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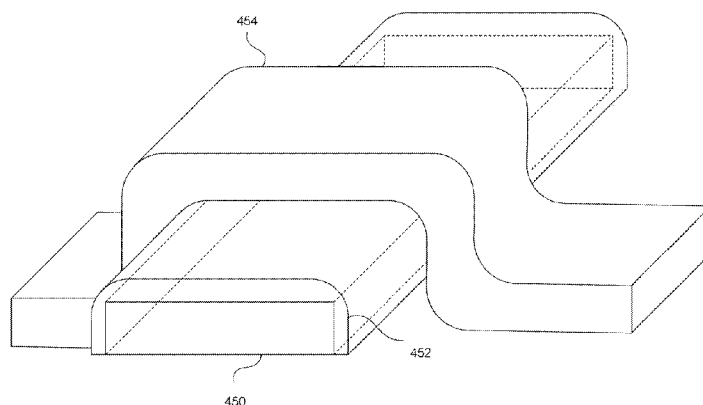


Fig. 6

(57) Abstract: A printhead with a number of top electrode-enclosed memristors 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 number of memristors. Each memristor includes a bottom electrode, a switching oxide disposed on a top surface of the bottom electrode and a number of side surfaces of the bottom electrode, and a top electrode disposed on a portion of a top surface of the switching oxide and a portion of a number of side surfaces of the switching oxide.

PRINthead WITH A NUMBER OF TOP ELECTRODE-ENCLOSED MEMRISTORS

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 top electrode-enclosed memristors 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 top electrode-enclosed memristors 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 top electrode-enclosed memristors according to one example of the principles described herein.

[0007] Fig. 4 is a cross-sectional view of a top electrode-enclosed memristor 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] Fig. 6 is a view of a top electrode-enclosed memristor in a cross bar memristor array according to one example of the principles described herein.

[0010] Fig. 7 is a view of top electrode-enclosed memristor in a one transistor-one memristor structure 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, memristors may be incorporated onto a silicon wafer during a back end of the line (BEOL) process that occurs at the end of fabrication of an integrated circuit. Also, memristors, while presenting beneficial memory endurance and retention, may use a high voltage to set the memristor to a particular value, which may lead to bits that are improperly set during a read/write operation.

[0016] Accordingly, the present disclosure describes a printhead with a memristor that alleviates these and other complications. For example, a top electrode-enclosed memristor as described in the present specification may utilize a particular architecture to facilitate a more simple switching mechanism and which may reduce a forming voltage for the memristor. Such a memristor includes a bottom electrode and a switching oxide that encompasses a number of surfaces of the bottom electrode. The memristor also includes a top electrode that encompasses a number of surfaces of the switching oxide.

[0017] More specifically, the present disclosure describes a printhead with a number of top electrode-enclosed memristors. 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 memristors. Each memristor includes a bottom electrode, a switching oxide disposed on a top surface of the bottom electrode and a number of side

surfaces of the bottom electrode, and a top electrode disposed on a portion of a top surface of the switching oxide and a portion of a number of side surfaces of the switching oxide.

[0018] The present disclosure describes a printer cartridge with a number of top electrode-enclosed memristors. The cartridge includes a fluid supply and a printhead to deposit fluid from the fluid supply onto a print medium. The printhead includes a number of memristors. Each memristor includes a bottom electrode, a switching oxide disposed on a top surface of the bottom electrode and a number of side surfaces of the bottom electrode, and a top electrode disposed on a portion of a top surface of the switching oxide and a portion of a number of side surfaces of the switching oxide.

[0019] A printer cartridge and a printhead that utilize a top electrode-enclosed memristor may be beneficial by providing a large amount of memory storage on a relatively small space on the printhead as compared to other memory devices. Additionally, a top electrode-enclosed memristor may facilitate a simpler switching mechanism which reduces the effects of stubborn or stuck bits. The top electrode-enclosed memristor also reduces the forming voltage of a memristor which reduces the potential of an overwritten or broken memristor. Thus, the top electrode-enclosed memristor as described herein may be 1) cost effective by reducing the manufacturing costs of a memory device on a printhead, 2) efficient by storing more information in a smaller footprint, and 3) reliable by reducing the potential of malfunctioning memory storage.

[0020] 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.

[0021] 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.

[0022] 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.

[0023] 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.

[0024] 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.

[0025] Still further, as used in the present specification and in the appended claims, the term "forming voltage" may refer to a voltage used to place a particular memristor in a "state" in which the memristor stores information.

[0026] 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.

[0027] 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.

[0028] 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.

[0029] 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 one or more print job commands and/or command parameters.

[0030] 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).

[0031] 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.

[0032] 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).

[0033] 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.

[0034] 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).

[0035] 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.

[0036] 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).

[0037] 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.

[0038] 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).

[0039] 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).

[0040] 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).

[0041] 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).

[0042] Fig. 2A is a diagram of a printer cartridge (114) and printhead (116) with a number of memristors having parallel current distributors 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.

[0043] 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).

[0044] 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).

[0045] 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.

[0046] 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).

[0047] 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.

[0048] Fig. 2B is a cross sectional 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. 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.

[0049] 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).

[0050] 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.

[0051] 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 the opening (246) and onto the print medium (Fig. 1, 126). In this example, the printhead (116) may be a piezoelectric inkjet printhead.

[0052] 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.

[0053] Fig. 3 is a block diagram of a printer cartridge (114) that uses a printhead (116) with a number of top electrode-enclosed memristors (348) 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).

[0054] 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 memristor (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).

[0055] A memristor has a metal-insulator-metal layered structure. More specifically, the memristor may include a bottom electrode (metal), a switching oxide (insulator or semi-conductor), and a top electrode (metal). A memristor 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 alloy oxide or tantalum oxide may be examples 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.

[0056] 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 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. In another 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.

[0057] 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).

[0058] 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).

[0059] 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.

[0060] Fig. 4 is a cross-sectional view of a top electrode-enclosed memristor (348) according to one example of the principles described herein. 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.

[0061] A memristor (348) has 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 Figs. 5 and 6. 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 memristor structure as depicted in Fig. 7.

[0062] The bottom electrode (450) may be an electrical connection between the memristor (348) and other components that may attach to the

bottom electrode (450). The bottom electrode (450) may include a top surface and a bottom surface. Via the bottom surface, the bottom electrode (309) may be coupled to a data line, which bottom surface is opposite a top surface of the bottom electrode (450). 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. Furthermore, as will be described below, the top electrode (454) may also be coupled to different components.

[0063] The bottom electrode (450) may be formed such that a top surface of the bottom electrode (450) and a side surface of the bottom electrode (450) form a right angle profile as indicated by the dashed circle (456). As depicted in Fig. 4, in some examples, the distance between the bottom electrode (450) and the top electrode (454) at the right angle profile indicated by (456) might be less than the distance between 1) a side surface of the bottom electrode (450) and the top electrode (454), 2) a top surface of the bottom electrode (450) and the top electrode (454), or 3) combinations thereof. The right angle of the profile of the bottom electrode (450) may generate an enhanced electrical field at this point. The enhanced electrical field increases the likelihood of a successful switching event of the memristor (348) through this point as less current is used during a switching event. While specific reference is made to a right angle profile, any profile may be used that generates an enhanced electrical field. The bottom electrode (450) may be formed of a metallic alloy or other material that facilitates passage of current throughout the bottom electrode (450).

[0064] The memristor (348) may also include a switching oxide (452) that is disposed on a top surface of the bottom electrode (450) and a number of side surfaces of the bottom electrode (450). In other words, the switching oxide (452) may encompass all surfaces of the bottom electrode (450) except a surface which receives a data line, or other electrical communication line. In some examples, the switching oxide (452) may encompass the entirety of a number of side surfaces. For example, as depicted in Fig. 6, the switching oxide (452) may cover more of the bottom electrode (450) than just the portion

of the bottom electrode (450) that is in line with the top electrode (454). Additional detail regarding the switching oxide (452) that encompasses the bottom electrode (450) is depicted in Figs. 6 and 7.

[0065] 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 current to pass to the memristor (348), allowing the memristor (348) to change state and thereby store information.

[0066] The switching oxide (452) has a number of surfaces. More specifically, the switching oxide (452) has a top surface (458) and a number of side surfaces (460-1, 460-2). In some examples, the side surfaces (460-1, 460-2) may be thinner than the top surface (458). While Fig. 4 depicts straight side surfaces (460-1, 460-2), the side surfaces (460) may be uneven, being thinner at the top near the top surface (458) and wider at the bottom near a bottom surface of the switching oxide (452). A side surface (460) that is thinner than a top surface (458) may provide another surface, in addition to the right angle indicated by circle (456), wherein conducting filaments are more likely to form, which conducting filaments allow current to pass through the memristor (348). In other words, during a switching event, a lower voltage may be used to “form” the memristor (348) or to execute a switching event, a switching event referring to a process of changing the resistance state of the memristor (348). In some examples, the switching oxides (452) may have a thickness of between about, a few nanometers to a dozen nanometers.

[0067] The particular profile of the switching oxide (452) may be selected during the formation of the switching oxide (452), for example by altering a physical vapor deposition angle and rotation.

[0068] In some examples, the switching oxides (452) may be formed by oxidizing the bottom electrode (450). For example, the switching oxides (452) may be formed by thermal oxidation, a process which exposes the bottom

electrode (450) 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 oxides (452) are formed by performing plasma oxidation, which exposes the bottom electrode (450) to oxygen plasma at controlled temperatures.

[0069] In another example, the switching oxides (452) are formed through a physical vapor deposition process wherein atoms or molecules may be ejected from a target material to the bottom electrode (450). 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 oxides (452). While specific examples of switching oxide (452) formation processes have been given, other oxide forming processes are also contemplated by the present specification.

[0070] In some examples, the switching oxides (452) may be made of a metallic oxide. Specific examples of switching oxide (452) 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 (452) 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, reactive sputtering from a metal target, atomic layer deposition (ALD), or oxidizing a deposited metal or alloy layer.

[0071] The memristor also includes a top electrode (454) disposed on at least a portion of a top surface (458) of the switching oxide (452) and a portion of a number of side surfaces (460) of the switching oxide (452). For example, as will be depicted in Fig. 6, in a cross bar array, the top electrode

(454) may be disposed on a portion of a top surface (458) and a portion of a number of side surfaces (460) of the switching oxide (452). In another example, as will be depicted in Fig. 7, in a one transistor-one memristor structure, the top electrode (454) may be disposed on the entire top surface (458) and the entirety of side surfaces (460) of the switching oxide (452).

[0072] As with the bottom electrode (450), the top electrode (454) may be an electrical connection between the memristor (348) and other components that may attach to the top electrode (454). 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.

[0073] 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.

[0074] A number of processes may be used to form the top electrodes (454). For example, the top electrode (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 (452) to form the top electrode (454). While specific reference is made to PVD, other processes may be used to form the top electrode (454). Examples of such processes include a lift-off process and shadow masking deposition, among other processes. The top electrode (454) may then be further altered via a number of processes including photolithography, lithography, and etching, among other surface altering processes.

[0075] A top electrode-enclosed memristor (348) as described herein may be beneficial by lowering a forming voltage of the memristor (348) and creating a simplified switching event. More specifically, the memristor (348) as described in the present specification provides a greater surface area wherein

current can be passed from the bottom electrode (450) to the top electrode (454). For example, the memristor (348) as described herein allows for a current to pass through a number of surfaces of the bottom electrode (450) through a number of surfaces (458, 460) of the switching oxide (452) as opposed to a purely linear current passage through a single surface of the bottom electrode (450) and the switching oxide (452). Still further the geometry of the switching oxide (452) which forms a shorter distance between the bottom electrode (450) and the top electrode (454) at a right angle profile (456) of the bottom electrode (450) allows for an enhanced electrical field. This simplified switching process indicates an increased likelihood of a switching event taking place, which improves the reliability of the memristor (348) and increases the fabrication yield of memristors (348) that produce a switching event. Moreover, the manufacturing process of the memristor (348) as described herein alleviates the need for a chemical-mechanical polishing operation.

[0076] 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 (562-1) may run in a first direction and a second number of elements (562-2) 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 (562-1) and the second number of elements (562-2) 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 (562-1) and the second number of elements (562-2) may be the bottom electrode (Fig. 4, 450) and the other may be the top electrode (Fig. 4, 545).

[0077] 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 (562-1) 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 (562-1) may share a bottom electrode (Fig. 4, 450). Continuing this example, a switching oxide (Fig. 4, 452) material may then be deposited on the first number

of elements (562-1) as described in connection with Fig. 4. The second number of elements (562-2) may then be disposed on the first number of elements (562-1) 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 (562-2) may share a top electrode (Fig. 4, 454).

[0078] Accordingly, a node being a memristor (348) may include a bottom electrode (Fig. 4, 450) from the first number of elements (562-1), 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 (562-2) disposed on the switching oxide (Fig. 4, 452).

[0079] Fig. 6 is a view of a top electrode-enclosed memristor (Fig. 3, 348) in a cross bar memristor array (Fig. 2, 240) according to one example of the principles described herein. More specifically, Fig. 6 depicts a single node of the cross bar memristor array (Fig. 2, 240), the node being a memristor (Fig. 3, 348) of the memristor array (Fig. 2, 240).

[0080] As described above, the memristor (Fig. 3, 348) may include a bottom electrode (450). The bottom electrode (450) may be formed from one of the first number of elements (Fig. 5, 562-1) or the second number of elements (Fig. 5, 562-2) and may be shared by a number of memristors (Fig. 3, 348). Put another way, a number of nodes may be formed in part by the intersection of one of the first number of elements (Fig. 5, 562-1) and one of the second number of elements (Fig. 5, 562-2). Similarly, as described above, the bottom electrode (450) may be formed such that a right angle profile is formed on the bottom electrode (450). The right angle profile may exhibit an enhanced electrical field which increases the likelihood of a switching event and lowers the voltage used to "form" the memristor (Fig. 3, 348). The right angle profile may exhibit a reduced distance between the bottom electrode (450) and the top electrode (454).

[0081] The memristor (Fig. 3, 348) may also include a switching oxide (452) that is disposed on a top surface of the bottom electrode (450) and a number of side surfaces of the bottom electrode (450). Disposing the switching oxide (452) on a number of side surfaces may be beneficial by providing a

greater surface area, and more directions, though which current may pass. For example, as opposed to passing current through a top surface of the bottom electrode (450) in a uni-directional fashion, the current may be passed through the top surface and the side surfaces of the bottom electrode (450) to the switching oxide (452). As described, the switching oxide (452) may be thinner along the side surfaces as compared to the top surface such that current is passed more easily through the number of side surfaces again improving the reliability of the memristor (Fig. 3, 348) as well as lowering the forming voltage of the memristor (Fig. 3, 348).

[0082] The memristor (Fig. 3, 348) also includes a top electrode (454) through which a current is passed from the switching oxide (452). As depicted in Fig. 6, a bottom surface of the top electrode (454) may be disposed on, and in contact with the switching oxide (452). For example, the top electrode (454) may be disposed on a portion of the top surface and a portion of a number of side surfaces of the switching oxide (452). Disposing the top electrode (454) on a number of side surfaces may be beneficial by providing a greater surface area, and more directions, though which current may pass. For example, as opposed to passing current through a top surface of the switching oxide (452) in a uni-directional fashion, the current may be passed through the top surface and the side surfaces of the switching oxide (452) to the top electrode (454).

[0083] Fig. 7 is a view of top electrode-enclosed memristor (348) in a one transistor-one memristor structure according to one example of the principles described herein. More specifically, Fig. 7 depicts a top electrode-enclosed memristor (348) that forms a one-to-one addressing structure with an integrated circuit. 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.

[0084] In this example, the memristor (348) may include a bottom electrode (450) that is encompassed on all side surfaces and the top surface by the switching oxide (452). A bottom surface of the bottom electrode (450) may be flush with a bottom surface of the switching oxide (452). Still further, in this example, the switching oxide (452) may be encompassed on all side surfaces and the top surface by the top electrode (454). A bottom surface of the top electrode (454) may be flush with a bottom surface of the switching oxide (452) and a bottom surface of the bottom electrode (450).

[0085] A printer cartridge (Fig. 1, 114) and printhead (Fig. 1, 116) with a number of top electrode-enclosed memristors (Fig. 3, 348) may have a number of advantages, including lowering a forming voltage of a memristor (Fig. 3, 348) by facilitating switching at a weak point within the memristor (Fig. 3, 348) and increasing the fabrication yield by reducing malfunctioning bits by implementing an easier switching mechanism. Additional advantages include simplifying manufacturing processes, increasing storage capacity of memory used on a printhead (Fig. 1, 116), improving printhead (Fig. 1, 116) memory performance, reducing cost of effective memristor (Fig. 3, 348) fabrication.

[0086] 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.

[0087] 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

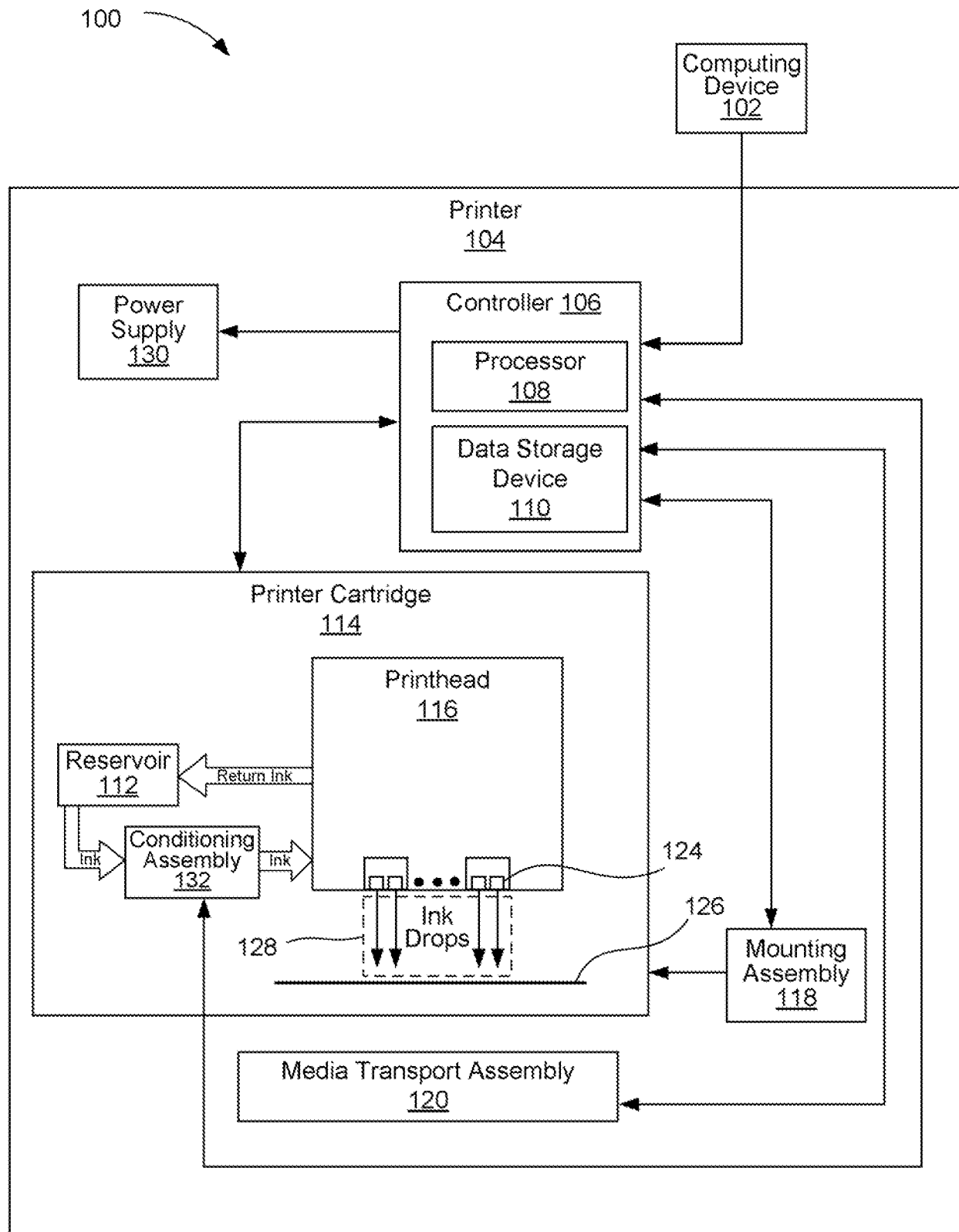
WHAT IS CLAIMED IS:

1. A printhead with a number of top electrode-enclosed memristors, 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 number of memristors, each memristor comprising:
 - a bottom electrode;
 - a switching oxide disposed on a top surface of the bottom electrode and a number of side surfaces of the bottom electrode; and
 - a top electrode disposed on a portion of a top surface of the switching oxide and a portion of a number of side surfaces 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 number of side surfaces of the switching oxide are thinner than the top surface of the switching oxide.
4. The printhead of claim 1, in which the switching oxide is disposed on all side surfaces of the bottom electrode.
5. The printhead of claim 1, in which the top electrode is disposed on a portion of all side surfaces of the switching oxide.

6. The printhead of claim 1, in which the top surface of the bottom electrode and a side surface of the bottom electrode form a right angle profile.
7. The printhead of claim 6, in which the right angle profile provides an enhanced electrical field between the bottom electrode and the top electrode.
8. The printhead of claim 1, in which a number of memristors share a bottom electrode, a switching oxide, a top electrode, or combinations thereof.
9. A printer cartridge with a number of top electrode-enclosed memristors, the cartridge comprising:
 - a fluid supply; and
 - a printhead to deposit fluid from the fluid supply onto a print medium, the printhead comprising:
 - a number of memristors, each memristor comprising:
 - a bottom electrode;
 - a switching oxide disposed on a top surface of the bottom electrode and a number of side surfaces of the bottom electrode; and
 - a top electrode disposed on a portion of a top surface of the switching oxide and a portion of a number of side surfaces 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, in which the printhead receives a control signal from a controller.
12. The cartridge of claim 9, in which the number of side surfaces of the switching oxide have an uneven profile.

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 number of memristors form a cross bar array.
15. The cartridge of claim 14, in which the number of memristors in the cross bar array share a bottom electrode, a switching oxide, a top electrode or combinations thereof.

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**Fig. 1**

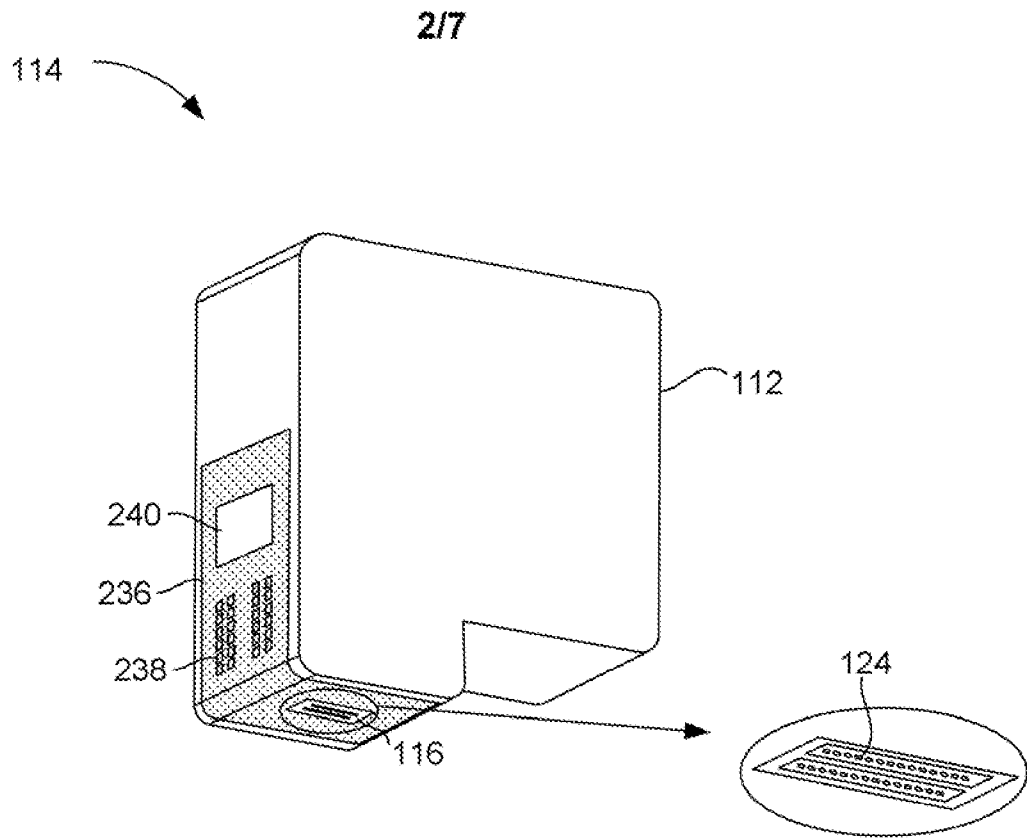


Fig. 2A

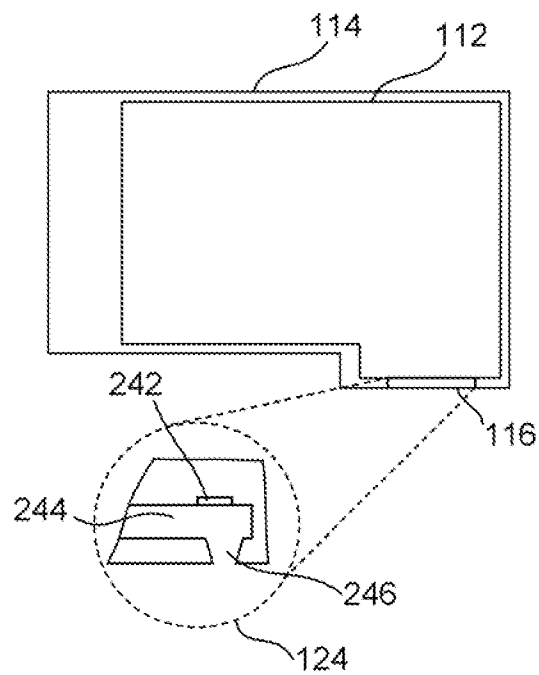
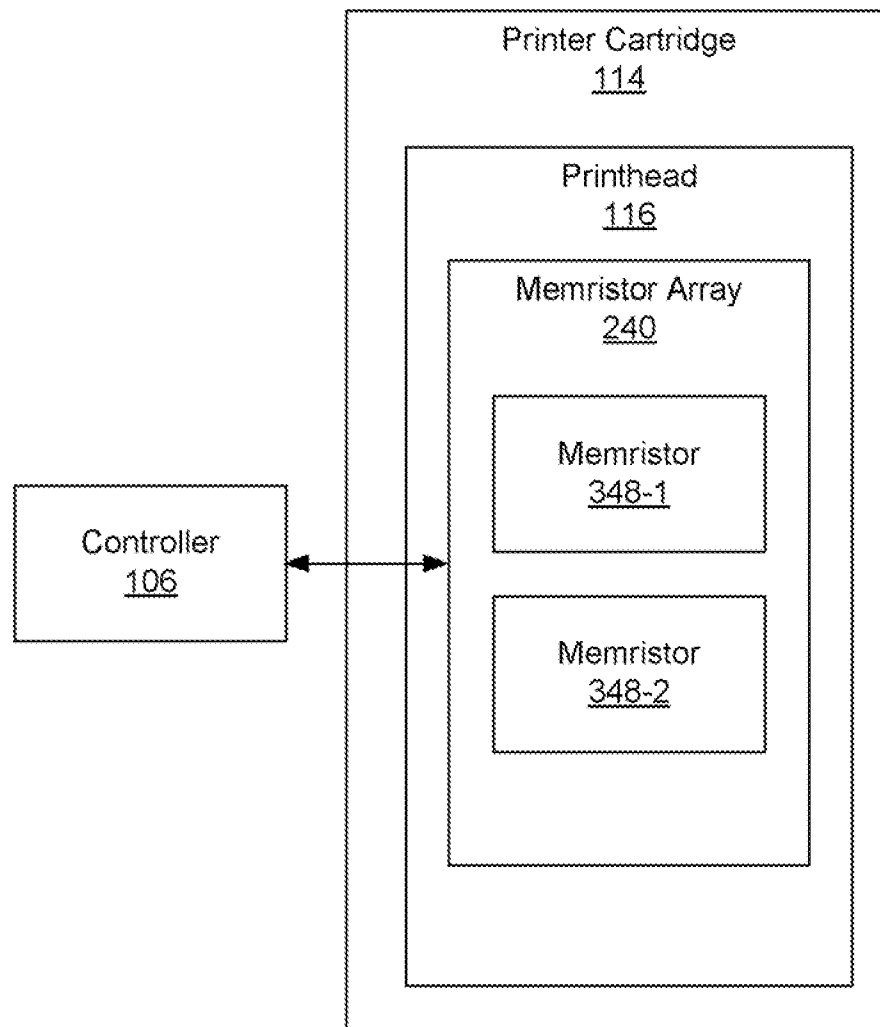


Fig. 2B

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**Fig. 3**

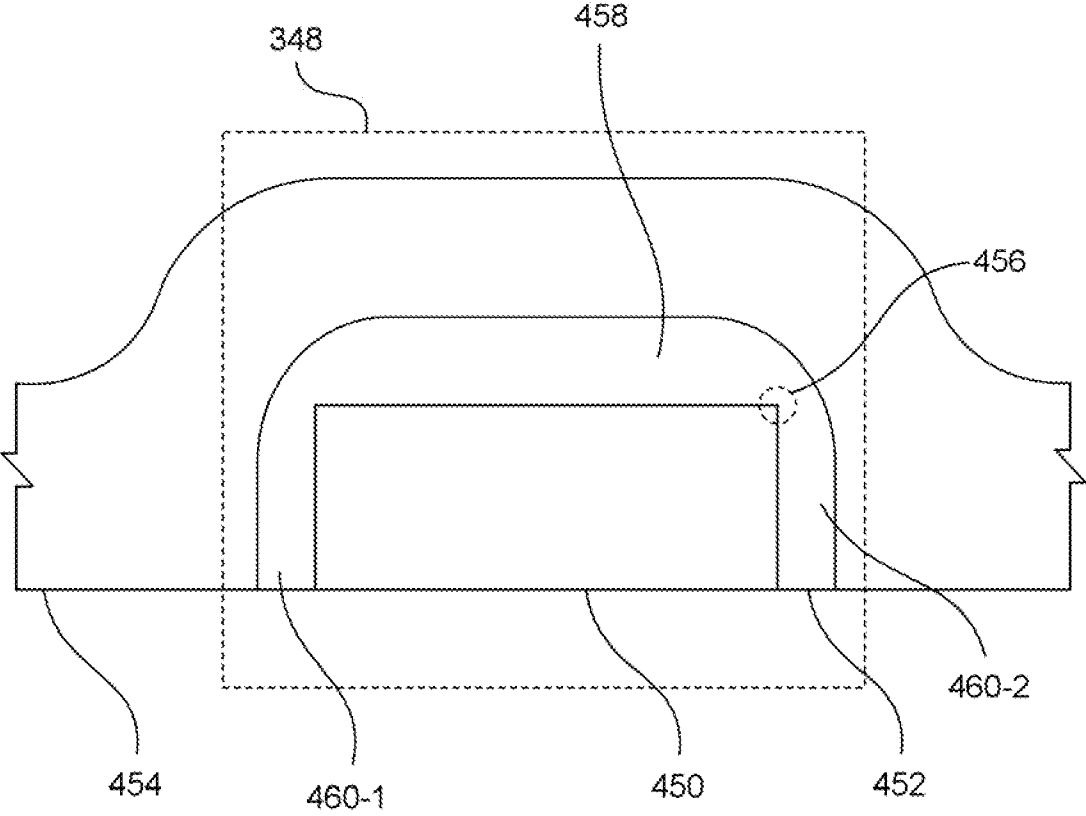
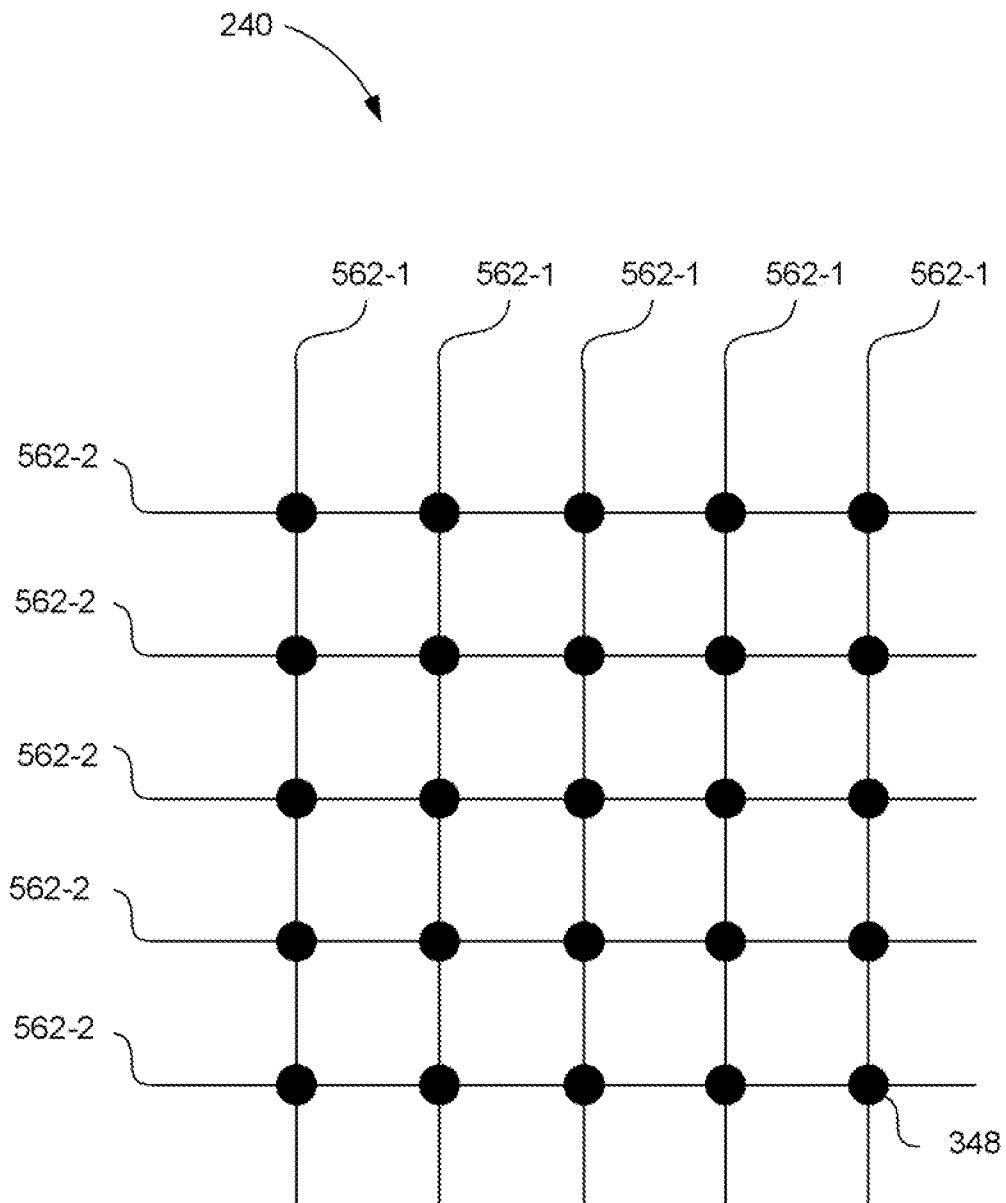


Fig. 4

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**Fig. 5**

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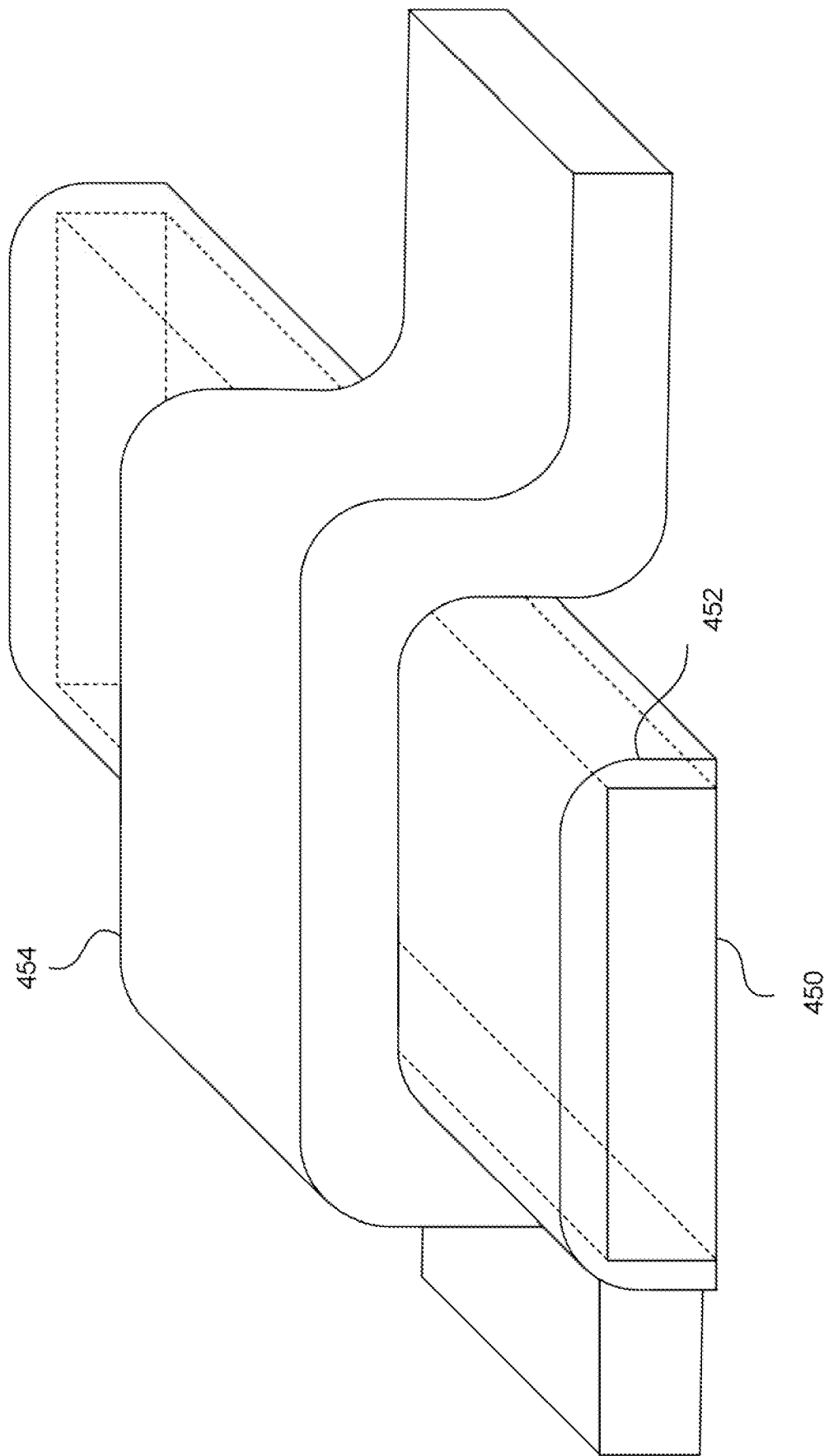


Fig. 6

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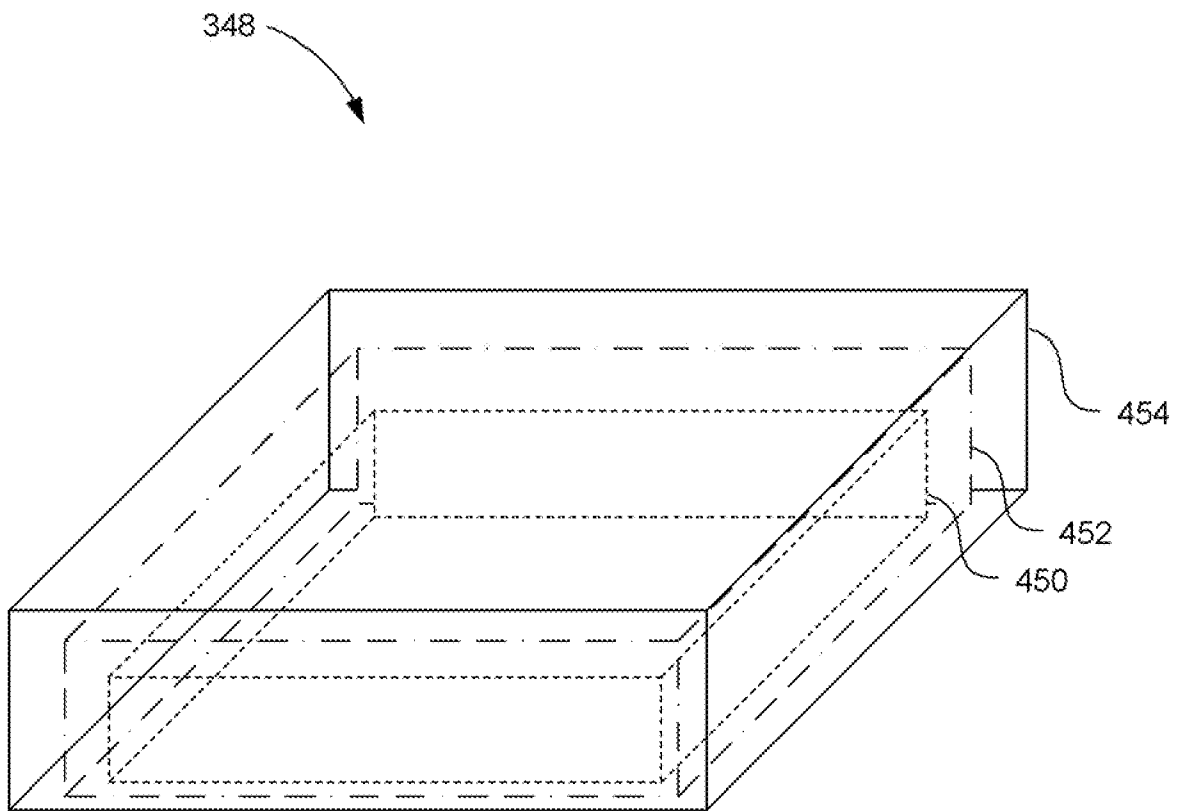


Fig. 7

A. CLASSIFICATION OF SUBJECT MATTER**B41J 2/175(2006.01)i, B41J 2/145(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 29/8605; B41J 29/38; B41J 2/145

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, switch, oxide, and insulator

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.	1–15
Y	US 2011-0310181 A1 (CURCIO et al.) 22 December 2011 See abstract, paragraphs [0023]–[0024], and figure 1.	1–7
Y	US 8325507 B2 (YANG et al.) 04 December 2012 See abstract, column 2, lines 21–38, and figure 1.	1–15
A	US 2009-0244132 A1 (BRUCE et al.) 01 October 2009 See abstract, paragraphs [0021]–[0029], and figures 1–2.	1–15
A	US 2009-0284558 A1 (CERUTTI, WALTER) 19 November 2009 See abstract, paragraphs [0004], [0046], [0053], [0057], and figures 1–1b.	1–15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 April 2015 (18.04.2015)

Date of mailing of the international search report

20 April 2015 (20.04.2015)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/048297

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0106930 A1	02/05/2013	US 8882217 B2	11/11/2014
US 2011-0310181 A1	22/12/2011	CN 102378691 A	14/03/2012
		CN 102378691 B	30/07/2014
		EP 2414162 A1	08/02/2012
		EP 2414162 A4	22/05/2013
		EP 2414162 B1	15/10/2014
		US 8596746 B2	03/12/2013
		WO 2010-114516 A1	07/10/2010
US 8325507 B2	04/12/2012	US 2012-0074372 A1	29/03/2012
US 2009-0244132 A1	01/10/2009	US 7815273 B2	19/10/2010
US 2009-0284558 A1	19/11/2009	CN 101360613 A	04/02/2009
		CN 101360613 B	18/05/2011
		EP 1963104 A1	03/09/2008
		US 7837288 B2	23/11/2010
		WO 2007-073750 A1	05/07/2007