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(54) Title: PRINTHEAD WITH A NUMBER OF MEMRISTORS HAVING METAL-DOPED METALORGANIC SWITCHING OXIDES

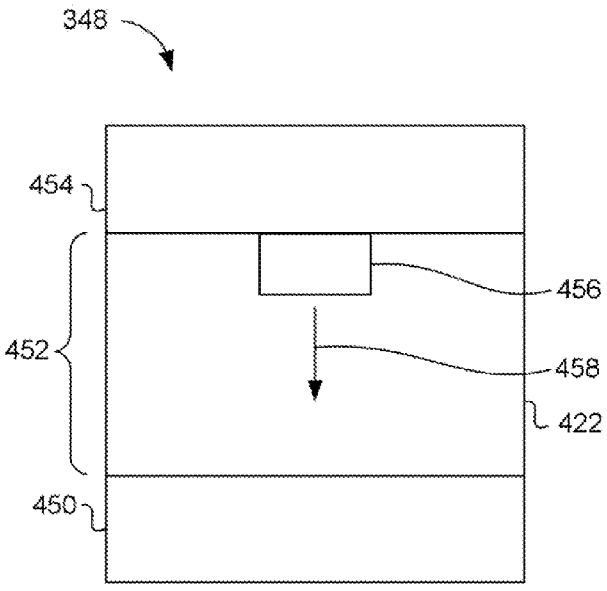


Fig. 4B

(57) Abstract: A printhead with a number of memristors having metal-doped metalorganic switching oxides 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 the print medium, and an ejector to eject the amount of fluid through the opening. The printhead also includes a memristor array with a number of memristors. Each memristor includes a bottom electrode and a switching oxide disposed on a top surface of the bottom electrode. The switching oxide includes a metal-doped metal-organic oxide insulator. Each memristor node also includes a top electrode disposed on a top surface of the switching oxide.

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PRINTHEAD WITH A NUMBER OF MEMRISTORS HAVING METAL-DOPED METALORGANIC SWITCHING OXIDES

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 having metal-doped metalorganic switching oxides 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 having metal-doped metalorganic switching oxides 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 having metal-doped metalorganic switching oxides according to one example of the principles described herein.

[0007] Figs. 4A and 4B are cross-sectional views of a memristor having metal-doped metalorganic switching oxides according to one example of the principles described herein.

[0008] Fig. 5 is a diagram depicting a cross bar memristor array according to one example of the principles described herein.

[0009] Figs. 6A and 6B are flowcharts of a method for forming a memristor with metal-doped metalorganic switching oxides according to one example of the principles described herein.

[0010] Fig. 7 is another cross-sectional view of a memristor with metal-doped metalorganic switching oxides according to one example of the principles described herein.

[0011] Throughout the drawings, identical reference numbers designate similar, but not necessarily identical, elements.

DETAILED DESCRIPTION

[0012] 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.

[0013] 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, encryption information, and other types of information on the rise, a manufacturer may desire to store more information on a memory device.

[0014] 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. However, while memristors may serve as beneficial memory storage devices, their use presents a number of complications.

[0015] For example, a switching event, i.e. the switching of a memristor between a low resistance state and a high resistance state, may occur at a voltage that is distinct from a voltage supplied from a device in which the memristor resides. In a specific example, a printer may include an application-specific integrated circuit (ASIC) that supplies a voltage of 15.5 volts (V). However, the switching voltage for a memristor may be much lower, for example between 1-3 V. In this example, the memristor may be over-stressed and the device may be shorted due to a hard breakdown.

[0016] Accordingly, the present disclosure describes a printhead with a memristor that alleviates these and other complications. More specifically, the present disclosure describes a printhead and printer cartridge that use memristors that have a high switching voltage. The higher switching voltage may make the memristor of the present specification more compatible with certain systems such as printers which supply a higher voltage to engage the memristor. Moreover, the memristors of the present disclosure may simplify manufacturing processing operations to further reduce the manufacturing cost of the memristor.

[0017] The memristors of the present specification may include a bottom electrode and a top electrode. Disposed between the electrodes is a switching oxide that is formed of a metalorganic insulator, such as tetraethyl orthosilicate (TEOS), which produces a memristor with a higher switching

voltage. Doped in the metalorganic insulator is a metal channel that reduces the resistance of the memristor to lower the switching voltage such that a lower voltage may be used to execute a switching event as compared to a memristor that has a switching oxide made up of a metalorganic oxide insulator without a metal-doped channel. In other words, the switching voltage of a memristor of the present specification may be adjusted based on the characteristics of the metalorganic (TEOS) oxide insulation and the metal channel to align with a supplied voltage from a controlling component such as a printer ASIC.

[0018] More specifically, the present disclosure describes a printhead with a number of memristors having metal-doped metalorganic switching oxides. The printhead includes a number of nozzles. 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 memristor array having a number of memristors. Each memristor includes a bottom electrode and a switching oxide disposed on a top surface of the bottom electrode. The switching oxide includes a metal-doped metalorganic oxide insulator. Each memristor also includes a top electrode disposed on a top surface of the switching oxide.

[0019] The present disclosure describes a printer cartridge with a number of memristors having metal-doped metalorganic switching oxides. 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 array with a number of memristors. Each memristor includes a bottom electrode and a switching oxide disposed on a top surface of the bottom electrode. The switching oxide includes a metal-doped metalorganic oxide insulator. Each memristor also includes a top electrode disposed on a top surface of the switching oxide.

[0020] A printer cartridge and a printhead that utilize memristors having metal-doped metalorganic switching oxides may be beneficial by providing a large amount of memory storage on a relatively small footprint as compared to other memory devices. Additionally, the metal-doped metalorganic switching oxide may allow for a fine-tuning of the memristor switching voltage by

altering the dimensions of the metalorganic oxide insulator, the metal channel, or combinations thereof and by altering the material of the metal channel. Additionally, the metal-doped metalorganic switching oxide may implement simpler manufacturing processes. Still further, the metal-doped metalorganic switching oxide may be less complex by avoiding the use of thin film switching oxides.

[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 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] Still 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 "metalorganic" may refer to a class of chemical compound that includes metallic molecules and organic molecules. Accordingly, a "metalorganic switching oxide" may refer to a switching oxide that includes a metalorganic compound. Similarly, a "metalorganic oxide insulator" may be an oxide insulator that is formed of a metalorganic compound such as tetraethyl orthosilicate.

[0027] Still further, as used in the present specification and in the appended claims the term "tetraethyl orthosilicate oxide memristor," "TEOS oxide memristor," or similar terminology is meant to refer broadly to a memristor in which the switching oxide includes, or is formed from, tetraethyl orthosilicate (TEOS).

[0028] Still further, as used in the present specification and in the appended claims, the term "switching voltage" may refer to the voltage that switches a memristor from a high resistance state to a low resistance state, from a low resistance state to a high resistance state, or combinations thereof.

[0029] Still further, as used in the present specification and in the appended claims, the term "supplied voltage" may refer to a voltage supplied by a component to switch a memristor from a high resistance state to a low resistance state, from a low resistance state to a high resistance state, or combinations thereof.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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 to 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 print job commands and/or command parameters.

[0034] A controller (106) of the printer (104) includes a processor (108), a data storage device (110), 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).

[0035] 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 an application specific integrated circuit (ASIC) of a printer (104) which determines 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.

[0036] 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).

[0037] The data storage device (110) may store data such as executable program code that is executed by the processor (108) or other 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.

[0038] 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).

[0039] 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 non-transitory medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0040] 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).

[0041] 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.

[0042] Nozzles (124) may be arranged in 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).

[0043] 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).

[0044] 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 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).

[0045] 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).

[0046] Fig. 2A is a diagram of a printer cartridge (114) and printhead (116) with a number of memristors having metal-doped metalorganic switching oxides 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.

[0047] 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 contains traces that electrically connect the memristor array (240) and printhead (116) with the conductive pads (238).

[0048] 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).

[0049] 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.

[0050] 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).

[0051] 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.

[0052] Fig. 2B is a cross sectional diagram of a printer cartridge (114) and printhead (116) with a number of memristors having metal-doped metalorganic switching oxides 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. 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.

[0053] 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. The printhead (116) may include a number of components for

depositing a fluid onto a print medium. 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 an opening (246) from a firing chamber (244), 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).

[0054] 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.

[0055] 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 fluid out the opening (246) and onto the print medium (Fig. 1, 126). In this example, the printhead (116) may be a piezoelectric inkjet printhead.

[0056] 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). In some examples, the printer cartridge (114) is removable from a printing system for example, as a disposable printer cartridge.

[0057] Fig. 3 is a block diagram of a printer cartridge (114) that uses a printhead (116) with a number of memristors (348) having metal-doped metalorganic switching oxides 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).

[0058] 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, a memristors (348) may be set to a particular resistance state. As memristors (348) are non-volatile, this resistance state is retained even when power is removed from the printhead (116).

[0059] 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), and a top electrode (metal). A memristor (348) may be an anion-based device or a cation-based device. In an anion-based device, an oxide insulator serves as the switching oxide whereas in a cation-based device, an oxide insulator serves as an electrolyte material that hosts a metal conductive filament. In this example, a metalorganic compound, such as TEOS, may be an example of an oxide insulator. In an anionic device, the switching mechanism is the motion of oxygen vacancies in the oxide insulator 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. The motion of these cations under electrical bias is responsible for the resistance switching.

[0060] The number of memristors (348) are grouped together into a memristor array (240). In some examples, the memristor array (240) may be a cross bar array. In this example, each memristor (348) may be formed at an intersection of a first set of elements and a second number of elements, the elements forming a grid of intersecting nodes, each node defining a memristor (348). In another example, the memristor array (240) may include a number of memristors (348) that form a one-to-one structure with a number of transistors. For example, an integrated circuit may include a number of addressing units. Each addressing unit may include a number of components that allow for multiplexing and logic operations. The memristor (348) may be designed to be individually addressed by a distinct addressing unit. In some examples, the addressing units may be transistors. In this example, the memristor (348) may share a one transistor-one memristor (1T1M) addressing structure with the addressing units of the integrated circuit.

[0061] 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).

[0062] 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 (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. The controller (106) may facilitate storing information to the memristor array (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 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).

[0063] 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.

[0064] Figs. 4A and 4B are cross-sectional views of a memristor (348) with a metal-doped metalorganic switching oxide according to one example of the principles described herein. More specifically, Fig. 4A is a cross-sectional view of a memristor (348) without a metal channel (456).

[0065] As described above, a memristor (348) is a non-volatile memory device that retains stored information even when not powered on. The memristor (348) may selectively store data based on a resistance state of the memristor (348). For example, the memristor (348) may be in a low resistance state indicated by a "1," or a high resistance state indicated by a "0." The memristors (348) in a memristor array (Fig. 2, 240) may form a string of ones and zeroes that will store the aforementioned data. If an analog memristor (348) is used, there may be many different resistance states.

[0066] A memristor (348) may switch between a low resistance state and a high resistance state during a switching event in which a voltage is passed through the memristor (348). Each memristor (348) has a switching voltage that refers to a voltage used to switch the state of the memristor (348).

When the supplied voltage is greater than the memristor (348) switching voltage, the memristor (348) switches state. As will be described below, the memristor (348) of the present specification may have a higher switching voltage.

[0067] The memristor (348) may have a metal-insulator-metal layered structure. More specifically, the memristor (348) may include a bottom electrode (450), a switching oxide (452), and a top electrode (454). As will be described in detail below, the memristor (348) may share a number of these components with other memristors (348), for example in a cross bar array as depicted in Fig. 5. In other examples, the memristor (348) may have distinct bottom electrodes (450), switching oxides (452), top electrodes (454), or combinations thereof in a one transistor-one memristors (1T1M) structure.

[0068] The bottom electrode (450) may be an electrical connection between the memristor (348) and other components. Examples of components that may attach to the bottom electrode (450) 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. The bottom electrode (450) 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.

[0069] A switching oxide (452) may be disposed on a top surface of the bottom electrode (450). The switching oxide (452) may be an insulator between the bottom electrode (450) and the top electrode (454). For example, in a first state, the switching oxide (452) may be insulating such that current does not readily pass from the bottom electrode (450) to the top electrode (454). Then, during a switching event, the switching oxide (452) may switch to a second state, becoming conductive. In a conductive state, the switching oxide (452) allows a memristor (348) to store information by changing the memristor state.

[0070] The switching oxide (452) may include a metalorganic oxide insulator (422). The term "oxide insulator" may refer to the oxide material insulating the bottom electrode (450) from the top electrode (454). A switching oxide (452) that includes a metalorganic oxide insulator (422) may be referred to as a metalorganic switching oxide (452). In one example, the metalorganic oxide insulator (422) may be formed of tetraethyl orthosilicate (TEOS). TEOS is a less-dense oxide that allows current to pass more readily than other materials. The formula for TEOS is $Si(OC_2H_5)_4$ and may be formed according to the following reaction:

$$SiO_2 + 2(C_2H_5)_2O \rightarrow Si(OC_2H_5)_4.$$

[0071] A TEOS oxide insulator (422) may be formed using plasma-enhanced chemical vapor deposition (PECVD), low-pressure chemical vapor deposition (LPCVD), or chemical vapor deposition (CVD), among other formation processes. Other examples of metalorganic compounds that may be used as an oxide insulator include trimethylaluminum (TMA), tetrakisethylmethylamino hafnium (TEMAH), bis)terriary butyl amino)-silane (BTBAS), butylimido)tris(diethylamido) tantalum (TBTDET), titanium (IV) isopropoxide (TTIP), and other metalorganic compounds.

[0072] Using a TEOS oxide insulator (422) in the switching oxide (452) may be beneficial in that it may allow for a thicker switching oxide (452) to be used in the memristor (348). Such a thicker switching oxide (452) may increase the robustness of the memristor (348) such that it is not as susceptible to breakdown. For example, without a TEOS oxide insulator (422) the switching voltage for a memristor (348) may be around 2-3V using a nano-meter range oxidized or PVD oxide. During a switching event, certain components such as printers (Fig. 1, 104) supply a higher voltage such as 15.5V to execute a switching event. The difference between the supplied voltage (15.5V) and the switching voltage (2-3V) may overload the memristor (348) such that it fails. Accordingly, a switching oxide (452) with a TEOS oxide insulator (422) may allow for a higher switching voltage of the memristor (348) such that it is not

overloaded during a switching event. Furthermore, manufacturing the TEOS oxide insulator (422) in the switching oxide (452) may rely on existing operations which reduce the cost of production.

[0073] To further refine the switching voltage of the memristor (348), the metalorganic oxide insulator (422) may include a metal channel (456) doped through the oxide insulator (422) of the switching oxide (452) as depicted in Fig. 4B. The metal channel (456) may be a conduit for passage of current from the bottom electrode (450) to the top electrode (454). The metal channel (456) may reduce the resistance of the switching oxide (452) thereby reducing the switching voltage of the memristor (348). In other words, the metalorganic oxide insulator (422) may increase the switching voltage of the memristors (348) to a first level that is greater than a nominal level. The metal channel (456) diffused in the metalorganic oxide insulator (422) may reduce the switching voltage to a second level that is less than the first level and that is greater than the nominal level. In this example, the switching oxide (452) with the metal-doped channel (456) and the metalorganic oxide insulator (422) allow for a customization of the memristors (348) switching voltage to a larger degree than memristors not implementing a metal-doped metalorganic switching oxide (452).

[0074] As described above, the metal channel (456) may be the metal that is doped into the metalorganic oxide insulator (422). In other words, the metal-doped metalorganic oxide insulator (422) may include the metal channel (456) doped into the oxide insulator (422). The metal channel (456) may be any material that reduces the resistance of the switching oxide (452). For example, the metal channel (456) may be titanium, copper, silver, aluminum, tantalum, tungsten, vanadium, scandium, calcium, and boron, among other materials. In some examples, the metal used in the metal channel (456) may be defined by a diffusion coefficient or solid solubility.

[0075] The metal channel (456) may be introduced into the metalorganic oxide insulator (422) by a number of processes including implanting followed by thermal annealing from a top surface of the metalorganic oxide insulator (422) towards a bottom surface of the metalorganic oxide insulator (422) as depicted by the arrow (458). The metal channel (456) may be

defined by its volume relative to the volume of the switching oxide (452). For example, the metal channel (456) may form between 0.1% and 50.0% of the volume of the switching oxide (452) of the memristor (348).

[0076] Implementing a metal channel (456) doped in a metalorganic oxide insulator (422) may be beneficial by allowing selection of a specified switching voltage while utilizing a thick switching oxide (452). As described above, doing so may allow for a higher switching voltage to be used for the memristor (348) while offering increased robustness based on the increased thickness of the switching oxide (452).

[0077] The memristor also includes a top electrode (454) disposed on a top surface of the switching oxide (452). As with the bottom electrode (450), the top electrode (454) may be an electrical connection between the memristor (348) and other components. Examples of components that may attach to the top electrode (454) 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. In some examples, the top electrodes (454) 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, and gold among other metallic materials.

[0078] Fig. 5 is a diagram depicting a cross bar memristor array (240) according to one example of the principles described herein. As described above, the memristor array (240) may be a cross bar array. In this example, a first number of elements (560-1) may run in a first direction and a second number of elements (560-2) may run in a second direction, the second direction being perpendicular to the first direction. The intersection of each of the first number of elements (560-1) and the second number of elements (560-2) may result in a node that defines a memristor (348). For simplicity, in Fig. 5 one memristor (348) is identified with a reference number. In Fig. 5, one of the first number of elements (560-1) and the second number of elements (560-2) may be the bottom electrode (Fig. 4, 450) and the other may be the top electrode (Fig. 4, 454).

[0079] A specific example of a memristor (348) in a cross bar array (240) is given as follows. In this example, the first number of elements (560-1) may form the bottom electrode (Fig. 4, 450) of a memristor (348). Each memristor (348) along a particular element of the first number of elements (560-1) may share a bottom electrode (Fig. 4, 450). Continuing this example, a switching oxide (Fig. 4, 452) may then be deposited on the first number of elements (560-1) as described in connection with Fig. 4, the switching oxide (Fig. 4, 452) including a metalorganic oxide insulator (Fig. 4, 422) and a metal channel (Fig. 4, 456). The second number of elements (560-2) may then be disposed on the first number of elements (560-1) to form the top electrodes (Fig. 4, 454) for the memristors (348). In this example, each memristor (348) along a particular element of the second number of elements (560-2) may share a top electrode (Fig. 4, 454).

[0080] Accordingly, a node being a memristor (348) may include a bottom electrode (Fig. 4, 450) from the first number of elements (560-1), a switching oxide (Fig. 4, 452) disposed on the bottom electrode (Fig. 4, 450), and a top electrode (Fig. 4, 454) from the second number of elements (560-2) disposed on the switching oxide (Fig. 4, 452).

[0081] While Fig. 5 depicts a number of memristors (348) in a cross bar array (240), the number of memristors (348) may form a one-to-one structure with a number of transistors. For example, an integrated circuit may include a number of addressing units. Each addressing unit may include a number of components that allow for multiplexing and logic operations. The memristor (348) may be designed to be individually addressed by a distinct addressing unit. In some examples, the addressing units may be transistors. In this example, the memristor (348) may share a one transistor-one memristor (1T1M) addressing structure with the addressing units of the integrated circuit.

[0082] Figs. 6A and 6B are flowcharts of methods (600, 610) for forming a memristor (Fig. 3, 348) having a metal-doped metalorganic switching oxide (Fig. 4, 452) according to one example of the principles described herein. Specifically, Fig. 6A allows for the metal channel (Fig. 4, 456) to be doped into a metalorganic oxide insulator (Fig. 4, 422) after formation of the top electrode

(Fig. 4, 454). In this example, the method (600) may include forming (block 601) a bottom electrode (Fig. 4, 450) of the memristors (Fig. 3, 348). The bottom electrode (Fig. 4, 450) may be formed from a metallic material such as an aluminum-copper alloy or other metallic materials. A number of processes may be used to form the bottom electrode (Fig. 4, 450). For example, the bottom electrode (Fig. 4, 450) may be formed by a metallic deposition process such as physical vapor deposition (PVD), in which a target material is vaporized, meaning atoms are dislodged from the surface of the target material. The atoms are then built up on a surface. More specifically, atoms of the target material may be built up on the surface of a substrate to form the bottom electrode (Fig. 4, 450). In some examples, the substrate may be a polycrystalline silicate. While specific reference is made to PVD, other processes may be used to form the bottom electrode (Fig. 4, 450). Examples of such processes include a lift-off process and shadow masking deposition, among other processes. The bottom electrode (Fig. 4, 450) may then be further altered via a number of processes including photolithography, lithography, and etching, among other surface altering processes.

[0083] The method (600) also includes forming (block 602) a metalorganic oxide insulator (Fig. 4, 422) on a top surface of the bottom electrode (Fig. 4, 450). For example, a TEOS oxide insulator (Fig. 4, 422) may be deposited on the bottom electrode (Fig. 4, 450). The TEOS oxide insulator (Fig. 4, 422) may be formed using PECVD, LPCVD, or CVD among other formation processes. The method (600) also includes forming (block 603) a metal channel (Fig. 4, 456) through the metalorganic oxide insulator (Fig. 4, 422). The metal channel (Fig. 4, 456) may be formed by diffusion of a metallic material through the oxide insulator (Fig. 4, 422). Other examples of mechanisms to form the metal channel (Fig. 4, 456) include implanting following a thermal annealing. Forming (block 603) a metal channel (Fig. 4, 456) through the metalorganic oxide insulator (Fig. 4, 422) may include doping the metalorganic oxide insulator (Fig. 4, 422) such that the metal channel (Fig. 4, 456) forms between 0.1% and 50.0% of the volume of the switching oxide (Fig. 4, 452).

[0084] The method (600) also includes forming (block 604) a top electrode (Fig. 4, 454) on a top surface of the metalorganic switching oxide (Fig. 4, 452). As described above, in some examples, the top electrodes (Fig. 4, 454) 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, and gold among other metallic materials.

[0085] A number of processes may be used to form (block 604) the top electrodes (Fig. 4, 454). For example, the top electrode (Fig. 4, 454) may be formed by a metallic deposition process such as physical vapor deposition (PVD), in which a target material is vaporized, meaning atoms are dislodged from the surface of the target material. The atoms are then built up on a surface. More specifically, atoms of the target material may be built up on the surface of the switching oxide (Fig. 4, 452) to form the top electrode (Fig. 4, 454). While specific reference is made to PVD, other processes may be used to form the top electrode (Fig. 4, 454). Examples of such processes include a lift-off process and shadow masking deposition, among other processes. The top electrode (Fig. 4, 454) may then be further altered via a number of processes including photolithography, lithography, and etching, among other surface altering processes.

[0086] Fig. 6B describes a method (610) wherein the metal channel (Fig. 4, 456) is formed after formation of the top electrode (Fig. 4, 454). The method (610) includes forming (block 611) a bottom electrode (Fig. 4, 450) of the memristors (Fig. 3, 348). This may be performed as described in connection with Fig. 6A. The method (610) also includes forming (block 612) a metalorganic oxide insulator (Fig. 4, 422) on a top surface of the bottom electrode (Fig. 4, 450). The method (600) also includes forming (block 613) a top electrode (Fig. 4, 454) on a top surface of the metalorganic oxide insulator (Fig. 4, 422). This may be performed as described in connection with Fig. 6A.

[0087] The method (610) also includes forming (block 614) a metal channel (Fig. 4, 456) through the top electrode (Fig. 4, 454) and oxide insulator (Fig. 4, 422). The metal channel (Fig. 4, 456) may be formed by diffusion of a metallic material through the top electrode (Fig. 4, 454) and oxide insulator (Fig.

4, 422), such that the metal channel (Fig. 4, 456) forms between 0.1% to 50.0% of the volume of the switching oxide (Fig. 4, 452). Other examples of mechanisms to form the metal channel (Fig. 4, 456) include implanting following a thermal annealing.

[0088] Fig. 7 is another cross-sectional view of a memristor (348) with a metal-doped metalorganic oxide insulator (422) according to one example of the principles described herein. The memristors (348) may include a bottom electrode (450), a switching oxide (452) with an oxide insulator (422) and a metal channel (456). The memristor (348) may also include a top electrode (454) as described above.

[0089] The memristor (348) may allow for the selection of a switching voltage of the memristors (348) based on different characteristics of the memristors (348). One such characteristic is the dimensions of the metalorganic oxide insulator (422). In other words, the switching voltage of the memristors (348) may, at least in part, rely on the thickness (762) of the metalorganic (i.e., TEOS) oxide insulator (422), with a thicker oxide insulator (422) resulting in a memristor (348) with a greater switching voltage. In some examples, the metalorganic oxide insulator (422) may be between 2,000 and 12,000 angstroms thick, or 200 to 1,200 nanometers (nm) thick.

[0090] Another such characteristic is the presence of a metal channel (456) in the metalorganic oxide insulator (422). For example, a metalorganic switching oxide (452) without a metal channel (456), as depicted in Fig. 4A, may result in a memristor (348) with a higher switching voltage as compared to a memristor (348) with a metal-doped metalorganic switching oxide (452) as depicted in Fig. 4B.

[0091] Another characteristic that may define the switching voltage is the material of the metal channel (456). For example, a tantalum metal channel (456) may result in a memristor (348) with a lower switching voltage as compared to a memristor (348) with another metal used as the channel. In some examples, the type of metal used in the metal channel (456) may be selected based on the thickness (762) of the metalorganic oxide insulator (422).

[0092] Another such characteristic is the width (764) of the metal channel (456). For example, a wider metal channel (456) may allow for more current to pass through as compared to a narrower metal channel (456). In some examples, the width (764) of the metal channel (456) may be selected to achieve a desired switching voltage for the memristors (348).

[0093] Each of the characteristics described above, (i.e., the thickness (762) of the metalorganic oxide insulator (422), the presence of the metal channel (456), the width (764) of the metal channel (456), and the material of the metal channel (456)), either alone or in combination may be selected based on a desired switching voltage for the memristors (348). For example, a value for number of these characteristics may be determined such that the switching voltage of the memristors (348) is between 7 volts and 12 volts.

[0094] Determining the values of these characteristics to achieve a particular switching voltage may be beneficial by allowing for customization of a memristor (348) switching voltage to achieve a particular value, for example to be compatible with a particular component such as a printer ASIC.

[0095] A printer cartridge (Fig. 1, 114) and printhead (Fig. 1, 116) with a number of memristors (Fig. 3, 348) having metal-doped metalorganic switching oxides (452) may have a number of advantages, including: (1) utilizing a low-cost simple implanting-annealing or deposition-annealing process to form the memristors (Fig. 3, 348) ; (2) utilizing a high switching voltage to be compatible with an ASIC system while avoiding destructive breakdown of the memristors (Fig. 3, 348); (3) allowing flexibility in selecting a switching voltage via the amount and type of metal doped in the metalorganic switching oxide (Fig. 4, 452); (4) being backward compatible with a number of printheads (Fig. 1, 116) and printer cartridges (Fig. 1, 114); (5) increasing storage capacity of memory used on a printhead (Fig. 1, 116) in a reduced space; (5) improving printhead (Fig. 1, 116) memory performance; and (6) reducing cost of effective memristor (Fig. 3, 348) fabrication.

[0096] 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 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.

[0097] 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.

CLAIMS

WHAT IS CLAIMED IS:

1. A printhead with a number of memristors having metal-doped metalorganic switching oxides, 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 the print medium; and

an ejector to eject the amount of fluid through the opening; and

a memristor array comprising a number of memristors, each memristor comprising:

a bottom electrode;

a switching oxide disposed on a top surface of the bottom electrode, in which the switching oxide comprises a metal-doped metalorganic oxide insulator; and

a top electrode disposed on a top surface of the switching oxide.

2. The printhead of claim 1, in which the fluid is inkjet ink.

3. The printhead of claim 1, in which the metal-doped metalorganic oxide insulator comprises doped tetraethyl orthosilicate (TEOS).

4. The printhead of claim 1, further comprising a metal channel diffused through the metalorganic oxide insulator to connect the bottom electrode and the top electrode.

5. The printhead of claim 4, in which a width of the metal channel is selected based on a thickness of the metalorganic oxide insulator.

6. The printhead of claim 4, in which a width of the metal channel is selected based on the metal used for the channel.

7. The printhead of claim 1, in which the metal-doped metalorganic oxide insulator is between 200 and 10,000 angstroms thick.

8. The printhead of claim 1, in which a switching voltage of a memristor is between 7 volts and 12 volts.

9. A printer cartridge with a number of memristors having metal-doped metalorganic switching oxides, the cartridge comprising:

a fluid supply; and

a printhead to deposit fluid from the fluid supply onto a print medium, the printhead comprising;

a memristor array comprising a number of memristors, each memristor comprising:

a bottom electrode;

a switching oxide disposed on a top surface of the bottom electrode, in which the switching oxide comprises a metal-doped metalorganic oxide insulator; and

a top electrode disposed on a top surface of the switching oxide.

10. The cartridge of claim 9, in which:

the fluid is inkjet ink;

the printer cartridge is an inkjet printer cartridge; and

the printhead is an inkjet printhead.

11. The cartridge of claim 9, further comprising a metal channel diffused through the metal-doped metalorganic oxide insulator to connect the bottom electrode and the top electrode.

12. The cartridge of claim 11, in which the metal channel is between 1 and 200 nanometers wide.

13. The cartridge of claim 9, in which the number of memristors form a one-to-one structure with a number of transistors.

14. The cartridge of claim 9, in which the memristor array is a cross bar array.

15. The cartridge of claim 14, in which a number of memristors share a bottom electrode, a top electrode or combinations thereof.

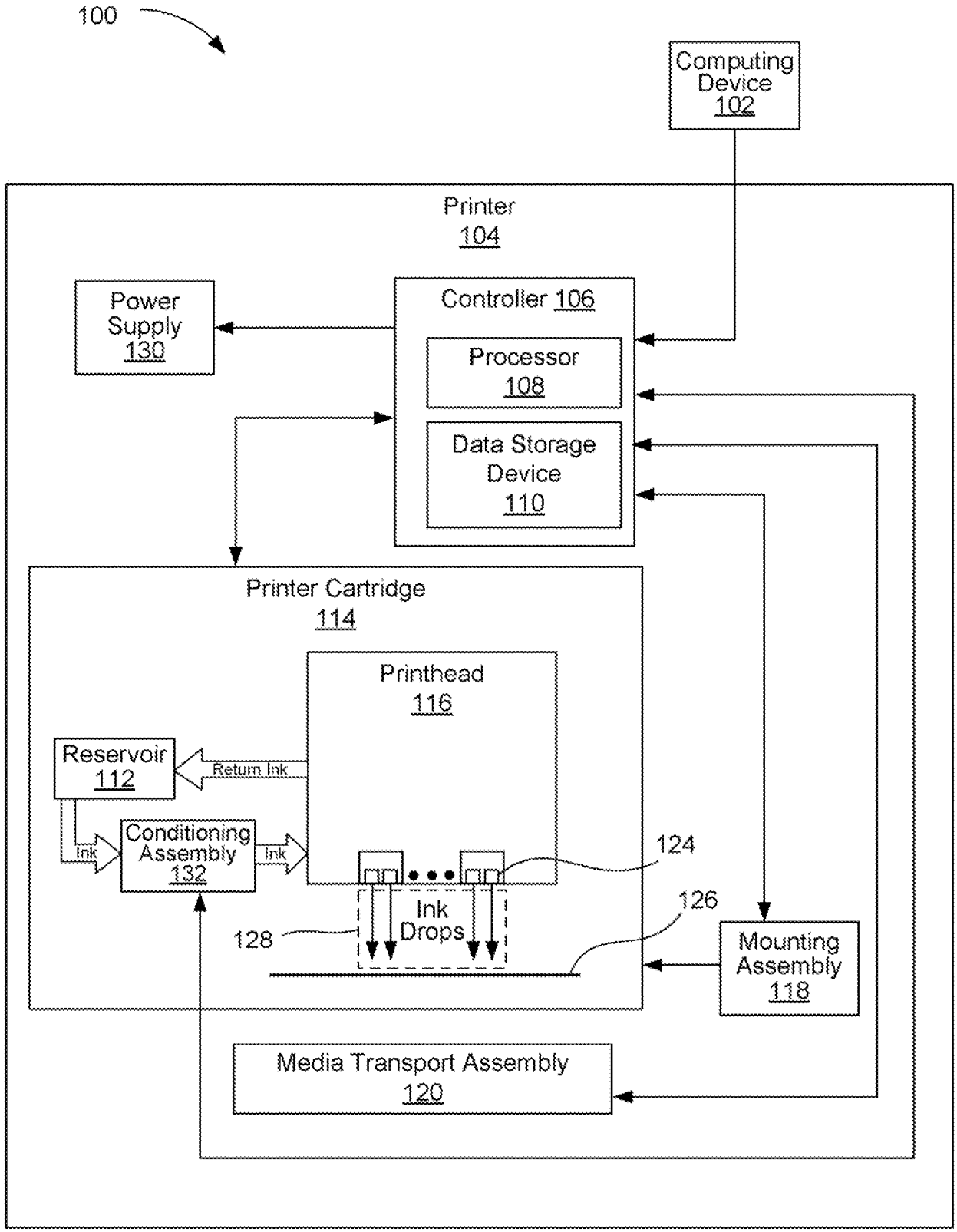

100
Computing Device 102
Printer 104
Power Supply 130
Controller 106
Processor 108
Data Storage Device 110
Printer Cartridge 114
Printhead 116
Reservoir 112
Return Ink
Ink
Conditioning Assembly 132
Ink
124
126
128
Ink Drops
Mounting Assembly 118
Media Transport Assembly 120

Fig. 1

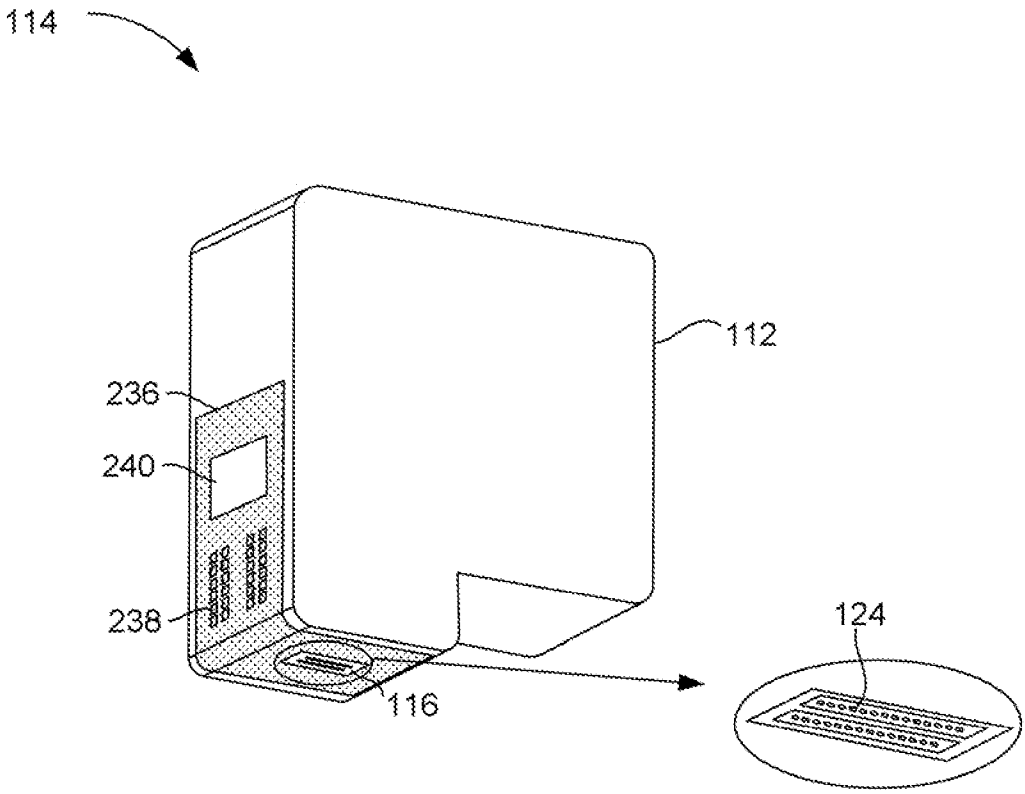


Fig. 2A

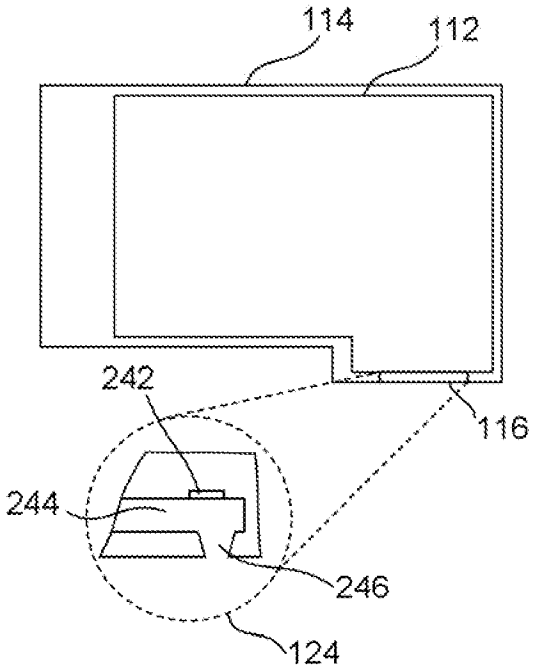


Fig. 2B

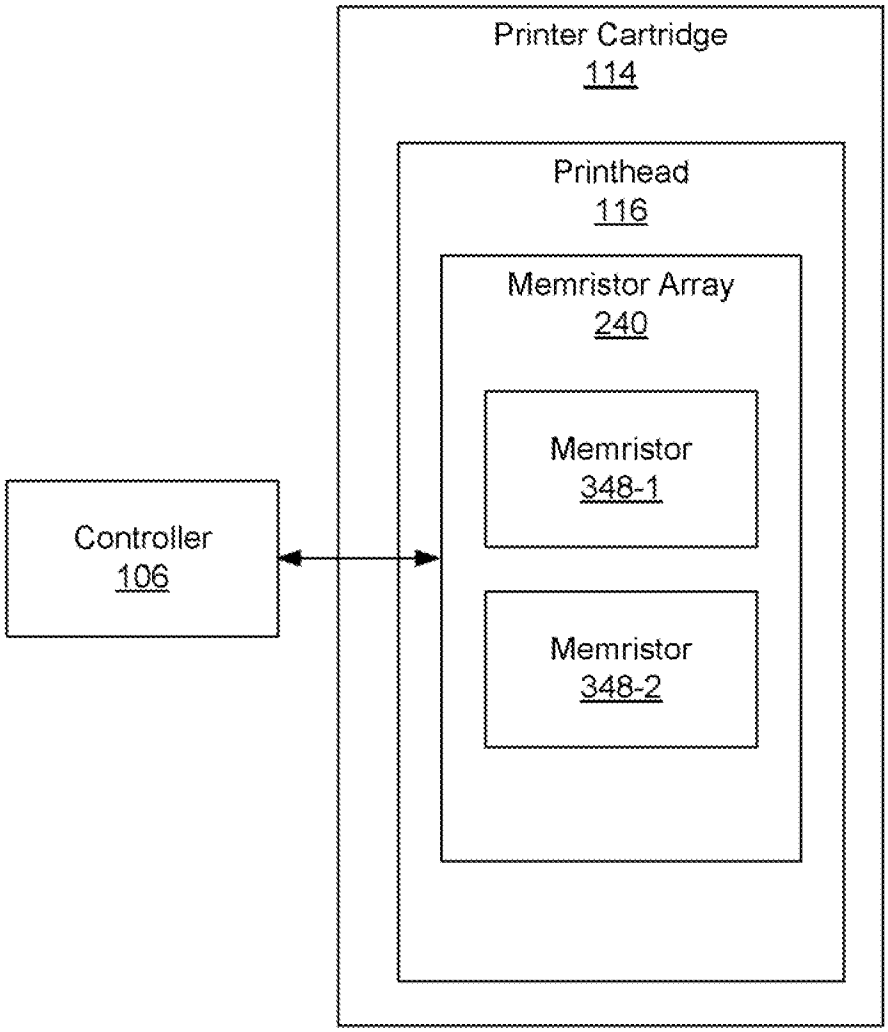

Printer Cartridge
114
Printhead
116
Memristor Array
240
Memristor
348-1
Memristor
348-2
Controller
106

Fig. 3

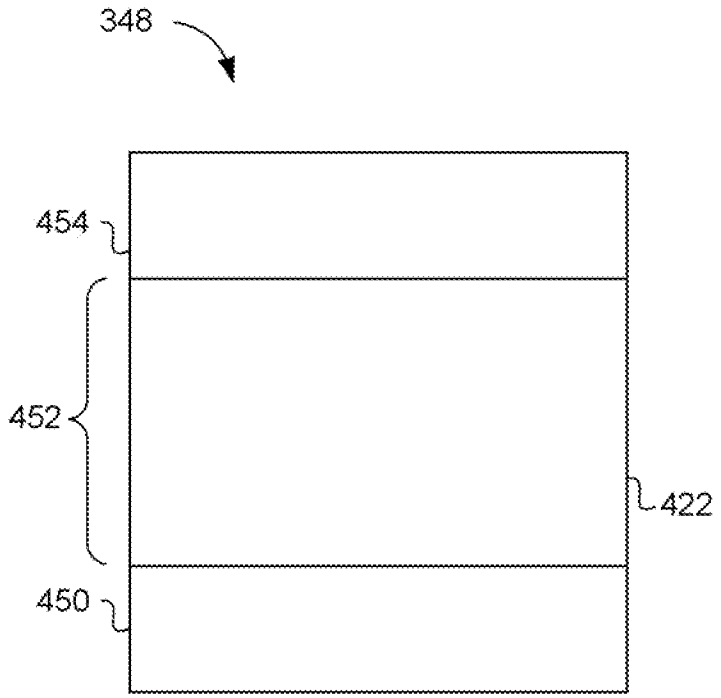


Fig. 4A

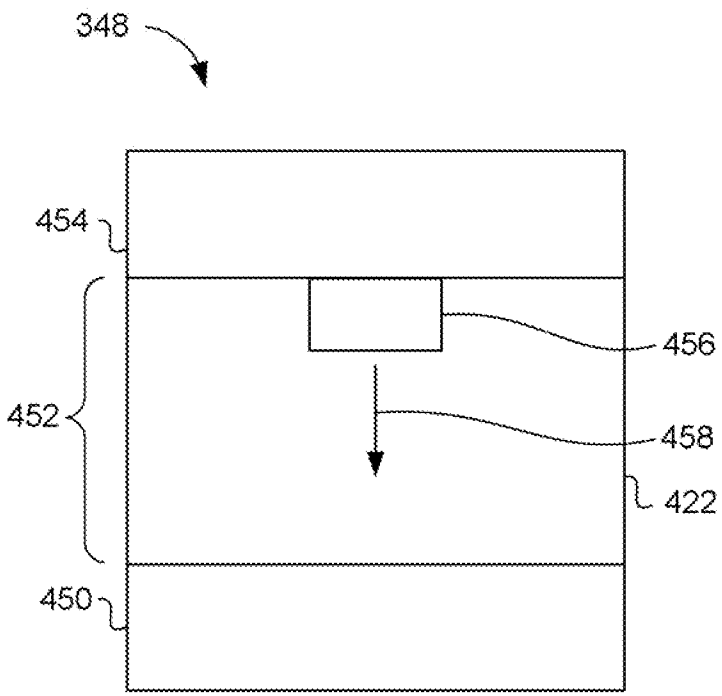


Fig. 4B

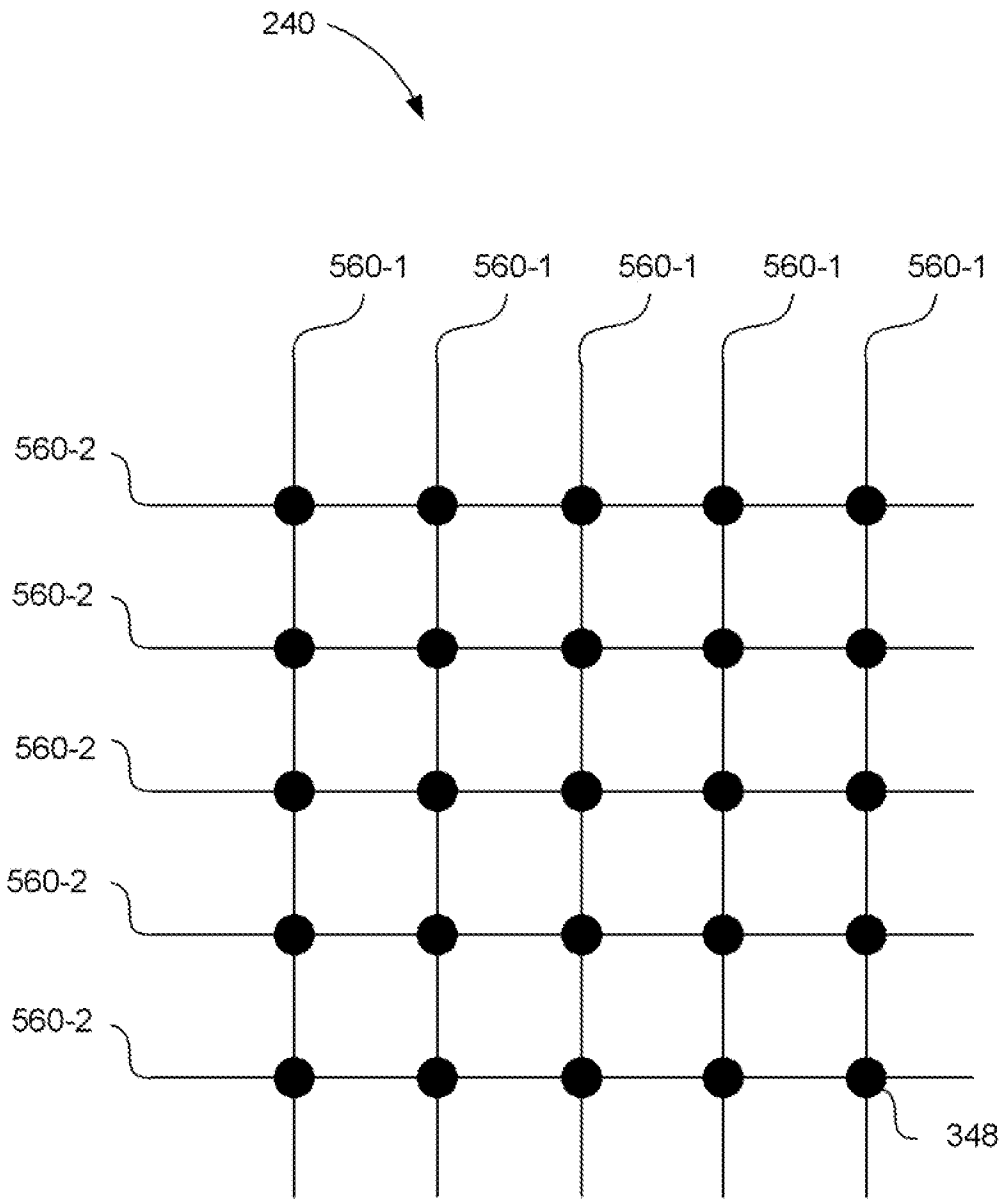


Fig. 5

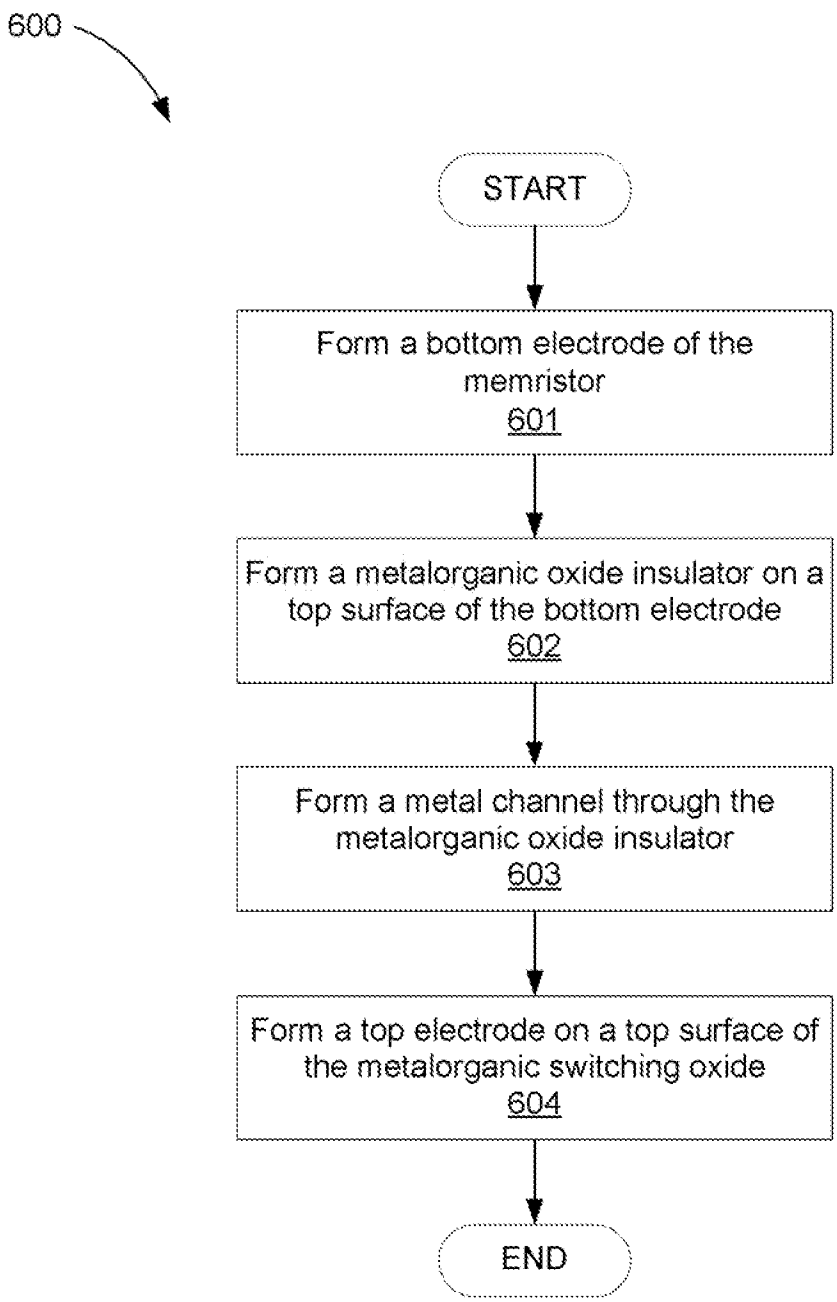

600
START
Form a bottom electrode of the memristor
601
Form a metalorganic oxide insulator on a top surface of the bottom electrode
602
Form a metal channel through the metalorganic oxide insulator
603
Form a top electrode on a top surface of the metalorganic switching oxide
604
END

Fig. 6A

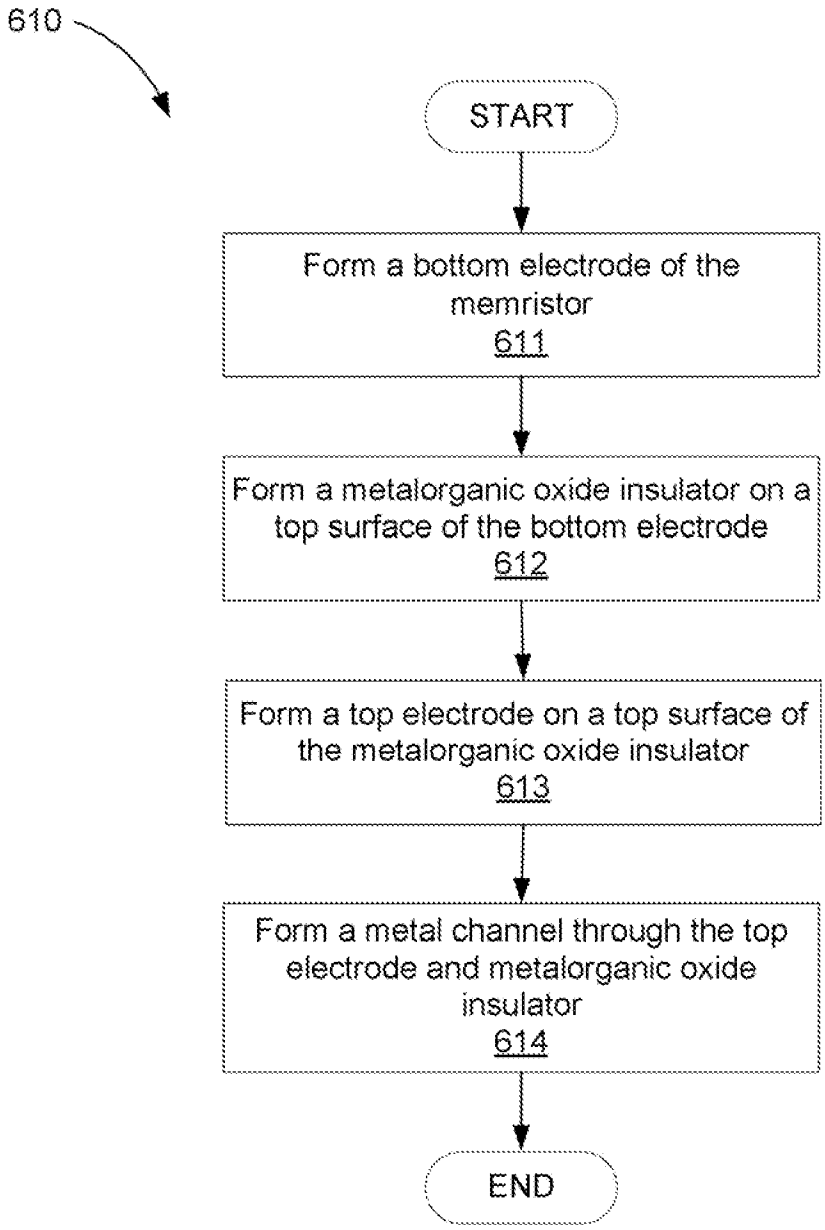

610
START
Form a bottom electrode of the memristor
611
Form a metalorganic oxide insulator on a top surface of the bottom electrode
612
Form a top electrode on a top surface of the metalorganic oxide insulator
613
Form a metal channel through the top electrode and metalorganic oxide insulator
614
END

Fig. 6B

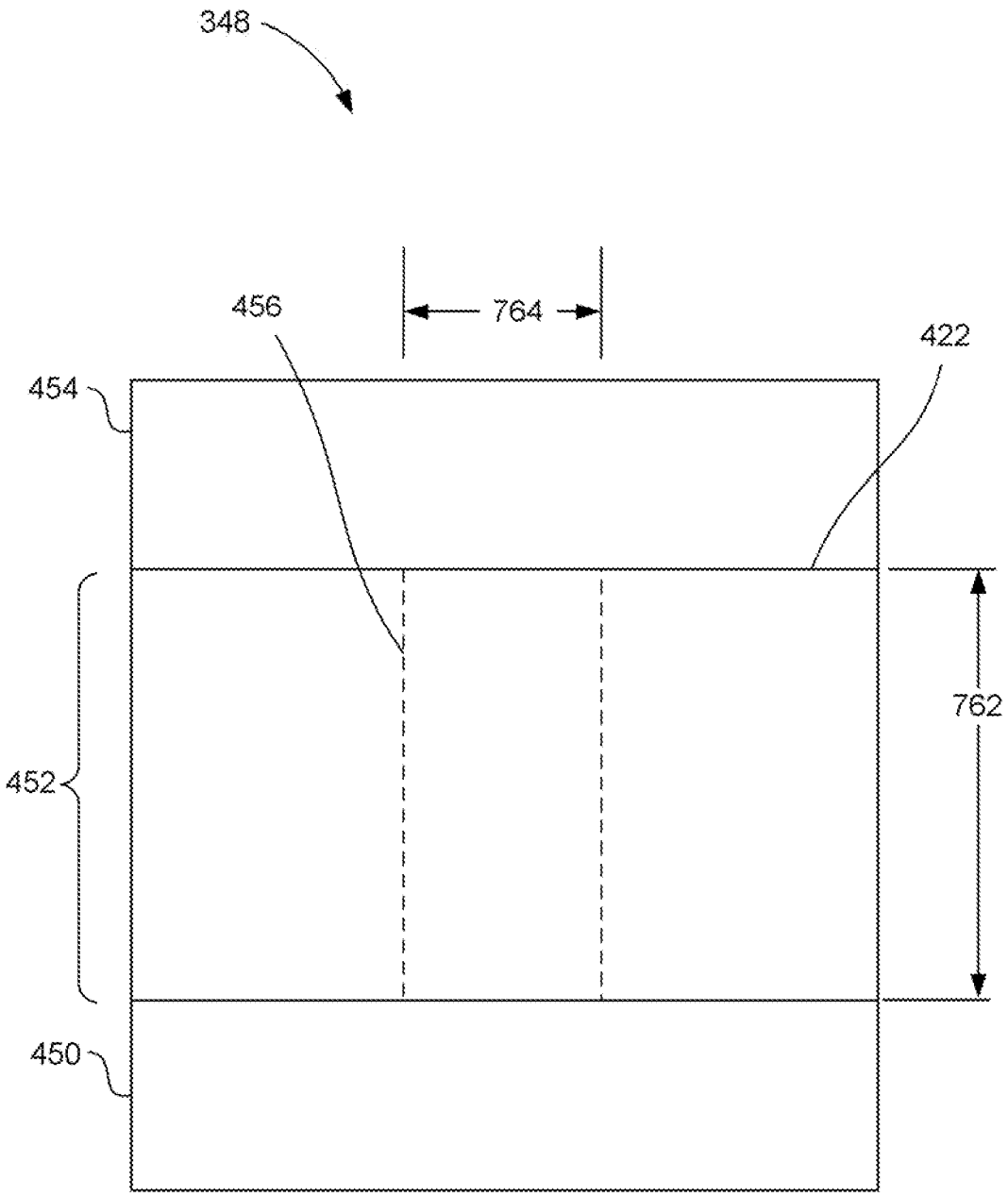


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/048323

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 2/04; B21D 53/76; H01L 21/04; B41J 2/07; H01L 21/31; H01L 21/314; H01L 29/8605; H01L 21/00; 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, nozzle, and metalorganic

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]-[0016], [0020]-[0023], and figures 1-3A, 5A.	1-2,7-10,13-15
A		3-6,11,12
Y	US 2011-0310181 A1 (CURCIO et al.) 22 December 2011 See abstract, paragraphs [0023]-[0024], and figure 1.	1-2,7-8
Y	US 7897411 B2 (ALLENSPACH et al.) 01 March 2011 See abstract, column 3, lines 21-61, and figure 1.	1-2,7-10,13-15
A	US 2010-0330813 A1 (NAKAGAWA et al.) 30 December 2010 See abstract and claim 22.	1-15
A	US 8325507 B2 (YANG et al.) 04 December 2012 See abstract, column 2, lines 21-38, and figure 1.	1-15

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

☒ See patent family annex.

* Special categories of cited documents:
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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
"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
15 April 2015 (15.04.2015)	**16 April 2015 (16.04.2015)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/048323

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