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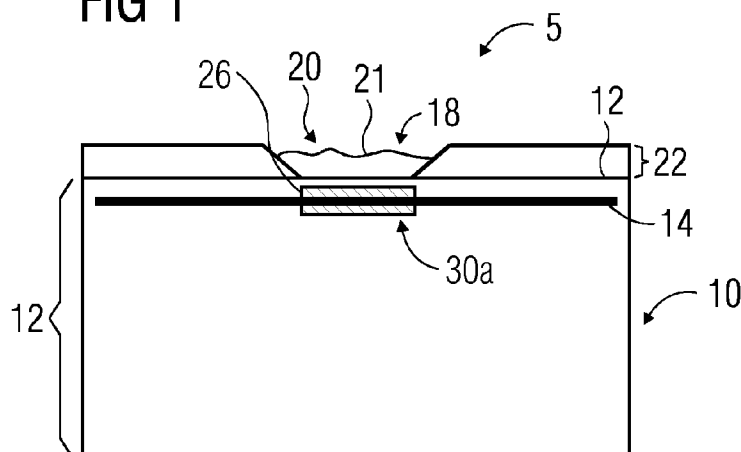
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(54) Title: INTEGRATED TEMPERATURE REGULATOR AND METHODS OF SELECTIVELY GENERATING HEAT AND REGULATING TEMPERATURE

FIG 1



(S7) Abstract: In the present technique, an integrated temperature regulator for regulating a temperature of an object is presented. The integrated temperature regulator includes a heating module and an object port. The heating module includes a semiconductor material substrate. The semiconductor material substrate includes at least one logic block at a given location. The logic block is operable to selectively generate a specific amount of heat for heating the object. The specific amount of heat generated is in response to at least one predetermined computational instruction provided as an input to the logic block. The object port is for receiving the object wherein the object port is in thermal contact with the logic block. The present technique also presents a method for selectively generating a specific amount of heat for heating an object and a temperature regulating method for regulating a temperature of an object.

Description

Integrated temperature regulator and methods of selectively generating heat and regulating temperature

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The present invention relates to integrated heating and cooling of liquid and colloidal compositions in applications that use or involve microfluidic or micromechanical technologies.

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Regulating temperature in small and localized area of an object or a part of the object is required for several chemical, electrochemical, micromechanical, biochemical, etc applications. For example several biochemical or

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electrochemical processes and tests may be carried out using microfluidic techniques. The microfluidic techniques deal

with the behavior, precise control and manipulation of fluids that are geometrically constrained to a small, typically sub-millimeter, scale, such as nanolitre and picolitre amounts of

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fluids. By use of the improvements described herein, applications of microfluidic techniques may include, but are not limited to enzymatic analysis for molecular biology, DNA analysis, chemical analysis, water analysis, pharmacological analysis, proteomics, clinical pathology, inkjet printing,

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real time testing of air/water samples for biological toxins and testing and analysis or monitoring of other dangerous pathogens. Fluids in such applications can be processed in various manners depending on the requirement. For example, for certain applications, the fluid is required to be

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processed at temperatures that need to be regulated accurately. This requires generation of localized heat for heating the fluid at accurately regulated temperatures. Some applications may require accurate temperature control with repeated specific temperature cycles to be carried out for

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the analysis. This involves generation of localized heat at accurately regulated temperatures and repeating the specific temperature cycles.

Additionally, in some applications, the fluid may be required to be transported in physical flow-paths, such as, micro-channels. One approach of accomplishing flow actuation in the micro-channels is by means of surface tension gradient. In the presence of a surface tension gradient fluids can be laterally transported. A surface tension gradient can be produced by several approaches: chemical, composition, thermal, electrochemical and photochemical, of which, thermal is the most versatile since it does not require special reactant chemical. The production of the surface tension gradient through thermal approach shall require generation of a thermal gradient which shall require generation of different amounts of localized heat at different locations i.e. the temperatures at different locations need to be specifically regulated. Generally, fluids move from a high temperature region to a lower temperature region.

As the amount of fluids to be processed for the aforementioned applications is small, microfluidic devices may be used for processing the fluids. The topology of the microfluidic device will depend on the type of application the microfluidic device is designed to perform. For example, for the processing of the fluid, the microfluidic device can comprise chambers and/or micro-channels depending on the requirement. The microfluidic device receives the heat for localized heating of the fluid from a heat generation device and transfers the same to the fluid. The heat generation device is configured to generate the heat for the localized heating of the fluid.

Generally, conventional heat generation device for localized heating involves the use of resistive heating elements, wherein the heat to be generated can be controlled by varying the voltage or current supplied to the heating elements or by varying the resistance of the heating elements. Construction of such heat generation devices is complicated and non-robust as the heating elements are connected with electrical wires for the supply of voltage/current. Moreover, the temperature

cannot be regulated accurately as the temperature is controlled responsive to the unit change in voltage, current or the resistance.

- 5 Thus there exists a requirement of such a technique which can enable regulating temperatures in localized manner in small areas of an object.

An object of the present invention is to provide a
10 temperature regulator used for localized regulation of temperature.

A further object is to provide a technique for selectively generating a specific amount of heat for heating an object.
15 Selective generation of the heat aids in achieving localized regulation of temperature.

A still further object is to provide a technique for regulating a temperature of an object by selectively
20 generating a specific amount of heat in a localized area.

A still further object of is to provide a technique for heating fluids in microfluidic channels. The microfluidic channels may be present in microfluidic devices.
25

According to a first aspect of the present technique, the above objectives may be achieved by incorporation of an integrated temperature regulator for regulating a temperature of an object. The integrated temperature regulator includes a
30 heating module and an object port. The heating module includes a semiconductor material substrate. The semiconductor material substrate includes at least one logic block at a given location. The logic block is operable to selectively generate a specific amount of heat for heating
35 the object. The specific amount of heat generated is in response to at least one predetermined computational instruction provided as an input to the logic block. The

object port is for receiving the object wherein the object port is in thermal contact with the logic block.

The term 'selectively' as used herein means that the specific amount of heat to be produced by the logic block can be selected as desired. This is achieved as the logic block is operable to produce the specific amount of heat responsive to i.e. in response to the computational instruction provided as input to the logic block. Achievement of generation of heat is enabled with more accurate control. The at least one of the computational instruction is predetermined for the specific amount of heat to be generated. For the specific amount of heat to be generated, the computational instruction can be predetermined and provided as an input to the logic block. This achieves in generating specific amount of heat with accurate control as the predetermined computational instruction can be easily created for accurate generation of the specific amount of heat as per the requirement.

According to an embodiment, the object port is positioned so as to receive and provide at least a part of the heat generated by the logic block to the object. Thus the object port may be formed or fabricated separate from the heating module and incorporated in the integrated temperature regulator or the object port may be formed integrated in the semiconductor material substrate. This provides flexibility in forming the object port and advantageously various techniques can be used to create the object port of various shapes and sizes and varyingly position them in the integrated temperature regulator enabling the object port to receive and provide the heat generated by the logic block to the object.

According to another embodiment, the object port is formed integrated in the semiconductor material substrate. As the integrated temperature regulator comprises the semiconductor material substrate, the object port to be heated can be advantageously formed on the semiconductor material

substrate. This may further aid in making the integrated temperature regulator compact.

According to yet another embodiment, the object port is positioned on the semiconductor material substrate. The object can be separately positioned on the semiconductor to receive the heat generated by the integrated temperature regulator. Thus the object port may be formed or fabricated separate from the semiconductor material substrate and subsequently incorporated in the integrated temperature regulator. This provides flexibility in forming the object port and advantageously various techniques can be used to create the object port of various shapes and sizes that can receive the object.

According to yet another embodiment, a location on the object port is assigned to the given location of the logic block. Thus, if the location on the object port is desired to be heated, the logic block at the given location can be selected easily and made to selectively generate the specific amount of heat for heating at least a part of the object received at the location on the object port. The selective generation of heat is by operating the logic block at the given location by providing the at least one predetermined computational instruction as an input to the logic block at the given location. In embodiments with several such logic blocks each at its unique given location, different location on the object port may be assigned to the different given locations of the different logic blocks, and then if it is desirable to heat the object port at a desired location, then the logic block whose given location is assigned with the desired location of the object port is selected and made to selectively generate the specific amount of heat and this enables local heating at the desired location of the object port and further of the object or a part of the object received at the desired location of the object port.

According to yet another embodiment, a plurality of the logic blocks is included in the integrated temperature regulator. The different logic blocks of the plurality are at corresponding given locations, and wherein the different

5 logic blocks are operable to selectively generate different specific amounts of heat for heating the object, wherein the different specific amounts of heat generated are in response to different predetermined computational instructions provided as an input to the different logic blocks. This

10 advantageously enables the integrated temperature regulator to provide different or varying heating to different locations on the object port.

According to yet another embodiment, the integrated

15 temperature regulator includes a controller for providing the different predetermined computation instructions to the different logic blocks. The different computational instructions are predetermined such that the different specific amounts of heat generated are such that a linear

20 thermal gradient is generated across at least a portion of the object port. Different amounts of heat can be generated based on the requirement for producing the thermal gradient. The computational instructions are predetermined such that at least one of the logic blocks is operable to generate

25 different amount of heat than at least one of the other of the logic blocks such that the thermal gradient is linear. For example, two of the logic blocks can be provided with different predetermined computational instructions to generate different amounts of heat thereby establishing the

30 linear thermal gradient across the portion of the object port extending across the given locations of the two logic blocks. Linear thermal gradient aids in uniform flow velocity of fluids that may be present in the object port. Additionally, linear thermal gradient enables in performing in the object

35 port continuous flow assays with ease.

According to yet another embodiment, in the integrated temperature regulator the different logic blocks of the

plurality are thermally isolated from each other. This helps in transferring the heat produced by each of the logic blocks independently to the object port and thus achieve better control of temperature at different locations of the object port.

According to yet another embodiment of the integrated temperature regulator, the heating module is a field programmable gate array (FPGA). FPGAs are readily available and thus the integrated temperature regulator can be readily fabricated. Moreover, different FPGAs have different compositions i.e. number and arrangement of the logic blocks in the FPGA and thus a given type of FPGA having a desired number and/or desired arrangement of the logic blocks can be incorporated in the integrated temperature regulator depending on the application in which the integrated temperature regulator is to be used.

According to yet another embodiment, the plurality of logic blocks are configured to process predetermined computational instructions to generate specific amounts of heat. The predetermined computational instructions provided to each of the logic blocks of the plurality are based on an amount of the heat required to be generated by the respective logic block. Thus each of the logic blocks can be operated to generate same amount of heat or different amounts of heat depending on the predetermined computational instruction provided to the logic blocks.

According to yet another embodiment, the semiconductor material substrate is packaged within an integrated circuit package. Thus, an off the shelf and readily available integrated circuit packaged within an integrated circuit package can be used for selectively generating heat.

According to yet another embodiment, at least one surface of the integrated circuit package is thermally connected to the semiconductor material substrate to receive the heat

generated. This results in efficient transfer of heat from the semiconductor material substrate to the surface of the integrated circuit package from which the heat is to be transferred to the object port and then to the object, if any, received by the object port.

According to yet another embodiment of the integrated temperature regulator, the object port comprises a microfluidic device. The microfluidic device may receive fluids and is used to carry out several techniques for example biochemical techniques such as enzymatic analysis for molecular biology, DNA analysis, etc, chemical techniques such as water analysis, fluid sample testing, etc, pharmacological analysis, proteomics, clinical pathology, inkjet printing, real time testing of air/water samples for biological toxins, testing and analysis or monitoring of other dangerous pathogens, and so on and so forth. The present technique thus can be advantageously used to provide localized and selective heating by providing specific amounts of heat to a part of or an entire microfluidic device.

According to yet another embodiment, the integrated temperature regulator includes a plurality of the logic blocks. The different logic blocks of the plurality are at corresponding given locations. The different logic blocks are operable to selectively generate different specific amounts of heat for heating the object. The different specific amounts of heat generated are in response to different predetermined computational instructions provided as an input to the different logic blocks. The different logic blocks are assigned to different locations of the microfluidic device. Thus, the present technique can be advantageously used to provide localized and selective heating by different specific amounts of heat to different parts of the microfluidic device.

According to yet another embodiment, the integrated temperature regulator includes a cooling module for cooling

the object. In this embodiment, the object port that receives the object is in thermal contact with the cooling module.

Thus the integrated temperature regulator is used for cooling the object besides heating the object by selectively

5 generating the heat. This allows temperature regulation over a larger range i.e. the cooling module can cool the object to temperatures below the ambient temperature and the heating module can heat the object to temperatures above the ambient temperature and thus the range between which the temperature
10 of the object may be regulated is increased.

According to yet another embodiment of the integrated temperature regulator, the object port is positioned in between the cooling module and the heating module. The object
15 port is in thermal contact on one of its sides with the cooling module and on another of its sides with the heating module. This provides a easy and simple arrangement of the cooling module, the heating module and the object port in the integrated temperature regulator.

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According to a second aspect of the present technique, a method for selectively generating a specific amount of heat for heating an object is presented. In the method, at least one predetermined computational instruction is selected from
25 a plurality of predetermined computational instructions. The predetermined computational instruction is such that the specific amount of heat is generated when logical operations corresponding to the predetermined computational instruction are performed by a logic block. Subsequently, the
30 predetermined computational instruction so selected is provided to the logic block. Finally, logical operations are performed by the logic block in response to the predetermined computational instruction so provided.

35 In an embodiment, the method further includes selecting a further predetermined computational instruction from the plurality of predetermined computational instructions. The further predetermined computational instruction is such that

a further specific amount of heat is generated when logical operations corresponding to the further predetermined computational instruction are performed by a further logic block. In this embodiment, subsequently, the further
5 predetermined computational instruction is provided to the further logic block. Subsequently, logical operations are performed by the further logic block in response to the further computational instruction so provided. Thus, the method is implementable with more than one logic block that
10 is used to provide same or different specific amounts of heat to the object.

According to a third aspect of the present technique, a processor for performing the above mentioned method and its
15 embodiments thereof is provided.

According to a fourth aspect of the present technique, a computer-readable medium having computer-executable instructions for performing the above mentioned method and
20 its embodiments thereof is provided.

According to a further aspect of the present technique, a temperature regulating method for regulating a temperature of an object is provided. The temperature regulating method
25 includes selectively generating a specific amount of heat according to the above mentioned method for selectively generating the specific amount of heat for heating the object and its embodiments thereof. Subsequently, the specific amount of heat is provided to the object.

30 According to an embodiment, the temperature regulating method further includes cooling the object by a cooling module.

According to still another embodiment, the prior embodiments
35 may be incorporated into devices and systems for analysis and monitoring in numerous applications.

According to an embodiment, an electrical property measurement system for determining an electrical property of a fluid is presented. The electrical property measurement system comprises the integrated temperature regulator and an electrical property measurement module. The integrated temperature regulator is as described in accordance with the first aspect of the present technique and embodiments thereof. In the integrated temperature regulator the object port may be a microfluidic well or groove or container adapted to receive the fluid. The object received by the object port is the fluid such as water. The integrated temperature regulator is adapted to regulate a temperature of the fluid to a desired temperature. The electrical property measurement module is adapted to measure the electrical property of the fluid at the desired temperature. The electrical property may be, but not limited to an electrical resistivity, an electrical conductance, and so on and so forth.

According to another embodiment, a biochemical property measurement system for determining a biochemical property of a sample is presented. The biochemical property measurement system comprises the integrated temperature regulator as described in accordance with the first aspect of the present technique and embodiments thereof and a biochemical property measurement module. In the integrated temperature regulator the object port may be a microfluidic well or groove or container adapted to receive the sample. The object received by the object port is the sample such as water, urine, blood, other body fluids, fluids containing toxins, pathogens, biomarkers, immunoreactants, and so on and so forth. The integrated temperature regulator is adapted to regulate a temperature of the sample to a desired temperature. The biochemical property measurement module is adapted to measure the biochemical property of the sample at the desired temperature. The biochemical property may be, but not limited to a presence or absence of a chemical, a tag, a biological or chemical reaction product, a pollutant, or a biological

molecule such as a protein, a pathogen, a biomarker, a toxin, a microorganism, a nucleic acid, and so on and so forth.

According to another embodiment, a fluid dispensing system
5 for dispensing a fluid at a given temperature is presented. The fluid dispensing system comprises the integrated temperature regulator as described in accordance with the first aspect of the present technique and embodiments thereof and a fluid dispensing module. In the integrated temperature
10 regulator the object port may be a fluid container or flow channel adapted to receive the fluid. The object received by the object port is the fluid such as water, ink, a chemical reagent solution, a biochemical reagent solution, a biological reagent solution, blood, other body fluids, fluids
15 containing toxins, pathogens, biomarkers, immunoreactants, and so on and so forth. The integrated temperature regulator is adapted to regulate a temperature of the fluid to a desired temperature. The fluid dispensing module is adapted to receive the fluid at the desired temperature from the
20 object port and to dispense the fluid so received to outside of the fluid dispensing system via an outlet of the fluid dispensing module.

The present invention is further described hereinafter with
25 reference to illustrated embodiments shown in the accompanying drawings, in which:

FIG 1 illustrates a schematic representation of an exemplary embodiment of an integrated temperature
30 regulator for regulating a temperature of an object placed in an object port of the integrated temperature regulator with a heating module,

FIG 2 illustrates a schematic representation of another
35 embodiment of the integrated temperature regulator,

FIG 3 illustrates a schematic representation of another embodiment of the integrated temperature regulator

and the object port positioned in accordance with aspects of the present technique,

FIG 4 schematically represents a top view of an exemplary embodiment of a microfluidic device included in the object port of the integrated temperature regulator,

FIG 5 schematically represents a top view of an exemplary embodiment of the heating module depicting a plurality of logic blocks of the integrated temperature regulator,

FIG 6 schematically represents a top view of another exemplary embodiment of the heating module depicting a plurality of logical circuits of the integrated temperature regulator,

FIG 7 schematically represents a top view of another exemplary embodiment of the heating module depicting the logic blocks arranged in the plurality of logical circuits of the integrated temperature regulator,

FIG 8 illustrates a schematic representation of another embodiment of the integrated temperature regulator depicting a cooling module and the object port positioned in accordance with aspects of the present technique,

FIG 9 illustrates a schematic representation of another embodiment of the integrated temperature regulator depicting a plurality of the cooling modules and the object port positioned in accordance with aspects of the present technique,

- FIG 10 schematically illustrates an exemplary embodiment
of a microfluidic device comprising a plurality of
fluid chambers,
- 5 FIG 11 schematically illustrates an exemplary embodiment
the integrated temperature regulator in conjunction
with an integrated circuit package,
- 10 FIG 12 schematically illustrates an exemplary embodiment
of the integrated temperature regulator comprising
a controller,
- 15 FIG 13 schematically illustrates another exemplary
embodiment of the integrated temperature regulator,
- 20 FIG 14 schematically illustrates another exemplary
embodiment of the integrated temperature regulator
and the object positioned onto the integrated
temperature regulator depicting a valve,
- 25 FIG 15a schematically illustrates an open position of the
valve,
- 30 FIG 15b schematically illustrates a close position of the
valve,
- 35 FIG 16 schematically illustrates an example of a
microfluidic device which can be reconfigured as
per the requirement of the microfluidic application
to be performed,
- FIG 17 illustrates an example of a microfluidic device
implemented as flow focusing structure,
- FIG 18 is a flow diagram illustrating a method for
selectively generating a specific amount of heat
for heating an object,

FIG 19 is a flow diagram illustrating a temperature regulating method for regulating a temperature of an object, and

5 FIG 20 schematically represents a system including the integrated temperature regulator, in accordance with aspects of the present technique.

Various embodiments are described with reference to the
10 drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be evident that such embodiments may
15 be practiced without these specific details.

FIG 1 illustrates a schematic representation of an exemplary embodiment of an integrated temperature regulator 5 for regulating a temperature of an object 21, in accordance with aspects of the present technique. The integrated temperature regulator 5 includes a heating module 10 and an object port 18. The heating module 10 includes a semiconductor material substrate 12. The semiconductor material substrate 12 includes at least one logic block 26 at a given location 30a.
25 The logic block 26 is operable to selectively generate a specific amount of heat for heating the object 21. The specific amount of heat generated is in response to at least one predetermined computational instruction provided as an input to the logic block 26. The object port 18 is for
30 receiving the object 21 wherein the object port is in thermal contact with the logic block 26. Thus, the heat generated from the logic block 26 is transferred to the object 21 via the object port 18. The object 21 may be a fluid such as a liquid or a colloidal composition and the object port 18 may
35 be, but not limited to, a fluid chamber 20, a microfluidic channel, a microfluidic well, a capillary tube, and so on and so forth.

In the above mentioned exemplary embodiment the temperature of the object 21 is regulated by heating the object 21 when positioned in the object port 18. Thus, the temperature of the object 21 may be raised to a desired temperature with respect to an ambient temperature i.e. the temperature at which the object 21 is before heating the object 21 by using the present technique. In further exemplary embodiments explained later in reference to other appended FIGs, especially FIGs 8 and 9, the temperature of the object 21 is regulated by heating the object 21 or by cooling the object 21 or by a combination thereof, when the object 21 is positioned in the object port 18. Thus, the temperature of the object 21 may be raised to or lowered to a desired temperature with respect to an ambient temperature i.e. the temperature at which the object 21 is before heating the object 21 or cooling the object 21 by using the present technique.

The logic block 26 comprises one or more logic gates (not shown) and any electronic interconnections between the logic gates or any electronic connections to or from any constituent logic gate. A logic gate, primarily implemented using diodes or transistors acting as electronic switches, is an idealized or physical device implementing a Boolean function, that is, it performs a logical operation on one or more logical inputs, and produces a single logical output. The logic block 26 may be part of a logical circuit 14 fabricated in the semiconductor material substrate 12. The logical circuit 14 means one or more logic block 26 and any electronic interconnections between the logic block 26 or any electronic connections to or from any constituent logic block 26. Thus the logic block 26 in the logical circuit 14 is operable to process the predetermined computational instructions. The term logical circuit 14 as used hereinafter means one or more of the logic block 26 with associated electronic connections and interconnections, if any.

The logic block 26 is operable to perform logical operations in response to i.e. responsive to the predetermined computational instructions. Thus, the logical circuit 14 or the logic block 26 can include any circuitry that can perform logical operations. In the shown example of FIG 1, the logical circuit 14 is formed on the surface of the semiconductor material substrate 12. However, the logical circuit 14 can also be formed within the semiconductor material substrate 12.

In accordance with aspects of the present technique, the predetermined computational instructions provided to the logic block 26 are predetermined such that the logic block 26 is operable to generate a specific amount of heat selectively by performing logical operations responsive to the predetermined computational instructions. To achieve this, the computational instructions can be predetermined such that a specific amount of heat is generated by the logic block 26 when performing the logical operations.

The term 'selectively' as used herein means that the specific amount of heat to be produced by the integrated temperature regulator 5 can be selected as per the requirement. The term 'specific amount of heat' as used herein refers to an amount of heat required to be produced for an application. Thus, selectively generating specific amount of heat means that a specific amount of heat required can be generated selectively as per the requirement by performance of the logical operations in response to the computation instruction and thus there is no requirement for switching on and switching off the integrated temperature regulator 5 to generate or not generate heat.

According to an embodiment herein, the object port 18 is positioned so as to receive and provide at least a part of the heat generated by the logic block 26 to the object 21, when the object 21 is received in the object port 18. The object port 18 that receives the object 21 to be heated by

the integrated temperature regulator 5 is positioned such that the object port 18 receives the heat produced by the logic block 26 of the integrated temperature regulator 5. The object port 18 can receive heat from the integrated
5 temperature regulator 5 by being in thermal contact with the logic block 26. The thermal contact of the object port 18 with the logic block 26 can be achieved, for example, by positioning the object port 18 on the semiconductor material substrate 12 or by positioning the object port 18 adjacent to
10 the semiconductor material substrate 12 with a suitable thermally conducting medium placed in-between the object port 18 and the semiconductor material substrate 12 or by thermally connecting the object port 18 to the semiconductor material substrate 12 and/or to the logic block 26 using heat
15 conducting elements. In the present embodiment depicted in FIG 1, the object port 18 is positioned on the semiconductor material substrate 12 and the object port 18 receives the heat generated by the logic block 26 by direct thermal contact.

20 Generally, the logic block 26 includes a combination of sequential logic and combinational logic. The heat is generated as a by-product of the logical operations performed by the logic block 26. The heat generated by the logic block
25 26 depends on the computational load of logical operations being performed. For example, higher the computational load of the logical operations being performed, greater is the quantity of the heat produced. The operating temperature of certain logic block 26 is greater than 70°C.

30 The logical operations for enabling the logic block 26 to selectively generate heat can be based on computational instructions provided to the logic block 26 or the logical circuit 14 as an input. The term "computational instructions"
35 used herein refers to processing instructions provided to the logic blocks 26 or the logical circuit 14.

For an example, the processing instructions can be part of a computer program or an algorithm. According to an aspect herein, the computer program or the algorithm can be derived such that the predetermined computational instructions

5 provided to the logic block 26 causes it to perform logical operations to selectively generate heat as desired. For example, the computer program or the algorithm can comprise equations which are predetermined such that the corresponding predetermined computational instructions when provided to the
10 logic block 26 or the logical circuit 14 causes it to produce the corresponding heat by performing logical operations identified by the corresponding equation. The equations can be predetermined for generating varying amounts of heat. Additionally, the equations can be derived such that a very
15 precise amount of heat can be generated. The generation of heat by the logic block 26 or the logical circuit 14 can be explained using the following equations.

$$P = \alpha V^2 C_l f \quad (1)$$

20 where, P is the dynamic power consumption of the logic block 26 or the logical circuit 14, α is the activity factor of the logic block 26 or the logical circuit 14 and is defined as the frequency of switching of logic gates of the logic block 26 or the logical circuit 14, V^2 is the voltage
25 supplied to the logic block 26 or the logical circuit 14 in Volts, C_l is the capacitive load and f is the clock frequency.

$$T \propto P \quad (2)$$

30 where, T is the temperature of the logic block 26 or the logical circuit 14 in °C (degree centigrade). From equations (1) it can be seen that the power consumption P of the logic block 26 or the logical circuit 14 varies with respect to voltage and clock frequency of the logic block 26 or the
35 logical circuit 14 and from equation (2) it can be seen that the temperature T is directly proportional to the power consumption P of the logic block 26 or the logical circuit 14. Thus, by varying the power consumption P of the logical

circuit 14 or the logic block 26, the temperature T can be varied and thus, the heat generated by the logic block 26 or the logical circuit 14 can be varied. For example, with increase in computational load, the logic block 26 or the logical circuit 14 is required to do the processing at a faster rate for the completion of a task. Faster processing rate is achieved with an increase in the clock frequency f of the logic block 26 or the logical circuit 14, which results in increased power consumption P . According to an aspect of the present technique, the logic block 26 or the logical circuit 14 is operable to selectively generate specific amount of heat depending on the computational load. The computational load of the logic block 26 or the logical circuit 14 depends on the computational instructions provided to the logic block 26 or the logical circuit 14.

Referring still to FIG 1, in the illustrated embodiment, the object port 18 to be heated is the fluid chamber 20. The fluid chamber 20 of the present embodiment is formed on a slab 22. The slab 22 is positioned such that the fluid chamber 20 receives the heat generated by the logic block 26. In the present embodiment, the slab 22 is arranged onto the semiconductor material substrate 12 and the fluid chamber 20 receives the heat generated via the semiconductor material substrate 12. The fluid chamber 20 is shaped to receive the object 21, i.e. the fluid 21 in this embodiment, to which the heat is to be transferred. In the illustrated embodiment, the integrated temperature regulator 5 is used for heating the fluid chamber 20 from which the heat is transferred to the fluid 21.

According to an aspect of the present technique, the computational instructions to be provided to the logic block 26 is predetermined to selectively generate specific amount of heat. The selection or predetermination of the computational instructions is aided through calibration. Thus, the integrated temperature regulator 5 is calibrated for the generation of varying amounts of heat responsive to

different computational instructions. The predetermined computational instructions or an indication for the generation of the predetermined computational instructions for different respective amounts of heat can be maintained as a look-up table. For example, the indication to the predetermined computational instructions can include, but not limited to, a clock frequency of operation of the logical circuit 14. Thereafter, the predetermined computational instructions can be generated such that the logic block 26 operates at the clock frequency specified in the look-up table for a specific temperature. In an exemplary embodiment of the present technique in accordance with aspects herein, the look-up table can be stored onto the logical circuit 14 if the logical circuit 14 is capable of storing a computer program. Alternatively, the look-up table can be stored externally and can be provided to the logic block 26 or the logical circuit 14 as an input. Similarly, the specific amount of heat can also be generated selectively by varying the voltage provided to the logic block 26 or the logical circuit 14. Also, a combination of the parameters mentioned in equation (1) can be varied to generate the specific amount of heat selectively.

Referring still to FIG 1, the logic block 26 or the logical circuit 14 can include any circuitry capable for processing computational instructions by performing logical operations. For example, the logic block 26 or the logical circuit 14 may be a constituent of, but not limited to, a processor, ASIC (application-specific integrated circuit), FPGA, and so on. The predetermined computational instructions can be provided to logic block 26 via input/output pads of the logic block 26 or the logical circuit 14. In accordance with an aspect of the present technique, the semiconductor material substrate 12 comprising the logic block 26 can be an integrated circuit as the integrated circuit comprises a logical circuit formed into the substrate of a semiconductor material. With respect to an integrated circuit, the semiconductor material substrate comprising the logical circuit is generally

referred to as a die which is a small block of semiconductor material, on which a given functional circuit is fabricated. The die is thereafter packaged in an integrated circuit package. For example, in case of a die, the predetermined
5 computational instructions can be provided to the logical circuit 14 fabricated therein via input/output pads of the die. Thus, a die of an integrated circuit can also form the heating module 10 of the integrated temperature regulator 5 of the embodiments described herein.

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Referring still to FIG 1, the fluid 21 may be heated to the desired temperature using the specific amount of heat generated selectively by the logic block 26 of the integrated temperature regulator 5. For example, according to aspects of
15 the present technique, the specific amount of heat produced selectively by the logic block 26 can be used for DNA (Deoxyribonucleic acid) sequencing. The amplification of DNA for DNA sequencing can be performed using a Polymerase Chain Reaction (PCR) process. The PCR process uses repeated thermal
20 cycling with each cycle comprising multiple discrete temperature steps. Thus, the PCR process requires accurate control of temperature to achieve the repeated thermal cycles in a Polymerase Chain Reaction (PCR). The predetermined computational instructions can be provided to the logic block
25 26 to generate the desired temperature at each step of the thermal cycle in a repeated manner. As the logic block 26 produces the specific amount of heat responsive to the predetermined computational instructions, the temperature can be controlled more accurately and precisely.

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Referring still to FIG 1, the object port 18 illustrated as the fluid chamber 20 is for exemplary purposes only. The object port 18 can be any device requiring specific amount of heat for performing a task. For example, the object port 18
35 can be an actuator or a valve of an implant drug delivery system which can be adapted to eject a portion of drug periodically. The actuator or the valve can be controlled to eject the portion of the drug using the heat generated by the

logic block 26 of the heating module 10. Advantageously, in an exemplary embodiment of the present technique, the logic block 26 or the logical circuit 14 can be programmed to generate the specific amount of heat to activate the actuator or the valve periodically.

FIG 2 illustrates a schematic representation of another embodiment of the integrated temperature regulator 5. In the illustrated embodiment of FIG 2, the logic block 26 or the logical circuit 14 is formed integrated in the semiconductor material substrate 12 i.e. fabricated inside the semiconductor material substrate 12. In the shown example of FIG 2, the semiconductor material substrate 12 comprises two layers 13a, 13b and the logical circuit 14 is formed between the layers 13a, 13b. For example, the layer 13a of the semiconductor material substrate 12 can be formed first, the logical circuit 14 formed on the layer 13a and thereafter the layer 13b can be formed over the layer 13a comprising the logical circuit 14. In the shown embodiment of FIG 2, the object port 18 which is the fluid chamber 20 is formed on the layer 13b of the semiconductor material substrate 12.

FIG 3 illustrates a schematic representation of another embodiment of the integrated temperature regulator 5 and the object port 18 positioned on the semiconductor material substrate 12, in accordance with aspects of the present technique. In the illustrated embodiment of FIG 3, the object port 18 may include a microfluidic device 23. A top view of an exemplary embodiment of the microfluidic device 23 included in the object port 18 of the integrated temperature regulator 5 is schematically depicted in FIG 4.

Generally, the microfluidic device 23 includes a plurality of fluid chambers (20a,20b,20c,20d,20e) connected by a network of micro-channels (24a,24b,24c,24d,24e). The microfluidic device 23 is configured to receive the fluid 21. The fluid 21 within the microfluidic device 23 may be transported through the micro-channels (24a,24b,24c,24d,24e) to and from the

fluid chambers (20a,20b,20c,20d,20e) by creating a surface tension gradient. In the example of the illustrated embodiment of FIG 3 and FIG 4, the surface tension gradient for transporting of the fluid 21 within the microfluidic device 23 may be produced by thermal approach.

The surface tension gradient by thermal approach can be achieved by maintaining a location from which the fluid is to be transported at a higher temperature compared to a temperature of a location to which the fluid is to be transported. To achieve this, the integrated temperature regulator 5 with a plurality of the logic block 26 may be advantageously used. A top view of an exemplary embodiment of the heating module 10 depicting the plurality of logic blocks 26 of the integrated temperature regulator 5 is schematically depicted in FIG 5. Each of the logic block 26 is at a given location 30a,30b,30c thereof.

According to the embodiment depicted in FIGs 3 to 5, a location or a region 28a,28b,28c on the object port 18 is assigned to the corresponding given location 30a,30b,30c of the logic blocks 26. One way of assigning locations 28a,28b,28c on the microfluidic device 23 to corresponding given locations 30a,30b,30c of the logic blocks 26 is by matching the coordinates of the microfluidic device 23 and the logical circuit 14. As the coordinates of the microfluidic device 23 and the logic blocks 26 are matched, the corresponding locations 30a,30b,30c of the logic blocks 26 can be identified easily by knowing the coordinates of the respective locations 28a,28b,28c on the microfluidic device 23.

Thus, if a particular location, say the location 28a, on the object port 18 i.e. the microfluidic device 23 is desired to be heated, the logic block 26 at the corresponding given location i.e. 30a can be selected easily and made to selectively generate the specific amount of heat for heating at least a part of the object 21 when received at the

particular location 28a on the object port 18 or the microfluidic device 23. The selective generation of heat is by operating the logic block 26 at the given location 30a by providing the at least one predetermined computational
5 instruction as an input to the logic block 26 at the given location 30a. In embodiments with several such logic blocks 26 each at its unique given location 30a, 30b, 30c, different location 28a, 28b, 28c on the object port 18 may be assigned to the different given locations 30a, 30b, 30c of the different
10 logic blocks 26. Now, if it is desirable to heat a different location on the object port 18 i.e. the microfluidic device 23 say the location 28c then the logic block 26 at the corresponding given location i.e. 30c needs to be provided with the predetermined computational instruction as an input
15 and subsequently made to perform logical operations in response to the predetermined computational instruction provided as the input. The locations 28a and 28b may be heated to different temperatures by providing different predetermined computational instruction as inputs to the
20 logic blocks 26 at the corresponding given location 30a and 30c, respectively.

This differential heating at the different locations 28a, 28b, 28c of the object port 18 or the microfluidic device
25 23 results in establishing a thermal gradient across the differentially heated locations 28a, 28b, 28c of the object port 18 or the microfluidic device 23, which in turn causes the surface tension gradient. For example, a thermal gradient may be established between the location 28a and 28c, and if
30 the location 28a is heated to and maintained at a temperature greater than the temperature of the location 28c, then the fluid 21 is made to flow in the microfluidic channel 24a from the location 28c towards the location 28a in the microfluidic device 23 i.e. the object port 18. It may be noted that the
35 thermal gradient across the two locations 28a and 28c of the microfluidic device 23 results from spatial dissipation of the heat generated by the logic blocks 26 at the

corresponding given locations 30a and 30c at the semiconductor material substrate 12.

Thus, the temperature along a desired flow path of the fluid 21 can be in a linearly decreasing order and as a result the fluid 21 is efficiently transported from a higher temperature region to a lower temperature region. The linearly decreasing order of the temperature is hereinafter referred to as linear thermal gradient. The linear thermal gradient provides the advantage of heating the fluid quickly to a desired temperature without having to heat the fluid to an excessively high temperature. Thus, the overall heat generated is less and this increases the longevity of the integrated temperature regulator 5 and the object port 18 and also the microfluidic device 23, if any. Additionally, as the heat generated is less, reduction in energy consumption is achieved. Moreover, the linear thermal gradient provides the advantage of uniform flow velocity of the fluid 21. Additionally, linear thermal gradient enables in performing in the object port 18 continuous flow assays with ease.

Referring still to FIG 3, however, in embodiments wherein the object port 18 is thermally connected to the logical circuit 14 using heat conducting elements (not shown), the thermal gradient can be created by arranging the plurality of heat conducting elements such that different amounts of heat is transferred to the different locations 28a, 28b, 28c of the microfluidic device 23 through each of the plurality of heat conducting elements to create the thermal gradient.

FIG 4 illustrates a top view of a microfluidic device 23 according to an embodiment herein. In the illustrated embodiment of FIG 4, the microfluidic device 23 comprises a plurality of fluid chambers 20 connected by a network of micro-channels 24. In the illustrated embodiment, the microfluidic device 23 illustrated as comprising five fluid chambers 20a, 20b, 20c, 20d, 20e and connected by the five micro-channels 24a, 24b, 24c, 24d, 24e is for illustration

purpose only and is not intended to depict a microfluidic device for any particular application. The number of fluid chambers 20 and the micro-channels 24, as well as the overall topology of the microfluidic device 23, will depend upon particular application which the microfluidic device 23 is designed to perform.

It may be noted that as depicted in FIG 5, the logical circuit 14 may comprises more than one logic blocks 26, wherein each of the logic blocks 26 are programmable independently of the other. The programmable logic blocks 26 hereinafter referred to as the logic blocks 26 can be reconfigured independently to perform same or different logical operations to generate same or different specific amounts of heat. Thus, the different logic blocks 26 can be reconfigured and thus, operable for performing same or different logical operations responsive to same or different predetermined computational instructions to selectively generate same or different specific amounts of heat to be transferred to the object port 18, or the microfluidic device 23 as depicted in FIG 4, and produce the desired thermal gradient, which in turn causes the surface tension gradient as desired within the fluid 21 contained in the object port 18 or in the microfluidic device 23 thereby causing the flow of the fluid 21 in the microfluidic device 23.

It may be noted, that as different location 28a, 28b, 28c in the microfluidic device 23 can be heated to different temperatures, a velocity of the flow of the fluid 21 can also be controlled accurately by controlling the thermal gradient at the different locations 28a, 28b, 28c in the microfluidic device 23 along the path of the fluid transport.

The computational instructions provided to each of the logic blocks 26 for performing different logical operations are determined such that the respective logic block 26 is operable to consume different amount of power as per the abovementioned equation (1) and thus generate different

amounts of heat to cause the thermal gradient. As mentioned previously, the predetermined computational instructions to be provided to the different logic blocks 26 can be part of a computer program or algorithm and can be derived such that the respective logic block 26 performs the logical operations responsive to the predetermined computational instructions and produces heat.

Referring still to FIG 5, the embodiment depicted herein schematically represents the logical circuit 14 comprising the plurality of independently programmable logic blocks 26. This arrangement of the logic blocks 26 may be that of a field programmable gate array (FPGA). The FPGA comprises one or more of programmable logic blocks 26 and reconfigurable interconnects (not shown) that allow the logic blocks 26 to be wired with each other and thus be in electrical communication with each other. The reconfigurable interconnects allow interconnecting the logic blocks of the FPGA to be configured differently. Thus, one or more of logic blocks 26 of the FPGA can be reconfigured and operable responsive to the predetermined computation instructions provided to the FPGA. Thus in one of the embodiments depicted in FIG 5, the heating module 10 may be, but not limited to, a FPGA.

Referring to FIG 4 and FIG 5 in combination with FIG 1, in the shown embodiment the object port 18 of FIG 3 is illustrated as having the microfluidic device 23. However it may be noted, that the integrated temperature regulator 5 according to the present technique may be used to simply heat the fluid chamber 20 of FIG 1 without a requirement of inducing any flow of the fluid 21 to or from the fluid chamber 20 of FIG 1. Furthermore, even in the microfluidic device 23 as depicted in FIG 4, a simple heating requirement of one or more of the fluid chambers 20a,20b,20c,20d,20e may be required without any requirement of inducing the flow of the fluid 21 to or from the fluid chambers 20a,20b,20c,20d,20e of FIG 4. In order to achieve this simple

heating, one or more of the logic blocks 26 may be reconfigured to perform logical operations such that the heat generated by the logic blocks 26 heats the fluid chamber 20 or the fluid chambers 20a,20b,20c,20d,20e to a specific
5 temperature avoiding resulting of any thermal gradient. In an exemplary embodiment, this can be achieved by configuring the logic blocks 26 at the different given locations 30a,30b,30c to produce heat such that the effect of spatial dissipation of heat is minimized and the thermal gradient is not created
10 by heating the fluid chamber 20 or the fluid chambers 20a,20b,20c,20d,20e and their surroundings uniformly.

It may be noted that advantageously, the surface transferring heat to the microfluidic device 23 can also be formed such
15 that the heat generated by the logic blocks 26 is transferred to the microfluidic device 23 with reduced spatial dissipation. For example, the surface of the semiconductor material substrate 12 can comprise multiple regions or locations corresponding to each logic block 26, wherein the
20 regions or locations are thermally isolated from each other.

In certain embodiments of the integrated temperature regulator 5 that include the plurality of the logic blocks 26, the different logic blocks 26 of the plurality may be
25 thermally isolated from each other. Thus, the heat produced by each of the logic blocks 26 is transferred to the different locations 28a,28b,28c of the object port 18 independent of one another.

30 It may be noted that, in the integrated temperature regulator 5 comprising the plurality of logic blocks 26, either one or more of the logic blocks 26 is configured together i.e. simultaneously to process predetermined computational instructions to generate same specific amounts of heat or
35 each one of the logic blocks 26 or different clusters of the logic blocks 26 wherein each cluster comprises more than one logic block 26 is configured independently to process same or different predetermined computational instructions to

generate same or different specific amounts of heat. Thus, either all the logic blocks 26 in the heating module 10 may be operated to generate same amount of heat or one or more of the logic blocks 26 in the heating module 10 may be operated to generate different amounts of heat depending on the predetermined computational instruction provided to the logic blocks 26.

Referring still to FIG 4 and FIG 5, the mechanism of producing thermal gradient described in the aforementioned paragraphs for transportation of the fluid 21 within the microfluidic device 23 is explained in further detail. For example, if the fluid 21 is stored or injected into the fluid chamber 20a and is required to be transported towards the fluid chamber 20b, the same can be achieved by generating a thermal gradient using the integrated temperature regulator 5 along the path of the micro-channel 24a. The thermal gradient generated produces the surface tension gradient required for laterally transporting the fluid 21. For example, the fluid 21 in fluid chamber 20a is heated to a first temperature to move the fluid away from the higher temperature of the fluid chamber 20a into the micro-channel 24a. The location 28c may be advantageously heated to a temperature which is greater than the temperature to which the fluid chamber 20a is heated to ensure that the fluid 21 does not flow towards the fluid chamber 20e. Thereafter, the fluid 21 in the micro-channel 24a is again heated at the location 28b to make it flow further towards the fluid chamber 20b, simultaneously maintaining the fluid chamber 20a at a temperature higher than the temperature of the location 28b. Advantageously, the location 28a can be heated to a temperature less than the temperature to which the fluid chamber 20a or the location 28b is heated. This way the fluid 21 is transported towards the fluid chamber 20b from the fluid chamber 20a. Moreover, in this technique of fluid transport, the fluid 21 is maintained in a heated state throughout its flow path and thus obviating the need to heat the fluid 21 to an excessively high temperature at the fluid chamber 20a. This

may help in preserving any quality of the fluid 21 or its components that may be adversely affected by exposure to excessively high temperatures.

5 FIG 6 illustrates a top view of another exemplary embodiment of the heating module 10 depicting a plurality of logical circuits 14 of the integrated temperature regulator 5. In the shown example of FIG 6, the semiconductor material substrate 12 of the integrated temperature regulator 5 comprises a
10 plurality of logical circuits 14, each operable to process computational instructions. Each of the logical circuits 14 is operable to perform logical operations responsive to the predetermined computational instructions. The integrated temperature regulator 5 of the present embodiment can be used
15 to heat the object port 18 of FIG 3 or to produce the thermal gradient as discussed in reference to FIG 4. For example, if the integrated temperature regulator 5 as depicted in FIG 6 is deployed to heat the object port 18 without creating a thermal gradient, the logical circuits 14 can be provided
20 with such predetermined computational instructions such that the integrated temperature regulator 5 produces the specific heat to which the object port 18 in its entirety is to be heated. For producing the thermal gradient, the computational instructions provided to the logical circuits 14 can be such
25 that one or more of the logical circuits 14 performs different logical operations to produce different amounts of heat as per equation (1) and hence generate the thermal gradient.

30 FIG 7 schematically represents a top view of another exemplary embodiment of the heating module 10 depicting the logic blocks 26 arranged in the plurality of logical circuits 14 of the integrated temperature regulator 5. In the shown example of FIG 7, each the logical circuits 14 comprises a
35 plurality of the logic blocks 26. The logic blocks 26 of each of the logical circuit 14 are operable for performing different logical operations to selectively generate heat to produce the thermal gradient. In accordance to the present

embodiment, the integrated temperature regulator 5 can be deployed to produce multiple independent thermal gradients and thus, for example, multiple microfluidic devices 23 of FIG 4 can be heated simultaneously using the integrated temperature regulator 5.

In accordance with aspects of the present technique, the integrated temperature regulator 5 may additionally comprise means for cooling the object 21 or the object port 18. FIG 8 illustrates a schematic representation of an embodiment of the integrated temperature regulator 5 depicting a cooling module 28 and FIG 9 illustrates a schematic representation of another embodiment of the integrated temperature regulator 5 depicting a plurality of the cooling modules 28.

The cooling module 28 functions to cool the object 21 or the object port 18. In this embodiment, the object port 18 that receives the object 21 is in thermal contact with the cooling module 28. Thus the integrated temperature regulator 5 may also be used for cooling the object 21 besides heating the object 21 by selectively generating the heat. The object port 18 may be positioned in between the cooling module 28 and the heating module 10 in the integrated temperature regulator 5. The object port 18 is in thermal contact on one of its sides (not shown) with the cooling module 28 and on another of its sides with the heating module 10. Thus the heating module 10 in the integrated temperature regulator 5 generates heat which may be used for generating temperatures above the ambient temperature, and the cooling module 28 in the integrated temperature regulator 5 generates a cooling effect and may be used for generating temperatures below the ambient temperature.

In the embodiment as illustrated in FIG 9, wherein the plurality of cooling modules 28 are present, different cooling effects can be produced at different locations 28a, 28b, 28c of the object port 18 or the microfluidic device 23. The cooling effect of the cooling modules 28 may also be

advantageously used, in combination with the heat generated from the logic blocks 26, in creating the thermal gradient in the microfluidic device 23.

5 The cooling module 28 may be, but not limited to, a Peltier cooler and can be controlled electrically for producing the desired cooling. The Peltier cooler is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending
10 on the direction of the current. The Peltier cooler is also called a Peltier device, a Peltier heat pump, a solid state refrigerator, or a thermoelectric cooler (TEC). The cooling side of the Peltier cooler is arranged in thermal contact with the object port 18. Such Peltier coolers are well known
15 in art of thermoelectric cooling and thus same has not been described herein for sake of brevity.

FIG 10 illustrates an exemplary microfluidic device 23 comprising a plurality of fluid chambers 20 according to an
20 embodiment herein. Advantageously, the fluid chambers 20 can be arranged as a 2D array. The microfluidic device 23 comprising the plurality of fluid chambers 20 arranged in the 2D array can be operated to perform the function of a microarray. The different fluid chambers
25 20a, 20b, 20c, 20d, 20e, 20f may be heated to or cooled to or maintained at same or different temperatures according to the aspects of the present technique by using the integrated temperature regulator 5. Thus, the fluid chambers 20 of the microfluidic device 23 can be used for performing different
30 reactions simultaneously which may need different or same temperature settings. For example, if the microfluidic device 23 is used as a DNA microarray, the fluid chambers 20 can be used for performing different DNA sequencing simultaneously. Further examples of use of the microarray may be different
35 biological assays, biochemical assays, electrochemical assays, chemical assays, immunological assays, and so on and so forth.

FIG 11 schematically illustrates an exemplary embodiment the integrated temperature regulator 5 in conjunction with an integrated circuit package 32. In an embodiment, the semiconductor material substrate 12 is packaged within the integrated circuit package 32. At least one surface 34 of the integrated circuit package 32 is thermally connected to the semiconductor material substrate 12 to receive the heat generated by the logic blocks 26. This results in efficient transfer of heat from the semiconductor material substrate 12 or the logic block 26 to the surface 34 of the integrated circuit package 32 from which the heat is to be transferred to the object port 18 and then to the object 21, if any, received by the object port 18.

Thus, a specialized integrated circuit package 32 capable of processing computational instructions can be configured as the integrated temperature regulator 5 as described in the embodiments herein as the integrated circuit package 32 comprises a substrate of semiconductor material with the logical circuit 14 and the logic blocks 26 fabricated in the semiconductor material. The computational instructions responsive to which the logical circuit 14 or the logic blocks 26 performs logical operations to selectively generate varying specific amounts of heat can be determined by calibrating the heat generated at the surface 34 of the integrated circuit package 32 onto which the object port 18 is positioned. The predetermined computational instructions can be provided to the logic blocks 26 or the logical circuit 14 via the input/output pins (not shown) provided on the integrated circuit package 32 or can be stored within a memory (not shown in FIG 11) in the integrated circuit package 32.

Generally the integrated circuit package 32 comprises heat sinks (not shown) to effectively dissipate the heat generated at the logic blocks 26 of the semiconductor material substrate 12 located inside the integrated circuit package 32 and thereafter to the environment. However, to realize

aspects of the present technique, the heat sinks can be arranged or positioned such that the heat generated by the logic blocks 26 or the logical circuit 14 is effectively transferred to the surface 34 so that the heat can be further transferred to the object port 18. In an alternate embodiment of the integrated temperature regulator 5, the heat sinks within the integrated circuit package 32 can be arranged such that the heat transferred to the surface 34 generates a thermal gradient. This can be achieved by transferring different amount of heat at different locations of the surface 34 of the integrated circuit package 32.

FIG 12 schematically illustrates an exemplary embodiment of the integrated temperature regulator 5 comprising a controller 38. The controller 38 may function to provide the same or different predetermined computation instructions to the different logic blocks 26 at given instances of time or after predetermined intervals of time. The controller 38 may be, but not limited to, a processor, a central processing unit (CPU), and so forth and may be optionally coupled to a display device 40 and further optionally to an input device 42. The display device 40 may be, but not limited to, a LED screen, a touch panel, a LCD screen, and so forth. The input device 42 may be, but not limited to, a mouse control, a keyboard, a touch based interface, and so forth. The controller 38 is operably coupled to the heating module 10 to aid sending predetermined computation instructions to the different logic blocks 26 of the heating module 10.

Optionally, a look-up table specifying the different predetermined computational instructions and/or references to the computational instructions to be generated may be stored at a memory 44 that is coupled to the controller 38. The memory 44 may be volatile such as random access memory (RAM) etc., non-volatile such as read only memory i.e. ROM, flash memory devices, etc., or a combination of the two. The specific temperature to be generated can be provided to the controller 38 through the input device 42. Based on the input

received, the controller 38 accesses the memory 44 and selects and provides the predetermined computational instructions to the logic block 26 responsive to which the logic block 26 can performs logical operations to generate the selected temperature. In embodiments of the integrated temperature regulator 5 wherein the computational instructions are required to be generated depending on the specific temperature provided as input, the controller 38 is configured to generate the predetermined computational instructions based on the references to the predetermined computational instructions in the look-up table.

FIG 13 schematically illustrates another exemplary embodiment of the integrated temperature regulator 5. According to the present embodiment, the predetermined computational instructions are stored onto the logical circuit 14 of the integrated temperature regulator 5. For example, the logical circuit 14 can comprise a memory unit (not shown) for storing the predetermined computational instructions therein. The logical circuit 14 obtains the predetermined computational instructions to be processed from the memory responsive to the input received and performs logical operations to generate the selected temperature.

FIG 14 perspective view of a schematically illustrated exemplary embodiment of the integrated temperature regulator 5 and the object 21 positioned onto the integrated temperature regulator 5 depicting a valve 46. In the present embodiment, the object port 18 may comprise the microfluidic device 23 as described in reference to FIG 4. In the shown example of FIG 14, the micro-channels 24 of the microfluidic device 23 comprises the valve 46 which is capable of being in an opened state or a closed state corresponding to an external stimulus. The external stimulus used for opening and/or closing the valve 46 may be, but not limited to, temperature at the valve 46. The valve 46 can be made using a shape-memory alloy such that one or more properties of the

valve 46 can be changed in a controlled manner by varying the temperature at the valve 46.

The shape-memory alloy, also referred to as SMA, smart metal, memory metal, memory alloy, muscle wire, smart alloy, is an alloy that "remembers" its original, cold-forged shape and returns to the pre-deformed shape when heated. This material is a lightweight, solid-state alternative to conventional actuators such as hydraulic, pneumatic, and motor-based systems. The valve 46 can be deformed and placed in the micro-channels 24. When the valve 46 in its deformed state, the micro-channel 24 may either be closed or open. Subsequently, the external stimulus, i.e. temperature of the valve 46 may be applied meaning the valve 46 is provided heat from the heating module 10 which results in change in the shape of the valve 46 to the pre-deformed state. When the valve 46 changes to its pre-deformed state, the micro-channel 24 may change to closed status from an earlier open status that existed prior to the heating or may change to open status from an earlier closed status that existed prior to the heating.

Thus by heating the valve 46 as per the requirement the flow of the fluid 21 in the micro-channels may be controlled by effect of valving. Thus the integrated temperature regulator 5 may be used as a control-valving enabled microfluidic device.

To further explain, the logic block 26 of the integrated temperature regulator 5 can be configured to generate heat to selectively heat the valve 46 to change one or more properties of the valve 46. For example, the valve 46 can be in an open position at a first temperature as depicted in FIG 15a, for example, room temperature, to allow flow of the fluid 21 through the micro-channel 24. The flow of the fluid may be stopped by changing the valve 46 to a closed position as depicted in FIG 15b. To block the flow of the fluid 21 through the micro-channel 24 by closing the valve 46, the

logic block 26 of the integrated temperature regulator 5 can be configured to produce a specific amount of heat such that the temperature of the valve 46 is raised to a second temperature. As an example, the second temperature may be higher than the first temperature and may result in closing of the micro-channel 24 by a change in shape of the valve 46. Thus, in this example the valve 46 is closed using the heat generated by the logic block 26. It may be noted that temperature at the valve 46 may be changed by heating the valve 46 using the heating module 10, by cooling the valve 46 using the cooling module 28, or by a combination of the two. The heating using the heating module 10 or the cooling using the cooling module 28 is achieved as described in reference to FIGs 1 to 13.

It may be noted that, although in the example explained above with reference to schematic depictions of FIGS 14, 15a and 15b, a single valve 46 and a single micro-channel 24 is illustrated, the microfluidic device 23 can comprises a plurality of fluid chambers 20, connected by a plurality of micro-channels 24. One or more of the valves 46 can be disposed in each of the micro-channels 24 and with the one or more valves 46 the flow of the fluid 21 through each of the micro-channels 24 can be controlled. Additionally, to provide metering of volumes of the fluid 21 flowing through the micro-channels 24, a set of valves 46 can be arranged in a single micro-channel 24. The fluid 21, i.e. the sample fluid or the reagent, can be loaded into the micro-channel 24 and thereafter can be segmented into separated liquid compartments by closing the set of valves 46. For providing a plurality of separate liquid compartments, corresponding number of valves 46 can be arranged into the single micro-channel 24.

Thus, the microfluidic device 23 with the plurality of fluid chambers 20, micro-channels 24 and valves 46 can be reconfigured as per the requirement of the microfluidic application to be performed using the integrated temperature

regulator 5. Thus, the microfluidic device 23 may comprise a plurality of reagent chambers for receiving reagents and a plurality reaction chambers for performing reactions and this can be achieved by using the separate liquid compartments. It may be noted that the microfluidic device 23 can be optionally configured to perform more than one microfluidic application simultaneously i.e. the microfluidic device 23 can be reconfigured as per the requirement.

FIG 16 schematically illustrates an example of a reconfigurable microfluidic device 23. The reconfigurable microfluidic device 23 of FIG 16 may be used in conjunction with the integrated temperature regulator 5 as described with reference to FIG 5, 6 or 7. Different regions of the reconfigurable microfluidic device 23 are assigned to different given locations 30a,30b,30c of the integrated temperature regulator 5 of FIG 5. The microfluidic device 23 is made reconfigurable by selectively heating the different locations or regions of the microfluidic device 23 using the specific amount of heat generated by the logic blocks 26 situated at the corresponding given location 30a,30b,30c of the integrated temperature regulator 5 of FIG 5.

For example, the microfluidic device 23 of FIG 16 includes reagent chambers 48 to hold the reagent, the fluid chambers 20 to hold the fluid 21, i.e. the sample 21, and the reaction chambers 50 which is the seat of the reaction intended to be performed in the microfluidic device 23. The reagent chambers 48, the fluid chambers 20 and the reaction chambers 50 are interconnected using micro-channels 24 as depicted schematically in FIG 16. The object is to use the microfluidic device 23 in such a way that the sample 21 from the fluid chamber 20 and the reagent from the reagent chamber 48 flow to the reaction chamber 50 and meet at the reaction chamber 50 wherein the reaction intended to be performed takes place. The reaction to take place may require a particular temperature at the reaction chamber 50 which can be achieved by the logic blocks 26 corresponding to the

location of the reaction chamber 23 in the microfluidic device 23. The reagent chamber 48 means a structure suitable to hold the reagent in liquid state and that is designed to prevent any unintended release of the reagent held in the reagent chamber 48. The reagent is required to be released from the reagent chamber 48 towards the reaction chamber 50 only when desired. The fluid chamber 20 means a structure suitable to hold the sample in liquid state and that is designed to prevent any unintended release of the sample held in the fluid chamber 20. The sample is required to be released from the sample chamber 20 towards the reaction chamber 50 only when desired. The reaction chamber 50 means a structure suitable to receive, to hold and to allow interaction of the sample and the reagent in liquid state incoming from the fluid chamber 20 and the reagent chamber 48, respectively. It may be noted that structurally the reagent chamber 48, the fluid chamber 20 and the reaction chamber 50 are similar. The reagent and the sample can be loaded or injected into the reagent chamber 48 and the fluid chamber 20 by an appropriate means such as micro-pipetting.

For an example, as per the schematic illustration in FIG 16, say the fluid 21 or the sample 21 to be analyzed is injected or micro-pipetted into the fluid chamber 20a. Say two chemical reagents, Reagent A and Reagent B are injected into the reagent chambers 48a and 48b, respectively. The sample 21 from the fluid chamber 20a and the Reagents A and B from the reagent chambers 48a and 48b, respectively, can be transported to reaction chambers 50a and 50b using thermal gradient which can be produced easily using the integrated temperature regulator 5 in accordance with aspects of the present technique.

As illustrated in the example of FIG 16, the sample 21 is transported from fluid chamber 20a via the micro-channel 24a to the reaction chamber 50a. The valves 46a, 46b, 46c, 46d arranged in the micro-channel 24a are maintained in the open positions and the valves 46i, 46e, 46o and 46x are maintained

in the closed position. As mentioned previously, the valves 46i, 46e, 46o, 46x can be closed by generating the specific amount of heat at the location of the valves 46i, 46e, 46o and 46x using the integrated temperature regulator 5. The

5 Reagent A is transported to the reaction chamber 50a via the micro-channel 24b, 24c and a portion of 24a. The valves 46l, 46n, 46f, 46e, 46c, and 46d along the flow-path of the Reagent A from the reagent chamber 48a to the reaction chamber 50a are maintained in the open position for
10 transporting the Reagent A from the reagent chamber 48a to the reaction chamber 50a. The valves 46j, 46k, 46m, 46g, 46b, 46o and 46x are maintained in the closed position so that the Reagent A does not spill to other locations during the transportation. Advantageously, the vales 46o and 46x are
15 maintained in the closed position so that the sample 21 or the Reagent A do not spill over from the reagent chambers 50a. In a similar manner, the sample 21 may be transported from the fluid chamber 20a to the reaction chamber 50b via the micro-channels 24a, 24c, and 24d and the Reagent B may be
20 transported from the reagent chamber 48b to the reaction chamber 50b via the micro-channels 24e, 24f, and 24d.

The aforementioned description provides a simple example as to how the microfluidic device 23 as described by the
25 embodiments herein can be reconfigured to perform a particular microfluidic application. However, the topology of the microfluidic device 23 can be more complex comprising many fluid chambers 20, micro-channels 24, valves 46, reagent chambers 48 and reaction chambers 50 to perform multiple
30 reactions or assays simultaneously. It may be noted that the reconfiguration of the microfluidic device 23 is achieved by configuring one or more logic blocks 26 within the corresponding location or region on the heating module 10 to perform operations responsive to the computational
35 instructions which are predetermined depending on the temperature to which the location on the microfluidic device 23 device is to be heated. Thus, in accordance with aspects of the present technique, the microfluidic device 23 can be

reconfigured as per the microfluidic application to be performed using the integrated temperature regulator 5. This provides easy means to reconfigure the microfluidic device 23 by controlling the operation of the microfluidic device 23 using the integrated temperature regulator 5.

In accordance with aspects of the present technique, the microfluidic device 23 of the integrated temperature regulator 5 may function as a flow focusing structure. The term 'flow focusing' means providing a focusing effect on a flow stream of the fluid 21 i.e. converging the flow stream in the flow path. FIG 17 illustrates an example of a microfluidic device 23 implemented as flow focusing structure. The microfluidic device 23 as the flow focusing structure of FIG 17 may be used in conjunction with the integrated temperature regulator 5 as described with reference to FIG 5, 6 or 7. For focusing the fluid flow of the fluid 21, an arrangement of micro-channels 24 comprises a central micro-channel 24i, and two symmetric side micro-channels 24j and 24k connected at a junction 52 to form a common outlet micro-channel 24l. Three different fluids 21a, 21b, 21c via the central micro-channel 24i and the symmetric channels 24j, 24k, respectively, are symmetrically contacted at the junction 52. The lateral width of the fluid 21a at the outlet micro-channel 24l can be adjusted accurately by varying the ratio of the flow rates of the fluids 21a, 21b, 21c. The flow rates of the fluids 21a, 21b, 21c may be varied by varying the thermal gradient created at the respective micro-channels 24i, 24j, 24k using the integrated temperature regulator 5 of FIG 5. Consequently, the flow of the fluid 21a can be focused in the outlet micro-channel 24l as depicted by the flow 53. Focusing of the fluid achieves in lateral focusing of micro-object like particles or cells in the fluid for analysis or for sorting in flow cytometry. The flow rates of the fluids 21a, 21b, 21c can be varied more accurately using the integrated temperature regulator 5 of the embodiments described herein as the temperature of each logic block 26 can be controlled more accurately and

precisely. Advantageously, the fluids 21b, 21c are immiscible with fluid 21a.

In accordance with aspects of the present technique, a method 500, as depicted in FIG 18, for selectively generating a specific amount of heat for heating an object 21 is presented. FIG 18 is a flow diagram illustrating the method 500. In the method 500, following a start step at 620, at least one predetermined computational instruction is selected from a plurality of predetermined computational instructions in a step 640. The predetermined computational instruction is such that the specific amount of heat is generated when logical operations corresponding to the predetermined computational instruction are performed by a logic block 26. The logic block 26 may be included in an integrated temperature regulator 5. The logic block 26 and the integrated temperature regulator may structurally and functionally be as described in reference to FIGs 1 to 17. Subsequently, in a step 660, the predetermined computational instruction so selected is provided to the logic block 26. Finally, in a step 680, logical operations are performed by the logic block 26 in response to the predetermined computational instruction so provided. The method of FIG 18 terminates at step 680.

In an embodiment, the method 500 may further include a step 650 of selecting a further predetermined computational instruction from the plurality of predetermined computational instructions. The further predetermined computational instruction is such that a further specific amount of heat is generated when logical operations corresponding to the further predetermined computational instruction are performed by a further logic block 26. The further logic block 26, along with its embodiments thereof, is same as the logic block 26 and may be included in the integrated temperature regulator 5. The further logic block 26 and the integrated temperature regulator may structurally and functionally be as described in reference to FIGs 1 to 17. In this embodiment,

subsequently, the further predetermined computational instruction is provided to the further logic block 26 in a step 670. Subsequently, in a step 690, logical operations are performed by the further logic block 26 in response to the further computational instruction so provided. The steps 650, 670 and 690 are independent of the steps 640, 660 and 680, and may be performed before or after or simultaneously along with the step 640, 660 and 680. In the method the specific amount of heat generated by the logic block 26 as a result of the steps 640, 660 and 680 may be same as or different from the further specific amount of heat generated by the further logic block 26 as a result of the steps 650, 670 and 690.

The embodiments described herein can be used for applications requiring generation of localized heating and for applications wherein accurate temperature control is required, including the applications where repeated specific thermal cycles are needed to be carried out without creating a thermal gradient. The embodiments can also be used for applications requiring the generation of a thermal gradient. As the heat generated by the integrated temperature regulator 5 is responsive to the computational instructions provided to the logic block 26 of the integrated temperature regulator 5, accurate control, over the heat generated by the logic block 26 can be achieved. The computational instructions can easily be determined for precisely and accurately generating specific amounts of heat. Additionally, for applications requiring generation of specific thermal cycles, the steps of the thermal cycles can be very accurately and precisely controlled. The generation of thermal gradient by programming the logic blocks 26 to perform different logical operations provides an easy method of generating the thermal gradient.

Moreover, as the heat is generated by performing logical operations, the requirement of specific heating elements for generation of heat is eliminated. This results in reducing the cost of the integrated temperature regulator 5 and achieves in providing a robust construction.

In accordance with aspects of the present technique, a computer-readable medium (not shown) having computer-executable instructions for performing the method as described in reference to FIG 18 is also presented. Furthermore, the method 500 of FIG 18 may be performed by a processor (not shown).

For the purposes of the present technique, the computer-readable medium, also referred to as a computer-usable medium, is any apparatus that can contain, store, communicate, propagate, or transport the computer-executable instructions, also referred to as computer programs, for use by or in connection with the integrated temperature regulator 5 of the present technique and/or to perform the method 500 for selectively generating the specific amount of heat for heating the object 21, in accordance with aspects of the present technique. The computer-readable medium is a physical computer-readable medium such as an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system (or apparatus or device), and so forth. Examples of the physical computer-readable medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk such as compact disk-read only memory (CD-ROM), compact disk-read/write (CD-R/W) and DVD.

In the present technique, a temperature regulating method 800 for regulating the temperature of the object 21 is also presented as depicted by the flow diagram of FIG 19. In the temperature regulating method 800, after a start step 820, a specific amount of heat is selectively generated in a step 840 according to the method 500 for selectively generating the specific amount of heat as described in reference to FIG 18. Subsequently, in a step 860 the specific amount of heat is provided to the object 21. The method 800 for regulating the temperature of the object 21 is terminated at a step 880.

Additionally, in an embodiment, the method 800 may further include a step 850 of cooling the object 21 by a cooling module 28. The cooling module 28 is structurally and functionally similar to the cooling module 28 as described in reference to FIGs 8 and 9.

In accordance with aspects of the present technique, the integrated temperature regulator 5, and its embodiments thereof, may be incorporated into devices and systems for analysis and monitoring in numerous applications. FIG 20 schematically represents a system 100 incorporating the integrated temperature regulator 5, in accordance with aspects of the present technique. For exemplary purposes, FIG 20 has been used hereinafter to describe the system 100 in its different embodiments, as an electrical property measurement system 100, a biochemical property measurement system 100, and a fluid dispensing system 100. It may be noted that a term 'regulate' as used hereinafter means to perform achievement of a desired temperature of the object 21 or to maintain the desired temperature of the object 21 or both.

According to an embodiment of the present technique, the electrical property measurement system 100 for determining an electrical property of a fluid 21 is presented. The electrical property measurement system 100 comprises the integrated temperature regulator 5 and an electrical property measurement module 110. The integrated temperature regulator 5 is as described in accordance with the first aspect of the present technique and embodiments thereof, as depicted and described in reference to FIGs 1 to 17. In the integrated temperature regulator 5 the object port 18 may be a microfluidic well or groove or container adapted to receive the fluid 21. The object 21 i.e. the fluid 21 received by the object port 18 may be, but not limited to, water. The integrated temperature regulator 5 is adapted to regulate a temperature of the fluid 21 to a desired temperature. The electrical property measurement module 110 is adapted to

measure the electrical property of the fluid 21 at the desired temperature. The electrical property may be, but not limited to an electrical resistivity, an electrical conductance, and so on and so forth. The electrical property measurement module 110 may be a device suitable to measure the electrical property, for example, when the electrical property to be measured is the electrical resistivity, the electrical property measurement module 110 may be, but not limited to an ohmmeter 110 or an electrical multimeter 110. Such devices or measurement modules suitable to function as the electrical property measurement module 110 to measure the electrical properties such as electrical resistivity, electrical conductance, etc. are well known in the art of electrical engineering and thus same has not been described herein for sake of brevity.

EXAMPLE 1

An example of use of the electrical property measurement system 100 is briefly explained hereinafter. Electrical resistivity at a given temperature is a measure to determine quality of water i.e. purity of water. A reading or measurement of 10 to 18.2 M Ω .cm (Megohm-cm) at 25°C for a given water sample indicates very high purity i.e. ultra-pure water. Similarly, 1 to 5 M Ω .cm at 25°C indicates pure water. It may be noted that the resistivity of water is temperature dependent. If temperature at which the resistivity is measured is raised by 1°C (degree centigrade), the resistivity measured also increases, for example the resistivity measure of the ultra-pure water increases by up to 6% (percentage). To assess the quality of a water sample, the object port 18, which may be the microfluidic device 23, of the integrated temperature regulator 5 receives the object 21 i.e. water 21 for this example.

35

In one exemplary way of using the electrical property measurement system 100, a temperature of the water 21 in the object port 18 is maintained at 25°C which is the desired

temperature by using the heat generated by the logic block 26 or by using the cooling module 28 or by a combination of the two. The resistivity of the water 21 at the desired temperature i.e. 25°C is measured using the electrical
5 property measurement module 110 to assess the quality of the water 21.

In another exemplary way of using the electrical property measurement system 100, the integrated temperature regulator
10 5 is used to change the temperature of the water 21 to a desired temperature say 10°C. This change in the temperature of the water 21 is effected by using either the logic block 26 or the cooling module 28 or by a combination of both depending on an initial temperature of the water 21.

15 Subsequently, the resistivity of the water 21 at the desired temperature i.e. 10°C is measured using the electrical property measurement module 110 to assess the quality of the water 21. Since the resistivity will now be increased manifold, due to the decrease in the temperature at which the
20 resistivity is measured, the resistivity measurement has a greater sensitivity. This greater sensitivity enables the electrical property measurement system 100 to be more accurate or to discern the difference between two samples with different trace amounts of contaminants. Thus, by using
25 the electrical property measurement system 100 in accordance with aspects of the present technique, the electrical resistivity may be measured with ease at the desired temperature, more accurately and precisely.

30 Referring again to FIG 20, according to another embodiment of the present technique, the biochemical property measurement system 100 for determining for determining a biochemical property of a sample 21 is presented. The biochemical property measurement system 100 comprises the integrated
35 temperature regulator 5 and a biochemical property measurement module 110. The integrated temperature regulator 5 is as described in accordance with the first aspect of the present technique and embodiments thereof, as depicted and

described in reference to FIGs 1 to 17. In the integrated temperature regulator 5 the object port 18 may be a microfluidic well or groove or container adapted to receive the object 21 i.e. the sample 21. The sample 21 may be, but
5 not limited to, water, urine, blood, other body fluids, fluids containing toxins, pathogens, biomarkers, immunoreactants, and so on and so forth. The integrated temperature regulator 5 is adapted to regulate a temperature of the sample 21 to a desired temperature. The biochemical
10 property measurement module 110 is adapted to measure the biochemical property of the sample 21 at the desired temperature. The biochemical property may be, but not limited to a presence or absence of a chemical, a tag, a biological or chemical reaction product, a pollutant, or a biological
15 molecule such as a protein, a pathogen, a biomarker, a toxin, a microorganism, a nucleic acid, and so on and so forth.

The biochemical property measurement module 110 may be a device suitable to measure the biochemical property, for
20 example, when the biochemical property to be measured is presence or absence or concentration of a biomolecule in the sample 21 by measuring a fluorescence in an emission spectrum after excitation of the sample 21 by a suitable incident light, the biochemical property measurement module 110 may
25 be, but not limited to an fluorometer or fluorimeter 110. Such devices or measurement modules suitable to function as the biochemical property measurement module 110 to measure the biochemical properties are well known in the art of biochemistry and thus same has not been described herein for
30 sake of brevity.

EXAMPLE 2

The sample 21 which needs to be tested for the presence or
35 absence or concentration of the biomolecule is received in the object port 18, advantageously in the microfluidic device 23 in the object port 18. The emission spectrum for the sample 21 is to be recorded and analysed for determining the

presence or absence or concentration of the biomolecule. For most substances including the biomolecules, the emission spectrum changes with a change in the temperature of the substance. Thus, in order to record a resulting emission spectrum from the sample 21 in an accurate and subsequently reproducible manner, it is important to regulate the temperature of the sample 21.

In one exemplary way of using the biochemical property measurement system 100, a temperature of the sample 21 in the object port 18 is maintained at a desired temperature say 25°C by using the heat generated by the logic block 26 or by using the cooling module 28 or by a combination of the two. The sample 21 is then excited by a suitable incident radiation and an emission spectrum of the sample 21 at the desired temperature i.e. 25°C is measured using the biochemical property measurement module 110, i.e. the fluorometer, to assess the presence or absence or concentration of the biomolecule in the sample 21. The use of incident radiation to excite the sample 21, recording of the emission spectrum, and analysis of the emissions spectrum to assess presence or absence or concentration of a biomolecule in a given sample are well known in the art of spectroscopy and thus the same has not been described herein for sake of brevity.

Referring again to FIG 20, according to another embodiment of the present technique, the fluid dispensing system 100 for determining for dispensing a fluid 21 at a given temperature is presented. The fluid dispensing system 100 comprises the integrated temperature regulator 5 and a fluid dispensing module 110. The integrated temperature regulator 5 is as described in accordance with the first aspect of the present technique and embodiments thereof, as depicted and described in reference to FIGs 1 to 17. In the integrated temperature regulator 5 the object port 18 may be a microfluidic well or groove or container adapted to receive the object 21 i.e. the fluid 21 that is to be dispensed by the fluid dispensing

system 100. The fluid 21 to be dispensed may be, but not limited to, water, ink, a chemical reagent solution, a biochemical reagent solution, a biological reagent solution, blood, other body fluids, fluids containing toxins,

5 pathogens, biomarkers, immunoreactants, and so on and so forth. The integrated temperature regulator 5 is adapted to regulate a temperature of the fluid 21 to a desired temperature. The regulation of the temperature of the fluid 21 may be advantageous to ensure desired physical parameters
10 of the fluid 21 for example a desired viscosity of the fluid 21 may be ensured by maintaining the fluid 21 for example an ink for an inkjet printer at a particular temperature i.e. the desired temperature. A temperature of the fluid 21 in the object port 18 is maintained at the desired temperature say
15 25°C by using the heat generated by the logic block 26 or by using the cooling module 28 or by a combination of the two.

The fluid dispensing module 110 is adapted to receive the fluid 21 at the desired temperature from the object port 18
20 and to dispense the fluid 21 so received to outside of the fluid dispensing system 100 via an outlet (not shown) of the fluid dispensing module 110. When the fluid dispensing system 100 is used in an inkjet printer, the fluid dispensing module 110 may be a printer head and the outlet may be the inkjet
25 nozzle.

Besides the embodiments described above in reference to FIG 20, the present technique may also be used in other applications which require localized regulation of
30 temperature. Thus, any sample, any reaction mixture i.e. a mixture containing reactants, any reagent in fluid or colloidal state, etc can be maintained at a desired temperature by using the present technique. The examples described hereinafter present uses of the present technique
35 in exemplary applications for illustration purposes.

EXAMPLE 3

In this example, the microfluidic device 23 as described in reference to FIG 16 of the integrated temperature regulator 5 is configured as an integrated system for performing polymerase chain reaction (PCR) from a bacterial DNA. The bacterial DNA is present inside the bacterial cells suspended in a sample solution. In one of the wells or fluid chambers 20a, the sample solution i.e. the object 18 is added by micro-pipetting. A bacterial cell lysis buffer, for example 25% (w/v) sucrose in 50 mM Tris-Cl (pH 7.4), is loaded into another fluid chamber i.e. reagent chamber 48 of the microfluidic device 23. The sample solution 18 and the bacterial cell lysis buffer are transported from the fluid chamber 20a and the reagent chamber 48 to the reaction chamber 50a in accordance with aspects of the present technique as described in reference to FIG 16. The bacterial cells in the sample solution 21 are lysed when mixed and subsequently incubated with the bacterial cell lysis buffer. The incubation is performed by maintaining the reaction chamber 50a containing the bacterial cells and the bacterial cell lysis buffer at a given temperature for a given period of time. The incubation i.e. maintaining the reaction chamber 50 at the given temperature for the given period of time is achieved by using the heat generated by the logic block 26 or by using the cooling module 28 or by a combination of the two. Alternatively, the sample solution and the bacterial cell lysis buffer may be directly added to the reaction chamber 50a and incubated. As a result of lysis, a cell lysate is produced in the reaction chamber 50a.

The cell lysate is then mixed with appropriate buffer solution which may be directly loaded into the reaction chamber 50a after the lysis is performed or may be pre-loaded in another reagent chamber 48 and be transported to the reaction chamber 50a after the lysis is performed. The cell lysate contains the bacterial DNA that works as a DNA template which is to be amplified by the PCR technique. The bacterial DNA gets mixed with the buffer solution and is subsequently transported, as described in reference to FIG

16, to another reaction chamber 50b. The reaction chamber 50b is pre-loaded with reagents for performing the polymerase chain reaction such as primers, a heat stable DNA polymerase enzyme, dNTPs (Deoxynucleoside triphosphates), divalent and
5 monovalent cations, buffer solution, etc.

After the bacterial DNA reaches the reaction chamber 50b and gets mixed with the reagents for performing the PCR, a series of multiple, for example 20 to 40, repeated temperature
10 cycles are performed. Each of the temperature cycle consists of 2-3 discrete temperature steps. Each of the temperature cycles is often preceded by a single temperature step (called, hold) at a high temperature ($>90^{\circ}\text{C}$). The temperatures used and the length of time they are applied in
15 each cycle depend on a variety of parameters which include the enzyme used for DNA synthesis, the concentration of divalent ions and dNTPs in the reaction, and the melting temperature of the primers. Each step requires accurate temperature control of the reaction chamber 50b i.e. the
20 reaction chamber 50b is required to be maintained at different desired temperatures for a predefined period of time, for example, initialization step requires a desired temperature of $94-96^{\circ}\text{C}$ for 1-9 minutes, denaturation step requires a desired temperature of $94-98^{\circ}\text{C}$ for 20-30 seconds,
25 annealing step needs a desired temperature of $50-65^{\circ}\text{C}$ for 20-40 seconds, and so on and so forth. The reaction chamber 50b is changed to and maintained at the respective desired temperatures for the corresponding period of time by using the heat generated by the logic block 26 or by using the
30 cooling module 28 or by a combination of the two.

EXAMPLE 4

The present technique may also be used to provide an input
35 feed of water to laboratory (lab) water systems. A typical lab water system produces at a given rate ultra-pure water for use in a variety of applications such as analytical chemistry, biological media preparation and preparing

reagents etc. These lab water systems normally comprise a series of ion exchange and adsorbent media cartridges and may include an ultrafiltration module and/or an ultraviolet light. The performance of the ion exchange and adsorbent media is affected by temperature. Ion exchange kinetics are improved with increasing temperature. Thus it is desirable to provide the input feed of water at a desired temperature to the laboratory (lab) water systems. The integrated temperature regulator 5, in accordance with aspects of the present technique, may be used as a means to regulate or control the input feed water at the desired temperature as the input feed water is fed to the lab water system. Seasonal variations in temperature that impact performance of the lab water system would be eliminated.

EXAMPLE 5

The present technique may also be used to sanitize an input laboratory (lab) water systems. As is generally known, the lab water systems must be periodically sanitized to prevent microorganisms from proliferating in the lab water systems. The standard method normally used to destroy microorganisms is to flush the lab water system with a chemical such as chlorine. This however results in the need to flush out the chemical and monitor the residual chlorine, and thus this standard method is undesirable. Alternatively, high temperature sanitization (80°C) is very effective at controlling proliferation of microorganisms. The lab water system is required to be flushed with water at high temperature. The high temperature of water can be achieved by using the heating module 10 of the integrated temperature regulator 5, in accordance with aspects of the present technique.

EXAMPLE 6

The present technique can also be used in increasing the efficiency of Ion Exchange Chromatography (hereinafter IC).

IC is an analytical technique that uses ion exchange resin to remove ions from a fluid sample and then elute the ions from the ion exchange resin by varying the concentration of the eluent over time. A conductivity measurement of the fluid sample is used to measure the concentration of the ion. It is generally known that temperature improves the kinetics of ion exchange resin and thus has an impact on IC resulting in an increase in efficiency of ion exchange at higher temperatures. Thus, an increase in temperature improves the efficiency and resolution of the IC device. An ability to control a temperature of the fluid sample being analyzed by IC makes the IC measurement more accurate. The integrated temperature regulator 5 of the present technique can be used to control the temperature of the fluid sample temperature being fed to the IC apparatus. The control or regulation of the temperature of the fluid sample may be achieved by heat generated by the logic block 26 or by using the cooling module 28 or by a combination of the two.

While this invention has been described in detail with reference to certain preferred embodiments, it should be appreciated that the present invention is not limited to the precise embodiments described herein. Rather, in view of the present disclosure which describes the current best mode for practicing the invention, many modifications and variations would present themselves, to those of skilled in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

Patent claims

1. An integrated temperature regulator (5) for regulating a temperature of an object (21), the integrated temperature regulator (5) comprising:
- a heating module (10) comprising a semiconductor material substrate (12), wherein the semiconductor material substrate (12) comprises at least one logic block (26) at a given location (30a,30b,30c), wherein the logic block (26) is operable to selectively generate a specific amount of heat for heating the object (21), wherein the specific amount of heat generated is in response to at least one predetermined computational instruction provided as an input to the logic block (26), and
 - an object port (18) for receiving the object (21) wherein the object port (18) is in thermal contact with the logic block (26).
2. The integrated temperature regulator (5) according to claim 1, wherein the object port (18) is positioned so as to receive and provide at least a part of the heat generated by the logic block (26) to the object (21).
3. The integrated temperature regulator (5) according to claim 2, wherein the object port (18) is formed integrated in the semiconductor material substrate (12).
4. The integrated temperature regulator (5) according to claim 2, wherein the object port (18) is positioned on the semiconductor material substrate (12).
5. The integrated temperature regulator (5) according to claim 1, wherein a location (28a,28b,28c) on the object port

(18) is assigned to the given location (30a,30b,30c) of the logic block (26).

5 6. The integrated temperature regulator (5) according to claim 1, comprising:
- a plurality of the logic blocks (26), wherein the different logic blocks (26) of the plurality are at corresponding given locations (30a,30b,30c), and wherein the different logic
10 blocks (26) are operable to selectively generate different specific amounts of heat for heating the object (21), wherein the different specific amounts of heat generated are in response to different predetermined computational instructions provided as an input to the different logic
15 blocks (26) of the plurality of the logic blocks (26).

7. The integrated temperature regulator (5) according to claim 6, comprising a controller (38) for providing the
20 different predetermined computation instructions to the different logic blocks (26), wherein the different computational instructions are predetermined such that the different specific amounts of heat generated are such that a linear thermal gradient is generated across at least a
25 portion of the object port (18).

8. The integrated temperature regulator (5) according to claim 6, wherein the different logic blocks (26) of the
30 plurality are thermally isolated from each other.

9. The integrated temperature regulator (5) according to claim 1, wherein the heating module (10) is a field
35 programmable gate array.

10. The integrated temperature regulator (5) according to claim 1, wherein the semiconductor material substrate (12) is packaged within an integrated circuit package (32).

5

11. The integrated temperature regulator (5) according to claim 1, wherein the object port (18) comprises a microfluidic device (23).

10

12. The integrated temperature regulator (5) according to claim 11, comprising:

- a plurality of the logic blocks (26), wherein the different logic blocks (26) of the plurality are at corresponding given locations (30a,30b,30c), and wherein the different logic blocks (26) are operable to selectively generate different specific amounts of heat for heating the object (21), wherein the different specific amounts of heat generated are in response to different predetermined computational instructions provided as an input to the different logic blocks (26), wherein the different logic blocks (26) are assigned to different locations (28a,28b,28c) of the microfluidic device (23).

25

13. The integrated temperature regulator (5) according to claim 1, comprising a cooling module (28) for cooling the object (21), wherein the object port (18) is in thermal contact with the cooling module (28).

30

14. The integrated temperature regulator (5) according to claim 13, wherein the object port (18) is positioned in between the cooling module (28) and the heating module (10).

35

15. A method (500) for selectively generating a specific amount of heat for heating an object (21), the method (500) comprising:

- selecting (640) at least one predetermined computational instruction from a plurality of predetermined computational instructions, wherein the predetermined computational instruction is such that the specific amount of heat is generated when logical operations corresponding to the predetermined computational instruction are performed by a logic block (26),
- providing (660) the predetermined computational instruction so selected to the logic block (26), and
- performing (680) logical operations by the logic block (26) in response to the predetermined computational instruction so provided.

16. The method (500) according to claim 14, comprising:

- selecting (650) a further predetermined computational instruction from the plurality of predetermined computational instructions, wherein the further predetermined computational instruction is such that a further specific amount of heat is generated when logical operations corresponding to the further predetermined computational instruction are performed by a further logic block (26),
- providing (670) the further predetermined computational instruction so selected to the further logic block (26), and
- performing (690) logical operations by the further logic block (26) in response to the further computational instruction so provided.

17. A processor for performing a method (500) according to claim 15 or 16.

18. A computer-readable medium having computer-executable instructions for performing a method (500) in accordance with claim 15 or 16.

5

19. A temperature regulating method (800) for regulating a temperature of an object (21), the temperature regulating method (800) comprising:

- selectively (840) generating a specific amount of heat according to claim 15 or 16, and
 - providing (860) the specific amount of heat so generated to the object (21).
- 10

15 20. The temperature regulating method (800) according to claim 19 further comprising cooling (850) the object (21) by a cooling module (28).

FIG 1

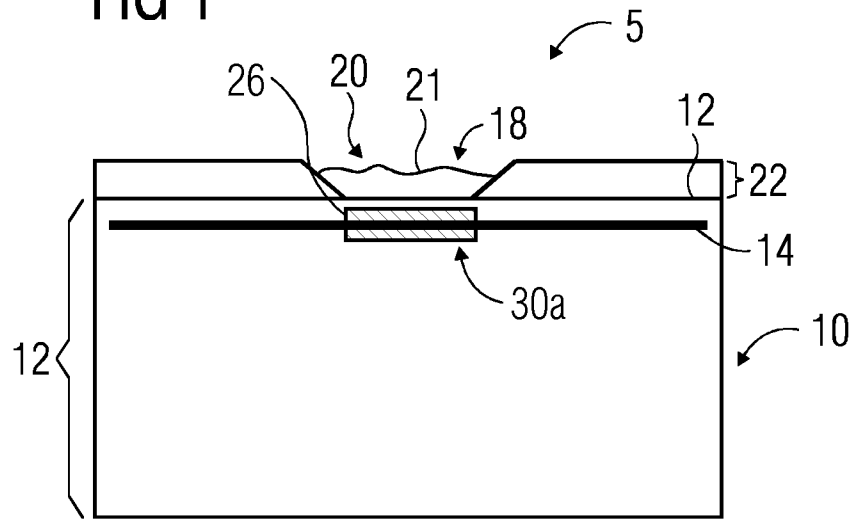


FIG 2

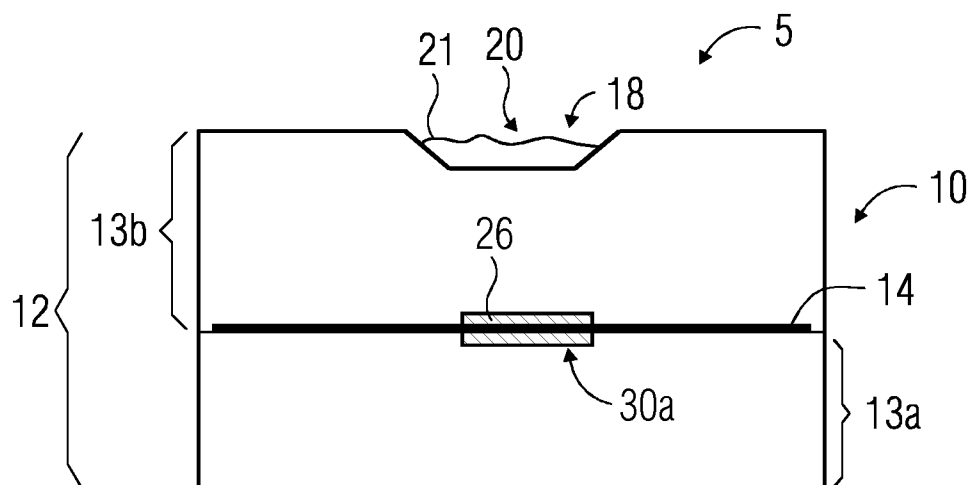


FIG 3

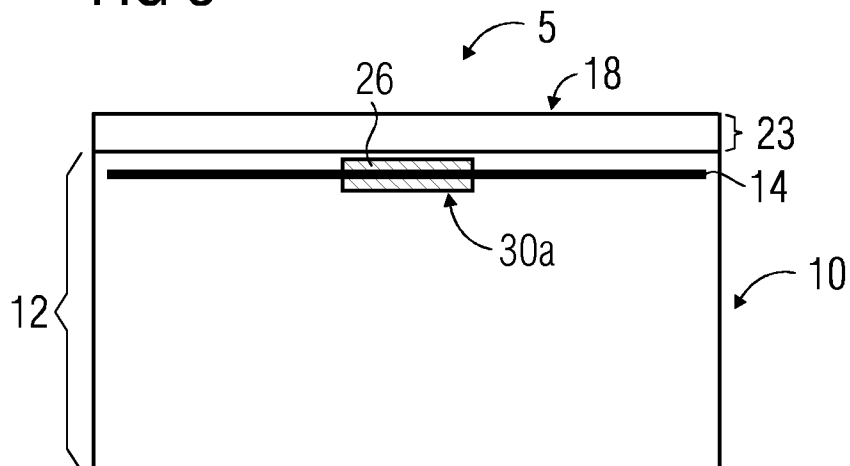


FIG 4

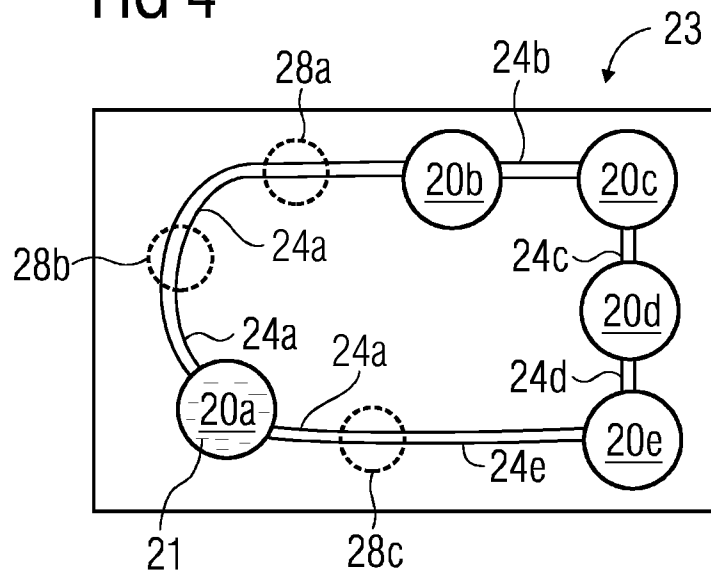


FIG 5

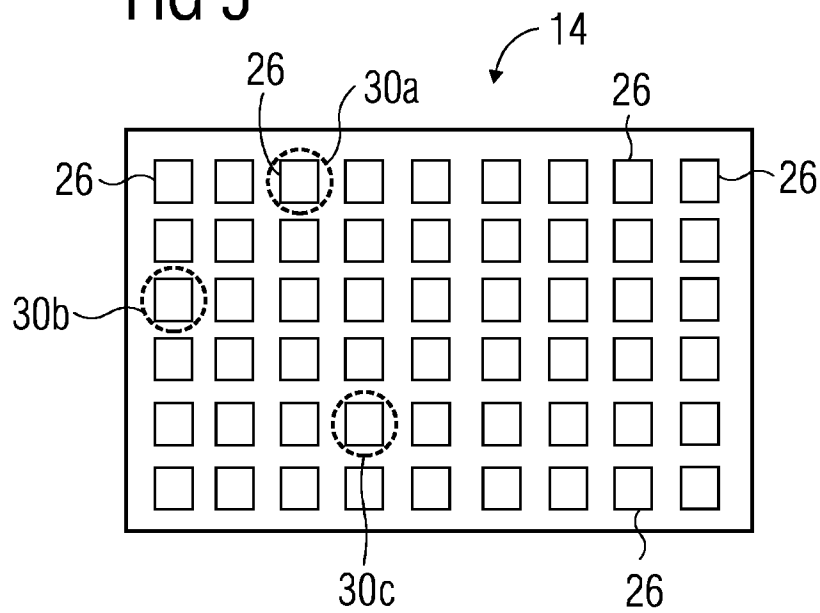


FIG 6

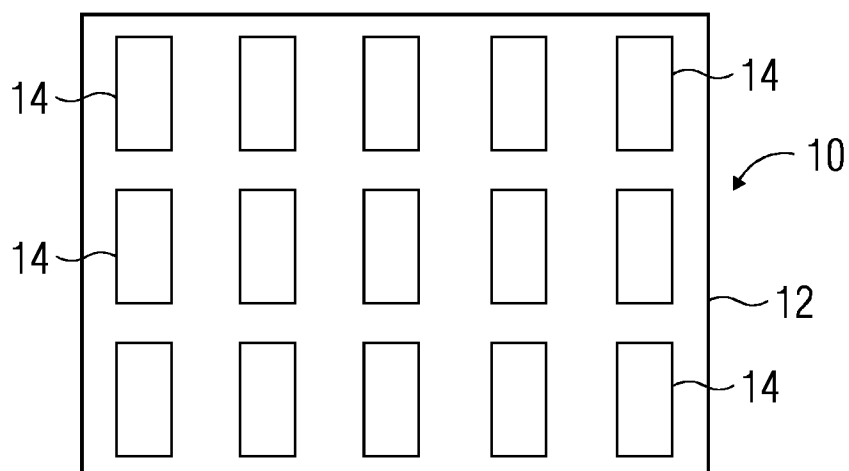


FIG 7

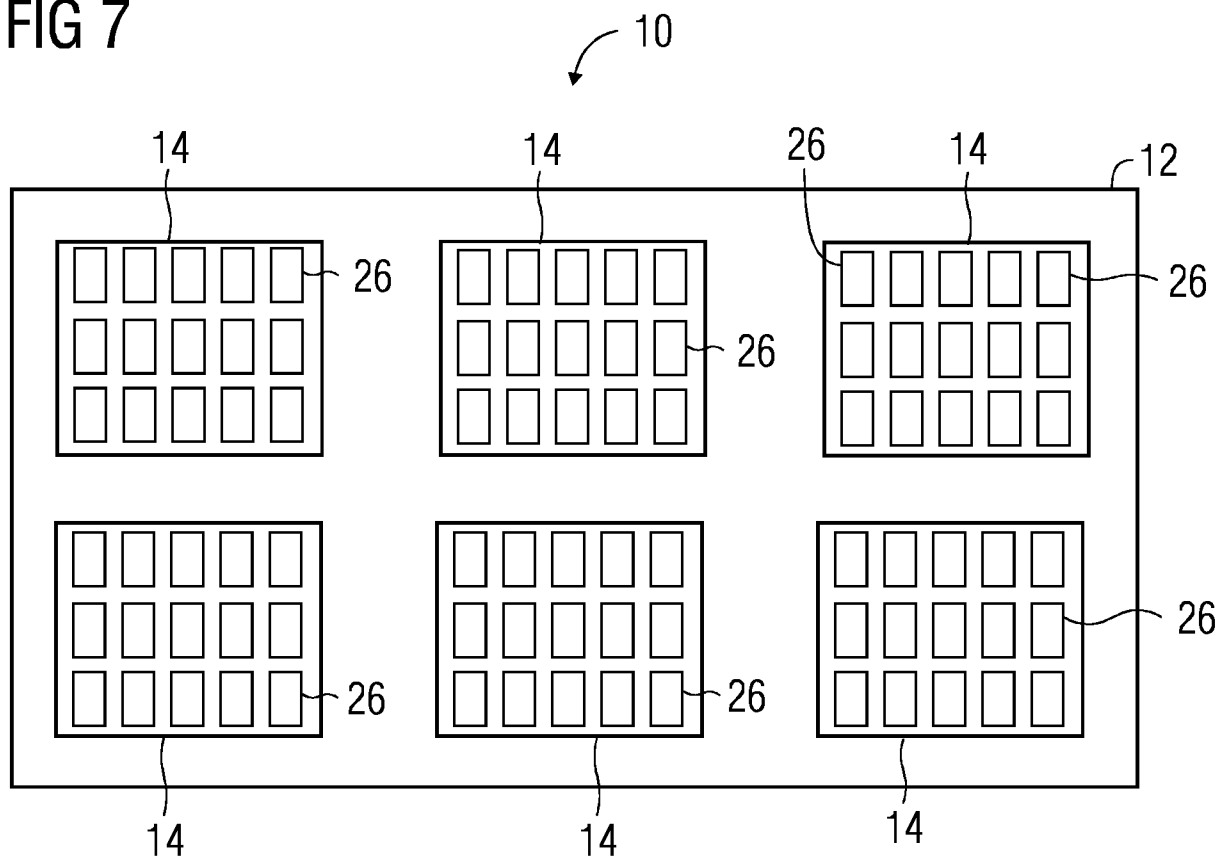


FIG 8

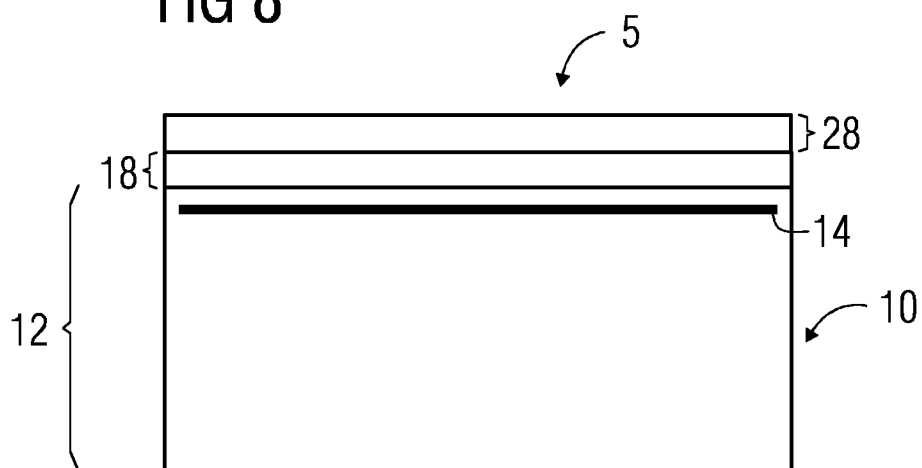


FIG 9

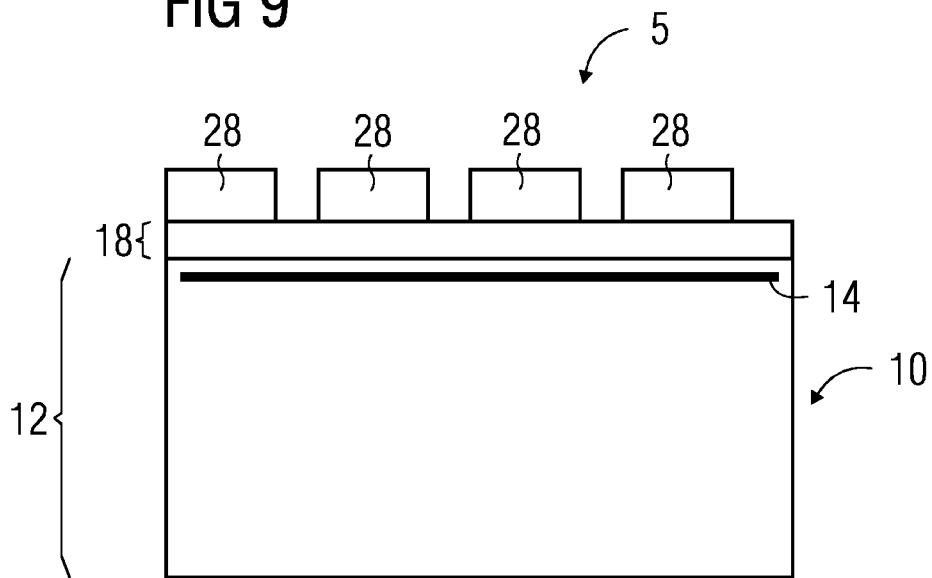


FIG 10

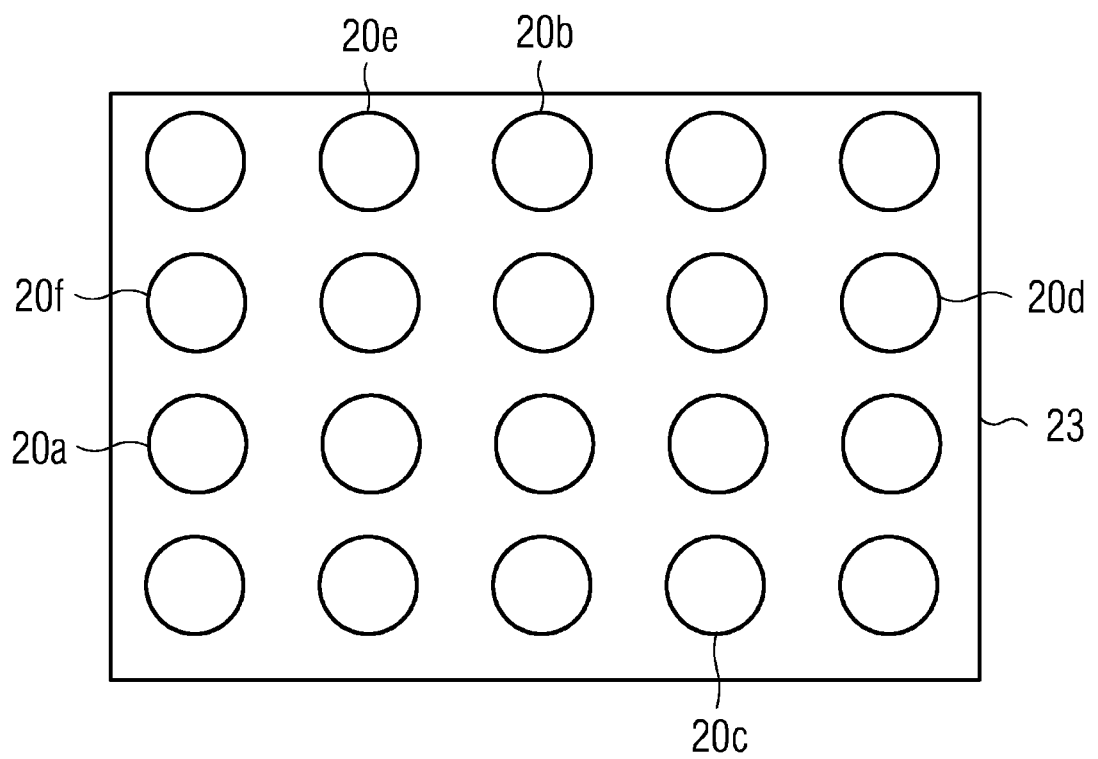


FIG 11

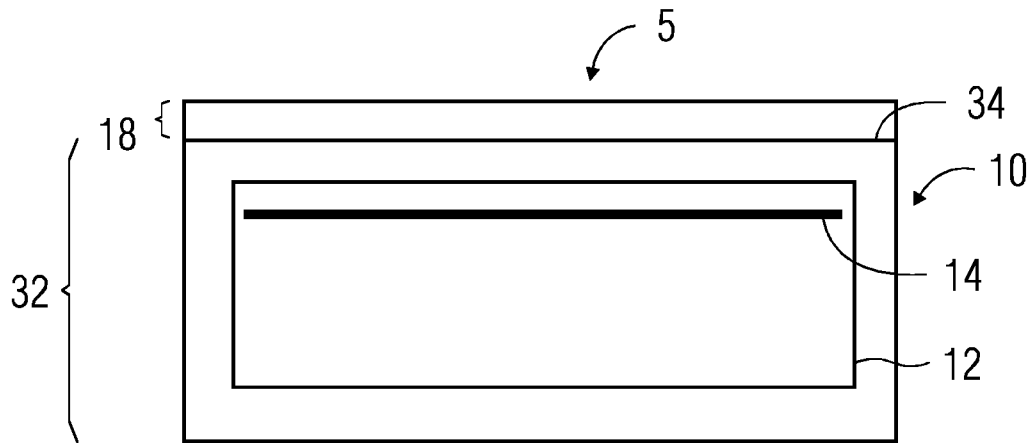


FIG 12

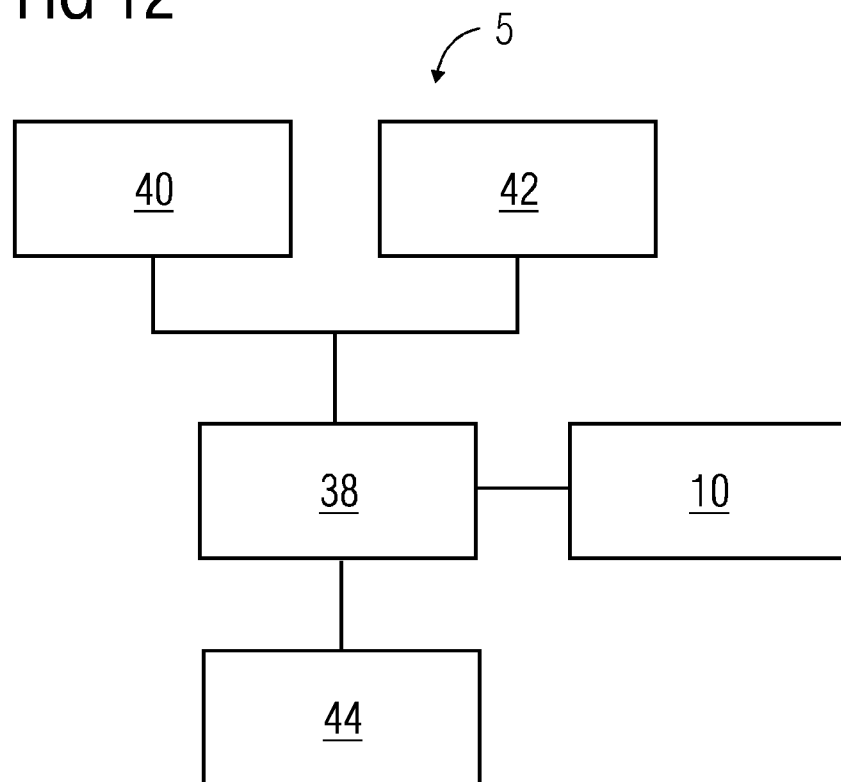


FIG 13

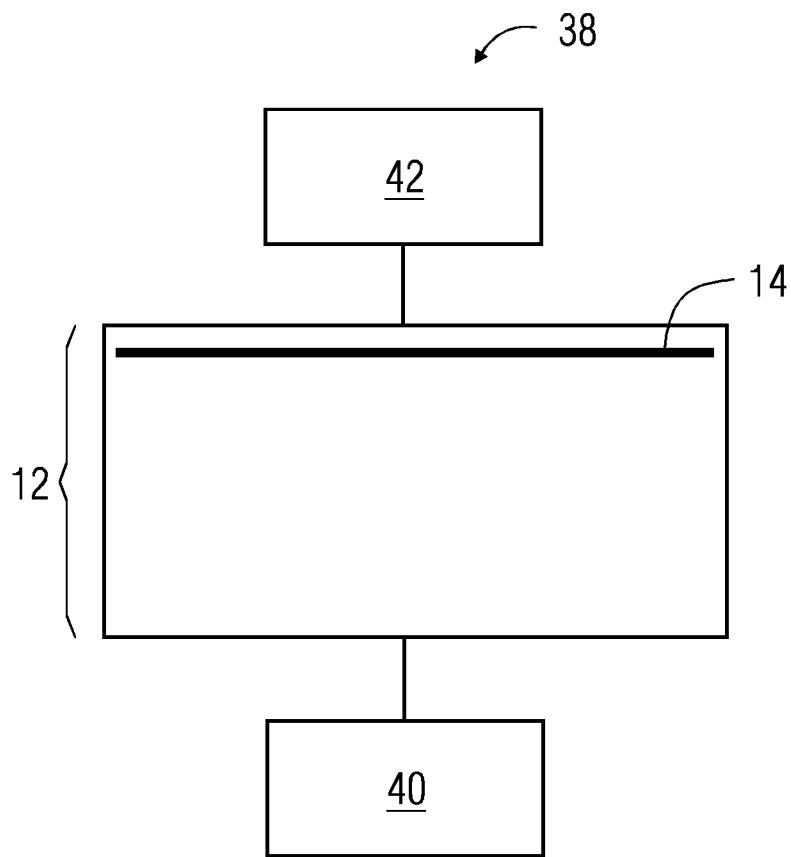


FIG 14

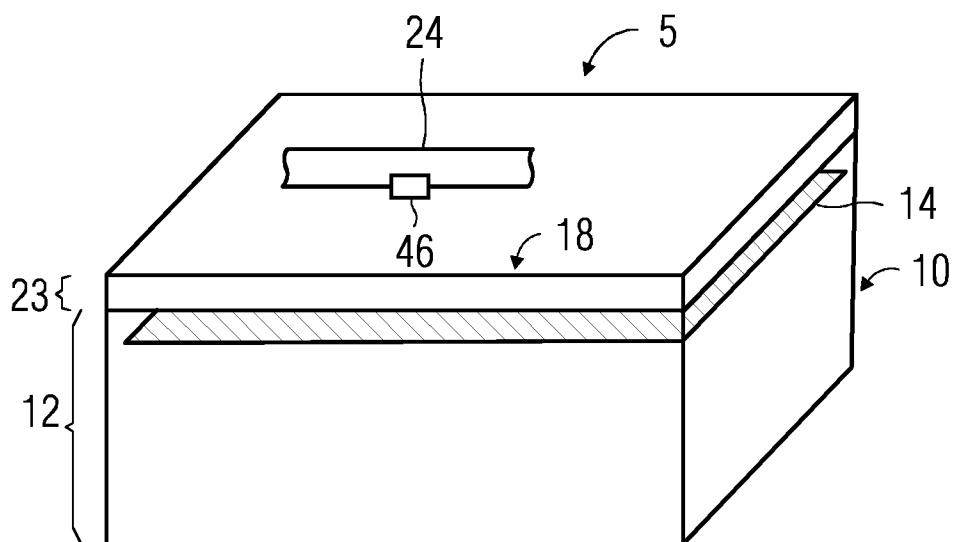


FIG 15a

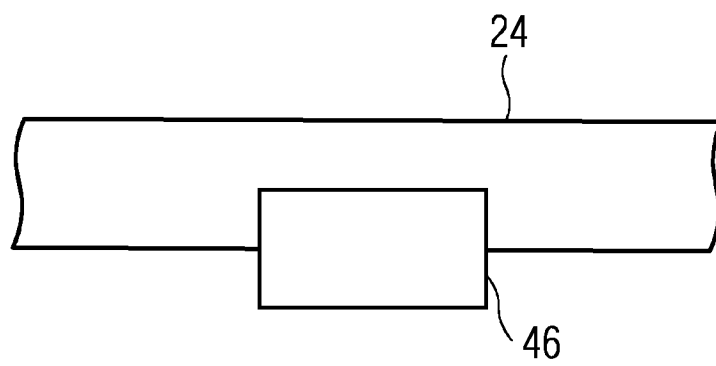


FIG 15b

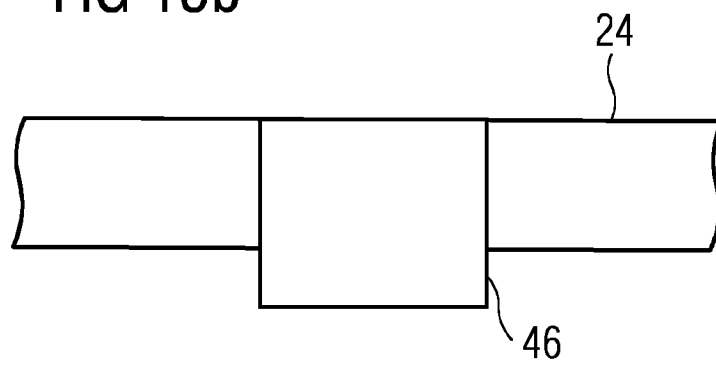


FIG 16

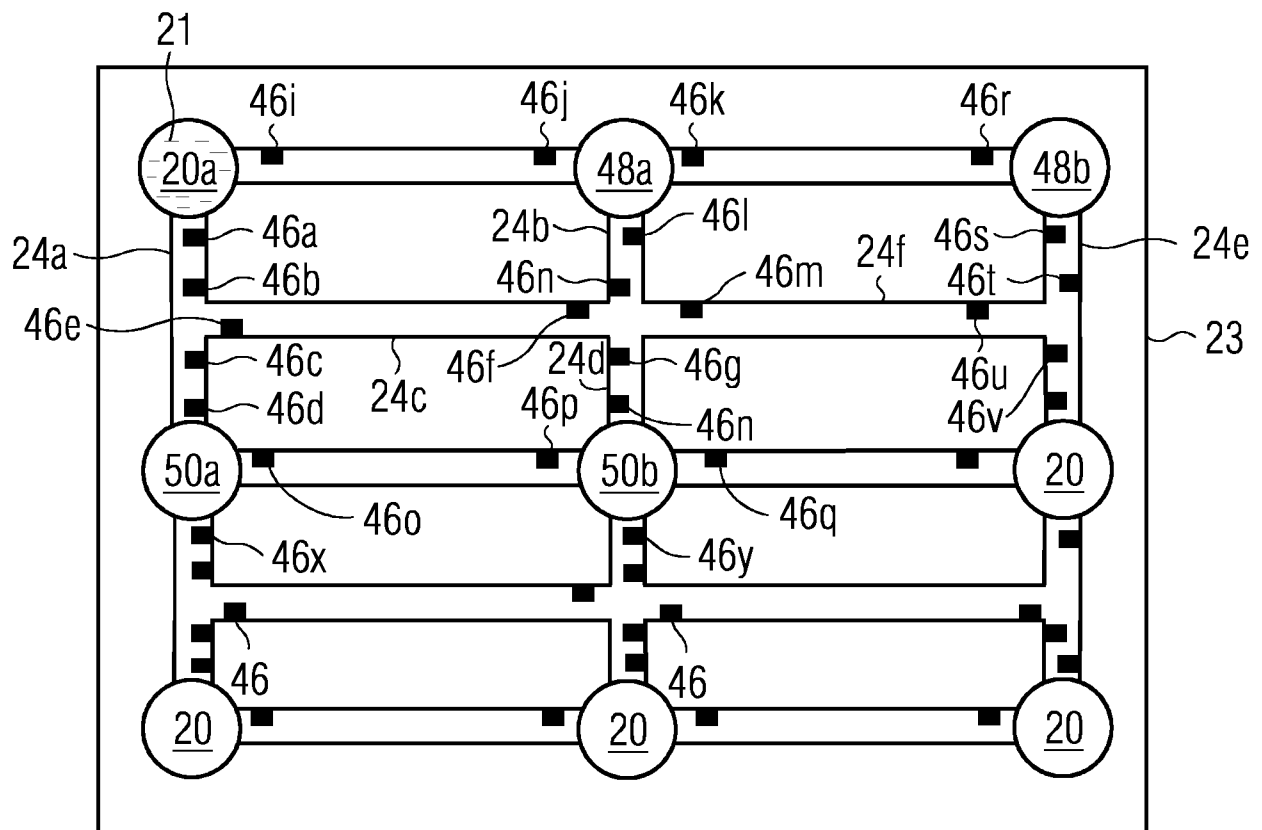


FIG 17

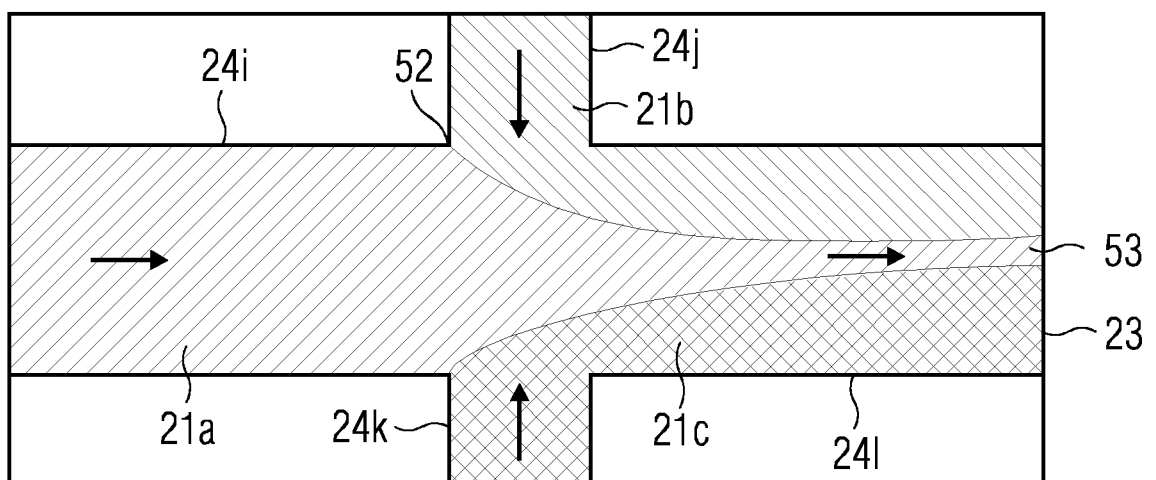


FIG 18

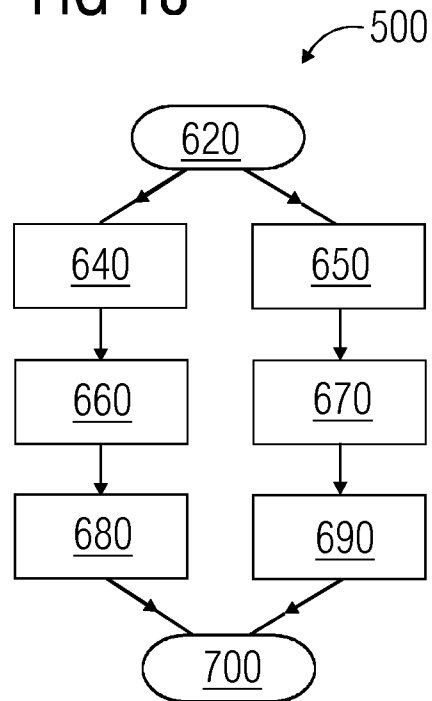


FIG 19

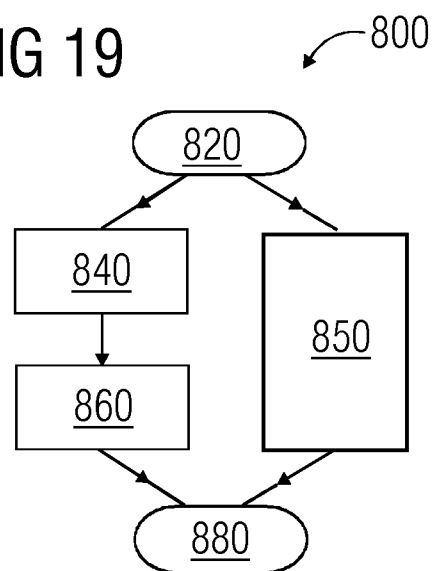
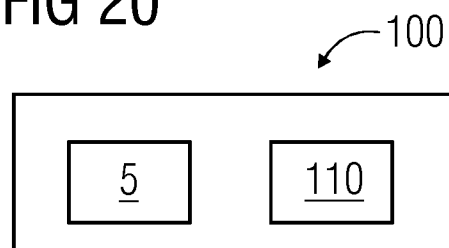


FIG 20



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/077917

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01L3/00 B01L7/00
ADD.

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)
B01L

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/120135 A2 (KONINKL PHILIPS ELECTRONICS NV [NL]; GILLIES MURRAY F [NL]; PONJEE MAR) 9 October 2008 (2008-10-09) page 3, line 10 - line 14 page 4, lines 1-8, 17-23 page 7, line 24 - page 8, line 1 page 10, line 16 - line 25 page 12, line 12 - line 14 page 18, line 21 - line 26 figures 1, 2, 3	1-20
A	----- US 2010/156444 A1 (PONJEE MARC WILHELMUS GIJSBERT [NL] ET AL) 24 June 2010 (2010-06-24) the whole document ----- -/--	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

9 July 2014

Date of mailing of the international search report

15/07/2014

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Bischoff, Laura

INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2008/038810 A1 (POLLACK MICHAEL G [US] ET AL) 14 February 2008 (2008-02-14) the whole document -----	1-20
A	US 2008/281471 A1 (SMITH GREGORY F [US] ET AL) 13 November 2008 (2008-11-13) the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/077917

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008120135	A2	09-10-2008	NONE

US 2010156444	A1	24-06-2010	AT 512714 T 15-07-2011
		EP 1998886 A1	10-12-2008
		EP 1999272 A1	10-12-2008
		EP 1999273 A1	10-12-2008
		JP 5133971 B2	30-01-2013
		JP 2009529908 A	27-08-2009
		JP 2009529909 A	27-08-2009
		JP 2009530635 A	27-08-2009
		JP 2011237454 A	24-11-2011
		US 2010156444 A1	24-06-2010
		US 2010167959 A1	01-07-2010
		US 2010229656 A1	16-09-2010
		WO 2007107892 A1	27-09-2007
		WO 2007107934 A1	27-09-2007
		WO 2007107947 A1	27-09-2007

US 2008038810	A1	14-02-2008	NONE

US 2008281471	A1	13-11-2008	NONE
