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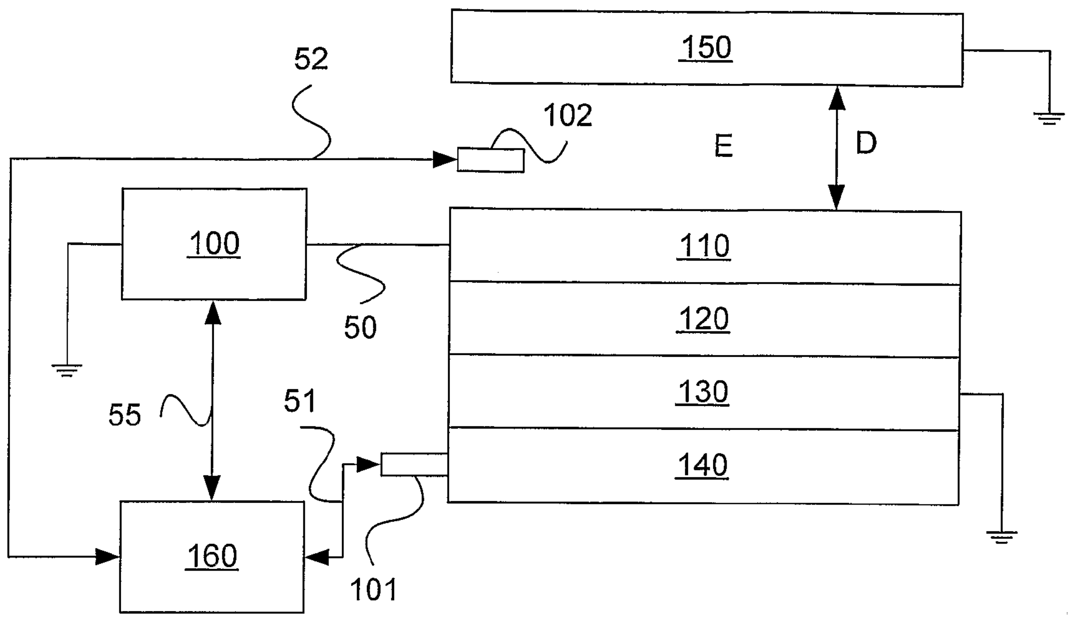
(54) Title: ARRANGEMENT AND METHOD FOR INCREASING HEAT TRANSFER



(57) Abstract: The invention relates to an arrangement comprising at least one heat source (140) being adapted to transfer heat to at least one first element (110), a power source (100) being provided for applying a first voltage (V1) to said first element (110), at least one second element (150) having a second voltage (V2), wherein an electric field (E), generated by a potential difference (V1-V2), between the first element (110) and the second element (150), causes an ionized medium, heated by the first element (110), to move towards the second element (150), thereby achieving an increased heat transfer from the first element (110).

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Arrangement and method for increasing heat transfer

Field of the invention

The invention relates in general to an arrangement and method for cooling a heat source and more particularly to an arrangement comprising a power source.

Furthermore, the invention relates to software adapted to perform a method for cooling a heat source when executed on a computer.

Even further, the invention relates to the use of such a system.

Background of the invention

Today, cooling techniques are widely used for cooling heated objects or heat sources such as electronic components, CPUs, etc. At least two different techniques are used for the purpose of transferring heat from a heat source.

Corona or ion wind cooling techniques refer essentially to the movement of gas induced by collisions between ions away from the vicinity of a high voltage discharge electrode and the surrounding volume of gas. In ion wind cooling systems a wind is created, which is similar to that created by a fan.

Another cooling technique is described in US 3,872,917. In US 3,872,917 there is depicted how a flow of ionized air from a sharp high voltage electrode to a grounded heat source is created. The ionized air flows towards the heat source and creates a forced convection effect similar to that of a fan.

When the ionized air comes into contact with the heat source it may deposit particles onto the heat source. This effect is known as the black-wall effect and is a common problem found in air ionizers, where after a short period of time there is a residue build up on the collector electrode. This residue build up will act as thermal insulation, and severely limit the heat transfer co-efficient over a short period of time.

The ionized air becomes neutralised as it comes into contact with the grounded heat source and this results in an exiting flow of neutralised air molecules that carry heat away from the heat source in a random direction. This disadvantageously creates a multitude of design problems.

Further, the system according to US 3,872,917 is difficult to employ in real applications, such as electronics cooling, because of non-containment of electric fields, increased space requirements, and complex positioning of components to make sure that ionized air flow to the heat source and not to any other component by accident.

Furthermore, the system according to US 3,872,917 suffers from the disadvantage of metal emission that occurs at sharp points on high voltage electrodes, which requires unneeded maintenance of the system.

Summary of the invention

One aspect of the present invention relates to the problem of improving heat transfer from a heat source. More particularly, according to an aspect of the invention, the present invention relates to the problem of improving heat transfer from a heat source in a cost effective way.

This problem is solved by an arrangement comprising at least one heat source being adapted to transfer heat to at least one first element, a power source being provided for applying a first voltage to said first element, at least one second element having a second voltage, wherein an electric field, generated by a potential difference, between the first element and the second element, causes an ionized medium, heated by the first element, to move towards the second element, thereby achieving an increased heat transfer from the first element.

This solution effectively eliminates dust and particle collection on the heat source being cooled and can therefore prolong the cooling efficiency of the arrangement. The arrangement is thus self cleaning. This provides the positive effect that objects, such as components, which are cooled, are not negatively influenced by a polluted environment. Furthermore, as a synergy effect, the arrangement reduces or eliminates the build up of heat on surrounding components.

The arrangement advantageously provides uniform cooling over a surface area of the first element. This reduces hot spots and decreases thermal stresses on the heat source being cooled.

Advantageously, low cost materials are used, which together with low energy consumption provides a cost effective method for improving heat transfer from the heat source. Furthermore, the construction of the arrangement is simple and easy to implement into production lines. The arrangement requires low to no maintenance and also has longevity.

The arrangement can be utilized so that the movement of the ionized medium causes repulsion of a thermal boundary layer on a surface of the first element, thereby further increasing the heat transfer from the first element.

Another advantage of the present invention is the flexibility of the arrangement's design. It can be manufactured to cool small micro-processors and can also be used in large industrial cooling applications, including all shapes and sizes in between, including the cooling of irregularly-shaped surfaces. If, for example, fans are used in large or complex applications, multiple fans are required, increasing design complexity and causing an associated increase in production time and cost.

The arrangement can further be configured so that a control unit is arranged to control the potential difference between the first and second element, increasing heat transfer from the first element.

Preferably said the arrangement further comprises a dielectric element. Preferably said first element is electrically conductive.

Preferably the first voltage is applied to the first element, and the first element is separated from the heat source by the dielectric element.

Preferably the heat source is provided with a conductive protection element provided between the heat source and the dielectric element.

Preferably the second element is arranged so that the heat transfer is performed in a controlled way, in at least one particular direction.

Preferably the second element is grounded.

Preferably the applied first voltage is in the range of 1-100 kV.

Preferably the arrangement further comprises a control unit arranged for communication with the power supply and/or the second element, wherein the control unit is arranged to control the potential difference between the first element and the second element.

The arrangement is silent when used, which is preferable, for example, in areas where people live or work.

The arrangement can easily be integrated into existing cooling applications, which use, for example, a fan for cooling a heat source. It can further operate independently or be integrated into existing cooling applications. In fact, a previously-provided fan can be used for transporting an ionized heated medium from the surface of the first element. Even further, a medium being partly ionized can be supplied to the surface of the first element where it is heated and thereafter transferred from said surface, thereby enhancing efficiency of the heat transfer from the heat source.

According to one embodiment the heat transfer can be accurately regulated. This is particularly advantageous when the arrangement according to the invention is applied to systems where the heat source is sensitive for temperature variations.

According to one aspect of the invention the high voltage potential applied to the heat source, combined with the force of the electric field, causes electrons thermionic emission to occur at relatively low temperatures of the heat source.

Advantageously no black-wall effect occurs on the heat source, because ionized air is not flowing towards the heat source.

Additional objects, advantages and novel features of the present invention will become apparent to those skilled in the art from the following details, as well as by practice of the invention. While the invention is described below, it should be understood that the invention is not limited to the specific details disclosed. The above-mentioned skilled persons having access to the teachings herein will recognise additional applications, modifications and embodiments in other fields, which are within the scope of the invention.

Brief description of the drawings

For a more complete understanding of the present invention and further objects and advantages thereof, reference is now made to the following description of examples - as shown in the accompanying drawings, in which:

Figure 1 schematically illustrates a cross-section view of an arrangement for heat transfer according to an aspect of the invention.

Figure 2 illustrates an arrangement for cooling a heat source according to an aspect of the invention.

Figure 3 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 4 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 5 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 6 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 7 illustrates an arrangement for removing heat from at least heat source according to an aspect of the invention.

Figure 8 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 9 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 10 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 11 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 12 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 13 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 14 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 15 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 16 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 17 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 18 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 19 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 20 illustrates an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 21 is a graph illustrating cooling efficiency of an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 22 is a graph illustrating cooling efficiency of an arrangement for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 23a illustrates a flow chart of a method for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 23b illustrates a flow chart of a method for increasing heat transfer from a heat source according to an aspect of the invention.

Figure 24 illustrates an apparatus according to an aspect of the invention.

Detailed description of the drawings

Figure 1 schematically illustrates a cross-section view of an arrangement for heat transfer according to an aspect of the invention.

A heat source 140 is thermally coupled to a first element 110. A dielectric element 120 is provided with the first element 110 on a first side thereof. The dielectric element 120 is provided with a third element 130 on a second side thereof. The dielectric element is provided between the heat source 140 and the first element 110. The third element 130 is thermally coupled to the heat source 140.

According to one embodiment the first element 110 is a conductive layer, which is provided on at least a part of the first side of the dielectric element 120. The first element 110 is electrically conductive. The first element 110 is a metal, alloy or an electrically conductive material, such as stainless steel, conductive paint comprising for example silver Ag, cast iron, Al, Zn or other. The first element 110 can be attached to the dielectric element by means of spray coating, sputtering, moulding, stamping, plating, brazing, metallization, welding, thermal glue or other. The dielectric element 120 is arranged to transfer heat from the heat source 140 to the first element 110. The dielectric element 120 is also arranged to insulate the heat source 140 from the high voltage applied to the first element 110.

The dielectric element 120 is provided with the third element 130 on at least a portion of the second side thereof. The third element 130 is electrically conductive. The third element 130 may have the same composition as the first element 110. The third element 130 can be attached to the dielectric element by means of spray coating, sputtering, moulding, stamping, welding, thermal glue or other. The dielectric element 120 is a solid, such as glass, dielectric refrigerant, plastic or an oxide of various metals, e.g. aluminium oxide. Alternatively the dielectric element is a combination of any dielectric materials. Alternatively, the dielectric element comprises a liquid or gas, such as dry air or distilled water, flourinert liquid or mineral or synthetic oil.

The dielectric material, according to an embodiment of the invention, is composed of a ceramic material like Aluminium Nitride, Aluminium Oxide, Boron Nitride, Magnesium Oxide, or Silicon Nitride.

Alternatively, the dielectric material, according to another embodiment of the invention, is composed of a compound comprising material of good thermal conductivity and a material of low electric conductivity, such as Boron Nitride powder mixed with polyester or epoxy.

The dielectric element can be a diamond wafer. The dielectric element may consist of composites like Diamond/Copper or Diamond/Silicon.

The heat source 140, the third element 130, the dielectric element 120 and the first element 110 are arranged for heat transfer from the heat source 140 to the first element 110 via the third element 130 and the dielectric element 120.

A second element 150 is provided at a distance D from an assembly comprising parts 110, 120, 130 and 140. D is a length between the first element and the second element 150. The distance D may be chosen with reference to a specific application, in which a method according to the invention is to be used. The distance D between the first element 110 and the second element 150 is preferably slightly greater than that at which arching would occur for a particular potential difference V1-V2 between the first element 110 and the second element 150. According to one embodiment the distance D is 1cm. According to another embodiment the distance D is variable between 0.5 and 5cm. It should however be noted that the second element 150 is separated from the assembly comprising parts 110, 120, 130 and 140. In particular the second part 150 is separated from the first element 110. Alternatively, the second part 150 is a portion of an earthed enclosure, which is described below with reference to Fig. 17.

According to one embodiment the second element 150 is rotating around at least one axis. The second element can be a wheel or a conveyor belt. According to another embodiment the heat source is rotating around at least one axis. According to one embodiment the second element 150 is one or more wires.

According to on embodiment the second element 150 is grounded. The third element 130 is also grounded.

Dimensions and sizes of the heat source 140 and the elements with reference to 110, 120, 130 and 150 may vary within wide ranges. For example, the heat source 140 and the elements depicted with reference to 110, 120, 130 and 150 may be plate shaped, as illustrated with reference to Fig. 1, for illustrative purposes, wherein the elements 130,120 and 110 are piled on the heat source 140. According to another embodiment the elements are block shaped or cylindrical, or a combination thereof. The elements may be irregularly shaped. Depending upon which application the arrangement is provided for a unique design may be applied.

A power source 100 is connected to the first element 110 via a wire 50. Alternatively a line 50 can be used. The power source 100 is adapted to provide a direct current high voltage V1 to the first element 110. Alternatively the power source 100 is adapted to provide a direct current high pulse voltage to the first element 110. The power source 100 is, according to one embodiment, a low amperage power source.

The power source 100 comprises a current limiter, which is a short-circuit protection device that automatically limits the current to a safe value. This is done when a current-limiting transistor senses an increase in load current. At this time the current-limiting transistor decreases the voltage on the base of a pass transistor in a regulator, causing a decrease in its conduction.

The applied voltage V1 is provided so as to ionize a medium provided between the first element 110 and the second element 150. In particular a part of the medium is ionized at the first element 110. More in particular, a part of the medium is ionized within the thermal boundary layer provided at the surface of the first element 110. A part of the medium is ionized within a laminar layer of the thermal boundary layer provided at the surface of the first element 110. This will be described in further detail below.

The medium can be any medium which can be ionized between the first element 110 and the second element 150 and thereby be transported within the electric field in a direction away from the first element 110. Preferably the medium is air.

A first sensor 101 is adapted for communication with a control unit 160 via a line 51. The first sensor 101 is a temperature sensor adapted to measure a temperature T1 of the heat source 140. Alternatively the first sensor 101 is adapted to indirectly measure temperature T1 at the third layer 130. This is an indicative measurement of the actual temperature T1 of the heat source 140. The first sensor is adapted to communicate the measured value T1 to the control unit 100.

A second sensor 102 is adapted for communication with a control unit 160 via a line 52. The second sensor 102 is a volume flow sensor adapted to measure a volume flow of the medium provided between the first element 110 and the second element 150. Alternatively the second sensor 102 is adapted to detect mass flow of the medium provided between the first element 110 and the second element 150. Alternatively the second sensor 102 is a temperature sensor adapted to measure a temperature T2 of the medium. The temperature T2 of the medium is an indirect indication of a temperature of the heat source 140. The second sensor is adapted to communicate a measured value of a quantity or quality, as described above, to the control unit 160 via the line 52. One quantity can be pressure. By measuring the pressure P between the first element 110 and the second element 150, an indication of a corresponding mass flow or volume flow can be calculated. The calculation can be performed in the control unit 160. According to one embodiment the second sensor 102 is arranged to measure a speed of the medium being transferred from the first element 110 towards the second element 150.

As mentioned the third element 130 is grounded. The purpose of this is to protect the heat source 140 from possible capacitive discharge or static discharge within the arrangement.

The dielectric element 120 is adapted to serve as a barrier between the electrically conductive first element 110 and the heat source 140, so as to protect the heat source 140 from possible corona discharge.

The heat source 140 can be any of a variety of different objects. For instance, according to one embodiment of the invention, the heat source is a central processing unit (CPU) or a chip provided in any apparatus, e.g. a computer, such as a micro-computer or a stationary PC or a laptop, CD player, DVD-player, TV, video player (such as VHS), game pad, multimedia box, or other stationary, portable or hand held devices.

The heat source can be a condenser, capacitor, or radiator, either in the sphere of industry or in everyday situations. The heat source can be part of a Peltier element. The heat source can be provided by a heat pipe or a plurality of heat pipes as will be described in further detail below. The heat source 140 can be a thermosyphon or a condenser in a water cooling system.

The heat source 140 can be provided in a heat pump, freezer, refrigerator, microwave oven, thermo-electrical refrigerator, or projector, such as an overhead, slide, or digital projector.

The heat source 140 can be used in cellular phone applications or within a radio base station, telephone switchboard, telephone exchange or teletype exchange.

Furthermore, the heat source 140 may be integrated in an air conditioning system, e.g. in a house, airplane or automobile.

Alternatively, the heat source is an electronic component such as a resistance, bobbin or iron core coil.

Alternatively, the heat source is an engine. Alternatively, the heat source is provided in a brake system in, for example, an automobile.

Alternatively, the heat source is a part of a resistor element used for heating a surrounding medium.
The power source 100 is arranged to provide the voltage V1 to the first element 110. The voltage V1 is in the range of 1-100 kV. According to one embodiment V1 is in the range 10-50 kV. According to another embodiment V1 is in the range 30-40kV.

Herein it is described that the elements 130 and 150, respectively, are set to ground. An alternative term for ground is earth. The ground can be a specified, by a user chosen voltage. Ground preferably has a voltage of 0V. The voltage applied to the second element is a voltage V2. According to one embodiment V2 is equal to 0V. According to another embodiment V2 is equal to +5V. According to yet another embodiment V2 is equal to -5V. According to yet another embodiment V2 varies in the range between -100V to +100V. According to one embodiment the voltage V2 is controllable by the control unit 160.

The control unit 160 is adapted to control the power source 100 via a line 55. The control unit 160 is arranged to control the power source 100 in dependence of a first signal S1. The control unit 160 is arranged to control the power source 100 in dependence of a second signal S2. Alternatively, the control unit 160 is arranged to control the power source 100 in dependence of both the first signal S1 and the second signal S2. The control unit 160 is arranged to control the applied voltage provided between the first element 110 and the second element 150 in a predetermined way. For example the control unit 160 is arranged to regulate the heat transfer from the first element 110. This can be made in various ways. One way is to transfer heat from the first element 110 to keep the temperature T1 of the heat source at a constant level, for example 50 degrees Celsius, or 100 degrees Celsius.

With reference to Figures 2- 20 alternative arrangements of the present invention are described. The arrangements can be used in combinations for specific applications and are thus not limited to schematic illustrations as indicated in said figures.

A process of transferring heat from the heat source 140 to the first element 110 and/or from the first element to the ambient medium is known as cooling or heat transfer.

As high voltage is applied to the first element 110 from the high voltage power source 100, there is a direct injection of free charges into the ambient medium, known as ionization. Furthermore, the ambient medium that is in direct contact with the first element 110 becomes ionized, causing the laminar thermal boundary layer surrounding the first element 110 to become ionized and, consequently repelled, by coulombic forces, away from the first element. This results in a disturbance of the lower laminar thermal boundary located directly at the surface of the first element 110, thereby improving heat transfer since no protecting laminar thermal boundary layer is provided.

Figure 2 illustrates an embodiment of an arrangement for cooling a heat source according to an aspect of the invention. Figure 2 illustrates an alternative assembly of the arrangement illustrated in Figure 1. Here no grounded electrically conductive layer 130 is provided. The heat source 140 is grounded.

The second element 150, according to this embodiment, is provided with a coating 152, which functions as a catalyst. According to this embodiment the catalyst is gold (Au). Alternatively the catalyst can comprise Silver (Ag), Platinum (Pt) or Manganese Dioxide (MnO2).

The coating 152 may alternatively be composed of Activated Carbon coatings, Manganese Oxide, Iodonium or Titanium Dioxide.

The coating 152 is provided on the second element 150 so as to reduce an amount of ozone created within the electric field E, for example in a case where the medium is air. The ozone created in the electric field E is moved towards the second element 150, and thereby the coating 152, by the ionized medium. At least a part of the ozone is converted to oxygen by the catalyst.

According to this embodiment the heat source 140 and the second element 150 are set to the same ground.

Figure 3 illustrates an embodiment of an arrangement for cooling a heat source according to an aspect of the invention.

This arrangement is similar to the system presented in Figure 1. However, the first element 110 on the first side of the dielectric medium 120 is provided with elongated elements 300. The elongated elements 300 have an elongated shape. The elongated elements 300 are attached to the first element 110 at one end thereof. The pin elements can be pin-like or needle-like. The elongated elements 300 can either form part of the first element 110 by being integrated moulded, or being fixedly secured to the layer 110 by, for example, a welding process. Preferably the elongated members are composed of essentially the same material as the layer 110.

The elongated elements 300 are oriented perpendicular to the first surface of the first element 110. A length axis of the elongated elements 300, respectively, is aligned with a direction pointing towards the second element 150 from the first element 110.

A configuration of the elongated elements 300 may vary. For example one elongated element 300 per square cm is provided on the first element 110. The configuration of the elongated elements 300 may be tailored.

It should be noted that a surface structure of the first element 110 may vary. For example, it can be roughened or contain holes. Alternatively, considering the elongated elements provided on the first element 110, elements having a semi-spherical shape can be attached to the first element 110, wherein a flat section thereof is attached to the surface of the first element 110.

According to one embodiment the first element 110 is a heat sink. A heat sink structure makes it is possible to transfer more heat from the first element 110. An increased heat dissipation of its surface, by virtue of the fact that there is an increased surface area, is enabled.

The second element 150 may be provided with elongated elements 302. The elongated elements 302 may essentially be equivalent to the elongated elements 300. The size of both the elements 300 and 302, respectively, may not be uniform but vary some. The elongated elements 302 are attached to the second element 150 in a way similar to how the elongated elements 300 are attached to the first element 110.

It should be noted that a surface structure of the second element 150 may vary. For example, it can be roughened or contain holes 153. According to one embodiment the holes are through holes. According to one embodiment the second element is provided with a plurality of apertures. Two holes 153 are illustrated in the figure.

The through holes are adapted to lead the moving medium from one side of the second element 150 to another side of the second element 150. Thereby the heated medium is transferred away from the heat source 140.

Figure 4 illustrates an embodiment of an arrangement for cooling a heat source according to an aspect of the invention.

An arrangement with reference to Figure 4 illustrates a fan which is provided so as to achieve a positive synergy effect of different aspects of heat transfer, namely to increase movement of the ionized heated medium towards the second element 150 from the first element 110.

As illustrated in the figure the second element 150 is provided in a vicinity of the first element 110 at a first side thereof. The fan 460 is provided at a second side of the first element 110.

Figure 5 illustrates an embodiment of an arrangement for cooling of a heat source according to an aspect of the invention.

The fan 460 is arranged to move the ionized heated medium from the first element 110 through holes provided in the second element 150 (not shown) by having a rotating direction enabling increased heat transfer from the first element 110.

Now referring to Figure 6, which illustrates an alternative embodiment of an arrangement for removing heat from a heat source according to an aspect of the invention, the fan 460 causes an increased transfer of the ionized heated medium from the first element 110 towards the second element 150, through the holes provided therein and away from the second element 150.

Figure 7 illustrates an embodiment of an arrangement for removing heat from at least heat source according to an aspect of the invention.

According to this embodiment of the invention a plurality of heat sources 140a, 140b and 140c are provided. It should be noted that the heat source 140c is not in physical contact with the third element as depicted with reference to for example Figure 1. Heat is transferred via convection or radiation from the heat source 140c to the third element 130 and the dielectric layer, and thus to the first element 110, via a medium provided around the heat source 140c.

According to one embodiment the arrangement comprises 10 heat sources 140a-j (not shown), which are cooled off according to the present invention.

Figure 8 illustrates an embodiment of an arrangement for removing heat from at least one heat source according to an aspect of the invention.

The arrangement comprises a plurality of heat sources 140a-c and two first element 110a and 110b. The power source 100 is arranged to provide a voltage V1a to the first element 110a via a wire 50a. The power source 100 is arranged to provide a voltage V1b to the first element 110b via a wire 50b.

According to one embodiment of the voltages V1a and V1b are equal. According to another embodiment the voltages V1a and V1b are mutually different. According to yet another embodiment the voltages V1a and V1b are independently controlled by the controller 160 (not shown) by means of the power source 100.

Figure 9 illustrates the embodiment of an arrangement for removing heat from several heat sources according to an embodiment of the invention.

Herein three heat sources 140a-c are to be cooled. The dielectric element 120 is provided with two first elements 110a and 110b connected to the power source 100 via wire 50a and 50b, respectively. Two second elements 150a and 150b are provided. The power source 100 is adapted to apply a second voltage V2a to the second element 150a via a line 152a. The power source 100 is adapted to apply a second voltage V2b to the second element 150b via a line 152b. The power source 100 is adapted to apply a first voltage V1a to the first element 110a via the line 50a. The power source 100 is adapted to apply a first voltage V1b to the first element 110b via the line 50b.

The control unit 160 is arranged to control the power source 100 via the wire 55. The control unit is arranged to control the first voltages V1a, V1b and the second voltages V2a, V2b. The control of the voltages V1a, V1b, V2a and V2b can be performed simultaneously. The control of the voltages V1a, V1b, V2a and V2b can be performed independently of each other. The control of the voltages V1a, V1b, V2a and V2b can be performed in dependence of measured information, such as a temperature T4 measured at the first element 110a by a temperature sensor 104. The temperature sensor 104 is adapted for communication with the control unit 160 by a line 54.

Thus, the control unit 160 can control heat transfer from the first elements 110a and 110b towards the second elements 150a and 150b by controlling the power source 100 to apply the voltages V1a, V1b, V2a and V2b as described above.

Figure 10 illustrates the embodiment of an arrangement for removing heat from a heat source according to an embodiment of the invention.

Two additional second elements 150c and 150d are provided on the dielectric element 120. The elements 150c and 150d are grounded. The heat source 140 is grounded. The elements 150c and 150d are provided so as to direct a flow of the ionized medium in specific directions and thus serve as a complement to the second element 150. According to one embodiment the second elements 150c and 150d are elongated.

According to one embodiment the element 150c and 150d are replaced by a cylinder 150e (not shown) provided around the first element 110. The cylinder 150e is provided on the dielectric element120.

Figure 11 illustrates the embodiment of an arrangement for removing heat from a heat source with reference to Figure 1.

Herein an illustration of the electric field is shown. As can be seen the electric field E according to this embodiment is essentially homogeneous between the first element 110 and the second element 150.

In contrast, Figure 12 illustrates an embodiment of an arrangement for removing heat from a heat source according to an aspect of the invention wherein an in-homogeneous electric field E is generated between the first element 110 and the second element 150 by applying a high voltage to the first element 110, while the second element 150 is earthed. Herein the second element 150 is relatively small in size compared with the first element 110. According to this embodiment the second element 150 is elongated or needle-shaped.

Figure 13 illustrates an embodiment of an arrangement for transferring heat from a heat source according to an aspect of the invention.

A heat pipe 170 is attached to the heat source 140 at a first end thereof. The heat pipe is earthed. The heat pipe is arranged to transfer heat, which heat is provided from the heat source. The heat pipe 170 is arranged to transfer heat from the first end to a second end. At the second end of the heat pipe the dielectric element 120 is provided. The first element 110 is in conductive contact with the dielectric element 120. The first element 110 is a heat sink.

The second element 150 is forming an earthen enclosure around the first element 110. The second element is preferably provided with a plurality of through holes. When applying a high voltage V1 to the first element 110 by means of the power source 100 a movement of the ionized medium heated by the first element 110 is created. The heated ionized medium moves towards the second element and creates a volume flow through the holes in the second medium 150, thereby transferring heat from the first element 110.

Figure 14 illustrates an embodiment of an arrangement for removing heat from a heat source according to an aspect of the invention.

The heat pipe 170 is thermally coupled to the heat source 140 at a first end thereof. The heat pipe is earthed. The heat pipe 170 is arranged to transfer heat from the first end, which heat is provided from the heat source, to a second end thereof according to a commonly known operation. At the second end of the heat pipe the dielectric element 120 is provided. The first element 110 is in thermal contact with the dielectric element 120. According to one embodiment the first element 110 is a plate.

Figure 15 illustrates an embodiment of an arrangement for removing heat from a heat source according to an aspect of the invention.

The dielectric element 175 and a dielectric fluid provided inside the heat pipe will serve as an insulator protecting against arching from the first element 110 and the heat source 140.

The arrangement is essentially identical to the arrangement with reference to Figure 13. However, the heat pipe 170 is provided with a dielectric element 175. The heat pipe provided with the dielectric element 175 is depicted in greater detail below. The dielectric element 120 is not provided.

Figure 16 schematically illustrates a heat pipe provided with a the first element 110 according to an aspect of the invention.

The heat pipe 170 is arranged to transfer heat from the heat source 140 (not shown) from a first end to a second end thereof. The second end is provided with the first element 110. The can be manufactured out of a conductive material such as Cupper Cu. The first element 110 can be a heat sink.

A dielectric element 175 is arranged between the first and second end of the heat pipe

Figure 17 illustrates an embodiment of an arrangement for removing heat from a heat source according to an aspect of the invention.

The dielectric medium 120 is thermally coupled to the third element 130. The third element 130 is earthed. The third element 130 is formed as a closure open in one end, as shown in the figure. Alternatively the third element 130 is a closure comprising the depicted parts but the heat source 140. The heat source 110 is in thermal contact with one side of the third element 130, which is analogue to the teachings with reference to figures described above. The first element 110 has a triangular shape seen in a cross-sectional view. The first element 110 is a cone. Alternatively, the first element 110 is a tetrahedron. Alternatively, the first element 110 is a spherical triangle. Alternatively, the first element 110 is a frustum of right cone.

The second element 150 is provided with a flange and is forming a cap. The second element 150 is provided with a plurality of through holes (not shown). The flange is composed of a dielectric material. The medium runs through the arrangement along a helically configured path, as can be seen in the figure. The medium is heated and ionized as described above and further transferred towards the second element 150.

Figure 18 illustrates an arrangement for transferring heat from a heat source according to an aspect of the invention.

Three distanced elongated elements 300a, 300b and 300c are provided on the first element 110, thereby creating separated electric fields E1, E2 and E3 respectively, when the first voltage V1 is applied to the first element 110.

Figure 19 illustrates an arrangement for transferring heat from a heat source according to an aspect of the invention.

A similar set up of the arrangement as depicted with reference to Figure 17 is shown in Figure 20. However, the medium has a flow directed from a base of the first element, along the surface of the first element 110, towards the second element 150. The ionization of the medium, as well as heat transfer from the first element 110 to the medium, takes place on or at the surface of the first element 110.

Herein the first element 110 is a prism. Alternatively, the first element is an elongated element having a triangular cross section area.

Figure 20 illustrates an arrangement for transferring heat from a heat source according to an aspect of the invention.

The arrangement illustrated in Figure 20 is essentially the same as the arrangement with reference to Figure 19. However, the arrangement according to Figure 20 is provided with an inlet pipe 250 adapted to lead the medium through the third element 130 towards the first element 110. Furthermore, the arrangement is provided with an outlet pipe 251 fixedly secured to the second element 150 at one end, which outlet pipe is adapted to lead the medium away from the second element 150.

Alternatively, the outlet pipe 251 and the inlet pipe 250 are detachable arranged.

Figure 21 illustrates two graphs NC1 and A1 indicating how the temperature T of the heat source varies per unit time t during cooling, according to one embodiment. It should be noted that cooling efficiency hereby disclosed are examples for illustrative purposes only. The graphs plot test data collected for two different cooling methods under essentially the same conditions, which is, for example, constant heating of the heat source 140 during cooling. The ambient temperature was 23 $^{\circ}C$. The applied voltage is 30kV, ground potential is 0V. The temperature T of the heat source was measured as a function of time t.

A first graph NC1 illustrates the case of natural convection. The temperature of the heat source stabilizes at a temperature T2 after t2 minutes.

A second graph A1 illustrates the case of cooling according to an embodiment of the present invention (Fig. 1). The temperature of the heated object stabilizes, or levels out, at a temperature T1 after t1 minutes. Here, an amount of cooling of the heat source 140 is essentially equal an amount of heat provided to the heat source 140.

In this particular case T1 is approximately 46 degrees Celsius and T2 is approximately 147 degrees Celsius. In this particular case t1 is approximately 7 minutes and t2 is approximately 35 minutes.

It should be noted that different efficiencies may be achieved under other conditions, i.e. when applying a higher voltage V1 to the first element 110.

Figure 22 illustrates cooling efficiency according to a test performed with reference to the set up according to Fig. 1. More particularly, Figure 22 illustrates two graphs NC2 and A2 indicating how the temperature T1 of the heat source 140 varies per unit time t during cooling. In this test the heat source 140 was heated to 150 degrees Celsius and thereafter cooled using natural convection (NC2). A second test was performed (graph A2) under essentially the same conditions but using the cooling method.

The temperature of the heat source stabilizes at a temperature T1 after t2 minutes.

A second graph A2 illustrates the case of cooling according to an embodiment of the present invention. The temperature of the heated object stabilizes, or levels out, at the temperature T1 after t1 minutes.

In this particular case, T0 is 150 degrees Celsius, T1 is about 35 degrees Celsius, t1 is about 7 minutes, and t2 is about 35 minutes.

Figure 23a schematically illustrates a method according to an embodiment of the invention. The method starts, then performs the step s230, and thereafter ends.

The method step s230 for improving heat transfer from at least one heat source in an arrangement comprising at least one first element and at least one second element;

wherein said heat source is adapted to transfer heat to said first element; said method comprising the step of:
-controlling heat transfer from the first element by applying an electric field between said first and second element.

According to one embodiment of the invention the method further comprises the step of:
-controlling said heat transfer is performed in a predetermined way so that a movement of ionized medium, heated by the first element, causes a thermal boundary layer provided on a surface of the first element to be repelled off, and thereby further increase the heat transfer from the first element.

According to another embodiment of the invention the method further comprises the steps of
-receiving a first signal comprising information about the heat transfer from the heat source, and
-controlling said heat transfer in dependence of said first signal.

According to yet another embodiment of the invention the method comprises the step of
-controlling said heat transfer by controlling said first or second provided voltage.

Figure 23b illustrates a flowchart for removing heat from an object according to an aspect of the invention.

According to a first method step s233 the first voltage V1 is applied to the first element 110 and the second voltage V2 is applied to the second element 150. Next, a method step 235 follows.

In method step 235 at least one temperature measurement is detected indicating the temperature of the heat source 140. Next, a method step 240 follows.

The method step 240 includes a choice of adjusting the applied voltages V1 and V2 or not. A decision is made in dependence of the temperature measurement according to step s235. If yes, a method step 245 follows. If no, a method step 250 follows.

The method step 245 includes adjustment of the applied voltages V1 and V2. Next, the method step 250 follows.

The method step 250 includes a choice of interrupting the method. If yes, the method ends. If no, the method step s235 follows.

With reference to Figure 24, a diagram of one way of embodying an apparatus 700 is shown. The above-mentioned control unit 160 may include the apparatus 700. The apparatus 700 comprises a non-volatile memory 720, a data processing device 730 and a read/write memory 740. The memory 720 has a first memory portion 750 wherein a computer program, such as an operating system, is stored for controlling the function of the apparatus 700. Further, the apparatus 700 comprises a bus controller, a serial communication port, I/O-means, an A/D-converter, a time date entry and transmission unit, an event counter and an interrupt controller (not shown).

The data processing device 730 may be embodied by, for example, a microprocessor.

The memory 720 also has a second memory portion 760. The program may be stored in an executable manner or in a compressed state.

When it is described that the data processing device 730 performs a certain function it should be understood that the data processing device 730 performs a certain part of the program which is stored in the memory 760 or a certain part of the program which is stored in the recording medium 762.

The data processing device 730 may communicate with a data port 799 by means of a data bus 783. The memory 720 is adapted for communication with the data bus 783 via data bus 785. The separate non-volatile recording medium 762 is adapted to communicate with the data processing device 730 via data bus 789. The read/write memory 740 is adapted to communicate with the data bus 783 via a data bus 785.

Parts of the methods described with reference to Figures 23a and 23b can be performed by the apparatus 700 by means of the data processing device 730 running the program stored in the memory portion 760. When the apparatus 700 runs the program, parts of the method described with reference to Figure 23a and/or Figure 23b are executed.

When data is received on the data port 799 said input data is temporarily stored in the read/write memory 740. When the received input data has been temporarily stored, the data processing device is set up to perform execution of code in a manner described above. According to one embodiment, data received on the data port 799 comprises information about heat transfer from the heat source. This information can be used by the apparatus 700 so as to control the applied voltage V1 and/or V2, which controls heat transfer from the heat source 140.

<u>Induced flows in a dielectric fluid provided between the grounded heat source 140 and the element 110</u>

According to one embodiment of the invention a dielectric fluid is provided between the heat source and the element 110. Thereby an increased heat transfer between the heat source 140 and the element 110 is achieved. By applying a high voltage to the element 110 an irregular electric field is generated between the grounded heat source 140 and the underside of the heat exchanger. Thereby regions of unequal field intensities causing a flow in the dielectric fluid are created.

Therefore, the dielectric fluid does not only acts as an insulating barrier, but also acts as a means to efficiently transfer heat to the heat exchanger without mechanical means, such as a pump.

Use of a dielectric fluid is particularly useful in applications involving cooling of a microchip or the like, since there today is an urgent need to spread the heat efficiently away from such a small surface area.

According to one embodiment of the invention, by using a dielectric enclosure between the heat exchanger and the heat source, there is created a strong flow within the fluid using electrohydrodynamic forces, which causes one or several means of creating motion within fluids. Thereby heat can be spread more efficiently away from the heat source by creating a turbulent motion in the dielectric fluid.

Application of a high voltage to the element 110 provided on the heat source 140 provides the synergy effect that there is created a fluid motion between the element 110 and the heat source140, while increased heat transfer from the element 110 is achieved.

One example of an application may be in the design of a peltier element where the ceramic plates may be replaced by using a dielectric fluid as insulating medium between the thermopiles and the underside of a heat exchanger. When high voltage is applied to the heat exchanger a motion can be generated in the dielectric medium to enhance heat transfer to the heat exchanger and then also to the grounded collector electrode.

Another example may be that of a heat source which may be located at some distance to the heat exchanger. The heat exchanger may be located at some distance away from the heat source for a number of reasons including, but not limited to, space requirements. Here a flow is generated in the dielectric liquid to transport heat effectively from the heat source to the heat exchanger. The heat exchanger has a high voltage applied to it and not only creates a flow in the dielectric element barrier but also increased heat transfer from the heat exchanger to the ambient air.

The foregoing description of the preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are suited to the particular use contemplated.

Claims

1. An arrangement comprising at least one heat source (140) being adapted to transfer heat to at least one first element (110), a power source (100) being provided for applying a first voltage (V1) to said first element (110), at least one second element (150) having a second voltage (V2), wherein an electric field (E), generated by a potential difference (V1-V2), between the first element (110) and the second element (150), causes an ionized medium, heated by the first element (110), to move towards the second element (150), thereby achieving an increased heat transfer from the first element (110).

2. An arrangement according to claim 1 wherein the arrangement further comprises a dielectric element (120).

3. An arrangement according to claim 1 or 2 wherein said first element (110) is electrically conductive.

4. An arrangement according to claim 2-3 wherein the first voltage (V1) is applied to the first element (110), and wherein the first element (110) is separated from the heat source by the dielectric element (120).

5. An arrangement according to any of claims 1-4 wherein the heat source is provided with a conductive protection element (130) provided between the heat source (140) and the dielectric element (120).

6. An arrangement according to any of claims 1-5 wherein the second element (150) is arranged so that the heat transfer is performed in a controlled way, in at least one particular direction.

7. An arrangement according to any of claims 1-6 wherein the second element (150) is grounded.

8. An arrangement according to any of claims 1-7 wherein the applied voltage V1 is in the range of 1-100 kV.

9. An arrangement according to claim 8 wherein the applied voltage V1 is in the range of 30-40 kV.

10. An arrangement according to any of the proceeding claims further comprising a control unit (160) arranged for communication with the power supply (100) and/or the second element (150), wherein the control unit (160) is arranged to control potential difference (V1-V2) between the first element (110) and the second element (150).

11. An arrangement according to any of the proceeding claims wherein the movement of the ionized medium causes a thermal boundary layer provided on a surface of the first element (110) to be repelled off, and thereby further increase the heat transfer from the first element (110).

12. An arrangement according to claim 10 wherein the control unit (160) is arranged to control the potential difference (V1-V2) between the first element (110) and the second element (150) so as to increase heat transfer from said first element (110).

13. Use of an arrangement comprising at least one heat source (140) being adapted to transfer heat to at least one first element (110), a power source (100) being provided for applying a first voltage (V1) to said first element (110), at least one second element (150) having a second voltage (V2), wherein an electric field (E), generated by a potential difference (V1-V2), between the first element (110) and the second element (150), causes an ionized medium, heated by the first element (110), to move towards the second element (150), thereby achieving an increased heat transfer from the first element (110).

14. Method for improving heat transfer from at least one heat source (140) in an arrangement comprising at least one first element (110) and at least one second element (150); wherein said heat source is adapted to transfer heat to said first element (110); said method comprising the step of:
-controlling heat transfer from the first element by applying an electric field between said first and second element.

15. Method according to claim 14 wherein the step of:
-controlling said heat transfer is performed in a predetermined way so that a movement of ionized medium, heated by the first element (110), causes a thermal boundary layer provided on a surface of the first element (110) to be repelled off, and thereby further increase the heat transfer from the first element (110).

16. Method according to claim 14 or 16 further comprising the steps of:
-receiving a first signal comprising information about the heat transfer from the heat source (140), and
-controlling said heat transfer in dependence of said first signal.

17. Method according to any of claims 14-16 comprising the step of:
-controlling said heat transfer by controlling said first or second provided voltage (V1, V2).

18 Computer programme comprising a programme code for performing the method steps of any of claims 14-17 when said computer programme is run on a computer.

19 Computer programme product directly storable in an internal memory of a computer, comprising a computer programme for performing the method steps according to any of claims 14-17, when said computer programme is run on the computer.

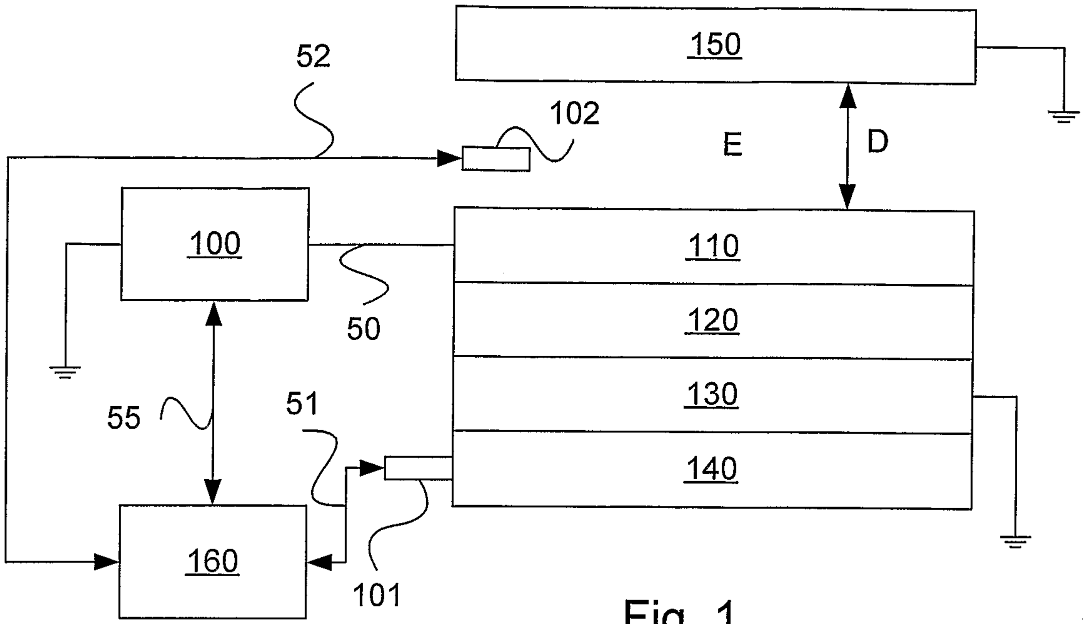
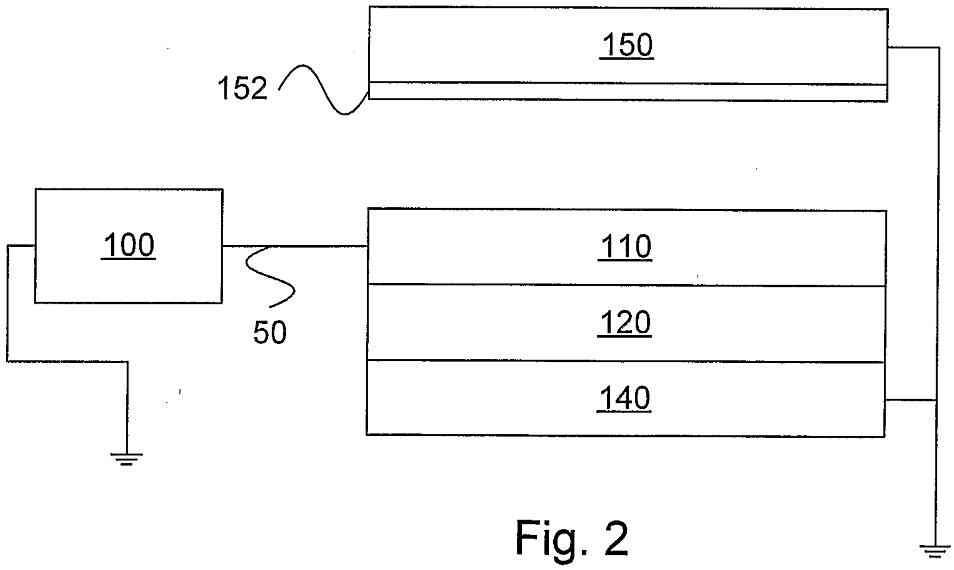

150
52
102
E
D
100
110
50
120
55
51
130
140
160
101

Fig. 1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152
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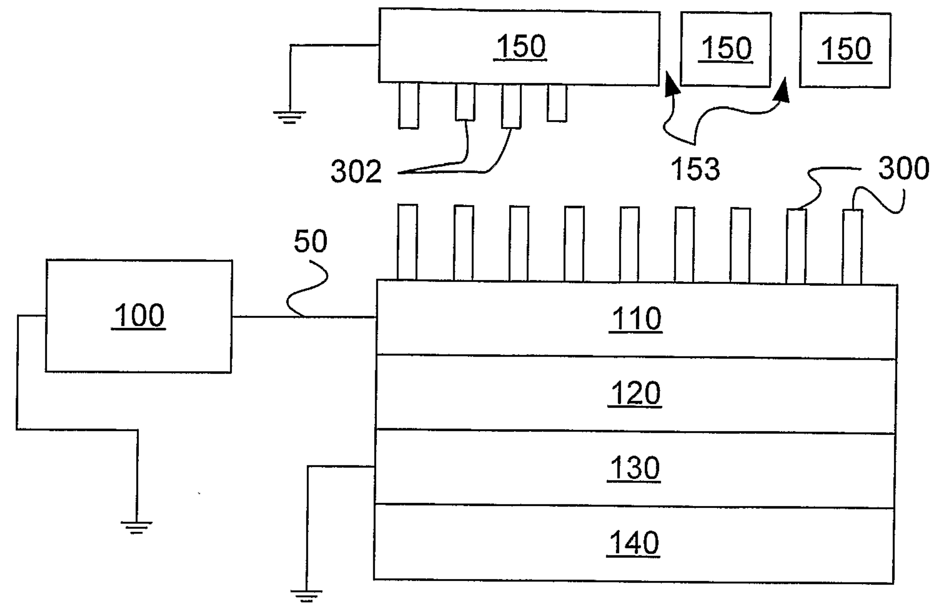
110
50
120
140

Fig. 2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150
150
302
153
300
50
100
110
120
130
140

Fig. 3

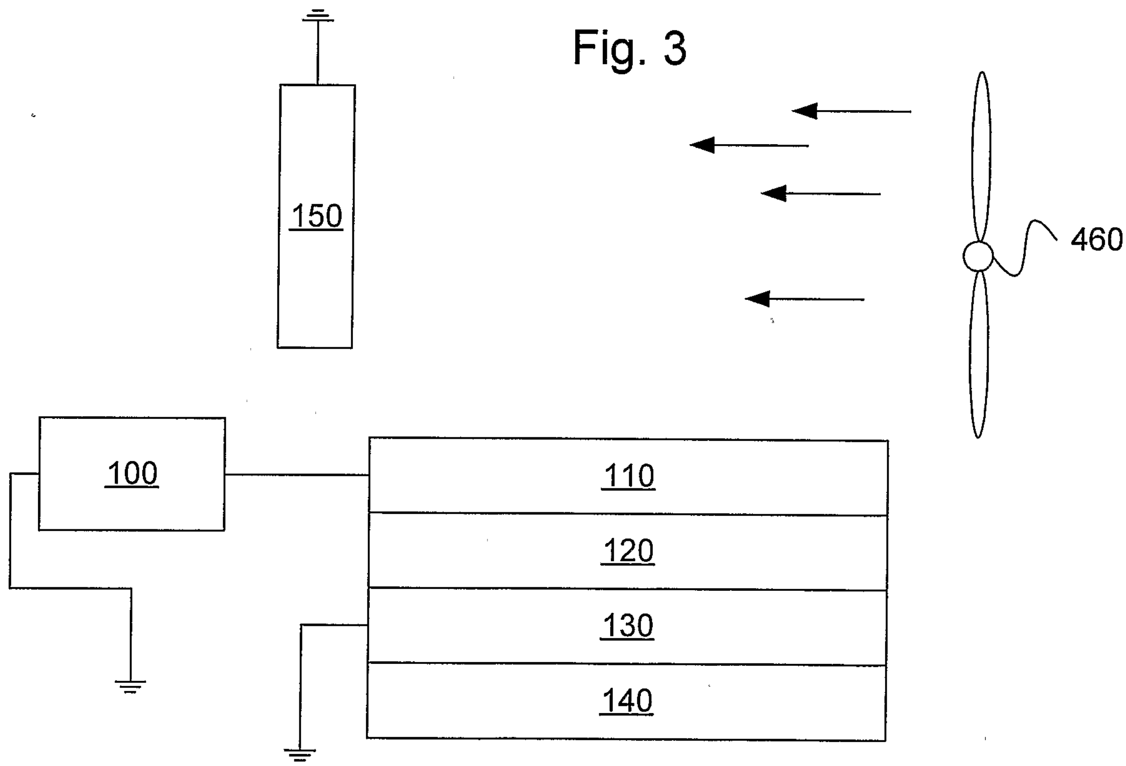

150
460
100
110
120
130
140

Fig. 4

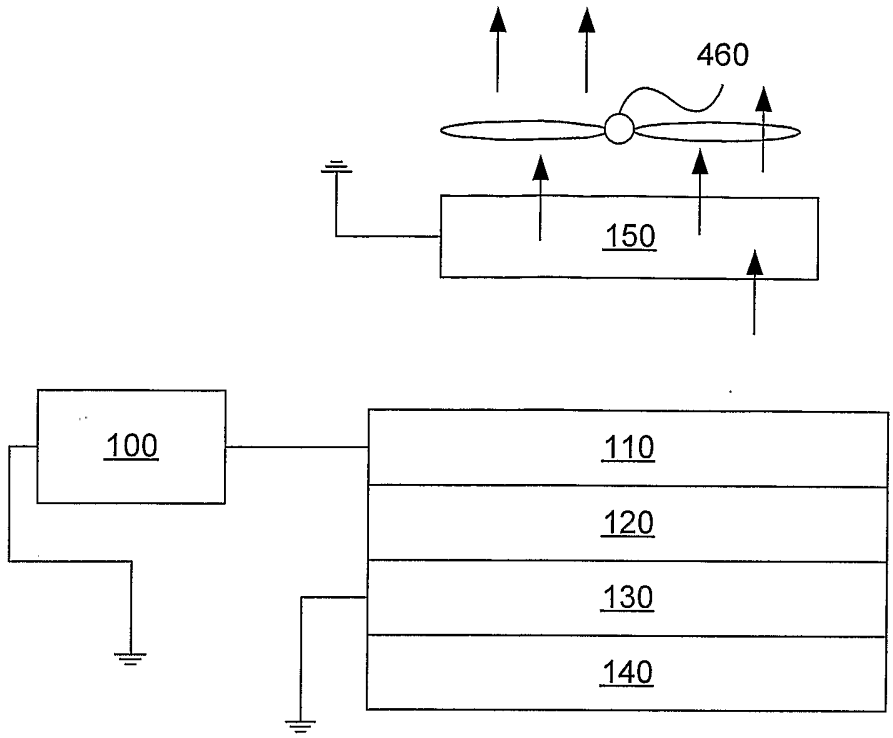


Fig. 5

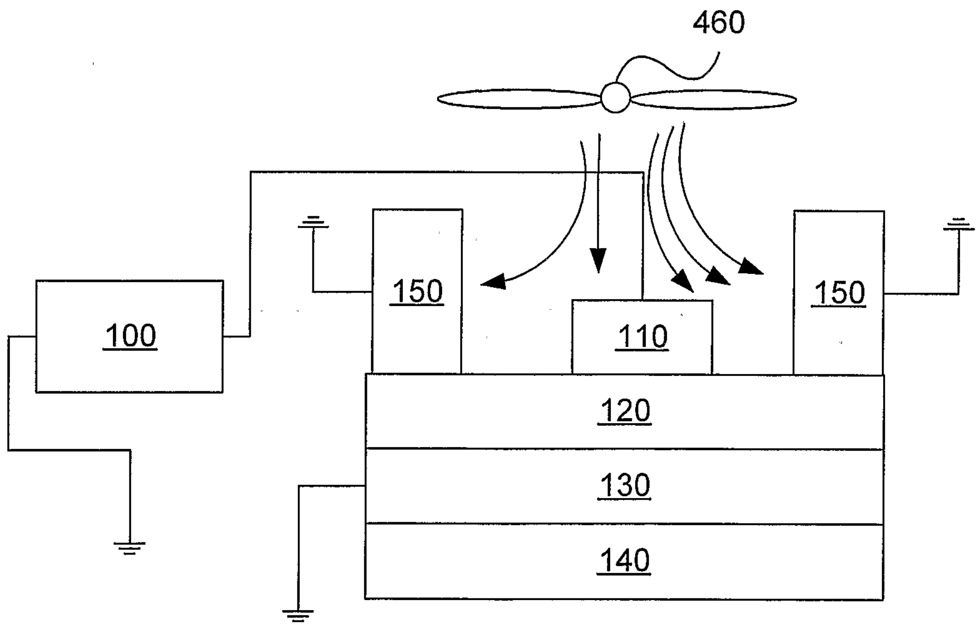


Fig. 6

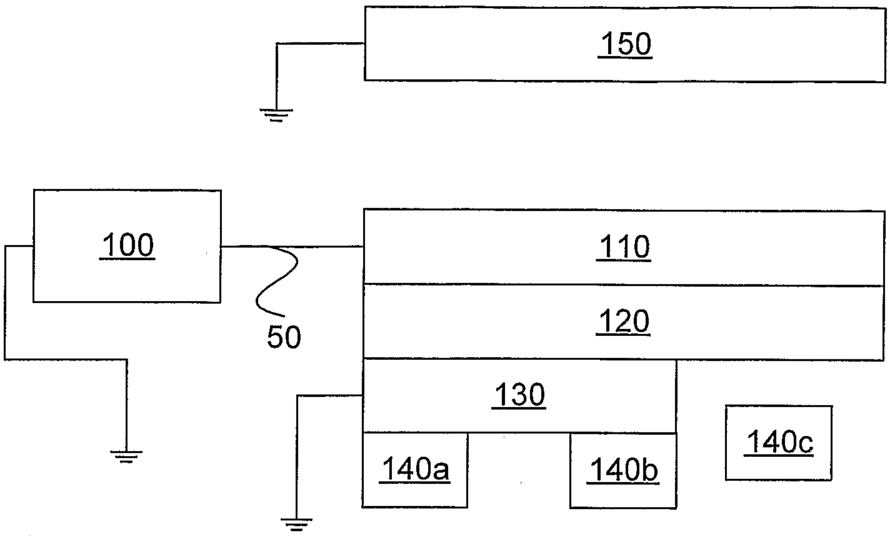
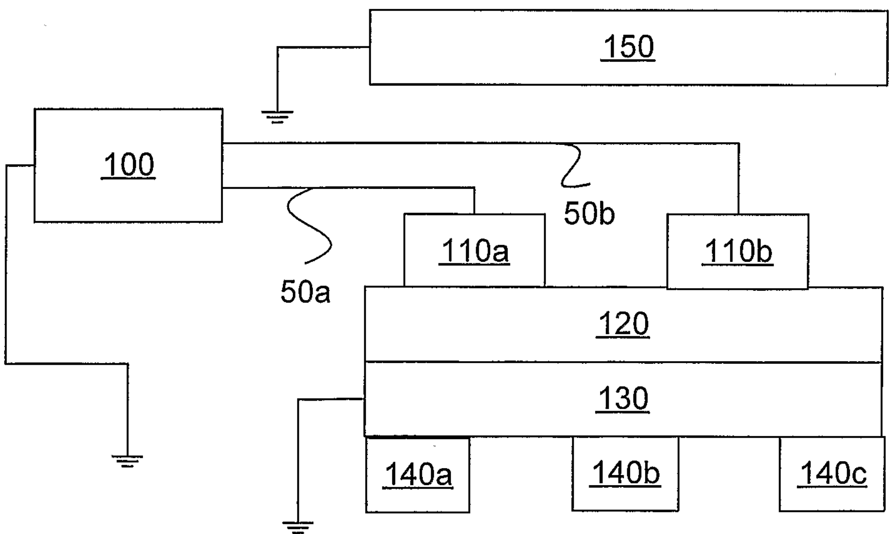

150
100
110
120
50
130
140a
140b
140c

Fig. 7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50b
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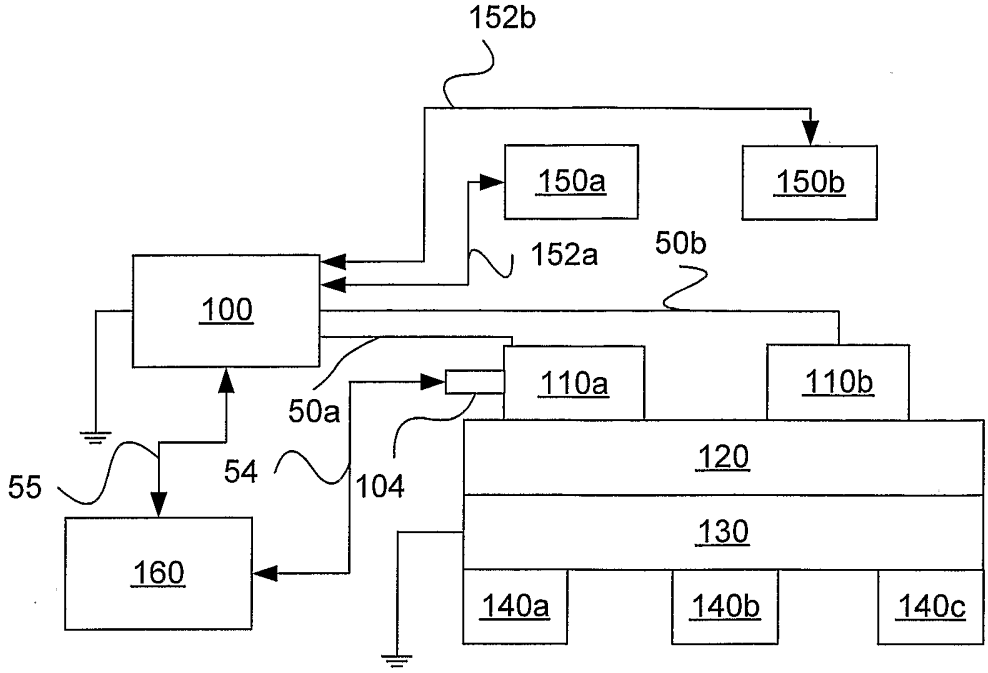
110b
50a
120
130
140a
140b
140c

Fig. 8


152b
150a
150b
152a
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100
110a
110b
50a
120
54
104
55
130
160
140a
140b
140c

Fig. 9

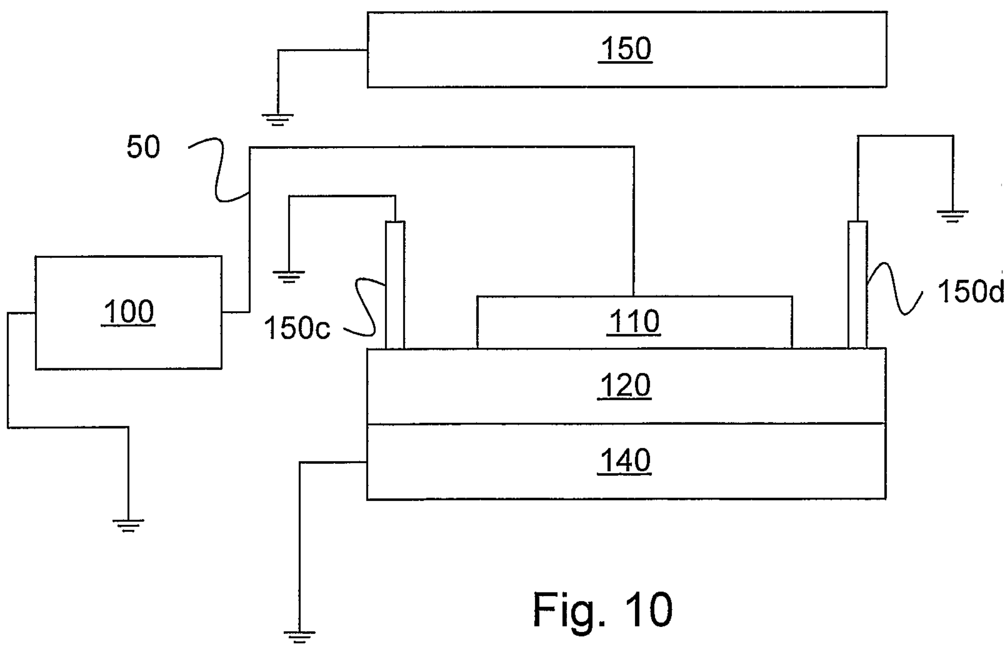
150
50
150d
100
150c
110
120
140

Fig. 10

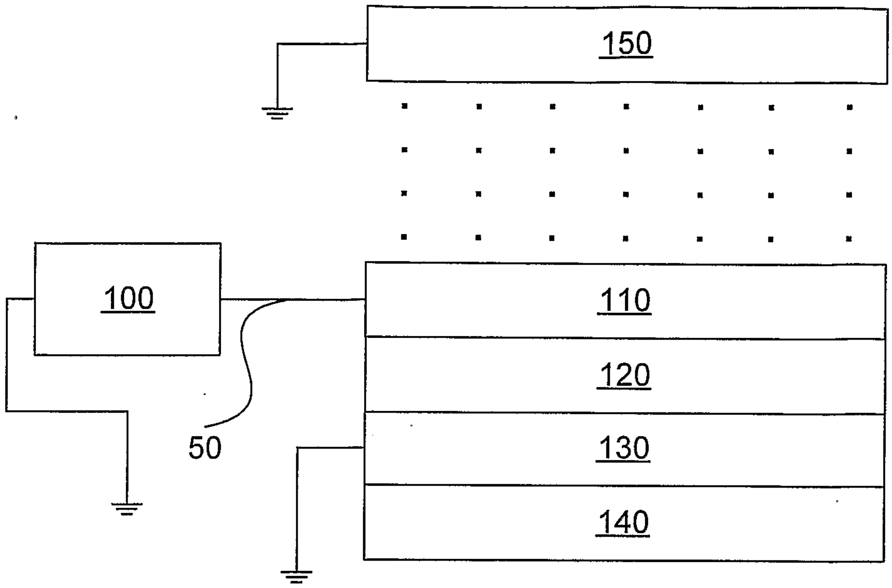

Fig. 11

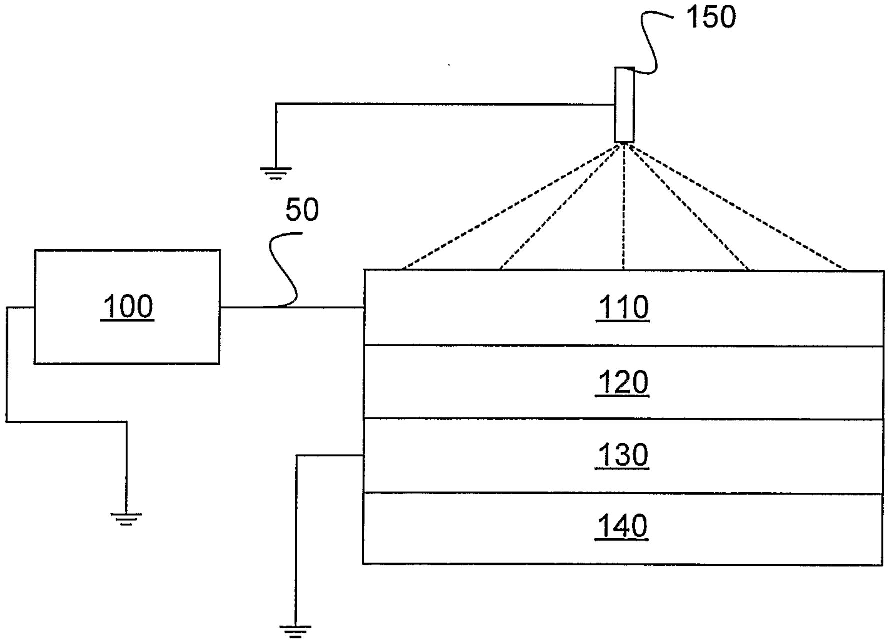

Fig. 12

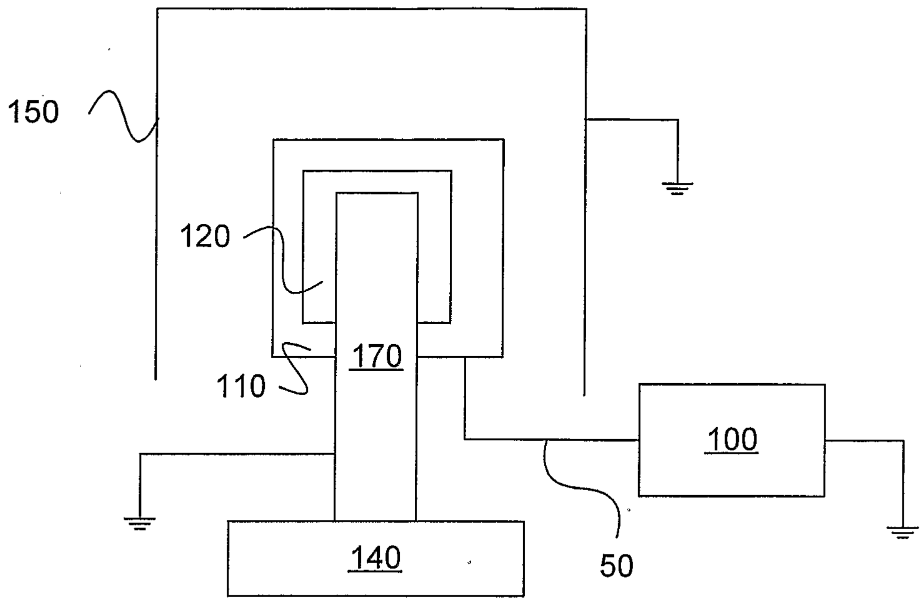

Fig. 13

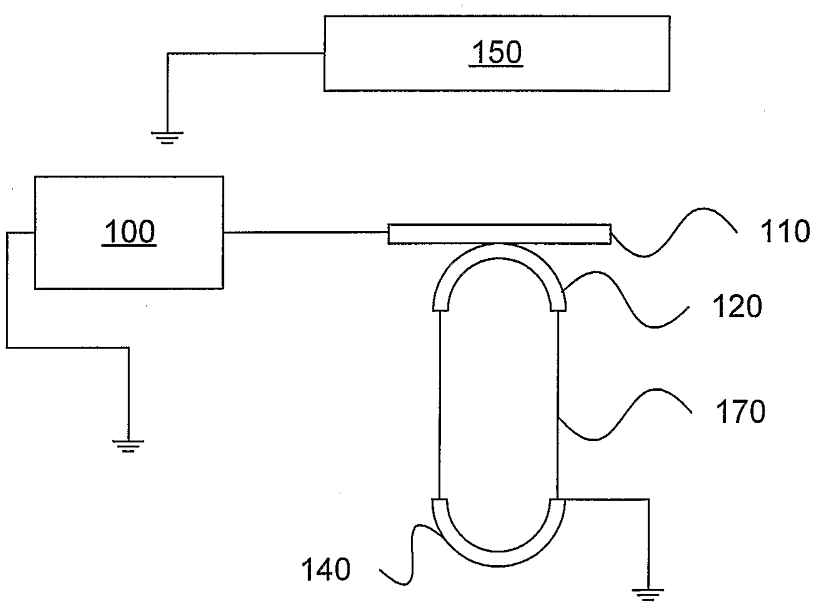

Fig. 14

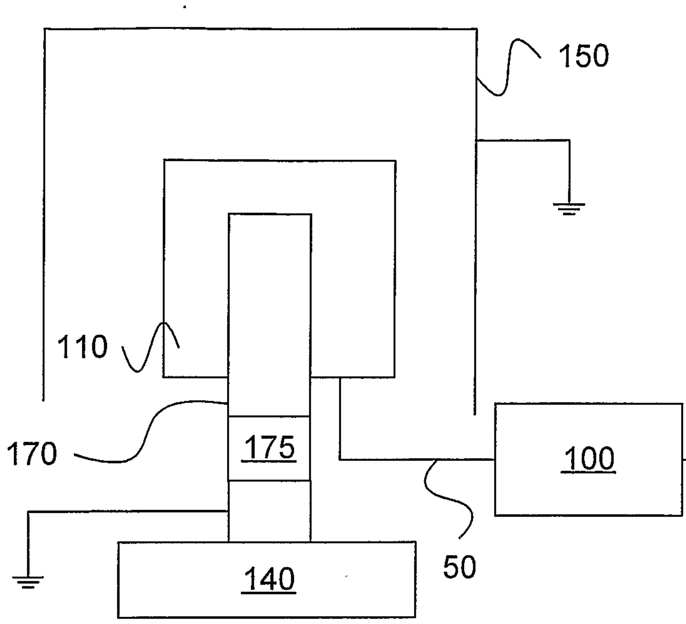

Fig. 15

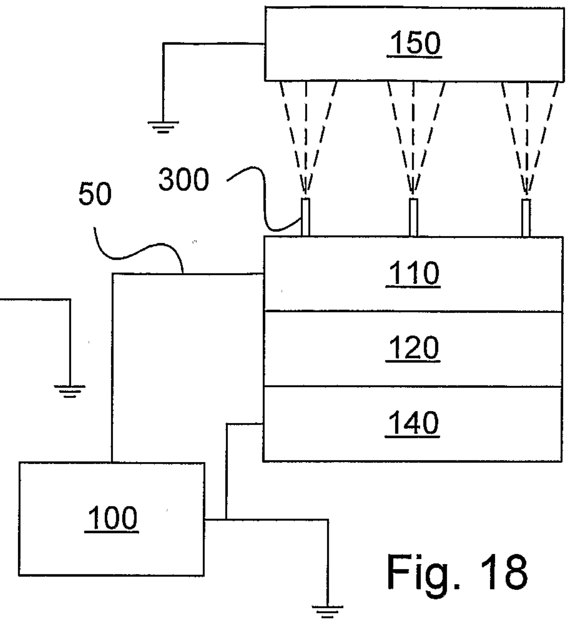

Fig. 18

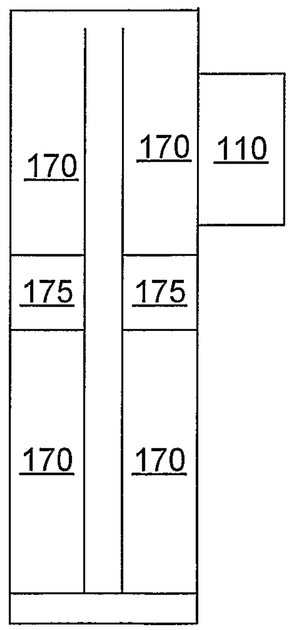

Fig. 16

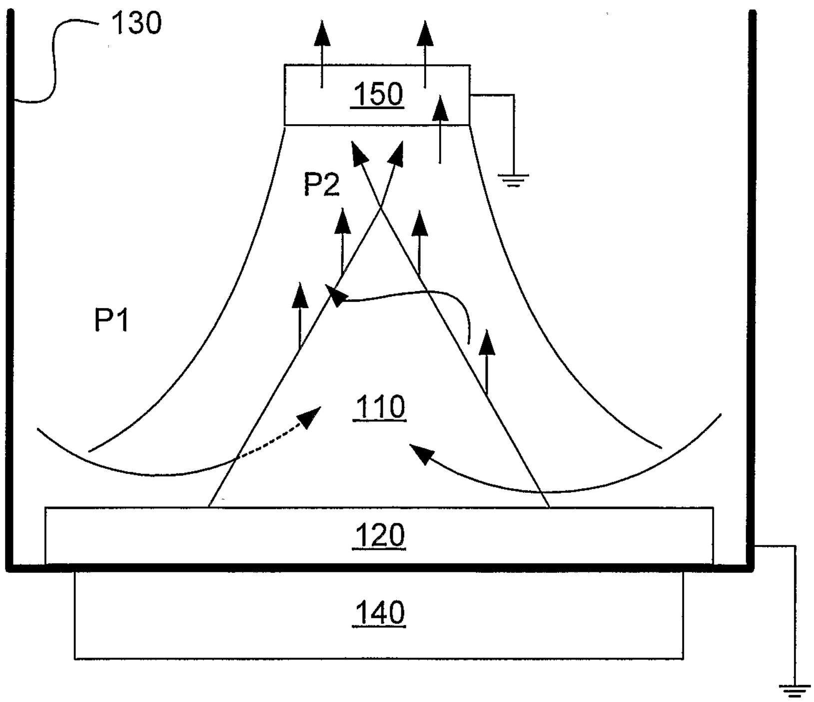

Fig. 17

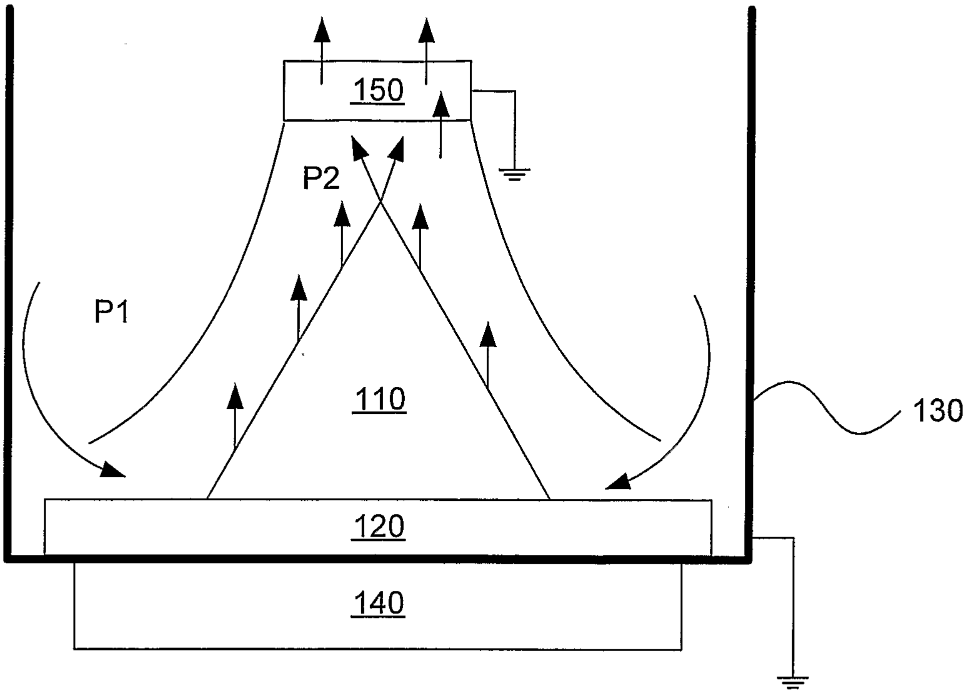

Fig. 19

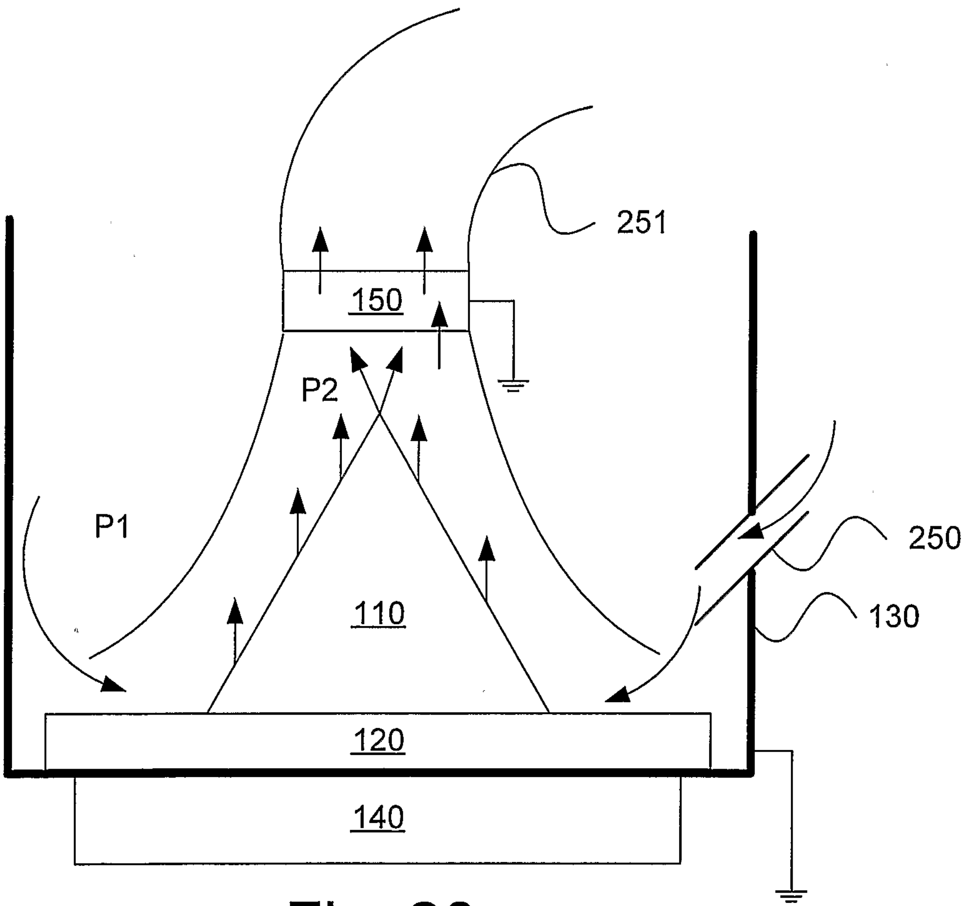

Fig. 20

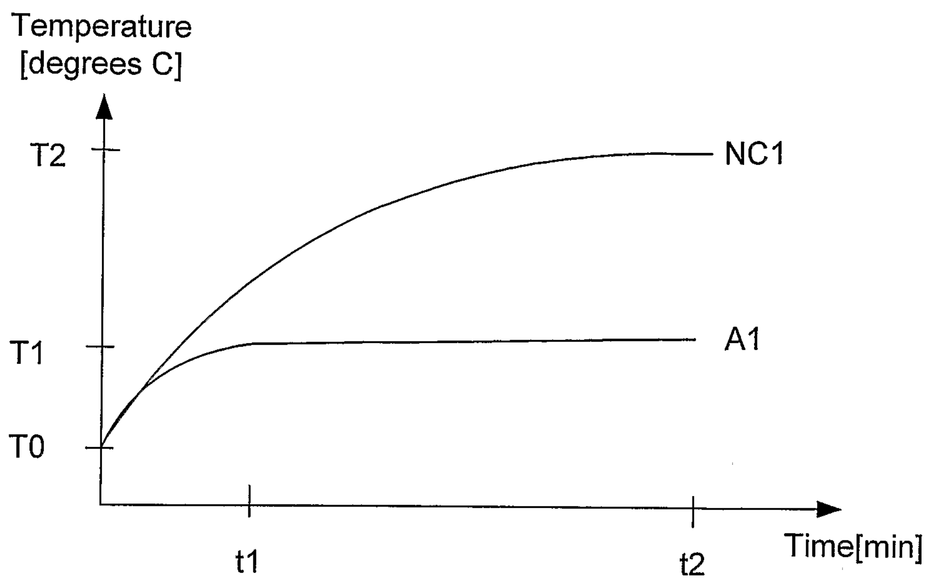
Temperature
[degrees C]
T2
T1
T0
NC1
A1
t1
t2
Time[min]

Fig. 21

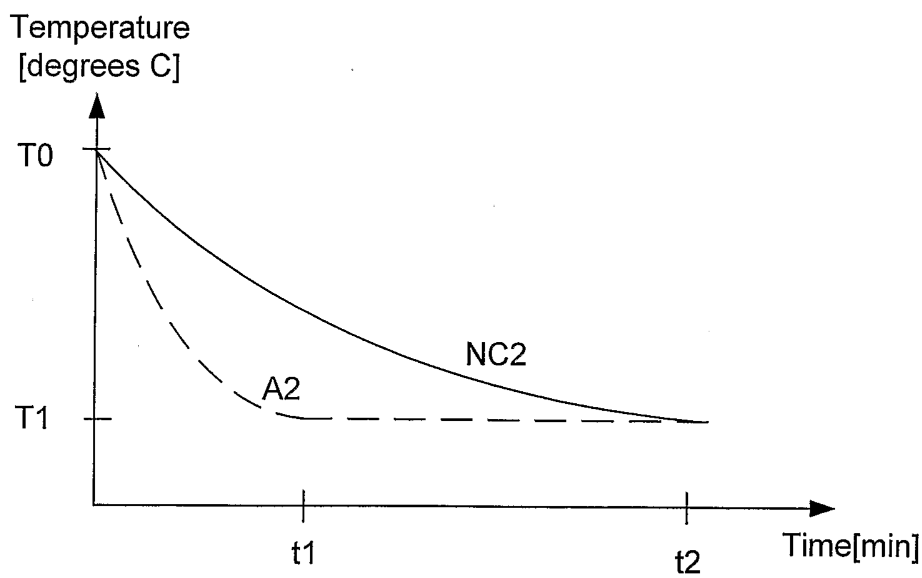
Temperature
[degrees C]
T0
T1
NC2
A2
t1
t2
Time[min]

Fig. 22

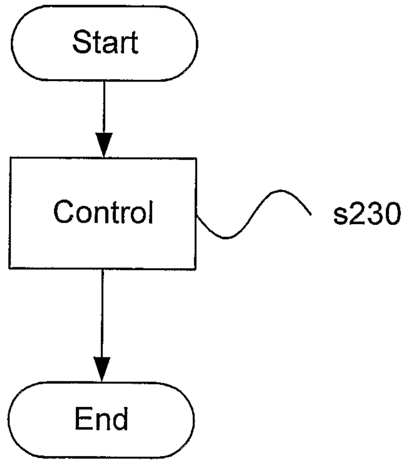

Fig. 23a

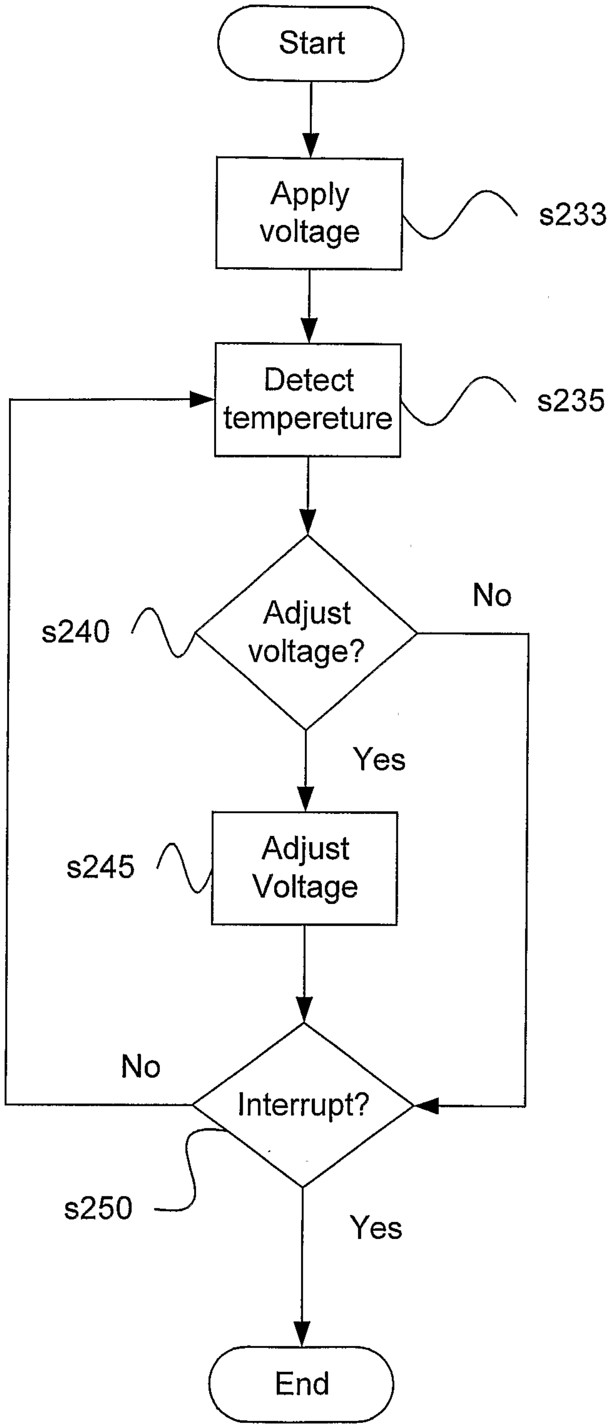

Fig. 23b

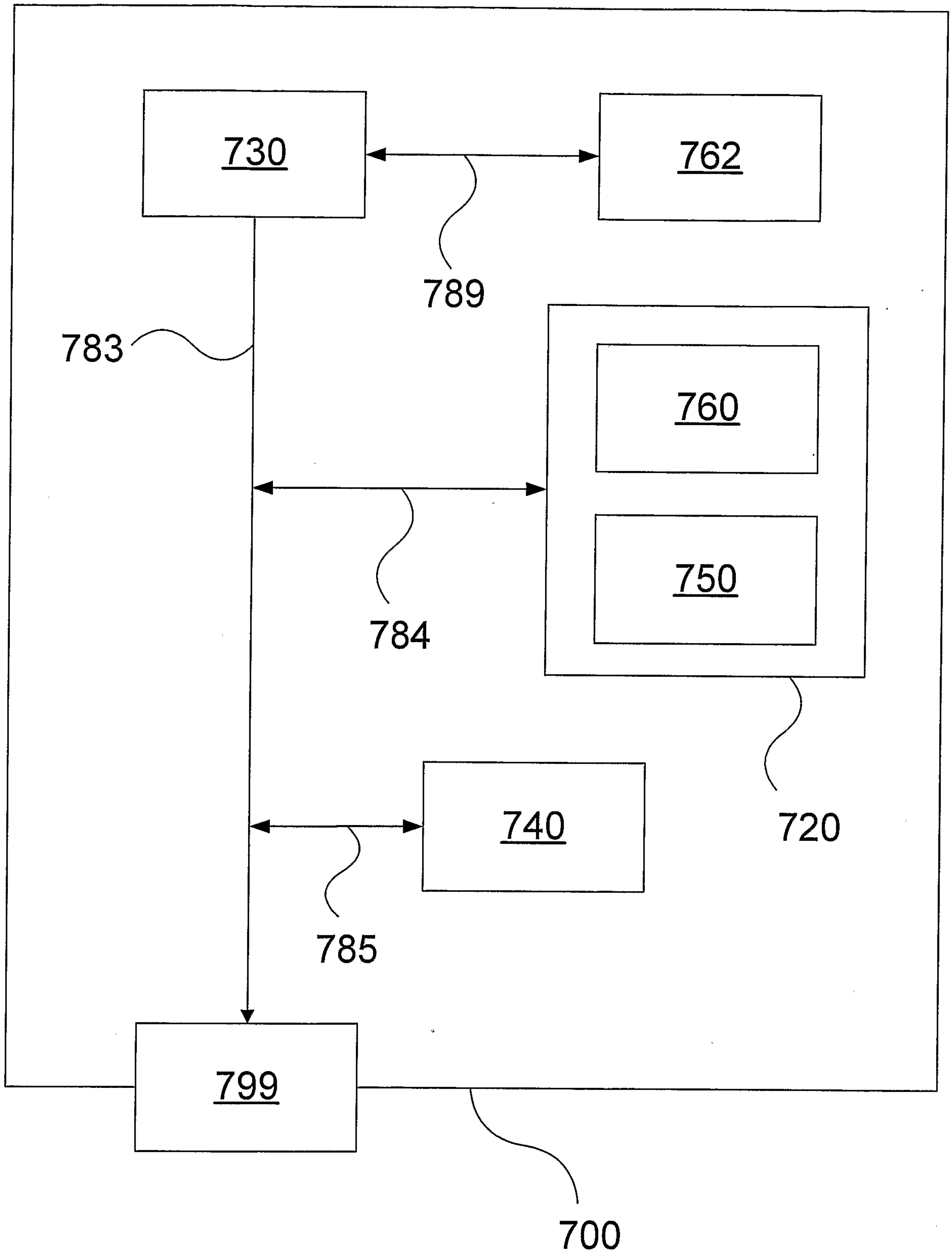

Fig. 24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 2005/001064

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F28F 13/16, H05K 7/20

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)

IPC7: F28F, H05K

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

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5533567 A (MAURICE H.P.M. VAN PUTTEN ET AL), 9 July 1996 (09.07.1996), whole document --	1-19
A	DATABASE WPI Week 199307 Derwent Publications Ltd., London, GB; Class Q78, AN 1993-057037 & SU1719876 A1 (MOSC MEAT DAIRY INST) 15 March 1992 (1992-03-15) abstract --	1-19
A	File EPODOC/EPO, RSITET STANKIN et al: "DEVICE USED TO ENHANCE THERMAL CONDUCTIVITY OF GASEOUS ATMOSPHERE BY IONIZATION" RU2115070 C1, 10 July 1998 (1998-07-10) --	1-19

[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
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Date of the actual completion of the international search	Date of mailing of the international search report
30 Sept 2005	04-10-2005
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Annette Riedel/MP Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 2005/001064

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