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[Continued on next page]

(54) Title: PRINTHEAD WITH TEMPERATURE SENSING MEMRISTOR

(57) Abstract: In the examples provided herein, a printhead includes a nozzle, a chamber to hold a fluid, an ejector to eject a portion of the fluid through the nozzle, where a temperature of the ejector increases to cause ejection of the portion of the fluid, and a memristor proximate to the ejector to sense a temperature near the ejector. The temperature sensed by the memristor is to be sampled over time for a sensed temperature profile for comparison to a baseline temperature profile.

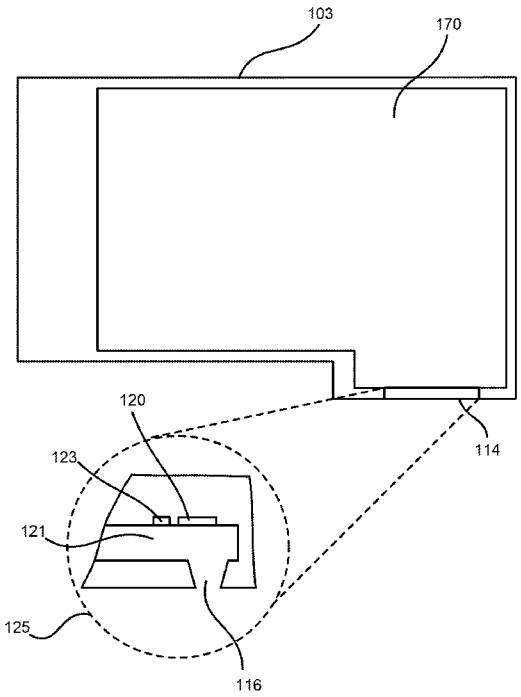


FIG. 1C

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PRINTHEAD WITH TEMPERATURE SENSING MEMRISTOR

BACKGROUND

[0001] The ability to detect low supply levels in ink supply reservoirs of inkjet printers is desirable for a number of reasons. For example, accurate low ink level indications help to avoid wasting ink, since inaccurate low ink level indications can result in the premature replacement of ink cartridges that still contain ink, and also to increase customer satisfaction by providing an indication that the printer will run out of ink before the ink supply runs out during a print job. Inkjet printing systems can also use ink level sensing to trigger certain actions that help prevent low quality prints that might result from inadequate supply levels.

[0002] Additionally, nozzles in inkjet printers may not fire or operate correctly due to a defect in the nozzle, a particle jam in the firing channel, or some other reason. If a nozzle does not fire, a condition called white line banding will occur where a white line appears in a print output where the nozzle would have deposited ink on the printing surface. While the white line banding issue can be fixed with a printhead that scans multiple times, it is a problem for one-pass printing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The accompanying drawings illustrate various examples of the principles described below. The examples and drawings are illustrative rather than limiting.

[0004] FIG. 1A shows a block diagram of an example inkjet printhead assembly with thermal-sensing memristors communicating with a controller.

[0005] FIG. 1B shows a perspective view of an example inkjet cartridge that includes an inkjet printhead assembly, ink supply assembly, and fluid chamber, and thermal-sensing memristors.

[0006] FIG. 1C depicts a diagram of an example printer cartridge that has a printhead with one or more memristors operating as thermal sensors.

[0007] FIG. 1D is a schematic cross-sectional view of an example memristor.

[0008] FIG. 2 shows a graph of current-voltage (I-V) curves for an example memristor.

[0009] FIG. 3A shows a drop of fluid as it is ejected through an example printhead nozzle.

[0010] FIG. 3B shows a top view of example inkjet firing chambers in a printhead.

[0011] FIG. 4A depicts a block diagram of an example printhead with one or more memristors operating as thermal sensors communicating with a controller.

[0012] FIG. 4B shows example components of a processor in the controller.

[0013] FIG. 4C shows example components of a memory in the controller.

[0014] FIGS. 5A-5D show various example designs and placements of a memristor used for thermal sensing relative to a heat-generating ejector.

[0015] FIG. 6 shows a graph of an example sampled temperature profile obtained from a memristor positioned near an ejector that has fired and an example baseline temperature profile.

[0016] FIG. 7 shows a top view of an example printhead having a single fluid slot formed in a substrate.

[0017] FIG. 8 depicts a flow diagram illustrating an example process of monitoring individual nozzles in a printhead.

[0018] FIG. 9 depicts a flow diagram illustrating an example process of determining whether an end of fluid supply condition exists.

DETAILED DESCRIPTION

[0019] The techniques presented below permit the detection of the end of a supply of fluid in a thermal inkjet printer and also permit monitoring whether the individual nozzles in an inkjet printhead are firing. The resistance of a memristor positioned close to an ejector firing resistor is measured, and the temperature at the memristor can be determined from the measured resistance. When the resistance is sampled over a period of time when the ejector firing resistor heats up to generate an ink drop for printing and then cools down again, a temperature profile over time at the memristor can be generated and compared to a baseline temperature profile. Significant deviations of the sampled temperature profile from the baseline temperature profile can indicate the end of supply of fluid or an inkjet nozzle problem.

[0020] FIG. 1A shows an example inkjet printhead assembly 102 communicating with a controller 203. Inkjet printhead assembly 102 includes at least one printhead 114 that ejects drops of ink through a plurality of orifices or nozzles 116 toward print media 118 so as to print onto the print media 118. Nozzles 116 are typically arranged in one or more columns or arrays such that properly sequenced ejection of ink from nozzles 116 causes characters, symbols, and/or other graphics or images to be printed on print media 118 as inkjet printhead assembly 102 and print media 118 are moved relative to each other. Memristors 123 are positioned to sense the temperature near ejectors for the nozzles 116.

[0021] Ink supply assembly 104 supplies fluid ink to printhead assembly 102 and includes a fluid chamber 170 for storing fluid, such as ink. In one implementation, the inkjet printhead assembly 102, ink supply assembly 104, and fluid chamber 170 are housed together in a replaceable device such as an integrated inkjet printhead cartridge 103, as shown in FIG. 1B. FIG. 1B shows a perspective view of an example inkjet cartridge 103 that includes inkjet printhead assembly 102, ink supply assembly 104, and fluid chamber 170. In addition to one or more printheads 114, inkjet cartridge 103 includes electrical contacts 105 and an ink (or other fluid) chamber 170. In some implementations cartridge 103 may have a

fluid chamber 170 that stores one color of ink, and in other implementations it may have a number of fluid chambers 170 that each store a different color of ink. Electrical contacts 105 carry electrical signals to and from controller 203, for example, resistance measurements of the memristors 123.

[0022] FIG. 1C is a diagram of an example printer cartridge 103 and example printhead 114 with one or more thermal-sensing memristors 123. The printer cartridge 103 may include a printhead 114 to carry out at least a part of the functionality of depositing fluid onto a surface, for example, as part of a printer, a fax machine, or other multi-purpose machine. The printer cartridge 103 may include a fluid chamber 170 to hold a fluid supply for supplying the fluid to the printhead 114 for deposition onto a surface. In some examples, the fluid may be ink. For example, the printer cartridge 103 may be an inkjet printer cartridge, the printhead 114 may be an inkjet printhead, and the ink may be inkjet ink.

[0023] The printhead 114 may include a number of fluid drop generators 125 for depositing fluid onto a surface. For example, components of a fluid drop generator 125 may include an ejector 120, a firing chamber 121, and a nozzle 116. The nozzle 116 may be a component that includes a small opening through which fluid, such as ink, is deposited onto a surface, such as a print medium. The firing chamber 121 may include a small amount of fluid. The ejector 120 is a component that ejects fluid through the nozzle 116. For example, the ejector 120 may be a firing resistor that heats up in response to an applied voltage. The printhead 114 may also include one or more memristors 123 for each fluid drop generator 125. As used herein, and in the appended claims, an "ejector" is a mechanism for ejecting fluid through a nozzle 116 from a firing chamber 121, where the ejector 120 may include a firing resistor or other thermal device for ejecting fluid from the firing chamber 121.

[0024] FIG. 1D shows a schematic cross-sectional view of an example memristor 123 in communication with a controller 203 for sampling the memristor's electrical characteristics. The memristor 123 may be used in a printhead 114. The memristor 123 includes a first electrode 12, a second electrode 14, and a switching material 16 sandwiched in between the electrodes 12, 14. The electrodes 12, 14

may be any suitable conductive material, such as aluminum, titanium, tantalum, gold, platinum, silver, tungsten, copper, etc., or composites of these conductive materials, such as AlCu, AlCuSi, TiN, and TaAl.

[0025] The switching material 16 may be a switching oxide made of a metallic oxide. Specific examples of switching oxide materials include magnesium oxide, titanium oxide, zirconium oxide, hafnium oxide, vanadium oxide, niobium oxide, tantalum oxide, chromium oxide, molybdenum oxide, tungsten oxide, manganese oxide, iron oxide, cobalt oxide, copper oxide, zinc oxide, aluminum oxide, gallium oxide, silicon oxide, germanium oxide, tin dioxide, bismuth oxide, nickel oxide, yttrium oxide, gadolinium oxide, and rhenium oxide, among other oxides. In addition to binary oxides, the switching oxides may be ternary and complex oxides such as silicon oxynitride. The oxides may be formed using a number of different processes such as sputtering from an oxide target, reactive sputtering from a metal target, atomic payer deposition (ALD), or oxidizing a deposited metal or alloy layer.

[0026] Memristive behavior in the memristor 123 is achieved by the movement of ionic species (e.g., oxygen ions or vacancies) within the switching material to create localized changes in conductivity via modulation of a conductive filament between two electrodes, which results in a low resistance "ON" state, a high resistance "OFF" state, or intermediate states. Initially, when the memristor is first fabricated, the entire switching material may be nonconductive. As such, an electroforming process may be required to form the conductive channel in the switching material between the two electrodes. The memristor remains in a particular resistance state until subsequent switching is triggered by the application of a switching voltage or current.

[0027] FIG. 2 depicts a graph 300 of example current-voltage (I-V) plots that show the conducting current for a memristor as a function of voltage. Curve 312 represents a virgin state, in which no forming or switching voltage has been applied to the memristor. Curve 314 represents an OFF state; curve 318 represents an ON state; and curve 316 represents an intermediate state. These I-V plots vary with temperature. As a result, the temperature of the memristor 123 can be determined

from a measurement of the resistance of the memristor. For a thermal-sensing application, the memristor 123 can be maintained in a single state, for example, the "OFF" state. A memristor 123 is useful for thermal-sensing applications having a temperature variation of a few hundred degrees.

[0028] FIG. 3A shows a drop of fluid 326 as it is ejected through an example printhead nozzle 394. In the example of FIG. 3A, the ejector is a firing resistor ejector 390. The firing resistor ejector 390 and the memristor 392 are formed on a substrate 340, for example, a silicon substrate. As the firing resistor ejector 390 heats up, a portion of the fluid in the firing chamber 396 vaporizes to form a bubble 350. The bubble 350 pushes a drop 326 of liquid fluid out the nozzle 394 and onto the surface. As the vaporized fluid bubble 350 pops, a vacuum pressure within the firing chamber 396 draws fluid into the firing chamber 396 from the fluid supply, and the process repeats. The vaporized fluid bubble 350 heats up the fluid around it, and the memristor 392 senses the heated fluid.

[0029] FIG. 3B shows a top view of example inkjet firing chambers 360 in a printhead, where the fluid is ink. Ink from an ink supply in fluid chamber 370 supplies the inkjet firing chambers 360. The inkjet firing chamber 360 can include an ejector firing resistor 390 and a memristor 392. When ejector firing resistor 390 heats up, the ink around it within the ink refill area 335 heats up. The horizontal pressure from the heating pushes the hot ink to flow through the ink refill area 335 which causes a change to the temperature near the ejector firing resistor 390 that is sensed by the memristor 392. In some implementations, the inkjet firing chamber 360 can include the ejector firing resistor 390 without the thermal-sensing memristor 392.

[0030] In some implementations there can be inkjet firing chambers 360 positioned along both sides of the fluid chamber 370. The inkjet firing chambers 360 can each include a thermal-sensing memristor 392, when each nozzle is to be monitored to detect whether the nozzle is firing (to be described below).

[0031] Alternatively, when detecting the end of the ink supply (to be described below), select ones of the inkjet firing chambers 360 can include a thermal-sensing memristor 392, and the rest of the inkjet firing chambers can include the ejector firing resistor 390 without the thermal-sensing memristor 392. For example, four inkjet firing chambers 360 with the thermal-sensing memristor 392 can be located generally near one of the four corners of the fluid chamber 370, while the rest of the inkjet chambers do not have the thermal-sensing memristor. However, any number of inkjet firing chambers 360 can include a thermal-sensing memristor 392 and be located anywhere around the fluid chamber 370.

[0032] FIG. 4A depicts a block diagram of an example printhead 114 communicating with a controller 203. The printhead 114 may include a number of printhead dies and a number of nozzles 116 (as depicted in FIG. 1C). The printhead dies may eject drops of fluid from the nozzles 116 onto a print medium in accordance with a received print job. More specifically, the printhead 114 may include a thin metallic piece of material to form a firing chamber 121 of an inkjet printer system.

[0033] The printhead 114 may include a memristor array 202 that includes one or more thermal-sensing memristors 123. As used herein, a thermal-sensing memristor 123 is a memristive device whose resistance changes as a function of temperature. Thus, the resistance of a memristor 123 can be measured to determine the temperature sensed at the location of the memristor 123. Each thermal-sensing memristor 123 is located near an ejector to sense the temperature near that ejector device and may, for example, be formed on top of an electro-plated substrate. The printhead 114 may be in communication with a controller 203 configured to measure the resistance or other electrical characteristic of each thermal-sensing memristor 123.

[0034] Electronic controller 203 typically includes a processor (central processing unit) 138, a memory 148 firmware, software, and other electronics for communicating with and controlling memristors 123 and inkjet printhead assembly 102 (as depicted in FIG. 1A). As shown in the block diagram of FIG. 4B, the

example processor 138 can include various components, such as a communication engine 212, a measurement engine 214, and a comparison engine 216. Each of the engines 212, 214, 216 can interact with the memory 148.

[0035] Communication engine 212 may be configured to receive signals to trigger the measurement of an electrical characteristic, such as resistance, of one or more of the memristors 123. Communication engine 212 may also be configured to report an end-of-supply status and/or an alert for any non-firing nozzles in the printhead assembly 102 based on the measurement of electrical characteristics of the memristors 123. In some implementations, the alert can be displayed as a message on the printer or an alert light can be triggered to turn on.

[0036] Measurement engine 214 may be configured to measure the resistance of the memristors 123. In some implementations, the measurement engine 214 may include circuitry configured to measure the voltage across the memristors 123 or the current running through the memristors 123 and convert the measured voltage or current to a corresponding resistance for a particular memristor 123.

[0037] Comparison engine 216 may be configured to convert the resistance values of the memristors 123 to a corresponding temperature to generate a temperature profile for each memristor 123 as a function of time. In some cases, each of the memristors 123 can be calibrated so that the comparison engine 216 can use a look-up table to determine the temperature sensed by a particular memristor 123 for a particular resistance value. Subsequently, the comparison engine 216 can compare the sampled temperature profile to a baseline temperature profile to determine whether an end-of-supply criterion has been met, or whether a particular nozzle in the printhead is not firing.

[0038] Memory 148 in controller 203 can include both volatile (i.e., random access memory) and nonvolatile (e.g., read-only memory, hard disk, floppy disk, etc.) memory components comprising computer/processor-readable media that provide for the storage of computer/processor-executable coded instructions, data structures, program modules, and other data for the inkjet printhead 114.

[0039] Memory 148 generally represents any number of memory components and is non-transitory in the sense that it does not encompass a transitory signal but instead is made up of one or more memory components configured to store the relevant instructions. In the example of FIG. 4C, example executable program instructions stored in memory 148 are depicted as communication module 262, measurement module 264, and comparison module 266. Communication module 262 represents program instructions that when executed, cause processor 138 to implement communication engine 212. Measurement module 264 represents program instructions that when executed, cause processor 138 to implement measurement engine 214. Comparison module 266 represents program instructions that when executed, cause processor 138 to implement comparison engine 216.

[0040] Memory 148 can also store data, such as resistance measurement readings for the one or more memristors 123, calibration look-up tables for the memristors 123, generated temperature profiles for the memristors 123, and/or baseline temperature profiles for the memristors 123.

[0041] FIGS. 5A-5D show various example designs and placements of a memristor 412, 414 relative to a heat-generating ejector 410. These examples show that when an application has a requirement that the thermal sensor has a small footprint on a silicon die, the memristor thermal sensor is suitable. In the example of FIG. 5A, a top plan view shows memristor 412 located next to the ejector 410. In the example of FIG. 5B, a top plan view shows two memristors 412, 414 positioned on opposite sides of the ejector 410. While two memristors 412, 414 are shown in FIG. 5B, more than two memristors can be used to sense the temperature near the ejector 410. The temperatures sensed by the multiple memristors 412, 414 can be used to determine the temperature near the ejector 410, for example, the temperature readings from the individual memristors 412, 414 can be averaged.

[0042] In the example of FIG. 5C, a top plan view shows a single memristor 416 fabricated to surround the ejector 410. In this configuration, the memristor 416 can sense the temperature around the ejector 410 without using multiple memristors, like in the example of FIG. 5B above.

[0043] FIG. 5D shows a side cross-sectional view of the ejector 410 and memristor 412. In the example of FIG. 5D, the memristor 412 is fabricated below the inkjet ejector 410, with a dielectric layer 411 separating the components. By fabricating the memristor 412 below the ejector 410, rather than next to the ejector, the area of space needed on the silicon die for the components is reduced.

[0044] Because the memristor 412, 414, 416 will be used to sense the temperature of the ink near the ejector 410, the memristor 412, 414, 416 should be positioned close to or proximate to the ejector 410. In some implementations, the distance between the memristor 412, 414, 416 and ejector 410 is approximately two microns, but the distance can be greater than or less than two microns.

[0045] FIG. 6 shows a graph 500 of an example sampled temperature profile 520 obtained from a memristor 392 positioned near a firing resistor ejector 390 (as shown in FIGS. 3A and 3B) that has fired and cooled down. Graph 500 in the example of FIG. 6 also shows an example baseline temperature profile 510 for comparison. The baseline temperature profile 510 is the expected temperature profile at the location of the memristor positioned near firing resistor ejector 390 when a fluid supply is present in the fluid chamber 370 and the firing resistor ejector 390 has heated up to eject a drop of fluid from the nozzle and then cooled down. Thus, a rise to the peak temperature is seen in the baseline temperature profile 510 with a subsequent falling of the temperature. In contrast, when the available fluid is near the end of its supply, the temperature profile at the location of the memristor will differ substantially from the expected baseline temperature profile because without the presence of the fluid supply, the temperature near the firing resistor ejector 390 increases much faster when the firing resistor ejector 390 heats up, and cools much slower when the firing resistor ejector 390 cools down after pushing a drop of fluid out of the nozzle 394. The reason is because the fluid absorbs some of the heat generated by the firing resistor ejector 390 when it heats up, and subsequently cooler fluid flows through the local ink refill area to cool the area near the firing resistor ejector 390. Consequently, when the fluid supply is very low, the sampled temperature profile 520 will have a shorter rise time, a higher peak temperature, a

longer full-width at half maximum, and a longer fall time than the expected temperature profile 510. Thus, the sampled temperature profile 520 will look significantly different from the expected temperature profile 510. Because there are large differences in the sampled and baseline temperature profiles, and the timeframe over which the temperature at the memristor rises and falls is on the order of several microseconds, the resistance measurements of the memristors can be sampled at relatively large time intervals, for example, on the order of 0.1 microseconds, to generate a sufficiently accurate sampled temperature profile to compare to the baseline temperature profile.

[0046] Furthermore, it is sufficient to monitor the temperature at a few locations relative to the fluid chamber 370 to determine when the available fluid is at the end of its supply. FIG. 7 shows a top view of an example printhead having a single fluid slot 600 formed in a substrate 602, for example, a silicon die or substrate. Various components integrated on the printhead die/substrate 602 include temperature-sensing fluid drop generators 604 having one or more memristors 622 for sensing the temperature of an ejector firing resistor 621 and non-temperature-sensing fluid drop generators 606 that do not have a memristor 622 for sensing the temperature of an ejector firing resistor 621. Although printhead 601 is shown with a single fluid slot 600, the principles discussed herein are not limited in their application to a printhead with just one fluid slot 600. Rather, other printhead configurations are also possible, such as printheads with two or more fluid slots. In a thermal inkjet printhead 601, the die/substrate 602 underlies a chamber layer having temperature-sensing fluid drop generators 604, non-temperature-sensing fluid drop generators 606, and a nozzle layer having nozzles formed therein. However, for the purpose of illustration, the fluid drop generator layer and nozzle layer in FIG. 7 are assumed to be transparent in order to show the underlying substrate 602. Therefore, temperature-sensing fluid drop generators 604 and non-temperature-sensing fluid drop generators 606 in FIG. 7 are illustrated using dashed lines.

[0047] The fluid slot 600 is an elongated slot formed in the substrate 602 that is in fluid communication with a fluid supply (not shown), such as fluid chamber 170

shown in FIG. 1C. In the example of FIG. 7, the fluid slot 600 has multiple temperature-sensing fluid drop generators 604 and non-temperature-sensing fluid drop generators 606 arranged along both sides of the slot. In some implementations, the temperature-sensing fluid drop generators 604 with one or more memristors 621 are positioned generally near one of four corners of the slot 600, toward the ends of the slot 600, as shown in the example of FIG. 7. In other implementations, there can be a different number of temperature-sensing fluid drop generators 604 with one or more memristors 622 per slot. While each temperature-sensing fluid drop generator 604 in FIG. 7 is located near an end-corner of a slot, this is not intended as a limitation on other possible locations. Thus, temperature-sensing fluid drop generators 604 can be positioned around a slot 600 in other areas, such as midway between the ends of the slot.

[0048] The controller 203 can sample the resistance of each of the one or more memristors 622 of a temperature-sensing fluid drop generator 604, convert the measured resistances to corresponding temperatures to generate a sampled temperature profile, and compare the sampled temperature profile with a baseline temperature profile to detect any substantial differences. In general, more than one temperature-sensing fluid drop generator 604 is used per slot to prevent local variations from triggering an end-of-supply alert. When multiple temperature-sensing fluid drop generators 604 are used, the total number of temperature-sensing fluid drop generators 604 that provide a temperature profile substantially different from a baseline temperature profile is used by the controller 203 to determine the next action to perform. For example, if four temperature-sensing fluid drop generators 604 are used, and a single memristor sensor 622 out of the four memristor sensors 622 in the temperature-sensing fluid drop generators 604 shows a substantial change in temperature from the expected temperature profile, the temperature profile differences could be due to a local variation, and no action is taken; if two memristor sensors show a substantial change in temperature from the expected temperature profile, the controller 203 can perform another measurement after a certain predetermined period of time has elapsed; and if three or four

memristor sensors show a substantial change in temperature from the expected temperature profile, the controller will send an end-of-supply alert. For a different number of temperature-sensing fluid drop generators 604, different criteria for triggering re-measurement and sending an end-of-supply alert can be used.

[0049] A memristor thermal sensor can also be used to detect whether a local nozzle is firing or not. For example, a nozzle may not fire due to a defect, clogging of the nozzle, or some other reason. If a nozzle does not fire, white line banding will be seen in a print image due to the inoperative nozzle. For one-pass printing, where the printhead passes over the surface to be printed a single time, rather than multiple times, detection of a non-firing nozzle would be very useful so that the user can be notified prior to scheduling of a print job. For nozzle firing detection, one or more memristors 622 are positioned near each ejector firing resistor 621 corresponding to a nozzle. Similar to the end-of-supply detection, resistance measurements are performed for each memristor 622 corresponding to each nozzle, a temperature profile is generated, and each temperature profile is compared to a baseline temperature profile.

[0050] Changes in temperature profile are used to identify whether a nozzle is operating. For example, the controller 203 can compare a measured peak temperature of the sampled temperature profile with the peak temperature of the baseline temperature profile. If the measured peak temperature is more than a threshold amount greater than the peak temperature of the baseline temperature profile, an alert can be sent for a non-operational nozzle. Alternatively, the controller 203 can compare a measured width of the sampled temperature profile, for example, a full width at half maximum. If the width of the sampled temperature profile is more than a threshold amount greater than the width of the baseline temperature profile, an alert can be sent for the non-operational nozzle. One or both of these quantitative comparisons can be used to determine whether a nozzle is operational. Other quantitative comparisons, such as rise time and fall time, can also be used instead of, or in addition to, one or both of these criteria for determining whether a nozzle is non-operational. Each temperature profile for one or more memristors 622

corresponding to a nozzle is analyzed independently of other temperature profiles for other nozzles.

[0051] FIG. 8 depicts a flow diagram illustrating an example process 700 of monitoring individual nozzles in a printhead.

[0052] At block 705, the controller takes a plurality of samples of an electrical characteristic of a first sensing memristor or multiple memristors, where the first sensing memristor or multiple memristors are positioned near a first firing resistor ejector of a printhead. Because the first firing resistor ejector increases in temperature to eject a portion of fluid through a first nozzle, the temperature sensed by the first sensing memristor or multiple memristors will change in response. The sampled electrical characteristic of the first sensing memristor or multiple memristors can be resistance. Alternatively, the voltage drop across the memristor(s) or the current through the memristor(s) can also be sampled to determine the resistance. Sampling should occur over the interval when the firing resistor ejector heats up to push a drop of fluid out of the nozzle through the cooling period after heating.

[0053] Then at block 710, the controller determines from the sampled electrical characteristic a time-sampled temperature profile. In some cases, a pre-calibrated look-up table for the first sensing memristor or multiple memristors can be used to convert the sampled electrical characteristic to a corresponding temperature.

[0054] Next, at block 715, the controller provides an alert as an output upon determining that at least one profile characteristic of the time-sampled temperature profile exceeds a corresponding threshold based on an expected temperature profile. Non-limiting examples of thresholds include a rise time, a peak temperature, a full width at half maximum, and a fall time of the temperature profile.

[0055] At decision block 720, the controller determines whether there are any other memristors to measure. If there are more memristors to be measured (block 720 – Yes), the process returns to block 705. If there are no more memristors to be measured (block 720 – No), the process ends at block 799. In some implementations, the nozzles of the printhead may operate simultaneously, so

blocks 705 through 715 may be performed simultaneously for multiple memristors in the printhead.

[0056] FIG. 9 depicts a flow diagram illustrating an example process 800 of determining whether an end of fluid supply condition exists.

[0057] At block 805, the controller takes a plurality of samples of an electrical characteristic of one or more memristors, where the one or more memristors are positioned near one or more ejectors of the printhead, and where the one or more ejectors independently increase in temperature to eject a portion of inkjet ink through one or more additional nozzles.

[0058] Next, at block 810, the controller determines from the sampled electrical characteristic of the one or more memristors, a time-sampled temperature profile for each of the one or more memristors.

[0059] Then at block 815, the controller determines a total number of the one or more memristors that have a time-sampled temperature profile with at least one profile characteristic that exceeds a corresponding threshold based on the expected temperature profile.

[0060] At decision block 820, the controller determines whether the total number is greater than a first predetermined number. If the total number is greater than the first predetermined number (block 820 – Yes), at block 825, the controller provides an end-of-supply alert.

[0061] If the total number is less than or equal to the first predetermined number (block 820 – No), then at decision block 830, the controller determines whether the total number is greater than a second predetermined number, where the second predetermined number is less than the first predetermined number. If the total number is greater than the second predetermined number (block 830 – Yes), the process returns to block 805 where the electrical characteristics of the memristors are sampled again.

[0062] If the total number is less than or equal to the second predetermined number (block 830 – No), the process ends at block 899. In this case, there is no indication that the fluid supply is nearing the end, and no alert is sent.

CLAIMS

What is claimed is:

1. A printhead comprising:

a sensing nozzle;

a chamber to hold a fluid;

a first ejector to eject a portion of the fluid through the sensing nozzle, wherein a first temperature of the first ejector increases to cause ejection of the portion of the fluid; and

a first memristor proximate to the first ejector to sense a second temperature near the first ejector,

wherein the sensed second temperature is to be sampled over time for a first sensed temperature profile for comparison to a baseline temperature profile.

2. The printhead of claim 1, further comprising:

additional nozzles;

additional ejectors, wherein each additional ejector ejects a portion of the fluid through a different one of the additional nozzles; and

additional memristors, wherein each of the additional memristors is proximate to a different one of the additional ejectors to sense an additional temperature near a corresponding one of the additional ejectors, wherein each of the sensed additional temperatures is to be sampled over time for an additional sensed temperature profile for each additional memristor for comparison to the baseline temperature profile,

wherein the sensing nozzle or a particular nozzle of the additional nozzles is triggered to be identified as problematic when at least one profile characteristic of the corresponding sampled

temperature profile exceeds a corresponding threshold based on the baseline temperature profile,

wherein when a total number of the first memristor and the additional memristors that have a corresponding sampled temperature profile with at least one profile characteristic that exceeds the corresponding threshold based on the baseline temperature profile is greater than a first predetermined number, the second temperature sensed by the first memristor and the additional temperature sensed by the additional memristors are further triggered to be sampled to determine additional sensed temperature profiles for determining an end of supply of the fluid, and

wherein when a total number of the first memristor and the additional memristors that have a corresponding sampled temperature profile with at least one profile characteristic that exceeds the corresponding threshold based on the baseline temperature profile is greater than a second predetermined number, an end-of-fluid-supply alert is triggered to be sent.

3. The printhead of claim 2, wherein the profile characteristics include:

a peak temperature,

a duration of elevated temperature,

a rise time, and

a fall time.

4. The printhead of claim 1, wherein the first memristor is positioned below the first ejector.

5. The printhead of claim 1, wherein the first memristor is positioned adjacent to the first ejector.

6. The printhead of claim 1, wherein the first memristor senses the second temperature at at least multiple points near the first ejector.

7. A system comprising:

a fluid supply;

a printhead to deposit fluid from the fluid supply onto a surface, the printhead comprising:

multiple nozzles;

a chamber to hold the fluid supply;

multiple ejectors, wherein each ejector ejects a portion of the fluid through a different one of the multiple nozzles onto the surface when the ejector increases in temperature; and

multiple memristors, wherein each of the memristors is positioned near a different one of the multiple ejectors to sense an ejector temperature near the corresponding ejector; and

a controller to:

sample over time sensed ejector temperatures from each of the multiple memristors to determine a sensed temperature profile for each of the multiple memristors; and

compare each of the sensed temperature profiles to an expected temperature profile.

8. The system of claim 7, wherein the controller further:

when a total number of the multiple memristors having a corresponding sampled temperature profile with at least one profile characteristic that exceeds a corresponding threshold based on the expected temperature profile is greater than a first predetermined number, continues to sample over time the sensed ejector temperatures of each of the multiple memristors; and

when a total number of the multiple memristors having a corresponding sampled temperature profile with at least one profile characteristic that exceeds a corresponding threshold based on the expected temperature profile is greater than a second predetermined number, sends an end-of-fluid-supply alert, and

further wherein the profile characteristics include:

a peak temperature, wherein the corresponding threshold is a peak expected temperature that is based on a peak temperature of the expected temperature profile, and

a duration of elevated temperature, wherein the corresponding threshold is based on a duration of the expected temperature profile at a predetermined temperature and the elevated temperature is based on the peak temperature of the expected temperature profile.

9. The system of claim 7, wherein the controller further:

sends an output that one or more specific nozzles are problematic when at least one profile characteristic of the corresponding sampled temperature profile of the one or more specific nozzles exceeds a corresponding threshold based on the expected temperature profile, and

further wherein the profile characteristics include:

a peak temperature,

a duration of elevated temperature,

a rise time, and

a fall time.

10. The system of claim 7, wherein at least some of the multiple memristors are positioned below a different one of the multiple ejectors.

11. The system of claim 7, wherein at least some of the multiple memristors are positioned adjacent to a different one of the multiple ejectors.

12. The system of claim 7, wherein at least some of the multiple memristors sense the ejector temperature at multiple points near the corresponding ejector.

13. A method comprising:

taking a plurality of samples of an electrical characteristic of a first memristor, wherein the first memristor is positioned near a first ejector of a printhead, wherein the first ejector increases in temperature to eject a portion of inkjet ink through a first nozzle;

determining from the sampled electrical characteristic a time-sampled temperature profile;

upon determining that at least one profile characteristic of the time-sampled temperature profile exceeds a corresponding threshold based on an expected temperature profile, providing an alert as an output.

14. The method of claim 13, wherein the profile characteristics include:

a peak temperature, a duration of elevated temperature, a rise time, and a fall time.

15. The method of claim 13, further comprising:

taking a plurality of samples of an electrical characteristic of one or more additional memristors, wherein the one or more additional memristors are positioned near one or more additional ejectors of the printhead, wherein the one or more additional ejectors independently increase in temperature to eject a portion of additional inkjet ink through one or more additional nozzles;

determining from the sampled electrical characteristic of the one or more additional memristors, an additional time-sampled temperature profile for each of the one or more additional memristors;

determining a total number of the first memristor and the one or more additional memristors that have a time-sampled temperature profile with at least one profile characteristic that exceeds a corresponding threshold based on the expected temperature profile;

when the total number is greater than a first predetermined number, providing an-end-of-ink-supply output;

when the total number is greater than a second predetermined number, performing further temperature monitoring of the first memristor and the one or more additional memristors, wherein the second predetermined number is less than the first predetermined number.

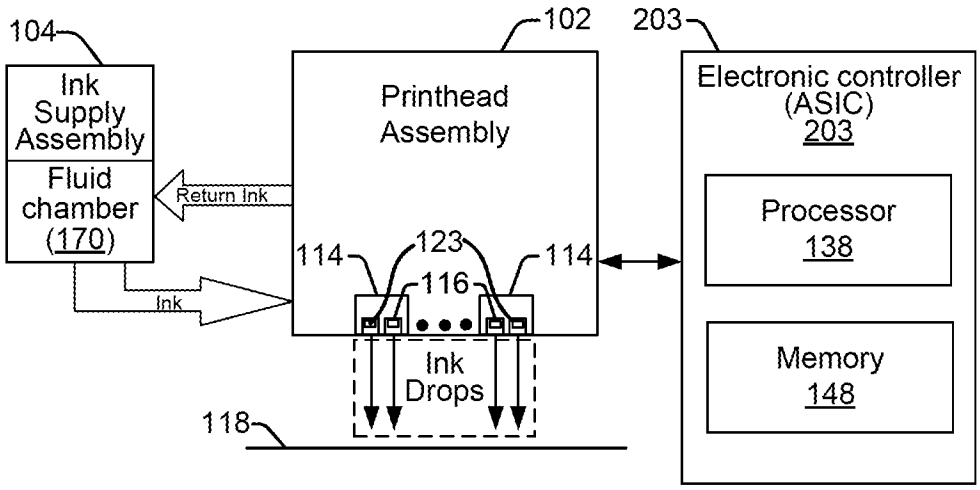

104
Ink Supply Assembly
Fluid chamber (170)
Return Ink
Ink
102
Printhead Assembly
114
123
116
114
Ink Drops
118
203
Electronic controller (ASIC) 203
Processor 138
Memory 148

FIG. 1A

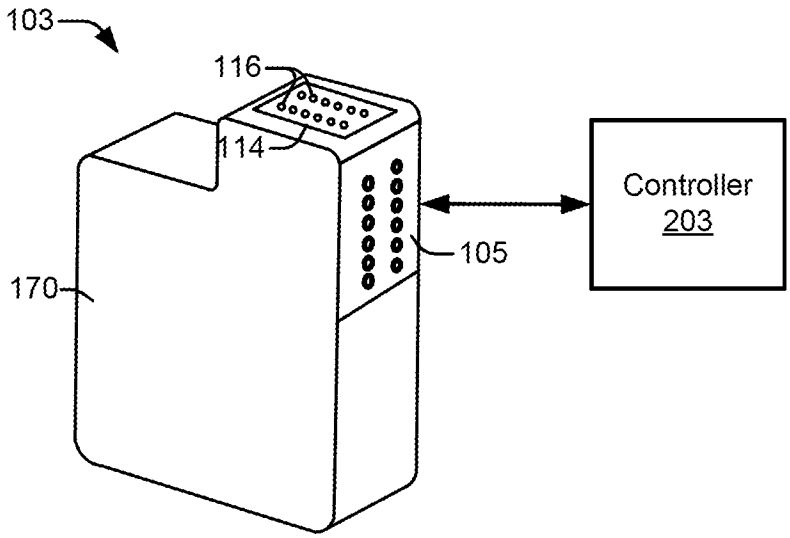

103
116
114
170
105
Controller 203

FIG. 1B

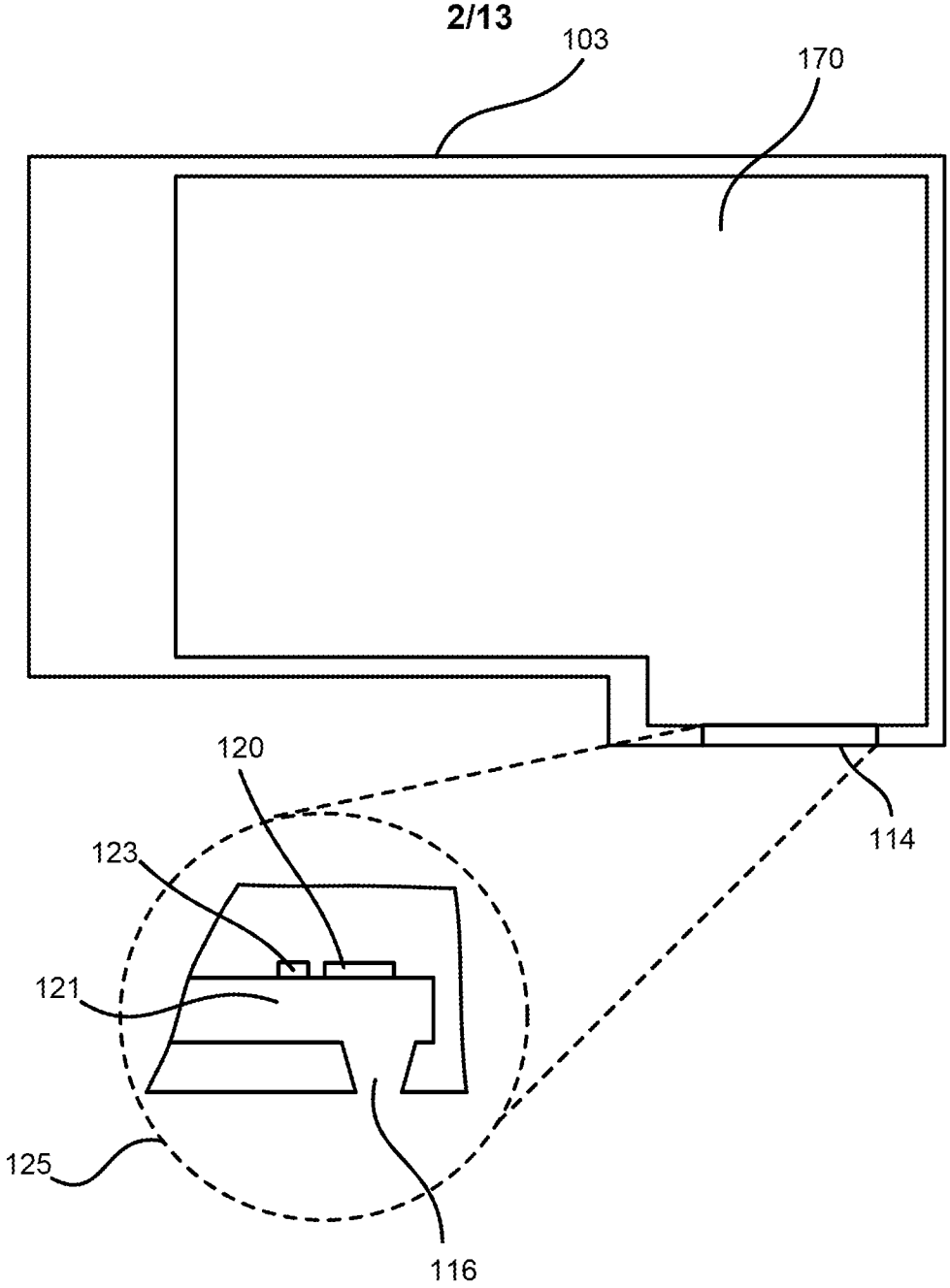


FIG. 1C

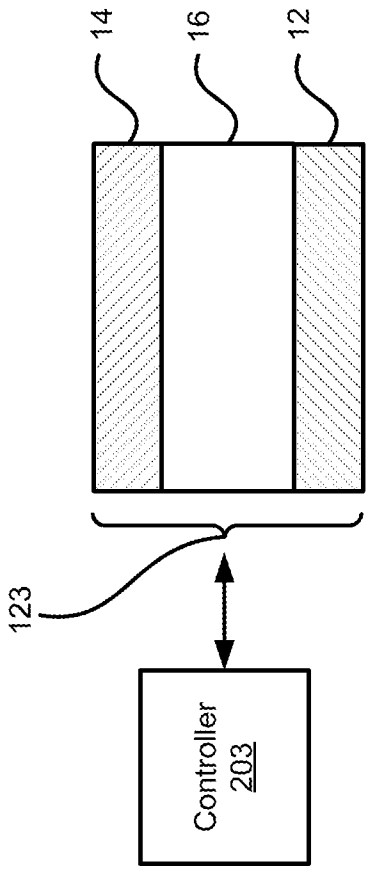


FIG. 1D

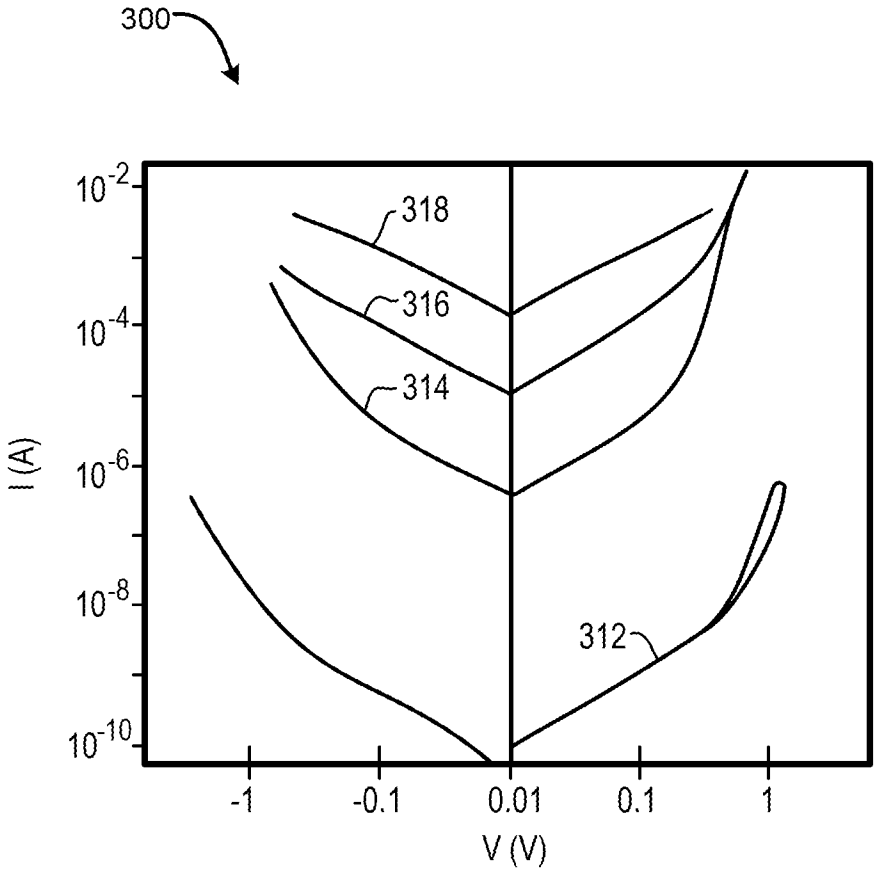


FIG. 2

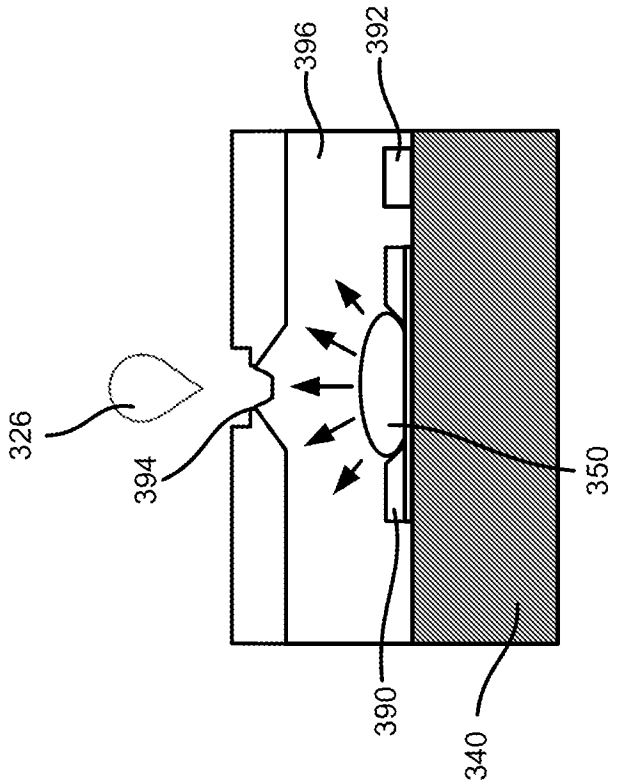


FIG. 3A

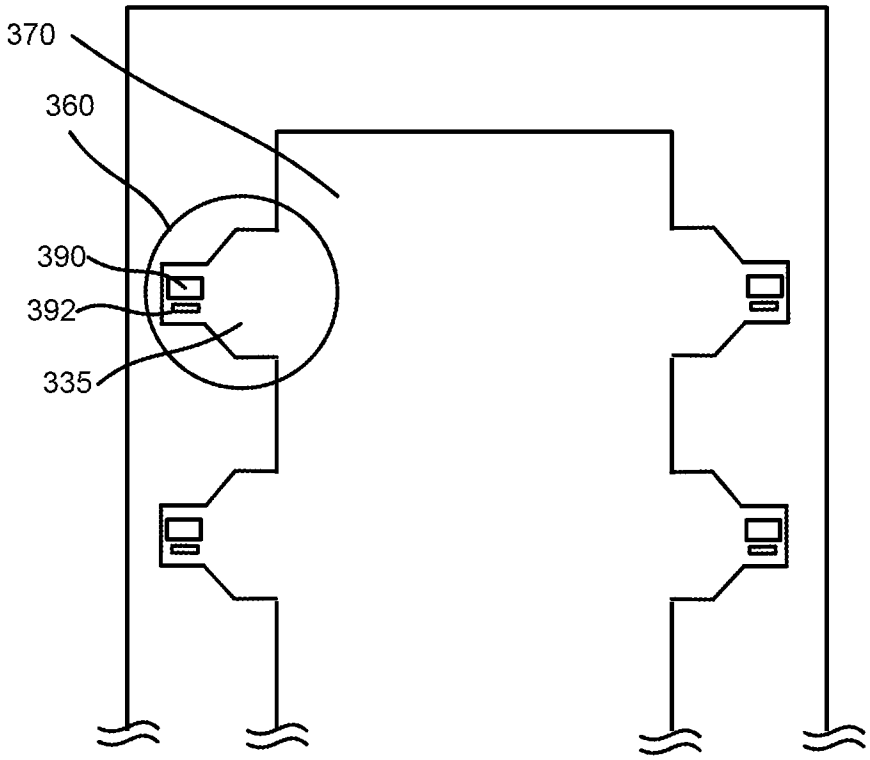


FIG. 3B

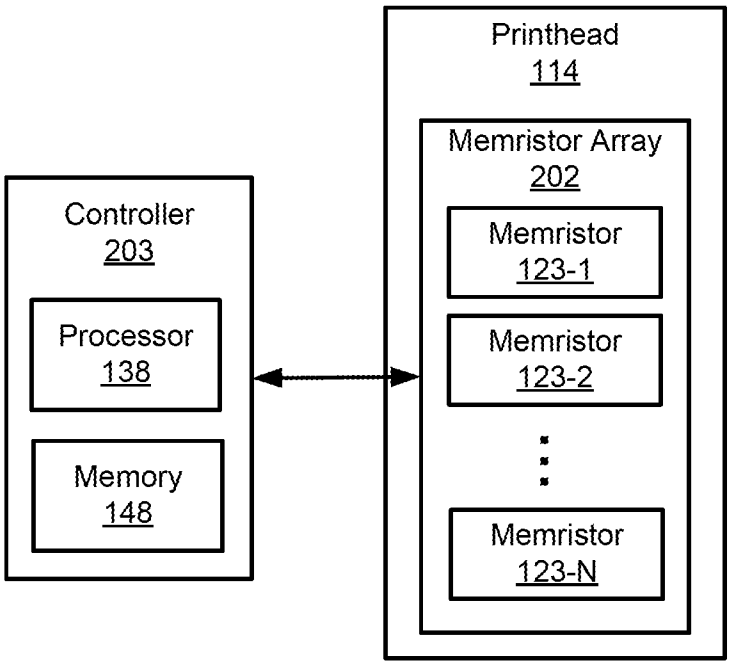

Printhead
114
Memristor Array
202
Memristor
123-1
Memristor
123-2
Memristor
123-N
Controller
203
Processor
138
Memory
148

FIG. 4A

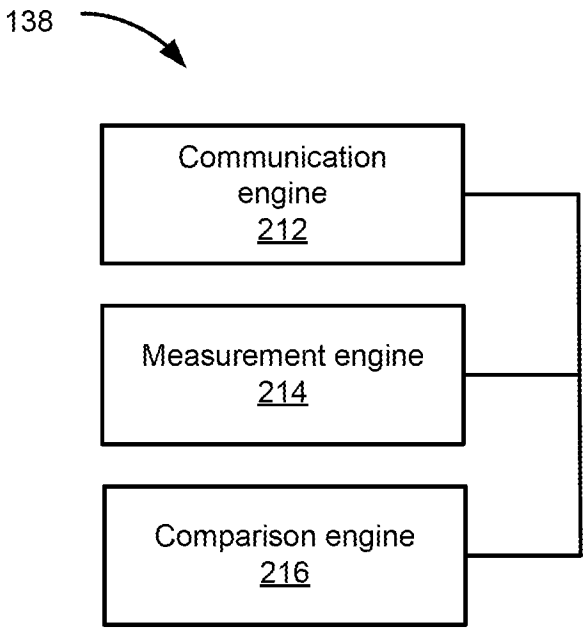

138
Communication engine 212
Measurement engine 214
Comparison engine 216

FIG. 4B

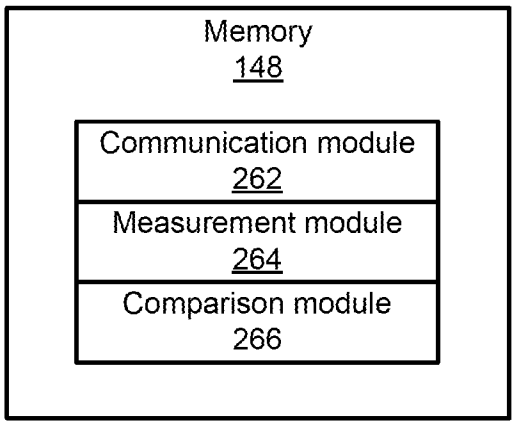

Memory 148
Communication module 262
Measurement module 264
Comparison module 266

FIG. 4C

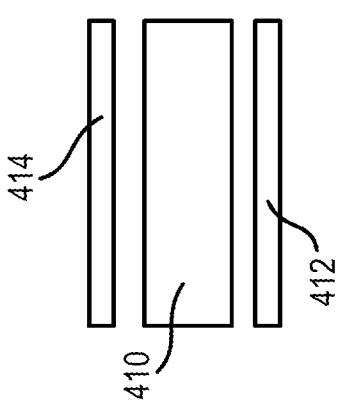


FIG. 5B

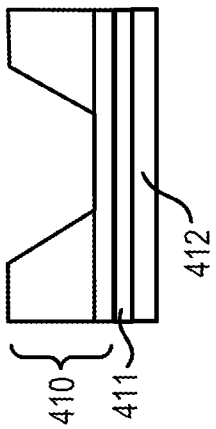


FIG. 5D

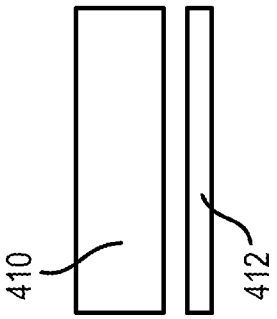


FIG. 5A

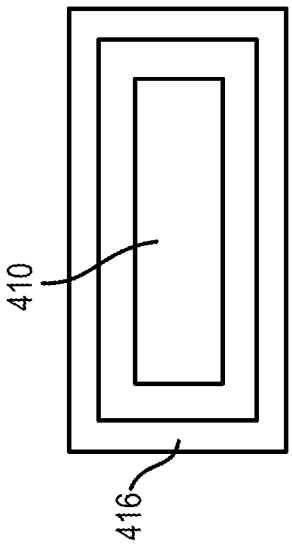


FIG. 5C

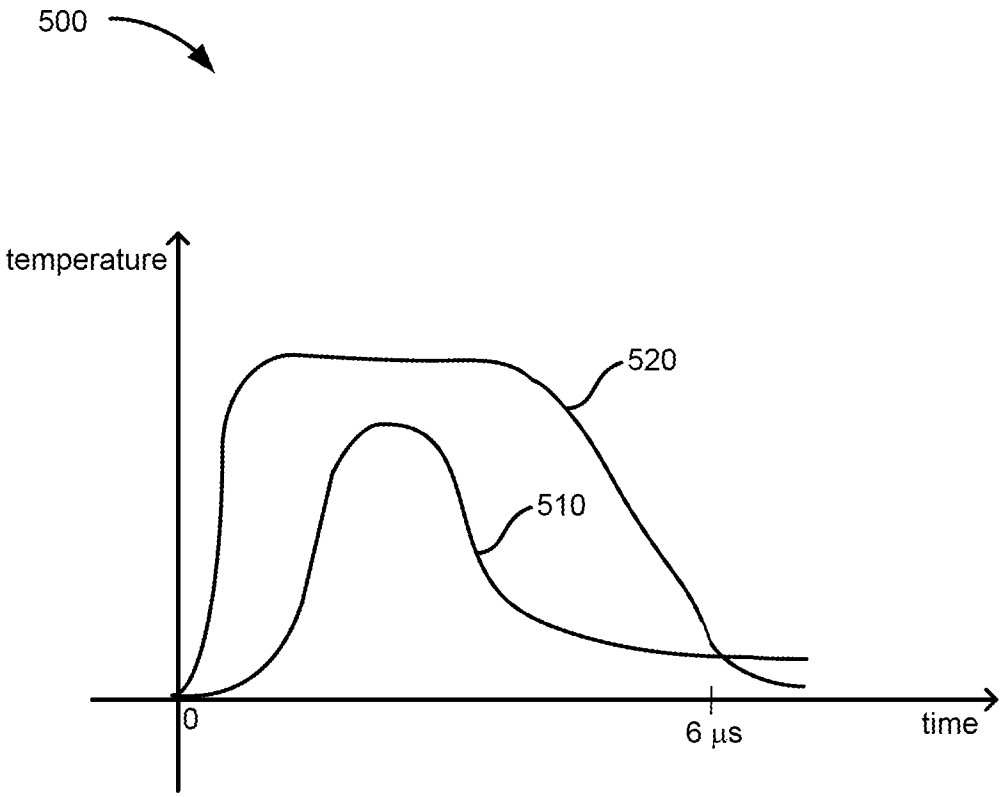


FIG. 6

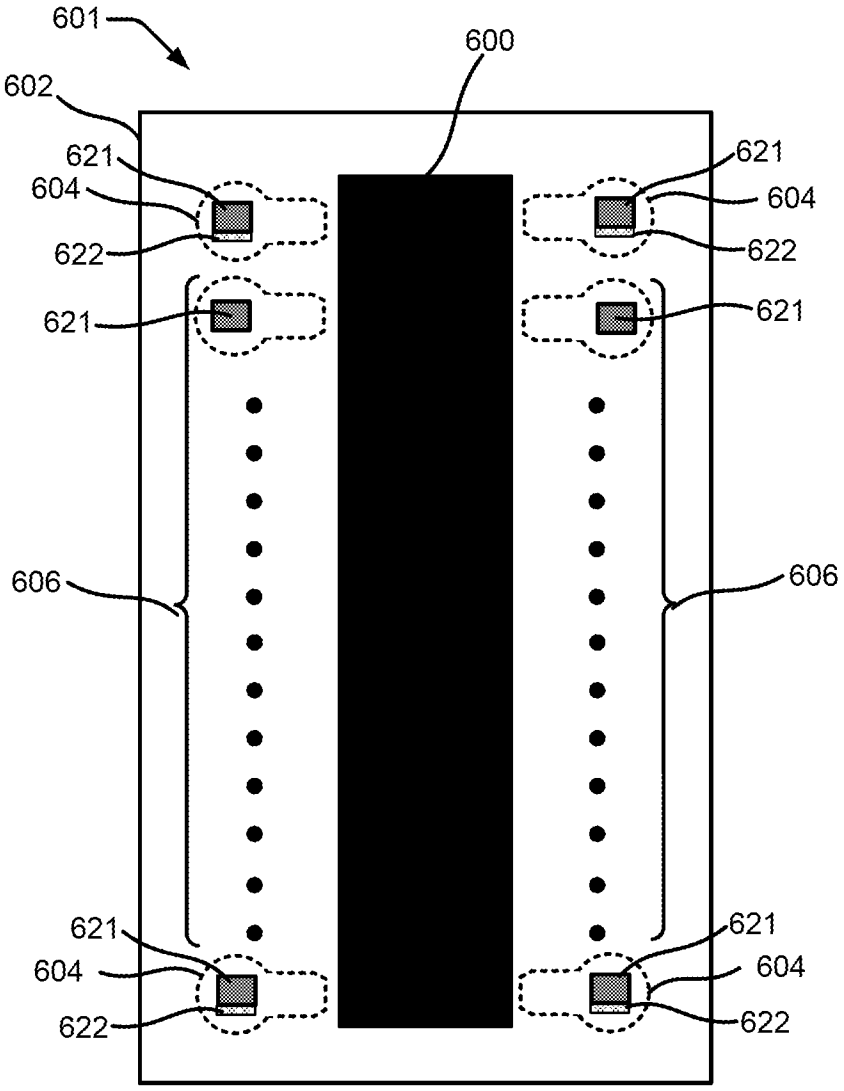

601
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FIG. 7

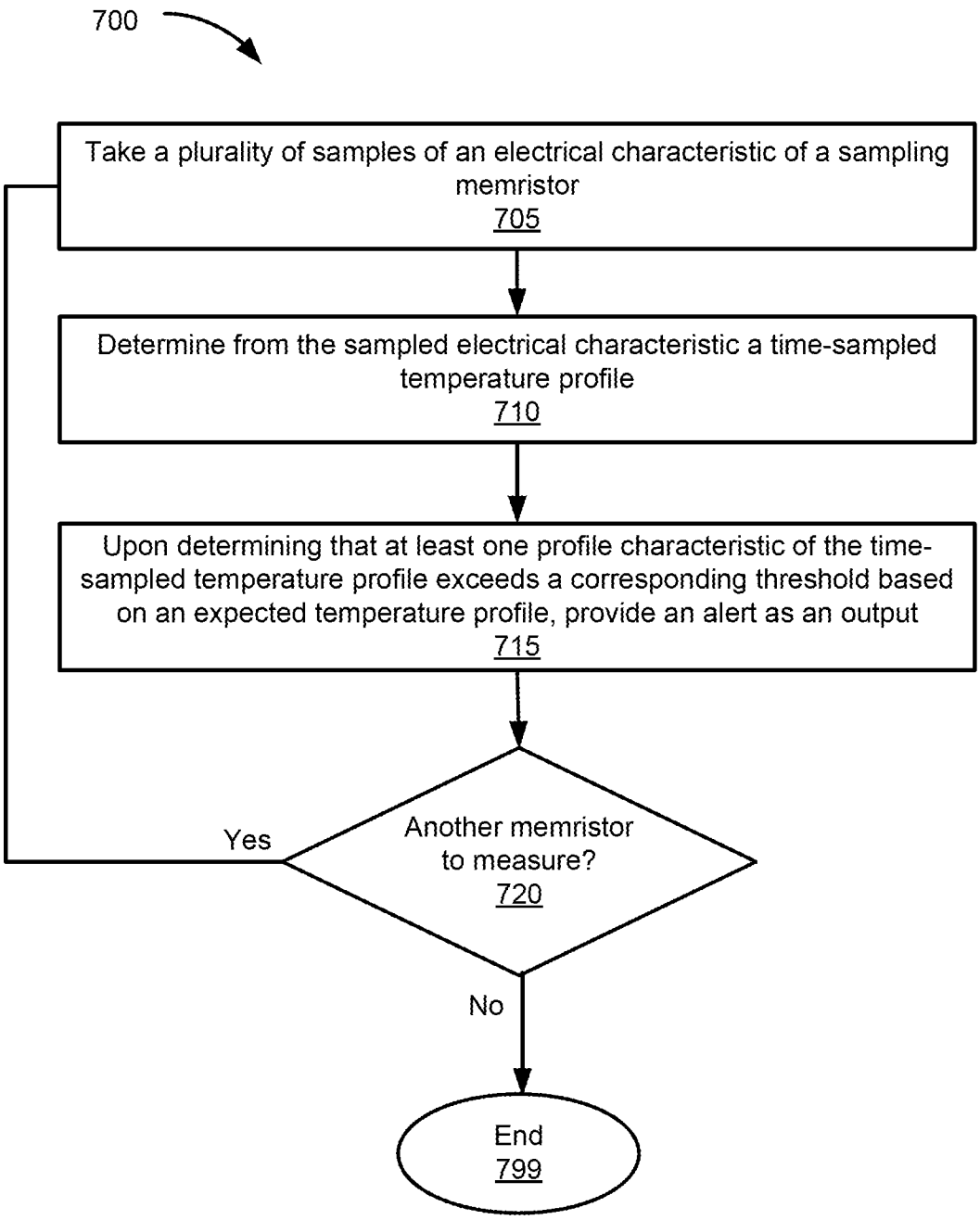

700
Take a plurality of samples of an electrical characteristic of a sampling memristor
705
Determine from the sampled electrical characteristic a time-sampled temperature profile
710
Upon determining that at least one profile characteristic of the time-sampled temperature profile exceeds a corresponding threshold based on an expected temperature profile, provide an alert as an output
715
Another memristor to measure?
720
Yes
No
End
799

FIG. 8

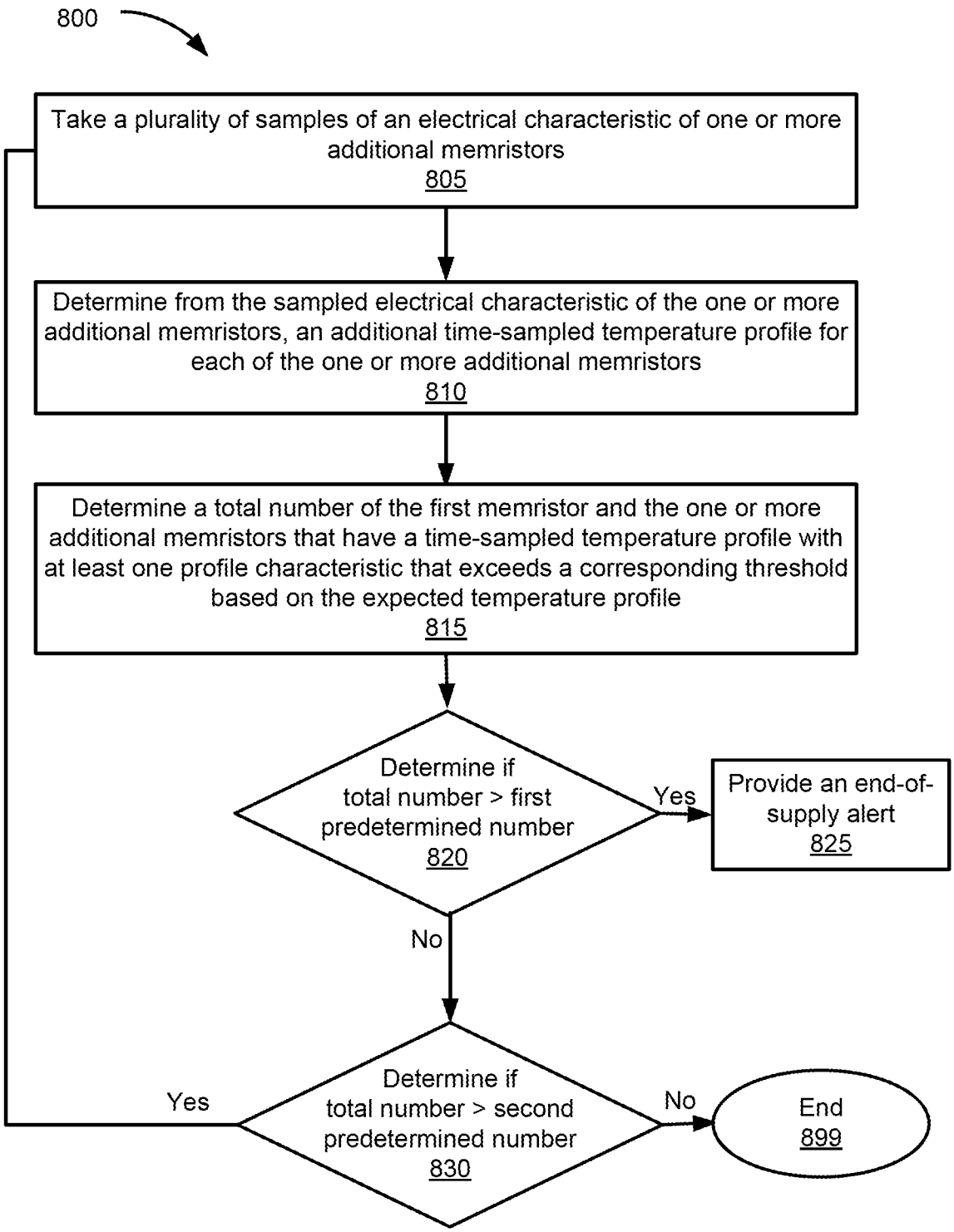

800
Take a plurality of samples of an electrical characteristic of one or more additional memristors
805
Determine from the sampled electrical characteristic of the one or more additional memristors, an additional time-sampled temperature profile for each of the one or more additional memristors
810
Determine a total number of the first memristor and the one or more additional memristors that have a time-sampled temperature profile with at least one profile characteristic that exceeds a corresponding threshold based on the expected temperature profile
815
Determine if total number > first predetermined number
820
Yes
Provide an end-of-supply alert
825
No
Determine if total number > second predetermined number
830
Yes
No
End
899

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/049124

A. CLASSIFICATION OF SUBJECT MATTER

B41J 2/175(2006.01)i, B41J 2/14(2006.01)i

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)
B41J 2/175; B41J 23/00; G06F 15/00; B41J 2/195; B41J 29/38; B41J 2/01; B41J 2/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: printer, printhead, nozzle, memristor, ejector, temperature, threshold, time, sample, comparison

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0295884 A1 (SMEKTALA, VOLKER) 25 November 2010 See abstract, paragraphs [0021]-[0025], [0032], [0037], claims 1, 6, 7, 14, 16, and figures 1, 2.	1-15
A	US 2008-0024551 A1 (BROOKMIRE et al.) 31 January 2008 See paragraphs [0049]-[0051], claims 1-9, and figure 1.	1-15
A	US 2006-0209111 A1 (USUI, TOSHIKI) 21 September 2006 See abstract, claim 1, and figures 4-6.	1-15
A	US 2010-0238226 A1 (TANAKA et al.) 23 September 2010 See paragraphs [0028]-[0030], claim 1, and figure 1B.	1-15
A	US 2002-0186266 A1 (CANTI et al.) 12 December 2002 See paragraphs [0023]-[0032], claims 1-6, and figure 1.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 2015 (28.04.2015)	**28 April 2015 (28.04.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. ++82 42 472 7140

Authorized officer
KIM, Jin Ho
Telephone No. +82-42-481-8699

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/049124

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