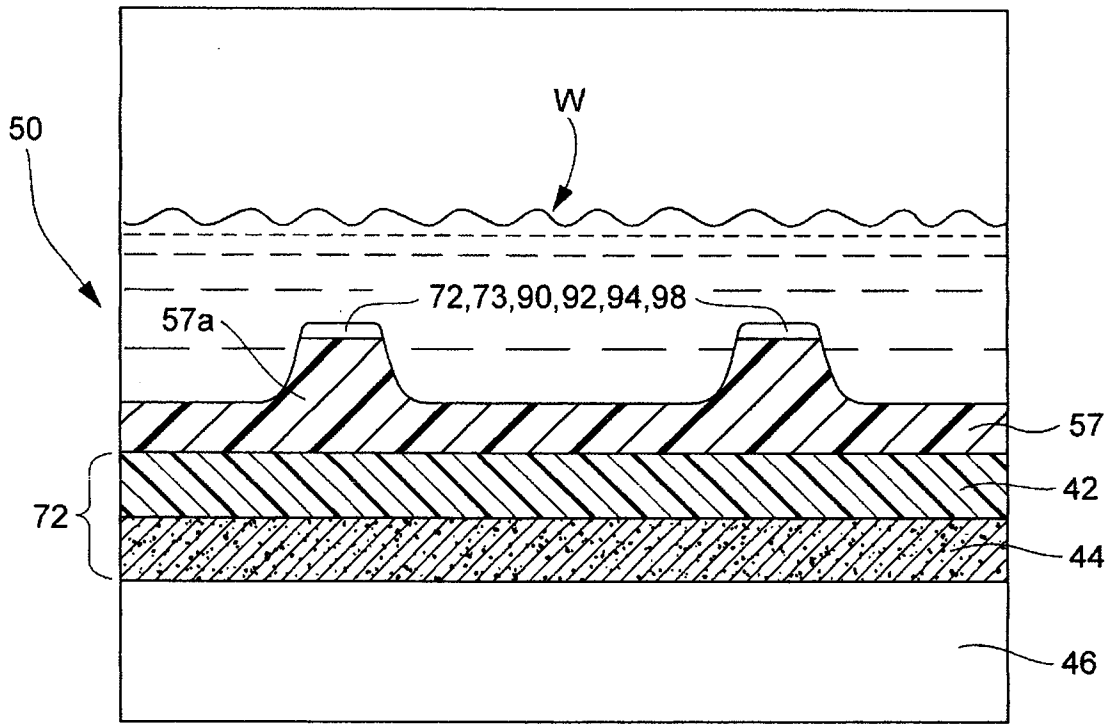
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Fig. 16

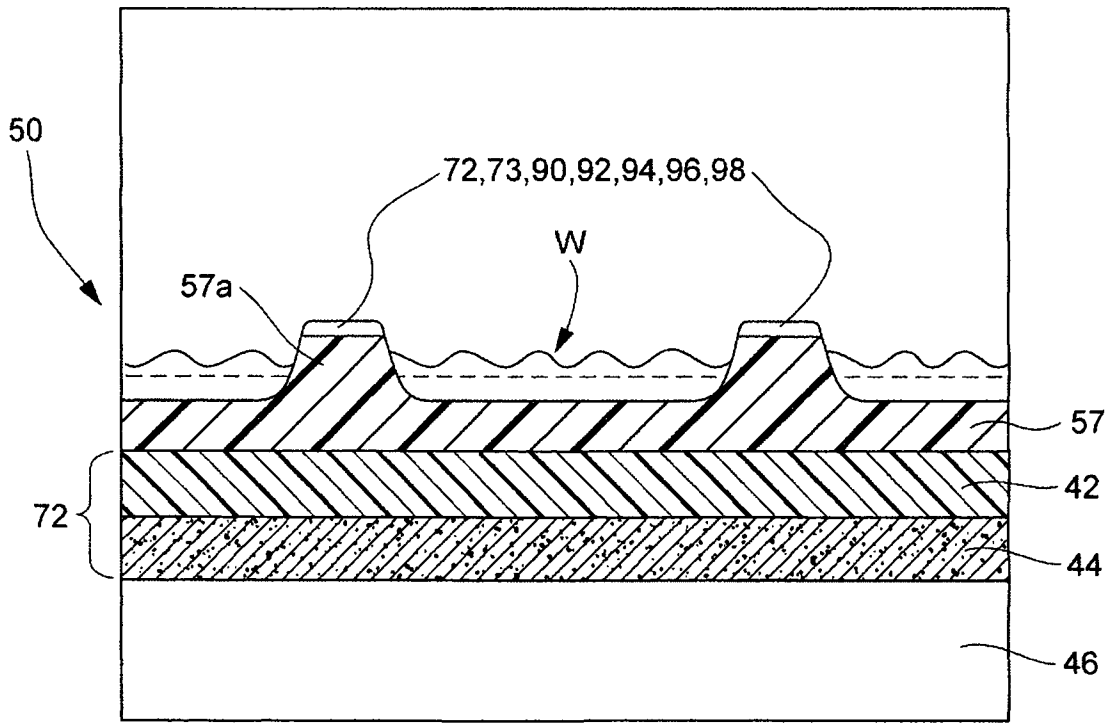
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Fig. 17

Fig. 18

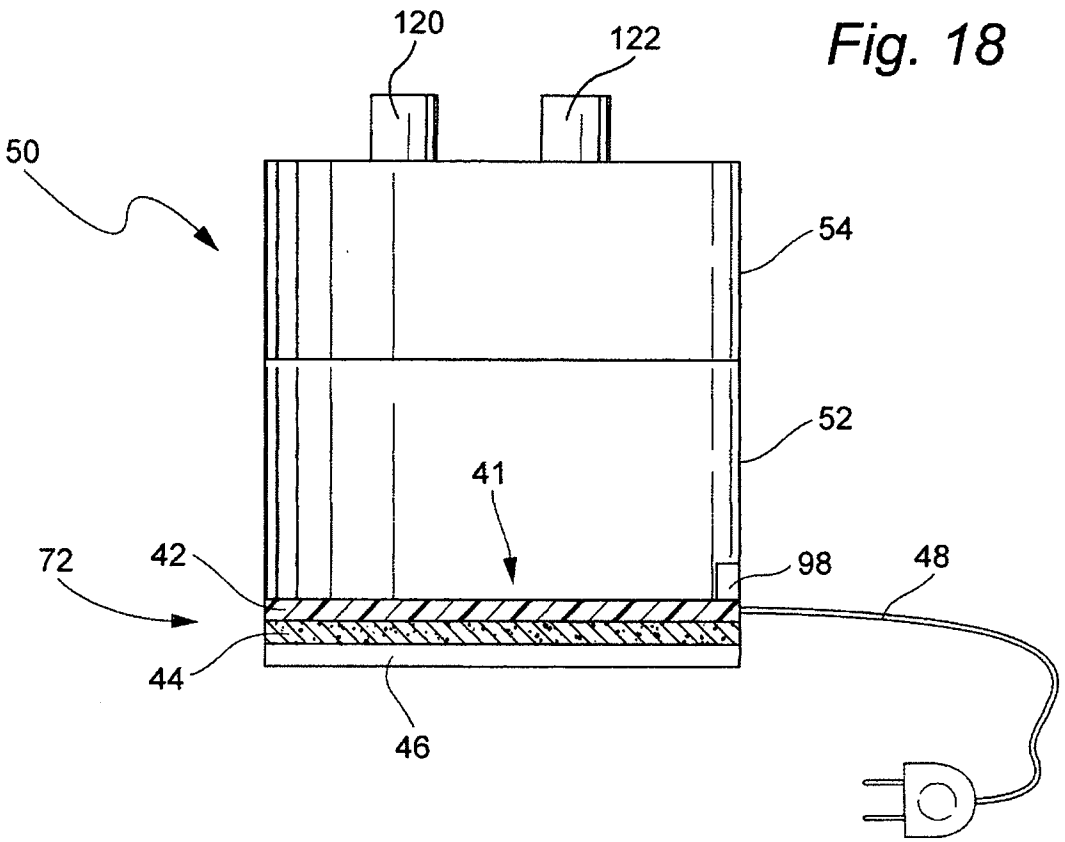
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Fig. 19

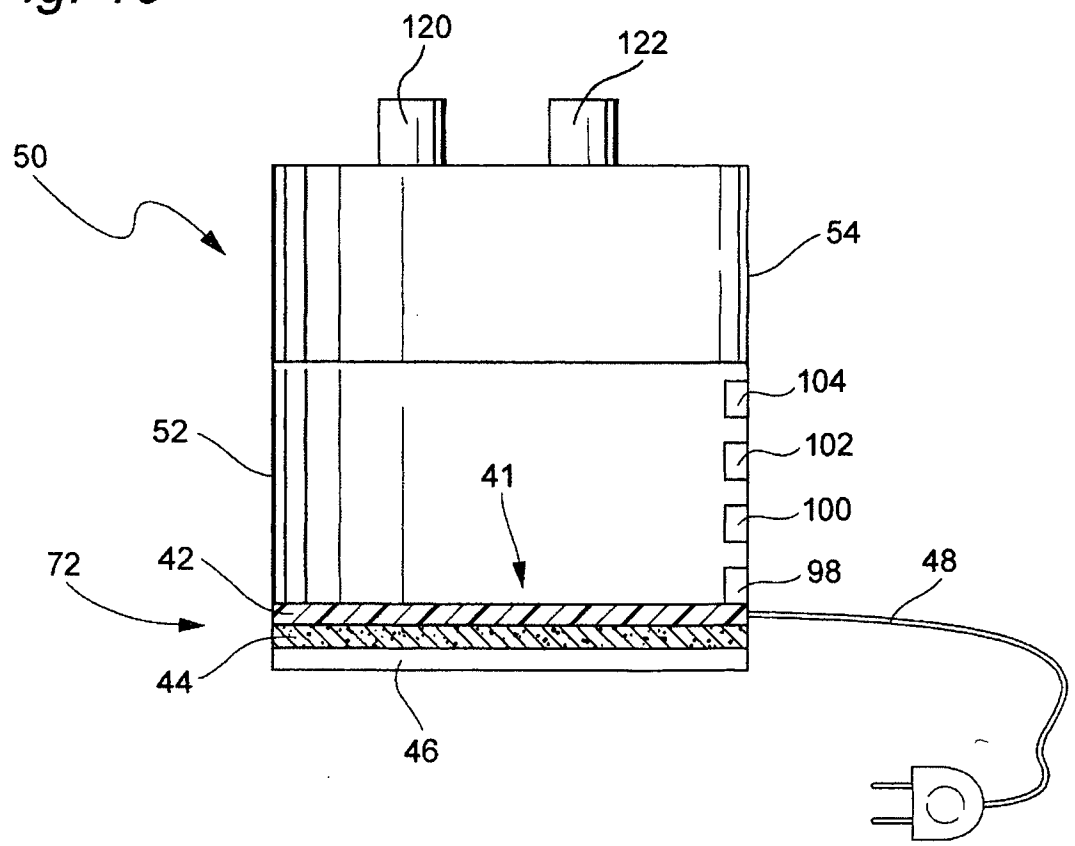
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Fig. 20

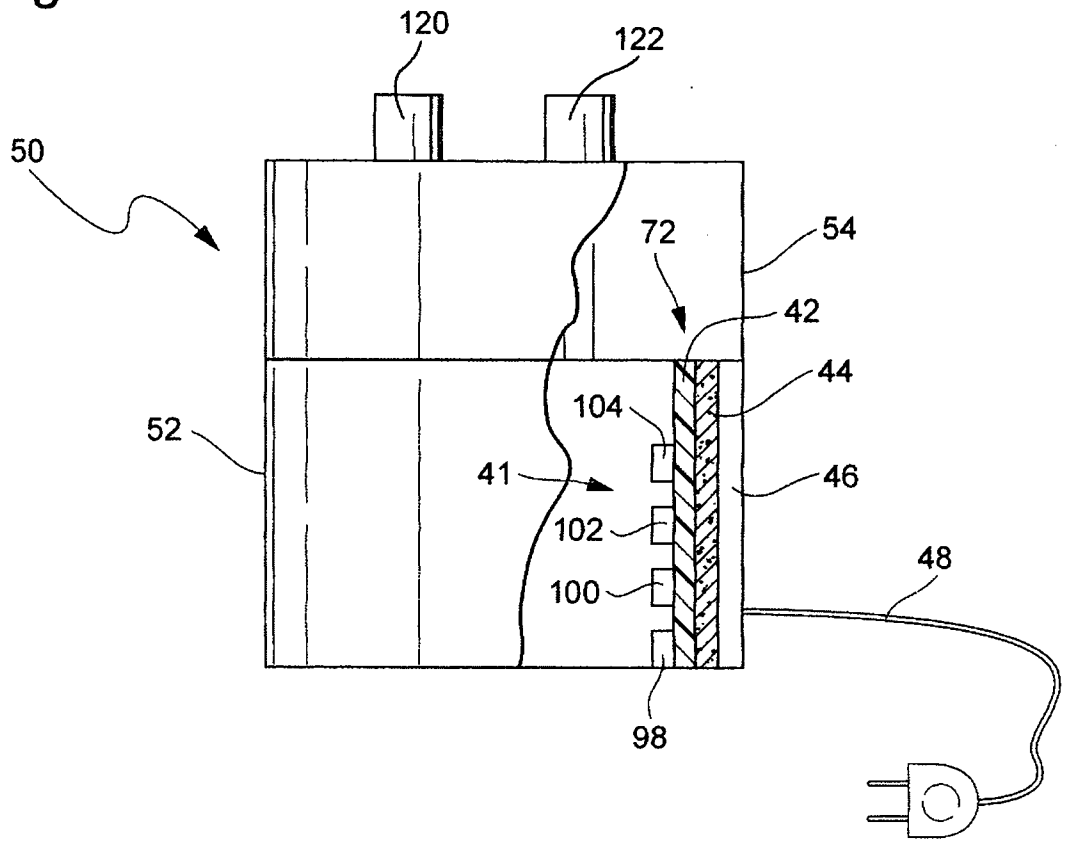
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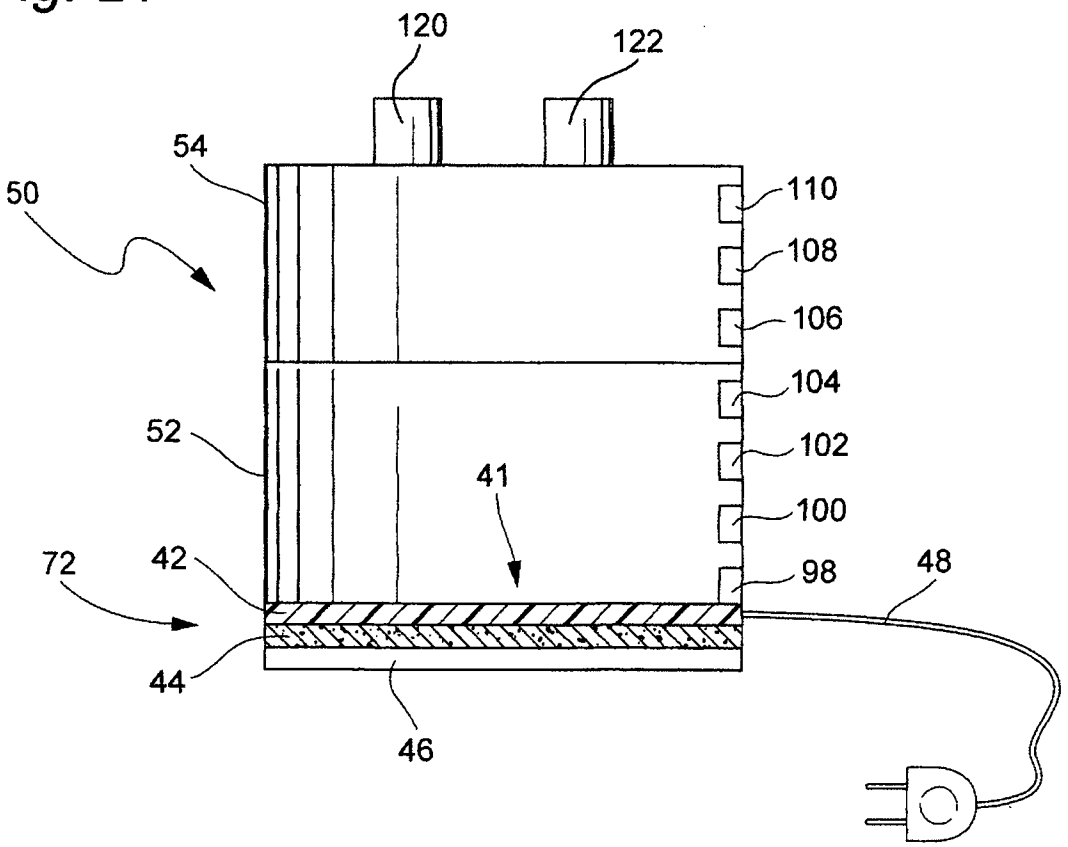
Fig. 21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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000799

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H05B 3/46 (2006.01) ***A61M 16/16*** (2006.01) ***H05B 3/48*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI, EPODOC, JAPIO, TXTEP1, TXTUS0, TXTUS1, TXTUS2, TXTUS3, TXTGB1, TXTWO1, TXTAU1, TXTCA1, Patentscope & keywords (humid+, respir+, PAP, heat+, element?, circuit?, co mo?ld, over mo?ld, insert mo?ld, forming, thermoplastic, tub?, jug?, polymer, film?, layer?, membrane? and similar words)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Patent Abstracts of Japan, JP 2006-151200 A (DENSO CORP) 15 June 2006 (machine translation retrieved, 30 July 2008 from internet) <URL: http://www4.ipdl.inpit.go.jp/Tokujitu/PAJdetail.ipdl?N0000=60&N0120=01&N2001=2&N3001=2006-151200> Abstract; figure 4, paragraphs 0004–0008, 0015–0016	1, 36–40, 46–49, 120–124
Y		44–45
X	FR 2856046 A1 (BIOMERIEUX Societé anonyme et al.) 17 December 2004 Abstract; figures 1A, 4; page 6, line 35, to page 8, line 19	1–8, 41–43, 46–49, 120
Y	As above	44–45, 53–119
X	US 2004/0155020 A1 (WORRELL et al.) 12 August 2004 Abstract; figures 3–4; paragraphs 0033–0077, 0088–0090, 0097, 0103	1–16, 21–52, 120–124
Y	As above	44–45, 53–119, 125–127

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
19 August 2008

Date of mailing of the international search report
26 AUG 2008

Name and mailing address of the ISA/AU

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000799

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	WO 2002/013578 A1 (WATLOW POLYMER TECHNOLOGY) 14 February 2002	
X	Abstract; figures 1–2, 6, 9A, 9D, 11D, 11F; page 9, lines 10–31; page 15, line 9, to page 28, line 25	1–20, 22–43, 46–52 120–124
Y	As above	44–45, 53–119
	WO 1997/039667 A1 (THERMION SYSTEMS INTERNATIONAL) 30 October 1997	
X	Abstract; figure 1; page 2, line 19, to page 4, line 28	1–8, 31–40, 46–52, 120–124
Y	As above	44–45, 53–119, 125–127
	EP 1369141 A1 (FISHER & PAYKEL HEALTHCARE LIMITED) 3 June 2003	
Y	Abstract; figures 1–5; paragraphs 0002, 0005, 0008–0012, 0018–0033	44–45, 53–119, 125–127
	US 5432322 A (INGRAM et al.) 11 July 1995	
A	Abstract; figure 2–3; column 2, lines 26–54	
	Note on the Y indications: EP 1369141 can be combined with any one of JP 2006-151200, FR 2856046, US 2004/0155020, WO 2002/013578 or WO 1997/039667 with respect to the claims shown above.	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2008/000799

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
JP	2006151200	NONE					
FR	2856046	EP	1633988	US	7159618	US	2006180223
		WO	2004113735				
US	2004155020	US	7019261				
WO	0213578	AU	49915/01	AU	78146/01	US	6392206
		US	6433317	US	6748646	US	2002088111
		WO	0178457				
WO	9739667	CA	2251950	EP	0959749	US	5981911
EP	1369141	AU	2003204474	CA	2431283	US	6953354
		US	2003236015				
US	5432322	AU	57268/94	EP	0746962	WO	9412004

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX