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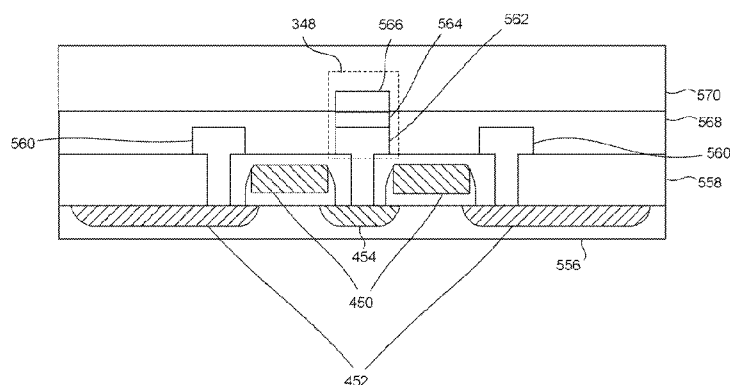
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(54) **Title:** PRINthead WITH A NUMBER OF MEMRISTORS DISPOSED ON ENCLOSED GATE TRANSISTORS

**Fig. 5**

(57) **Abstract:** A printhead with a number of memristors disposed on enclosed gate transistors is described. The printhead includes a number of nozzles to deposit an amount of fluid onto a print medium. Each nozzle includes a firing chamber to hold the amount of fluid, an opening to dispense the amount of fluid onto a print medium, and an ejector to eject the amount of fluid through the opening. The printhead also includes a number of transistors. Each transistor includes a source, a drain, and an enclosed gate. The enclosed gate electrically isolates the drain and the source. The printhead also includes a number of memristors. Each memristor is disposed on a drain of a corresponding transistor.



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PRINthead WITH A NUMBER OF MEMRISTORS DISPOSED ON ENCLOSED GATE TRANSISTORS

BACKGROUND

[0001] A memory system may be used to store data. In some examples, imaging devices, such as printheads may include memory to store information relating to printer cartridge identification, security information, and authentication information, among other types of information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The accompanying drawings illustrate various examples of the principles described herein and are a part of the specification. The illustrated examples do not limit the scope of the claims.

[0003] Fig. 1 is a diagram of a printing system according to one example of the principles described herein.

[0004] Fig. 2A is a diagram of a printer cartridge with a number of memristors disposed on enclosed gate transistors according to one example of the principles described herein.

[0005] Fig. 2B is a cross sectional diagram of a printer cartridge with a number of memristors disposed on enclosed gate transistors according to one example of the principles described herein.

[0006] Fig. 3 is a block diagram of a printer cartridge that uses a printhead with a number of memristors disposed on enclosed gate transistors according to one example of the principles described herein.

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[0007] Fig. 4 is a top view of a memristor disposed on an enclosed gate transistor according to one example of the principles described herein.

[0008] Fig. 5 is a cross sectional view of a memristor disposed on an enclosed gate transistor according to one example of the principles described herein.

[0009] Fig. 6 is a circuit diagram of a number of memristors disposed on enclosed gate transistors according to one example of the principles described herein.

[0010] Throughout the drawings, identical reference numbers designate similar, but not necessarily identical, elements.

DETAILED DESCRIPTION

[0011] Memory devices are used to store information for a printer cartridge. Printer cartridges include memory to store information related to the operation of the printhead. For example, a printhead may include memory to store information related 1) to the printhead; 2) to fluid, such as ink, used by the printhead; or 3) to the use and maintenance of the printhead. Other examples of information that may be stored on a printhead include information relating to 1) a fluid supply, 2) fluid identification information, 3) fluid characterization information, and 4) fluid usage data, among other types of fluid or imaging device related data. More examples of information that may be stored include identification information, serial numbers, security information, feature information, Anti-Counterfeiting (ACF) information, among other types of information. While memory usage on printheads is desirable, changing circumstances may reduce their efficacy in storing information.

[0012] For example, an increasing trend in counterfeiting may lead to current memory devices being too small to contain sufficient anti-counterfeiting information and security and authentication information. Additionally, with loyalty customer reward programs, new business models and other customer relation management programs through cloud-printing and other printing architectures, additional market data, customer appreciation value information,

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encryption information, and other types of information on the rise, a manufacturer may desire to store more information on a memory device.

[0013] Moreover, as new technologies develop, circuit space is at a premium. Accordingly, it may be desirable for the greater amounts of data storage to occupy less space within a device. Memristors may be used due to their non-volatility, low operational power consumption characteristics, and their compact size. A memristor selectively stores data based on a resistance state of the memristor. For example, a memristor may be in a low resistance state indicated by a "1," or a high resistance state indicated by a "0." Memristors may form a string of ones and zeroes that will store the aforementioned data. If an analog memristor is used, there may be many different resistance states.

[0014] A memristor may switch between a low resistance state and a high resistance state during a switching event in which a voltage is passed to the memristor. Each memristor has a switching voltage that refers to a voltage used to switch the state of the memristors. When the supplied voltage is greater than the memristor switching voltage, the memristor switches state. The switching voltage is largely based on the size of the memristor. For example, a larger memristor may use a larger voltage to execute a switching event. While memristors may be beneficial as memory storage devices, their use presents a number of complications. For example, in some memristor array structures, selection of an individual memristor within the array may be complicated such that there are inefficiencies in the memristor array.

[0015] According, the present specification describes memristors in a one transistor-one memristor structure. In other words, each memristor in a particular array has a counterpart transistor to control reading from, and writing to, the memristor. Such a structure may be beneficial by avoiding sneak current issues, specifically and uniquely identifying a target memristor and further ensuring proper addressing of the memristors in a memristor array. Still further, a one transistor-one memristor structure may allow for a smaller memory array to include more data storage capability.

[0016] The present specification also describes a memristor that is positioned on a drain of a transistor, in which the transistor is an enclosed-gate

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transistor where the gate of the transistor is an enclosed loop that electrically isolates the source from the drain.

[0017] Positioning the memristor on a drain of the transistor may be beneficial in that it alleviates a separate routing mechanism between a memristor and a transistor in a one transistor-one memristor memory array.

[0018] The present disclosure describes a printhead with a number of memristors disposed on enclosed gate transistors. The printhead includes a number of nozzles to deposit an amount of fluid onto a print medium. Each nozzle includes a firing chamber to hold an amount of fluid, an opening to dispense the amount of fluid onto a print medium, and an ejector to eject the amount of fluid through the opening. The printhead also includes a number of transistors. Each transistor includes a source, a drain, and an enclosed gate that electrically isolates the drain and the source. The printhead also includes a number of memristors, each memristor being disposed on a drain of a corresponding transistor.

[0019] The present disclosure describes a printer cartridge with a number of memristors disposed on enclosed gate transistors. The cartridge includes a fluid supply and a printhead to deposit fluid from the fluid supply onto a print medium. The printhead includes a memristor-transistor structure that includes a number of transistors. Each transistor includes a source, a drain, and an enclosed gate that electrically isolates the drain and the source. The memristor-transistor structure also includes a number of memristors, each memristor being disposed on a drain of a corresponding transistor.

[0020] A printer cartridge and a printhead that utilize a memristor-transistor structure having a number of memristors disposed on enclosed gate transistors may be beneficial by providing a simplified and cost-effective manufacturing process to produce a memristor that is relatively small while storing a large amount of information. Additionally, using a memristor may also allow for increased security using multi-level programming.

[0021] As used in the present specification and in the appended claims, the term "printer cartridge" may refer to a device used in the ejection of ink, or other fluid, onto a print medium. In general, a printer cartridge may be a

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fluidic ejection device that dispenses fluid such as ink, wax, polymers or other fluids. A printer cartridge may include a printhead. In some examples, a printhead may be used in printers, graphic plotters, copiers and facsimile machines. In these examples, a printhead may eject ink, or another fluid, onto a medium such as paper to form a desired image or a desired three-dimensional geometry.

[0022] Accordingly, as used in the present specification and in the appended claims, the term "printer" is meant to be understood broadly as any device capable of selectively placing a fluid onto a print medium. In one example the printer is an inkjet printer. In another example, the printer is a three-dimensional printer. In yet another example, the printer is a digital titration device.

[0023] Still further, as used in the present specification and in the appended claims, the term "fluid" is meant to be understood broadly as any substance that continually deforms under an applied shear stress. In one example, a fluid may be a pharmaceutical. In another example, the fluid may be an ink. In another example, the fluid may be a liquid.

[0024] Still further, as used in the present specification and in the appended claims, the term "print medium" is meant to be understood broadly as any surface onto which a fluid ejected from a nozzle of a printer cartridge may be deposited. In one example, the print medium may be paper. In another example, the print medium may be an edible substrate. In yet one more example, the print medium may be a medicinal pill.

[0025] Further, as used in the present specification and in the appended claims, the term "memristor" may refer to a passive two-terminal circuit element that maintains a functional relationship between the time integral of current, and the time integral of voltage.

[0026] Still further, as used in the present specification and in the appended claims, the term "continuous shape" or similar terminology may refer to a shape, or a portion of a shape that does not have a defined beginning or ending point. Examples of continuous shapes include circles, ovals, squares, triangles, and rectangles.

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[0027] Yet further, as used in the present specification and in the appended claims, the term "a number of" or similar language may include any positive number including 1 to infinity; zero not being a number, but the absence of a number.

[0028] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present systems and methods. It will be apparent, however, to one skilled in the art that the present apparatus, systems, and methods may be practiced without these specific details. Reference in the specification to "an example" or similar language means that a particular feature, structure, or characteristic described is included in at least that one example, but not necessarily in other examples.

[0029] Turning now to the figures, Fig. 1 is a diagram of a printing system (100) according to one example of the principles described herein. The printing system (100) includes a printer (104). The printer (104) includes an interface with a computing device (102). The interface enables the printer (104) and specifically the processor (108) to interface with various hardware elements, such as the computing device (102), external and internal to the printer (104). Other examples of external devices include external storage devices, network devices such as servers, switches, routers, and client devices among other types of external devices.

[0030] In general, the computing device (102) may be any source from which the printer (104) may receive data describing a print job to be executed by the controller (106) of the printer (104) in order print an image onto the print medium (126). For example, via the interface, the controller (106) receives data from the computing device (102) and temporarily stores the data in the data storage device (110). Data may be sent to the printer (104) along an electronic, infrared, optical, or other information transfer path. The data may represent a document and/or file to be printed. As such, data forms a print job for the printer (104) and includes one or more print job commands and/or command parameters.

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[0031] A controller (106) of the printer (104) includes a processor (108), a data storage device (110), firmware, software, and other electronics for communicating with and controlling the printhead (116), mounting assembly (118), and media transport assembly (120). The controller (106) receives data from the computing device (102) and temporarily stores data in the data storage device (110).

[0032] The controller (106) controls the printhead (116) in ejecting fluid from the nozzles (124). For example, the controller (106) defines a pattern of ejected fluid drops that form characters, symbols, and/or other graphics or images on the print medium (126). The pattern of ejected fluid drops is determined by the print job commands and/or command parameters received from the computing device (102). The controller (106) may be a printer (104) application specific integrated circuit (ASIC) to determine the level of fluid in the printhead (116) based on resistance values of memristors integrated on the printhead (116). The printer ASIC may include a current source and an analog to digital converter (ADC). The ASIC converts a voltage present at the current source to determine a resistance of a memristor, and then determine a corresponding digital resistance value through the ADC. Computer readable program code, executed through executable instructions enables the resistance determination and the subsequent digital conversion through the ADC.

[0033] The processor (108) may include the hardware architecture to retrieve executable code from the data storage device (110) and execute the executable code. The executable code may, when executed by the processor (108), cause the processor (108) to implement at least the functionality of printing on the print medium (126), and actuating the mounting assembly (118) and the media transport assembly (120) according to the present specification. The executable code may, when executed by the processor (108), cause the processor (108) to implement the functionality of providing instructions to the power supply (130) such that the power supply (130) provides power to the components of the printer (104).

[0034] The data storage device (110) may store data such as executable program code that is executed by the processor (108) or other

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processing device. The data storage device (110) may specifically store computer code representing a number of applications that the processor (108) executes to implement at least the functionality described herein.

[0035] The data storage device (110) may include various types of memory modules, including volatile and nonvolatile memory. For example, the data storage device (110) of the present example includes Random Access Memory (RAM), Read Only Memory (ROM), and Hard Disk Drive (HDD) memory. Many other types of memory may also be utilized, and the present specification contemplates the use of many varying type(s) of memory in the data storage device (110) as may suit a particular application of the principles described herein. In certain examples, different types of memory in the data storage device (110) may be used for different data storage needs. For example, in certain examples the processor (108) may boot from Read Only Memory (ROM), maintain nonvolatile storage in the Hard Disk Drive (HDD) memory, and execute program code stored in Random Access Memory (RAM).

[0036] Generally, the data storage device (110) may include a computer readable medium, a computer readable storage medium, or a non-transitory computer readable medium, among others. For example, the data storage device (110) may be, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the computer readable storage medium may include, for example, the following: an electrical connection having a number of wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store computer usable program code for use by or in connection with an instruction execution system, apparatus, or device. In another example, a computer readable storage medium may be any

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non-transitory medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0037] The printing system (100) includes a printer cartridge (114) that includes a printhead (116), a reservoir (112), and a conditioning assembly (132). The printer cartridge (114) may be removable from the printer (104) for example, as a replaceable printer cartridge (114).

[0038] The printer cartridge (114) includes a printhead (116) that ejects drops of fluid through a plurality of nozzles (124) towards a print medium (126). The print medium (126) may be any type of suitable sheet or roll material, such as paper, card stock, transparencies, polyester, plywood, foam board, fabric, canvas, and the like. In another example, the print medium (126) may be an edible substrate. In yet one more example, the print medium (126) may be a medicinal pill.

[0039] Nozzles (124) may be arranged in one or more columns or arrays such that properly sequenced ejection of fluid from the nozzles (124) causes characters, symbols, and/or other graphics or images to be printed on the print medium (126) as the printhead (116) and print medium (126) are moved relative to each other. In one example, the number of nozzles (124) fired may be a number less than the total number of nozzles (124) available and defined on the printhead (116).

[0040] The printer cartridge (114) also includes a fluid reservoir (112) to supply an amount of fluid to the printhead (116). In general, fluid flows from the reservoir (112) to the printhead (116), and the reservoir (112) and the printhead (116) form a one-way fluid delivery system or a recirculating fluid delivery system. In a one-way fluid delivery system, fluid supplied to the printhead (116) is consumed during printing. In a recirculating fluid delivery system, however, a portion of the fluid supplied to printhead (116) is consumed during printing. Fluid not consumed during printing is returned to the reservoir (112).

[0041] The reservoir (112) may supply fluid under positive pressure through a conditioning assembly (132) to the printhead (116) via an interface connection, such as a supply tube. The reservoir (112) may include pumps and

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pressure regulators. Conditioning in the conditioning assembly (132) may include filtering, pre-heating, pressure surge absorption, and degassing. Fluid is drawn under negative pressure from the printhead (116) to the reservoir (112). The pressure difference between the inlet and outlet to the printhead (116) is selected to achieve the correct backpressure at the nozzles (124).

[0042] A mounting assembly (118) positions the printhead (116) relative to media transport assembly (120), and media transport assembly (120) positioning the print medium (126) relative to printhead (116). Thus, a print zone (128), indicated by the dashed box, is defined adjacent to the nozzles (124) in an area between the printhead (116) and the print medium (126). In one example, the printhead (116) is a scanning type printhead (116). As such, the mounting assembly (118) includes a carriage for moving the printhead (116) relative to the media transport assembly (120) to scan the print medium (126). In another example, the printhead (116) is a non-scanning type printhead (116). As such, the mounting assembly (118) fixes the printhead (116) at a prescribed position relative to the media transport assembly (120). Thus, the media transport assembly (120) positions the print medium (126) relative to the printhead (116).

[0043] Fig. 2A is a diagram of a printer cartridge (114) and printhead (116) with a number of memristors disposed on enclosed gate transistors according to one example of the principles described herein. As discussed above, the printhead (116) may comprise a number of nozzles (124). In some examples, the printhead (116) may be broken up into a number of print dies with each die having a number of nozzles (124). The printhead (116) may be any type of printhead (116) including, for example, a printhead (116) as described in Figs. 2A and 2B. The examples shown in Figs. 2A and 2B are not meant to limit the present description. Instead, various types of printheads (116) may be used in conjunction with the principles described herein.

[0044] The printer cartridge (114) also includes a fluid reservoir (112), a flexible cable (236), conductive pads (238), and a memristor array (240). The flexible cable (236) is adhered to two sides of the printer cartridge (114) and

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contains traces that electrically connect the memristor array (240) and printhead (116) with the conductive pads (238).

[0045] The printer cartridge (114) may be installed into a cradle that is integral to the carriage of a printer (Fig. 1, 104). When the printer cartridge (114) is correctly installed, the conductive pads (238) are pressed against corresponding electrical contacts in the cradle, allowing the printer (Fig. 1, 104) to communicate with, and control the electrical functions of, the printer cartridge (114). For example, the conductive pads (238) allow the printer (Fig. 1, 104) to access and write to the memristor array (240).

[0046] The memristor array (240) may contain a variety of information including the type of printer cartridge (114), the kind of fluid contained in the printer cartridge (114), an estimate of the amount of fluid remaining in the fluid reservoir (112), calibration data, error information, and other data. In one example, the memristor array (240) may include information regarding when the printer cartridge (114) should be maintained. The memristor array (240) may include other information as described below in connection with Fig. 3.

[0047] To create an image, the printer (Fig. 1, 104) moves the carriage containing the printer cartridge (114) over a print medium (Fig. 1, 126). At appropriate times, the printer (Fig. 1, 104) sends electrical signals to the printer cartridge (114) via the electrical contacts in the cradle. The electrical signals pass through the conductive pads (238) and are routed through the flexible cable (236) to the printhead (116). The printhead (116) then ejects a small droplet of fluid from the reservoir (112) onto the surface of the print medium (Fig. 1, 126). These droplets combine to form an image on the surface of the print medium (Fig. 1, 126).

[0048] The printhead (116) may include any number of nozzles (124). In an example where the fluid is an ink, a first subset of nozzles (124) may eject a first color of ink while a second subset of nozzles (124) may eject a second color of ink. Additional groups of nozzles (124) may be reserved for additional colors of ink.

[0049] Fig. 2B is a cross sectional diagram of a printer cartridge (114) and printhead (116) with a number of memristors disposed on enclosed gate

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transistors according to one example of the principles described herein. The printer cartridge (114) may include a fluid supply (112) that supplies the fluid to the printhead (116) for deposition onto a print medium (Fig. 1, 126). In some examples, the fluid may be ink. For example, the printer cartridge (114) may be an inkjet printer cartridge, the printhead (116) may be an inkjet printhead, and the ink may be inkjet ink.

[0050] The printer cartridge (114) may include a printhead (116) to carry out at least a part of the functionality of depositing fluid onto a print medium (Fig. 1, 126). The printhead (116) may include a number of components for depositing a fluid onto a surface. For example, the printhead (116) may include a number of nozzles (124). For simplicity, Fig. 2B indicates a single nozzle (124), however a number of nozzles (124) are present on the printhead (116). A nozzle (124) may include an ejector (242), a firing chamber (244), and an opening (246). The opening (246) may allow fluid, such as ink, to be deposited onto a surface, such as a print medium (Fig. 1, 126). The firing chamber (244) may include a small amount of fluid. The ejector (242) may be a mechanism for ejecting fluid through the opening (246) from the firing chamber (206), where the ejector (242) may include a firing resistor or other thermal device, a piezoelectric element, or other mechanism for ejecting fluid from the firing chamber (244).

[0051] For example, the ejector (242) may be a firing resistor. The firing resistor heats up in response to an applied voltage. As the firing resistor heats up, a portion of the fluid in the firing chamber (244) vaporizes to form a bubble. This bubble pushes liquid fluid out the opening (246) and onto the print medium (Fig. 1, 126). As the vaporized fluid bubble pops, a vacuum pressure within the firing chamber (244) draws fluid into the firing chamber (244) from the fluid supply (112), and the process repeats. In this example, the printhead (116) may be a thermal inkjet printhead.

[0052] In another example, the ejector (242) may be a piezoelectric device. As a voltage is applied, the piezoelectric device changes shape which generates a pressure pulse in the firing chamber (244) that pushes a fluid out

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the opening (246) and onto the print medium (Fig. 1, 126). In this example, the printhead (116) may be a piezoelectric inkjet printhead.

[0053] The printhead (116) and printer cartridge (114) may also include other components to carry out various functions related to printing. For simplicity, in Figs. 2A and 2B, a number of these components and circuitry included in the printhead (116) and printer cartridge (114) are not indicated; however such components may be present in the printhead (116) and printer cartridge (114).

[0054] Fig. 3 is a block diagram of a printer cartridge (114) that uses a printhead (116) with a number of memristors disposed on enclosed gate transistors according to one example of the principles described herein. In some examples, the printer cartridge (114) includes a printhead (116) that carries out at least a part of the functionality of the printer cartridge (114). For example, the printhead (116) may include a number of nozzles (Fig. 1, 124). The printhead (116) ejects drops of fluid from the nozzles (Fig. 1, 124) onto a print medium (Fig. 1, 126) in accordance with a received print job. The printhead (116) may also include other circuitry to carry out various functions related to printing. In some examples, the printhead (116) is part of a larger system such as an integrated printhead (IPH). The printhead (116) may be of varying types. For example, the printhead (116) may be a thermal inkjet (TIJ) printhead or a piezoelectric inkjet (PIJ) printhead, among other types of printhead (116).

[0055] The printhead (116) includes a memristor array (240) to store information relating to at least one of the printer cartridge (114) and the printhead (116). In some examples, the memristor array (240) includes a number of memristors (348) formed in the printhead (116). To store information, each memristor (348) may be set to a particular logic state. As memristors (348) are non-volatile, this logic state is retained even when power is removed from the printhead (116).

[0056] A memristor (348) has a metal-insulator-metal layered structure. More specifically, the memristor (348) may include a bottom electrode (metal), a switching oxide (insulator or semiconductor), and a top

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electrode (metal). A memristor (348) may be classified as an anion device which includes an oxide insulator. Examples of such oxide insulators include transition metal oxides, complex oxides, and large band gap dielectrics in addition to other non-oxide materials. In this example, an aluminum copper silicon oxide, tantalum oxide, or other oxide may be an example of a switching oxide in an anion device. In an anionic device, the switching mechanism is the oxygen vacancies in the oxide that are positively charged. By comparison, in a cation device the electrodes (i.e., the bottom electrode, the top electrode, or combinations thereof) are formed from an electrochemically active metal such as copper or silver.

[0057] The number of memristors (348) are grouped together into a memristor array (240). As described above, the memristors (348) may have a one-to-one relationship with a number of addressing transistors. In this example, the memristor array (240) may be a one transistor-one memristor (1T1M) memristor array (240). While Fig. 3 depicts two memristors (348-1, 348-2) and a single memristor array (240), the printhead (116) may include any number of memristor arrays (240) with any number of memristors (348). For example, a memristor array (240) may be a cross bar array with 8 rows and 8 columns which includes 64 memristors (348).

[0058] The memristor array (240) may be used to store any type of data. Examples of data that may be stored in the memristor array (240) include fluid supply specific data and/or fluid identification data, fluid characterization data, fluid usage data, printhead (116) specific data, printhead (116) identification data, warranty data, printhead (116) characterization data, printhead (116) usage data, authentication data, security data, Anti-Counterfeiting data (ACF), ink drop weight, firing frequency, initial printing position, acceleration information, and gyro information, among other forms of data. In a number of examples, the memristor array (240) is written at the time of manufacturing and/or during the operation of the printer cartridge (114).

[0059] In some examples, the printer cartridge (114) may be coupled to a controller (106) that is disposed within the printer (Fig. 1, 104). The controller (106) receives a control signal from an external computing device

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(Fig. 1, 102). The controller (106) may be an application-specific integrated circuit (ASIC) found on the printer (Fig. 1, 104). A computing device (Fig. 1, 102) may send a print job to the printer cartridge (114), the print job being made up of text, images, or combinations thereof to be printed.

[0060] The controller (106) may facilitate storing information to the memristor arrays (240). Specifically, the controller (106) may pass at least one control signal to the number of memristors (348). For example, the controller (106) may be coupled to the printhead (116), via a control line such as an identification line. Via the identification line, the controller (106) may change the resistance state of a number of memristors (348) in the memristor array (240) to effectively store information to a memristor array (240). For example, the controller (106) may send data such as authentication data, security data, and print job data, in addition to other types of data to the printhead (116) to be stored on the memristor array (240).

[0061] While specific reference is made to an identification line, the controller (106) may share a number of lines of communication with the printhead (116), such as data lines, clock lines, and fire lines. For simplicity, in Fig. 3 the different communication lines are indicated by a single arrow.

[0062] Fig. 4 is a top view of a memristor (348) disposed on an enclosed gate (450) transistor according to one example of the principles described herein. As described above, a number of memristors (348) may be grouped together into a memristor array (Fig. 2, 240). Each memristor (348) in the memristor array (Fig. 2, 240) may be part of a memristor-transistor structure, in which each memristor (348) corresponds to a distinct transistor. Such a one-to-one structure may be beneficial by simplifying the data storage to an individual memristor (348). More detail concerning the components of a memristor (348) is given below in connection with Fig. 5.

[0063] A transistor is a device that regulates current and acts as a switch for electronic signals. For example, a transistor may allow current to flow through the memristor (348), which flow changes a state of the memristor (348), i.e., from a low resistance state to a high resistance state or from a high resistance state to a low resistance state. As described above, this change of

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state allows a memristor (348) to store information. A transistor may include a source (452), a gate (450), and a drain (454). Electrical current flows from the drain (454) to the source (452) based on an applied voltage at the gate (450). For example, when no voltage is applied at the gate (450), no current flows between the source (452) and the drain (454). By comparison, when there is an applied voltage at the gate (450), current readily flows between the source (452) and the drain (454). In some examples, the source (452) and the drain (454) may be formed of n-type semiconductors indicating that the source (452) and drain (454) contain larger electron concentration than concentration of holes. The source (452) and the drain (454) may be disposed in a substrate, such as a p-type substrate that has a larger concentration of holes than electrons. In some examples, the source (452) may be a continuous shape that surrounds the enclosed gate (450) of the transistor. In other words, the enclosed gate (450) may be positioned within a central portion of the enclosed source (452).

[0064] The gate (450) may be an enclosed gate (450) to isolate the source (452) from the drain (454). In other words, the drain (454) may be positioned within a central portion of the enclosed gate (450). As used in the present specification and in the appended claims, the enclosed gate (450) may be any continuous shape that surrounds the drain (454). While Fig. 4 depicts a square-shaped enclosed gate (450), the enclosed gate (450) may be any shape. The gate (450) may be made of any semi conductive or conductive material that allows for current to flow between the source (452) and the drain (454). For example, the gate may be made of a polycrystalline silicon material.

[0065] As described above, a transistor allows for electrical signals to be passed between the controller (Fig. 1, 106) and the memristor array (Fig. 2, 240) of which the memristor (348) is a part. Accordingly, each component within the transistor may be coupled to routing elements (460) that couple the components to other devices. For example, the source (452) may be coupled to a first routing element (460-1) that is coupled to ground. The drain (454) may be coupled to another routing element (460-3) that couples the transistor, and corresponding memristor (348), to an identification line such that the memristor (348) may store information. The gate (450) may be coupled to another routing

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element (460-2) that is coupled to the controller (Fig. 1, 106) such that the memristor (348) may be accessed, and may subsequently store information.

[0066] As described above, a memristor (348) may be disposed on a drain (454) of each transistor. More specifically, as indicated in Fig. 5 as well, the bottom electrode of a memristor (348) may be disposed on a top surface of the drain (454) of the transistor. A memristor (348) disposed on a drain (454) of an enclosed gate (450) transistor may be beneficial by reducing the footprint of the memristor (348) on a printhead (Fig. 1, 116). Additionally as the memristor (348) bottom electrode is disposed directly on the drain (454), no additional routing elements are used to join the memristor (348) to the transistor.

[0067] Fig. 5 is a cross sectional view of a memristor (348) disposed on an enclosed gate (450) transistor according to one example of the principles described herein. The transistor may include a source (452) and a drain (454). In some examples, the source (452) and the drain (454) may be n-type components that are electrically isolated by being formed in a p-type substrate (556). As can be seen in Fig. 5, as well as previously illustrated in Fig. 4, the source (452) may be an enclosed source (452) that surrounds the enclosed gate (450), which enclosed gate (450) surrounds the drain (454).

[0068] In some examples, the enclosed gate (450) may be formed in a dielectric layer (558) of the structure. The dielectric layer (558) may electrically isolate the transistor from other components such as the memristor (348). In some examples, the dielectric layer (558) may be an undoped silicon glass (USG) layer. In another example, the dielectric layer (558) may be a borophosphosilicate glass (BPSG) layer. While specific reference is made to specific dielectric layers (558), the dielectric layer (558) may be any layer that isolates the transistor components from the memristor (348) such as a phosphosilicate glass (PSG) layer, a USG layer combined with BPSG, PSG, or combinations thereof.

[0069] The source (452) of the transistor may be coupled to routing elements (560) that allow signals, such as control signals, to pass from the controller (Fig. 1, 106) to the memristor (348). The control signals may alter a state of the memristor (348) such that information may be stored therein. The

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routing elements (560) may pass through the dielectric layer (558) and the memristor substrate as described below.

[0070] The memristor (348), indicated in Fig. 5 by the dashed box, may have a metal-insulator-metal layered structure. More specifically, the memristor (348) may include a bottom electrode (562), a switching oxide (564), and a top electrode (566).

[0071] The bottom electrode (562) may be disposed on a top surface of the drain (454) and may be an electrical connection between the memristor (348) and other components. For example, a surface of the bottom electrode (562) may be coupled to a routing element (560) via the transistor elements (i.e., source (452), gate (450), and drain (454)). The routing element (560) may be an electrical communication component that allows a control signal to pass through the memristor (348). For example, the controller (Fig. 1, 106) may pass a control signal through the gate (450) to change the state of the memristor (348) such that the memristor (348) may store information for the printer cartridge (Fig. 1, 114).

[0072] The bottom electrode (562) may be formed of a number of metallic materials, or any other material that conducts electricity. Examples of such metallic materials include titanium nitride, tantalum, tantalum nitride, platinum, aluminum, copper, and an aluminum-copper alloy, aluminum-copper-silicon alloy, among other metallic materials.

[0073] The memristor (348) also includes a switching oxide (564) that is disposed on top of the bottom electrode (562). The switching oxide (564) may be an insulator between the bottom electrode (562) and the top electrode (566). For example, in a first state, the switching oxide (564) may be insulating such that current does not readily pass between the bottom electrode (562) to the top electrode (566). Then, during a switching event, the switching oxide (564) may switch to a second state, becoming conductive. In a conductive state, the switching oxide (564) allows a memristor (348) to store information by changing the memristor state.

[0074] In some examples, the switching oxide (564) may be formed by oxidizing the bottom electrode (562). For example, the switching oxide (564)

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may be formed by thermal oxidation, a process which exposes the bottom electrode (562) to oxidizing agents at elevated temperatures. Specific examples of thermal oxidation processes that may be used include a furnace oxidation process, a rapid thermal process, a rapid thermal oxidation, and a rapid thermal annealing, among other oxidation processes. In some examples, the switching oxide (564) is formed by performing plasma oxidation, which exposes the bottom electrode (562) to oxygen plasma at controlled temperatures.

[0075] In another example, the switching oxide (564) is formed through a physical vapor deposition process wherein atoms or molecules may be ejected from a target material towards the bottom electrode (562). For example, a target material is bombarded with energetic particles. In response, atoms or molecules of the target material are dislodged and built up to form the switching oxide (564). While specific examples of switching oxide (564) formation processes have been given, other oxide forming processes are also contemplated by the present specification.

[0076] In some examples, the switching oxide (564) may be made of a metallic oxide. Specific examples of switching oxide (564) 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 the binary oxides presented, the switching oxides (564) may be ternary and complex oxides such as silicon oxynitride. The oxides presented may be formed using a number of different processes such as sputtering from an oxide target or oxidizing a deposited metal or alloy layer.

[0077] In some examples, a bottom electrode interface layer, top electrode interface layer, or combinations thereof may be disposed between the bottom electrode (562), top electrode (566), respectively, and the switching oxide (564) to facilitate an improved switching behavior of memristor (348).

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[0078] The switching oxide (564) and a portion of the bottom electrode (562) and a portion of the routing elements (560) may be disposed in a memristor substrate layer (568). The memristor substrate layer (568) may insulate the memristor (348) and prevent undesirable current leak in the memristor array (Fig. 2, 240). In some examples, the memristor substrate layer (568) may be at least one of USG, BPSG, PSG or combinations thereof.

[0079] The memristor (348) also includes a top electrode (566) that is disposed on a top surface of the switching oxide (564). As with the bottom electrode (562), the top electrode (566) may be an electrical connection between the memristor (348) and other components. Via a top surface, the top electrode (566) may be coupled to a control line of a computing device (Fig. 1, 102), such as an identification (ID) line. Other examples of components that may attach to the top electrode (566) include a ground connection, a number of connection pads, a current regulator, a capacitor, a resistor, and metal traces, among other memristor array (Fig. 2, 240) components.

[0080] In some examples, the top electrode (566) may be formed from a metallic material such as tantalum or a tantalum-aluminum alloy, or other conducting material such as titanium, titanium nitride, copper, aluminum, platinum, and gold among other metallic materials. In some examples, a passivation layer (570) may be disposed on top of the top electrode (566). The passivation layer (570) protects the memristor (348) and other components from environmental factors such as air and water. Examples of passivation layer (570) materials include silicon carbide (SiC), silicon nitride (SiN), and combinations thereof, among other passivation materials (570). In some examples, a top electrode interface layer may be disposed between the switching oxide (564) and the top electrode (566) to facilitate a more effective passage of current through the memristor (348). The top electrode interface layer may be formed of tantalum nitride, titanium nitride, tantalum, and combinations thereof among other interface layer materials.

[0081] Fig. 6 is a circuit diagram of a number of memristors (348) disposed on enclosed gate transistors (672) according to one example of the principles described herein. Each transistor (672) in Fig. 6 is depicted by a

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dashed box. Each transistor (672-1, 672-2, 672-3) includes a source (452-1, 452-2, 452-3), a gate (450-1, 450-2, 450-3) and a drain (454-1, 454-2, 454-3) as described above. Each transistor (672) may have a corresponding memristor (348) deposited on top of the drain (454) of the transistor (672). In a circuit diagram this may indicate that the memristors (348-1, 348-2, 348-2) are in series with the transistors (672-1, 672-2, 672-3).

[0082] As described above, in some examples, the memristors (348) may form part of a memristor array (Fig. 2, 240). In this example, a computing device (102) may include a multiplexer may be used to generate multiple voltages to be applied to the gates (401-1, 401-2, 401-3) of the memristors (302-1, 302-2, 302-3) thereby changing the resistance states, and storing information to, the memristors (302-1, 302-2, 302-3).

[0083] Each of the memristors (348) may be coupled to an identification (ID) line (674). Via the ID line (674), a controller (Fig. 1, 106) may read data from, and write data to, the memristors (348). Accordingly, each memristor (348) may be individually accessed by the ID line (674). More specifically, the ID line (674) may be able to access, and retrieve, information from a memristor (348).

[0084] A printer cartridge (Fig. 1, 114) with a printhead (Fig. 1, 116) with a number of memristors (Fig. 3, 348) with enclosed gate transistors may have a number of advantages, including: (1) avoiding sneak path current complications; (2) removing routing structures between a memristor and a transistor; (3) providing a compact transistor and memristor structure; (4) improving printhead (Fig. 1, 116) memory performance; and (5) reducing cost of effective memristor (Fig. 3, 348) fabrication.

[0085] Aspects of the present system are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to examples of the principles described herein. Each block of the flowchart illustrations and block diagrams, and combinations of blocks in the flowchart illustrations and block diagrams, may be implemented by computer usable program code. The computer usable program code may be provided to a processor of a general

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purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the computer usable program code, when executed via, for example, the processor (Fig. 1, 108) of the printer (Fig. 1, 104) or other programmable data processing apparatus, implement the functions or acts specified in the flowchart and/or block diagram block or blocks. In one example, the computer usable program code may be embodied within a computer readable storage medium; the computer readable storage medium being part of the computer program product. In one example, the computer readable storage medium is a non-transitory computer readable medium.

[0086] The preceding description has been presented to illustrate and describe examples of the principles described. This description is not intended to be exhaustive or to limit these principles to any precise form disclosed. Many modifications and variations are possible in light of the above teaching.

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CLAIMS

WHAT IS CLAIMED IS:

1. A printhead with a number of memristors disposed on enclosed gate transistors, the printhead comprising:
 - a number of nozzles to deposit an amount of fluid onto a print medium, each nozzle comprising:
 - a firing chamber to hold the amount of fluid;
 - an opening to dispense the amount of fluid onto a print medium;
 - and
 - an ejector to eject the amount of fluid through the opening; and
 - a number of transistors, each transistor comprising:
 - a source;
 - a drain; and
 - an enclosed gate, in which the enclosed gate electrically isolates the drain and the source; and
 - a number of memristors, each memristor being disposed on a drain of a corresponding transistor.
2. The printhead of claim 1, in which the fluid is inkjet ink.
3. The printhead of claim 1, in which each memristor comprises:
 - a bottom electrode;
 - a switching oxide; and
 - a top electrode;in which the bottom electrode of the memristor is disposed on a top surface of the drain of the corresponding transistor.
4. The printhead of claim 3, in which the top electrode is coupled to a control line of a computing device.

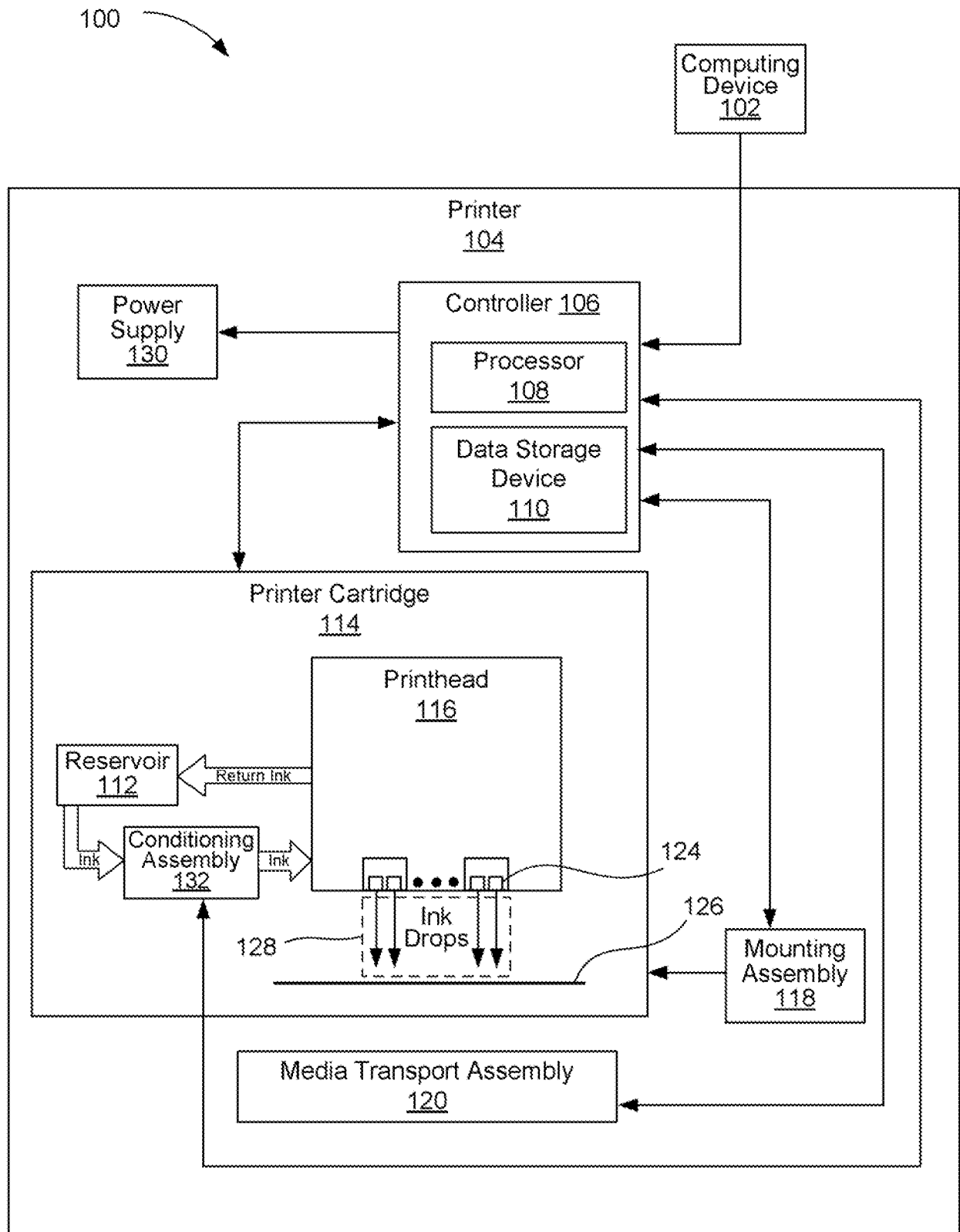
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5. The printhead of claim 1, further comprising a bottom electrode interface layer, a top electrode interface layer, or combinations thereof.
6. The printhead of claim 1, in which the enclosed gate is a continuous shape surrounding the drain of the transistor.
7. The printhead of claim 1, in which the source is a continuous shape surrounding the enclosed gate of the transistor.
8. A printer cartridge with a number of memristors disposed on enclosed gate transistors, comprising:
 - a fluid supply; and
 - a printhead to deposit fluid from the fluid supply onto a print medium, the printhead comprising:
 - a memristor-transistor structure comprising:
 - a number of transistors, each transistor comprising:
 - a source;
 - a drain; and
 - an enclosed gate, in which the enclosed gate electrically isolates the drain and the source; and
 - a number of memristors, each memristor being disposed on a drain of a corresponding transistor.
9. The cartridge of claim 8, in which:
 - the fluid is inkjet ink;
 - the printer cartridge is an inkjet printer cartridge; and
 - the printhead is an inkjet printhead.
10. The cartridge of claim 8, further comprising a controller to pass at least one control signal to the number of memristors.

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11. The cartridge of claim 8, in which the drain is positioned within a central portion of the enclosed gate.
12. The cartridge of claim 8, in which the source is an enclosed source.
13. The cartridge of claim 12, in which the enclosed gate is positioned within a central portion of the enclosed source.
14. The cartridge of claim 8, in which:
 - a bottom electrode of the memristor is disposed on a top surface of the drain; and
 - a top electrode of the memristor is coupled to a computing device.
15. The cartridge of claim 8, in which the number of memristors and number of transistors in the memristor-transistor structure have a one-to-one structure.

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**Fig. 1**

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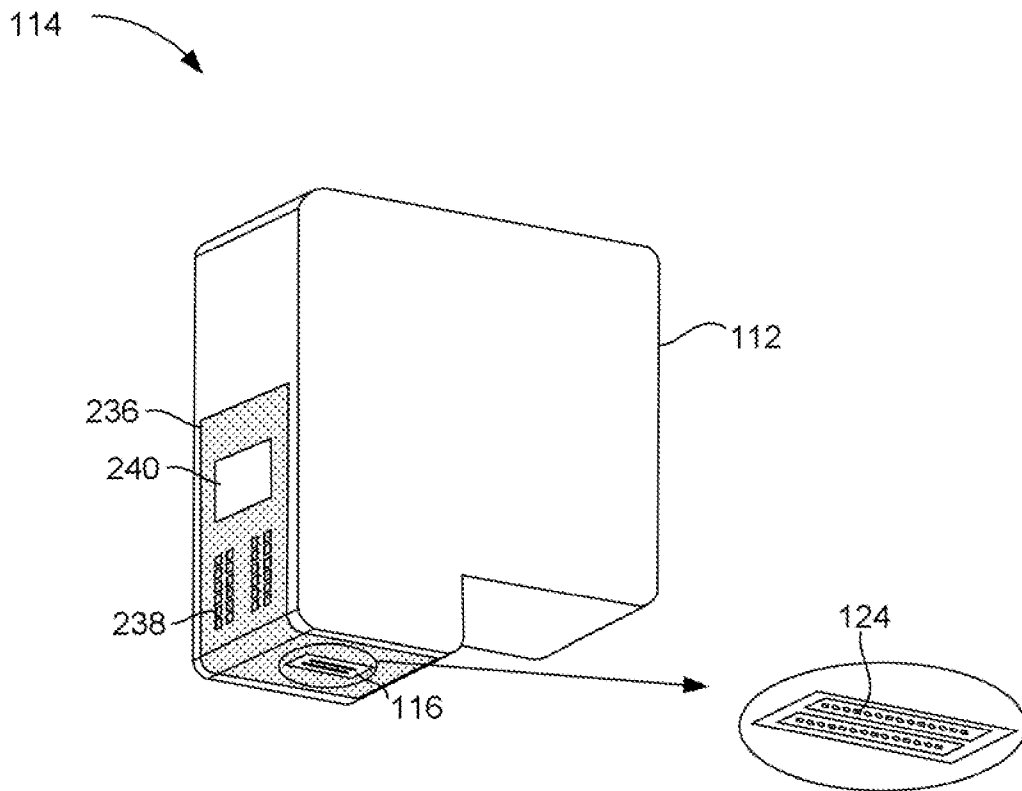


Fig. 2A

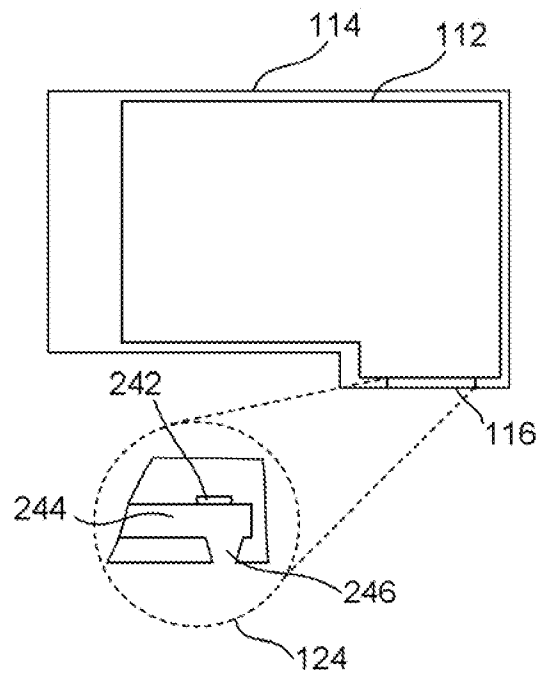
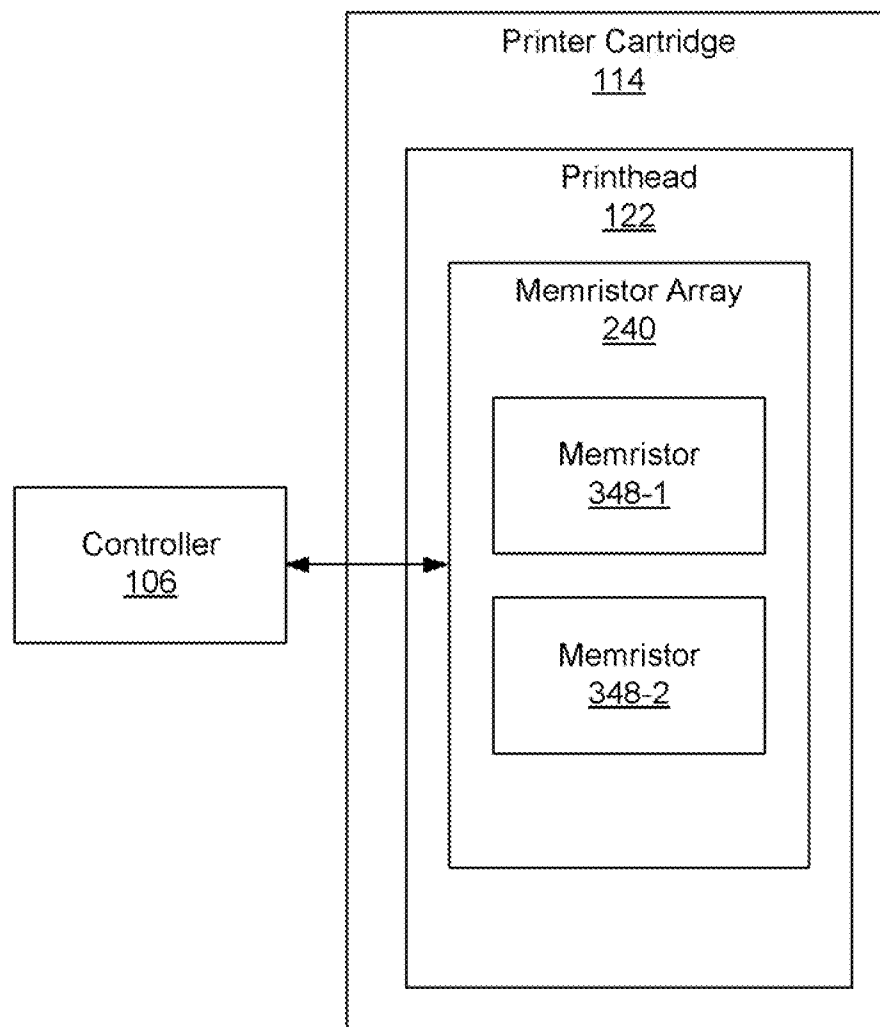
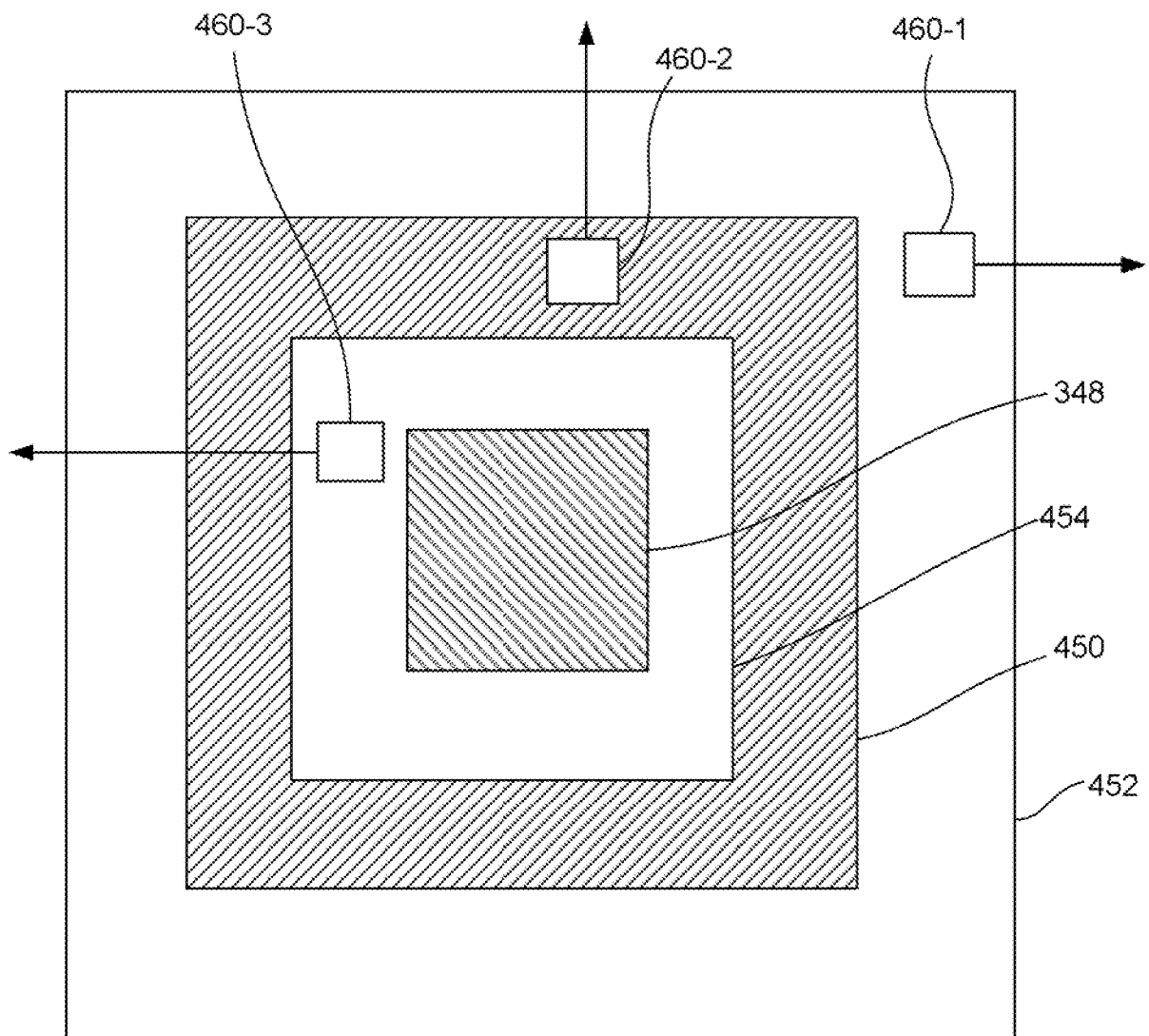


Fig. 2B

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**Fig. 3**

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**Fig. 4**

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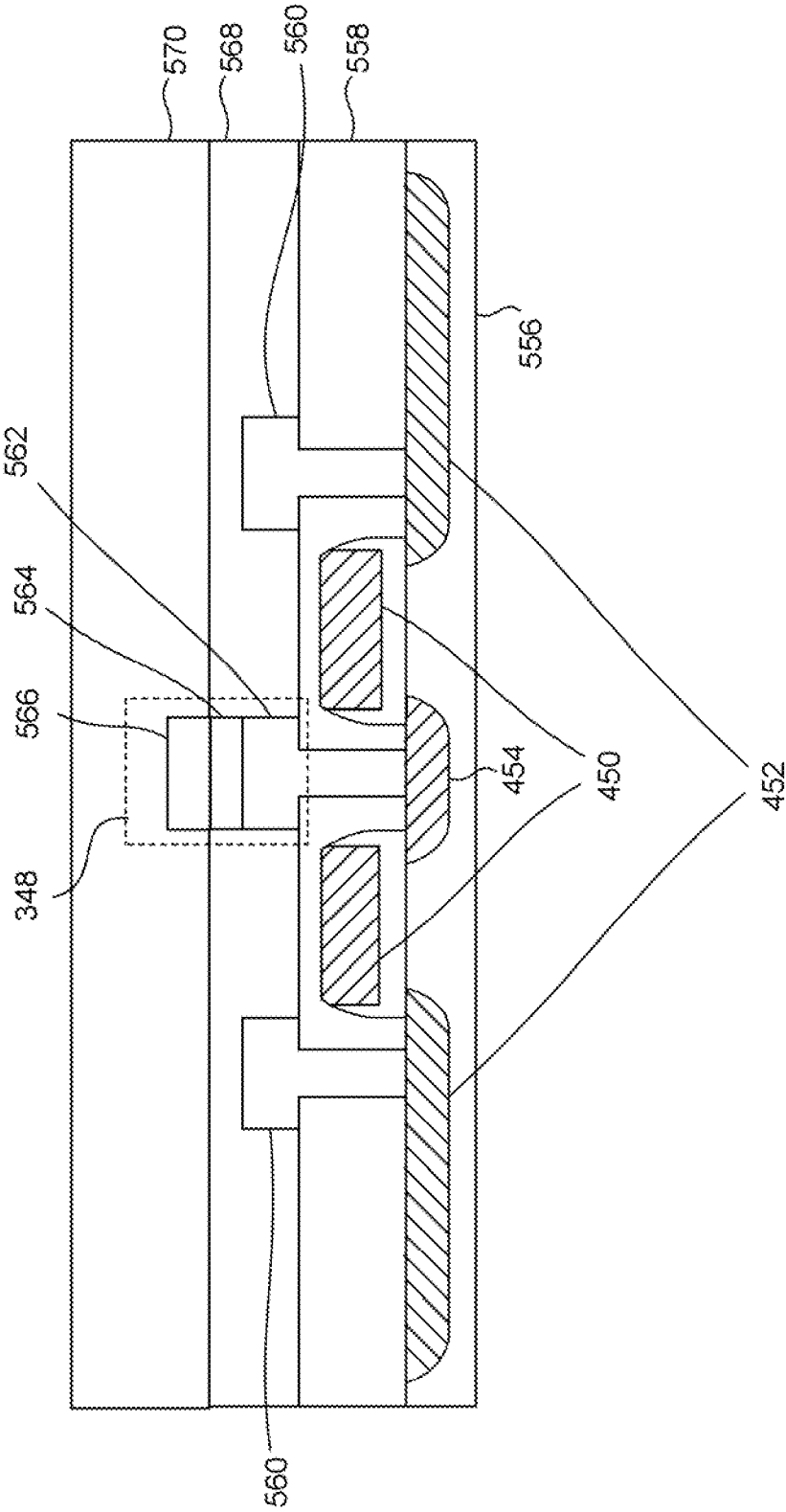
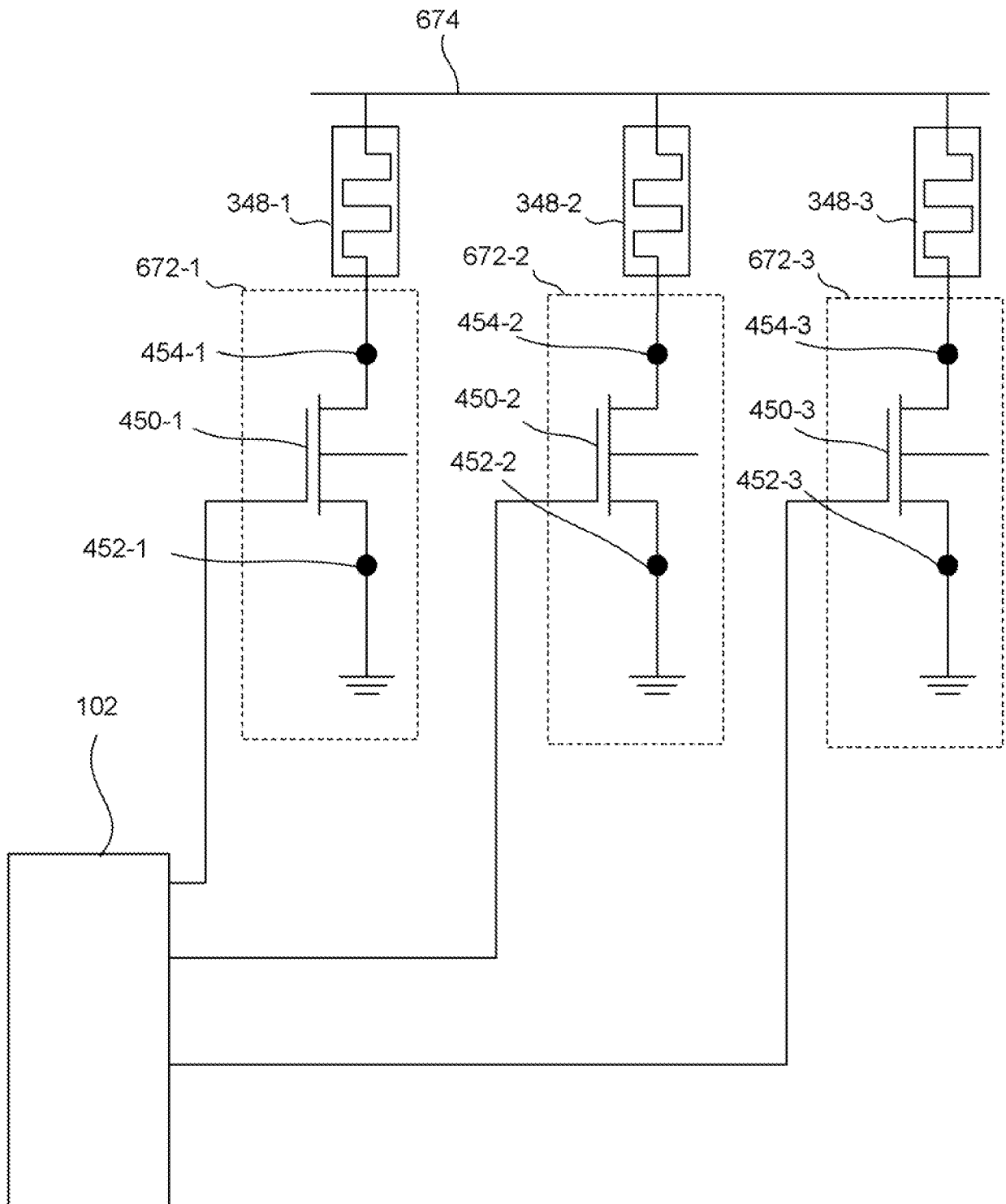


Fig. 5

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**Fig. 6**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/048288**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; G06N 3/063; B41J 2/04; B21D 53/76; B41J 2/07; H01L 21/77; H01L 27/04; B41J 29/38; 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: memristor, non-volatile, printhead, ejector, transistor, gate, and drain

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0106930 A1 (LEA et al.) 02 May 2013 See abstract, paragraphs [0014]-[0018], [0023], and figures 1-3A.	1-15
Y	US 2011-0310181 A1 (CURCIO et al.) 22 December 2011 See abstract, paragraphs [0023]-[0024], and figure 1.	1-7
Y	US 2014-0166957 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.) 19 June 2014 See abstract, paragraphs [0019], [0023], [0035], [0041]-[0045], claim 1, and figures 1-3.	1-15
A	US 2011-0106742 A1 (PINO, ROBINSON E.) 05 May 2011 See abstract and claims 1-7.	1-15
A	US 2009-0244132 A1 (BRUCE et al.) 01 October 2009 See abstract, paragraphs [0021]-[0029], and figures 1-2.	1-15

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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

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

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

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"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

16 April 2015 (16.04.2015)

Date of mailing of the international search report

17 April 2015 (17.04.2015)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/048288

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