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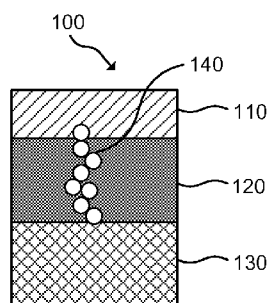


FIG. 1C

(57) Abstract: A memory cell may include a memristor, a volatile conducting bridge selector, and a resistor. The volatile conducting bridge selector may be coupled with the memristor and include a solid electrolyte layer and plurality of mobile ions within the solid electrolyte layer. The resistor may be coupled in series to the volatile conducting bridge selector.

MEMORY CELLS WITH VOLATILE CONDUCTING BRIDGE SELECTORS

BACKGROUND

[0001] Memristors are devices that can be programmed to different resistive states by applying a programming energy, such as a voltage. Selectors are passive two terminal devices that may control the electrical properties such as the conductivity of electronic devices containing the selectors. Selectors may be combined with memristors to form crossbar arrays of memory devices. Large crossbar arrays of memory devices can be used in a variety of applications, including random access memory, non-volatile solid state memory, programmable logic, signal processing control systems, pattern recognition, and other applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The following detailed description references the drawings, wherein:

[0003] FIG. 1A is a cross-sectional view of an example memory cell with a volatile conducting bridge selector;

[0004] FIG. 1B is a cross-sectional view of an example memory cell with a volatile conducting bridge selector in an off state;

[0005] FIG. 1C is a cross-sectional view of an example memory cell with a volatile conducting bridge selector in an on state;

[0006] FIG. 2 is a diagram of an example crossbar array;

[0007] FIG. 3 is a graph showing the current-voltage relationship of an example volatile conducting bridge selector; and

[0008] FIG. 4 is a graph showing the current-voltage relationship of an example volatile conducting bridge selector and the current load placed on a memristor as a result of the state of the selector.

DETAILED DESCRIPTION

[0009] Memristors are devices that may be used as components in a wide range of electronic circuits, such as memories, switches, radio frequency circuits, and logic circuits and systems. In a memory structure, a crossbar array of memory devices having memristors may be used. When used as a basis for memory devices, memristors may be used to store bits of information, 1 or 0. The resistance of a memristor may be changed by applying an electrical stimulus, such as a voltage or a current, through the memristor. Generally, at least one channel may be formed that is capable of being switched between two states—one in which the channel forms an electrically conductive path (“on”) and one in which the channel forms a less conductive path (“off”). In some other cases, conductive paths represent “off” and less conductive paths represent “on”.

[0010] Using memristors in crossbar arrays may lead to read or write failure due to sneak currents leaking through the memory cells that are not targeted—for example, cells on the same row or column as a targeted cell. Failure may arise when the total current through the circuit from an applied voltage is higher than the current through the targeted memristor due to current sneaking through untargeted neighboring cells. Using a transistor coupled in series with each memristor has been proposed to isolate each cell and overcome the sneak current. However, using a transistor with each memristor in a crossbar array limits array density and increases cost, which may impact commercialization. As a result, effort has been spent to investigate using a nonlinear selector coupled in series with each memristor in order to increase the current–voltage (I-V) nonlinearity of each memory cell of a crossbar array.

[0011] Some proposed selectors include volatile conducting bridge (VCB) selectors, which use the formation of conducting bridges to allow the selector to be in at least two resistance states. For example, the selector may be in a more resistance state when a conducting bridge is not formed through the selector, while the selector may be in a less resistance state when a conducting bridge is formed. VCB selectors may have an on-switching voltage which is the voltage level that causes switching of the selector from an off, high-resistance state to an on, low-resistance state. Conversely, VCB selectors may have

an off-switching voltage which is the voltage level that causes switching of the selector from an on state to an off state.

[0012] However, current solutions may have relatively high on-switching voltages and relatively low off-switching voltages. Furthermore, current solutions may have very low resistances in the on state. While this nonlinear behavior may be desirable, it may need to unintended writing of a memristor. A target cell in a crossbar array may be read by applying a voltage greater than the on-switching voltage of the VCB selector because the off state of the VCB selector may be significantly more resistive than the memristor. The resistance of the VCB selector may drop significantly at the on-switching voltage, at which point, most of the applied voltage is dropped across the memristor, which may lead to unintended writing of the memristor.

[0013] Examples disclosed herein provide for memory cells with volatile conducting bridge selectors and a series resistor. Example memory cells may include a memristor, a VCB selector, and a series resistor. The series resistor may add resistance to the memory cell when the VCB selector is in an on state. According, this may prevent the formation of a large enough voltage across the memristor to unintendedly write it.

[0014] Referring now to the drawings, FIG. 1A, FIG. 1B, and FIG. 1C show cross-sectional views of an example memory cell 100 with a volatile conducting bridge selector 120. Memory cell 100 may have a memristor 110, volatile conducting bridge (VCB) selector 120 coupled with the memristor, and a resistor 130 coupled in series with VCB selector 120. As used herein, components may be coupled by forming an electrical connection between the components. For example, VCB selector 120 may be coupled to memristor 110 by forming a direct, surface contact or by other forms of physical connection.

[0015] Memristor 110 may be a device that provides memory properties to memory cell 100. Memristor 110 may have a resistance that changes with an applied electrical stimulus, such as voltage or current. Furthermore, memristor 110 may “memorize” its last resistance. In this manner, each memristor 110 may be set to at least two states. For example, a voltage larger than a write voltage of memristor 110 may switch it from an off, insulating state to an on, conducting state. Furthermore in some examples, other components may be coupled

with memristors 110. For example, each memristor may be coupled in series with resistors, transistors, or selectors.

[0016] In some examples, a memristor may be nitride-based, meaning that at least a portion of the memristor is formed from a nitride-containing composition. A memristor may also be oxide-based, meaning that at least a portion of the memristor is formed from an oxide-containing material. Furthermore, a memristor may be oxy-nitride based, meaning that at least a portion of the memristor is formed from an oxide-containing material and that at least a portion of the memristor is formed from a nitride-containing material. Example materials of memristors may include tantalum oxide, hafnium oxide, titanium oxide, yttrium oxide, niobium oxide, zirconium oxide, or other like oxides, or non-transition metal oxides, such as aluminum oxide, calcium oxide, magnesium oxide, dysprosium oxide, lanthanum oxide, silicon dioxide, or other like oxides. Further examples include nitrides, such as aluminum nitride, gallium nitride, tantalum nitride, silicon nitride, and oxynitrides such as silicon oxynitride. In addition, other functioning memristors may be employed in the practice of the teachings herein.

[0017] Memristor 110 may be have linear or nonlinear current-voltage (I-V) behavior. Nonlinear may describe a function that grows faster than a linear function. For example, this may mean that current flowing through memristor 110 increases faster than linear growth with relation to applied voltage. For example, typical materials may follow Ohm's law, where the current through them is proportional to the voltage. In some examples, as the voltage is increased, the current flowing through a nonlinear memristor 110 may disproportionately increase. As a result, the I-V behavior in this voltage range may be highly nonlinear.

[0018] VCB selector 120 may be an electrical device that may be used in memory cell devices to provide desirable electrical properties. For example, VCB selector 120 may be a 2-terminal device or circuit element that admits a current that depends on the voltage applied across the terminals. VCB selector 120 may be coupled in series with memristor 110 or active regions of other memristor devices.

[0019] VCB selector 120 may have a solid electrolyte layer and a plurality of mobile ions 140 within the solid electrolyte layer. In some examples, the solid electrolyte layer may include an oxide, such as silicon oxide or aluminum oxide. Mobile ions 140 may include

metals such as copper or silver that are mobile within the solid electrolyte layer. Mobile ions 140 may form conducting bridges to allow VCB selector 120 to be in at least two resistance states. For example, VCB selector 120 may be in a more resistive, off state when a conducting bridge is not formed, while VCB selector 120 may be in a less resistive, on state when a conducting bridge is formed. FIG. 1B shows memory cell 100 with VCB selector 120 in the off state, where the mobile ions 140 are dispersed. FIG. 1C, on the other hand, shows memory cell 100 with VCB selector 120 in the on state, where the mobile ions 140 are aligned to form a conducting bridge. Conducting bridges may be volatile, meaning that a certain voltage is used to maintain the conducting bridges.

[0020] VCB selectors 120 may have an on-switching voltage which is the voltage level that causes switching of the selector from an off state to an on state. Conversely, VCB selector 120 may have an off-switching voltage which is the voltage level that causes switching of the selector from an on state to an off state. In some examples, the off-switching threshold voltage of VCB selector 120 may be lower than its on-switching voltage. In some examples, threshold voltages may not be confined to specific voltage values. In some examples, the on-switching voltage and the off-switching voltage may be voltage ranges where the conducting bridge formation can occur. Furthermore, if the voltage applied drops under the off-switching voltage, VCB selector 120 may automatically switch back to the off state, thereby giving the selector its volatility.

[0021] Furthermore, in some examples, the resistance of VCB selector 120 in an off state may be higher than the resistance of the memristor 110 in its off state. As a result, when VCB selector 120 is off, most of the voltage is dropped across the VCB selector. Accordingly, memristor 110 may not be easily accessible while VCB selector 120 is off. Thus, VCB selector 120 in the off state may prevent writing or reading of memristor 120, and may contribute to limiting sneak current through memory cell 100.

[0022] Continuing to refer to FIG. 1A-1C, resistor 130 may be a passive two-terminal component that provides resistance. Resistor 130 may be any resistor that provides a resistance. For example, Resistor 130 may be a metal, semiconductor, or other types of materials. In some examples, resistor 130 may be a separate component in series with VCB selector 120 and memristor 110. However, in some examples, resistor 130 may be a part of

other components, such as electrodes, which would provide a similar resistance. In some examples, the resistance of resistor 130 is smaller than the resistance of the volatile conducting bridge selector 120 in an off state and greater than the resistance of the volatile conducting bridge selector 120 in an on state. Furthermore, in some examples, the resistance of resistor 130 may be of a similar order of magnitude as the resistance of memristor 110.

[0023] The presence of resistor 130 may prevent unintended switching of memristor 110 in response to a voltage larger than the on-switching voltage of selector 120 being applied across memory cell 100. As described herein, the resistance of VCB selector 120 may drop significantly at the on-switching voltage, at which point, most of the applied voltage is dropped across memristor 110, which may lead to unintended writing of the memristor. Resistor 130 may add resistance to memory cell 100 as VCB selector switches to the on state. This may prevent a snapback effect that may unintentionally write memristor 110. Accordingly, memristor 110 may be read without unintended writing, while application of additional voltage may then write the memristor.

[0024] In some examples, resistor 130 may have nonlinear I-V behavior. For example, the current passing through resistor 130 may increase nonlinearly with increased voltage. This may aid the writing of memristor 110 as the current allowed through memory cell 100 and to memristor 110 then increases nonlinearly. Alternatively, in some examples, resistor 130 may be linear.

[0025] FIG. 2 is a diagram of an example crossbar array 200. Crossbar array 200 may be a configuration of row lines 210 and column lines 220 with junctions 230 coupled between lines at cross-points. In some examples, row lines 210 are in parallel with each other and perpendicular to column lines 220, which may in turn be in parallel to each other. Each junction 230 may be coupled between a unique combination of one row line 210 and one column line 220. In other words, no junctions share both a row line and a column line. As used herein, components may be coupled by forming an electrical connection between the components. For example, junctions 230 may be coupled to the lines by forming a direct, surface contact or other forms of connection. Crossbar array 200 may be used in a variety of applications, including in memristor technologies described herein.

[0026] Row lines 210 may be electrically conducting lines that carry current throughout crossbar array 100. Row lines 210 may be in parallel to each other, generally with equal spacing. Row lines 210 may sometimes be referred to as bit lines. Depending on orientation, row lines 210 may alternatively be referred to as word lines. Similarly, column lines 220 may be conducting lines that run perpendicular to row lines 210. Column lines 220 may be referred to as word lines in some conventions. In other orientations, column lines 220 may refer to bit lines. Row lines 210 and column lines 220 may be made of conducting materials, such as platinum (Pt), tantalum (Ta), hafnium (Hf), zirconium (Zr), aluminum (Al), cobalt (Co), nickel (Ni), iron (Fe), niobium (Nb), molybdenum (Mo), tungsten (W), copper (Cu), titanium (Ti), tantalum nitrides (TaN_x), titanium nitrides (TiN_x), WN_2 , NbN , MoN , TiSi_2 , TiSi , Ti_5Si_3 , TaSi_2 , WSi_2 , NbSi_2 , V_3Si , electrically doped polycrystalline Si, electrically doped polycrystalline Ge, and combinations thereof. Row lines 210 and column lines 220 may serve as electrodes that deliver voltage and current throughout crossbar array 200.

[0027] Junctions 230 may form the connections between row lines 210 and column lines 220. Junctions 230 may include memory cells, such as memory cell 100. A memory cell may be any device or element that stores digital data. For example, memory cell may be volatile or nonvolatile memory. In some examples, a memory cell may have a resistance that changes with an applied voltage or current. Furthermore, a memory cell may “memorize” its last resistance. In this manner, a memory cell may be set to at least two states. Such an array of a plurality of memory cells may, for example, be utilized in nonvolatile resistive memory, such as random access memory (RRAM), or other applications as described herein.

[0028] A memory cell may include a volatile conducting bridge selector. VCB selectors may be an electrical device that may be used to provide desirable electrical properties. For example, VCB selectors may be 2-terminal devices that allow a current that depends on the voltage applied across the terminals.

[0029] As described herein, VCB selectors may have a solid electrolyte layer and a plurality of mobile ions within the solid electrolyte layer. In some examples, the solid electrolyte layer may include an oxide, such as silicon oxide or aluminum oxide. Mobile ions may include metals such as copper or silver that are mobile within the solid electrolyte layer.

Mobile ions may form conducting bridges to allow VCB selectors to be in at least two resistance states. For example, VCB selectors may be in a more resistive, off state when conducting bridges are not formed, while VCB selectors may be in a less resistive, on state when conducting bridges are formed.

[0030] VCB selectors may have on-switching voltages or voltage ranges which are the voltage levels that cause switching of the selector from an off state to an on state. Conversely, VCB selectors may have off-switching voltages or voltage ranges which are the voltage levels that cause switching of selectors from an on state to an off state. In some examples, the off-switching threshold voltage of VCB selectors may be lower than on-switching voltages. In some examples, threshold voltages may not be confined to specific voltage values. In some examples, the on-switching voltage and the off-switching voltage may be voltage ranges where the conducting bridge formation is possible.

[0031] In some examples, memory cells may include memristors. Memristors may provide the memory cells with the memristive properties described above. Memristors may be based on a variety of materials. Memristors may be oxide-based, meaning that at least a portion of the memristor is formed from an oxide-containing material. Memristors may also be nitride-based, meaning that at least a portion of the memristor is formed from a nitride-containing composition. Furthermore, memristors may be oxy-nitride based, meaning that a portion of the memristor is formed from an oxide-containing material and that a portion of the memristor is formed from a nitride-containing material. In some examples, memristors may be formed based on tantalum oxide (TaO_x) or hafnium oxide (HfO_x) compositions. Other example materials of memristors may include titanium oxide, yttrium oxide, niobium oxide, zirconium oxide, aluminum oxide, calcium oxide, magnesium oxide, dysprosium oxide, lanthanum oxide, silicon dioxide, or other like oxides. Further examples include nitrides, such as aluminum nitride, gallium nitride, tantalum nitride, and silicon nitride. In addition, other functioning materials may be employed in the practice of the teachings herein. For example, memristors may have multiple layers that include electrodes and dielectric materials.

[0032] Furthermore, memory cells may include a resistor coupled in series with a VCB selector. The resistor may prevent unintended switching of a memory cell in response to a

voltage larger than the on-switching voltage of a VCB selector being applied across the memory cell. As described herein, the resistance of a VCB selector may drop significantly at the on-switching voltage, at which point, most of the applied voltage is dropped across the memory cell, which may lead to unintended writing of the memory cell. A resistor may add resistance to the memory cell when the VCB selector switches to the on state. This may prevent a snapback effect that may unintentionally write the memory cell.

[0033] In further examples, junctions 230 may include additional components. For example, junctions 230 may have additional electrodes, selectors, and other circuit elements. In some examples, junctions 230 may include nonlinear selectors, optical selectors, hybrid selectors, and other components.

[0034] Nonlinear selector may have a resistance that decreases faster than linear growth with relation to applied voltage. For example, typical materials may follow Ohm's law, where the current through them is proportional to the voltage. For a nonlinear selector, as the voltage is increased, the current flowing through the selector may disproportionately increase. As a result, the I-V behavior in this voltage range may be highly nonlinear. Nonlinear selectors may be based on a number of materials, including metal oxides and metal nitrides. Non-limiting examples include niobium oxide, tantalum oxide, vanadium oxide, titanium oxide, and chromium oxide.

[0035] In some implementations, a nonlinear selector may exhibit negative differential resistance (NDR), which further adds to the nonlinearity. Negative differential resistance is a property in which an increase in applied current may cause a decrease in voltage across the terminals, in certain current ranges. In some examples, negative differential resistance may be a result of heating effects on certain selectors. In some examples, NDR effect may further contribute to the nonlinearity of nonlinear selectors.

[0036] Furthermore, other additional components may include selectors, memristors, resistors, transistors, and dielectric materials.

[0037] FIG. 3 is a graph 300 showing the current-voltage relationship of an example volatile conducting bridge selector, such as VCB selector 120 of FIG. 1. The horizontal axis

of graph 300 depicts voltage in volts, and the vertical axis of graph 300 depicts current in amperes.

[0038] As shown in graph 300, the current passed through the VCB selector is relatively low as voltage is increased across the selector while it is in the default off state. At the on-switching voltage range, shown by the right vertical line, the resistance of the VCB selector sharply drops as the selector switches from its off state to its on state. As a result, the current passed through the VCB selector increases rapidly to on state levels. To maintain the on state, voltage above the off-switching voltage range of the VCB selector is to be applied. The off-switching voltage range is depicted as around the left vertical line. When voltage less than the off-switching voltage is applied, the selector will switch back to the off state, as shown by the sudden drop in current.

[0039] FIG. 4 is a graph 400 showing the current-voltage relationship of an example volatile conducting bridge selector, such as VCB selector 120, and the current load placed on a memristor, such as memristor 110, as a result of the state of the selector. Horizontal axis 402 depicts voltage, and vertical axis 404 depicts current.

[0040] Curve 410 depicts the I-V behavior of the VCB selector in the off state. As shown, the current through the selector is relatively low as voltage is applied and increased. After the on-switching voltage current through the selector greatly increases. Curve 412 shows the I-V behavior of the selector in the on state, showing that the current through the selector is relatively higher in relation to applied voltage.

[0041] Curve 420 shows the I-V behavior of a linear selector. Curve 425 shows the current load dropped across a memristor in series with the VCB selector. In the off state of the VCB selector, the current across the memristor is low because of the high resistance of the VCB selector in the off state. However, in the on-state of the VCB selector, the current load dropped across the memristor is much higher as shown by the intersection of curves 420 and 412. As described herein, this may cause unintended writing of the memristor.

[0042] Curve 414 shows the on state I-V behavior of the VCB selector coupled with a resistor, such as the linear selector related to curve 420. The resistor may increase the resistance of the combined memory cell, such as memory cell, containing the memristor,

the VCB selector, and the resistor, when the VCB is in the on state. As shown, the intersection of curves 420 and 414 occur at lower current level than the intersection of curves 420 and 412. As a result, the current dropped across the memristor may be lower with the added resistor.

[0043] As depicted in FIG. 4, the voltage range for reading the memristor for a memory cell with a VCB selector without an added resistor may be voltage range 430. On the other hand, the voltage range for reading the memristor for a memory cell with a VCB selector and a series resistor may be the more focused voltage range 440.

[0044] The foregoing describes a number of examples for memory cells with volatile conducting bridge selectors and their applications. It should be understood that the memory cells described herein may include additional components and that some of the components described herein may be removed or modified without departing from the scope of the memory cells or their applications. It should also be understood that the components depicted in the figures are not drawn to scale, and thus, the components may have different relative sizes with respect to each other than as shown in the figures.

[0045] It should be noted that, as used in this application and the appended claims, the singular forms “a,” “an,” and “the” include plural elements unless the context clearly dictates otherwise.

CLAIMS

What is claimed is:

1. A memory cell, including:
a memristor;
a volatile conducting bridge selector coupled with the memristor, wherein the volatile conducting bridge selector comprises a solid electrolyte layer and a plurality of mobile ions within the solid electrolyte layer; and
a resistor coupled in series with the volatile conducting bridge selector.
2. The memory cell of claim 1, wherein the volatile conducting bridge selector has an on-switching threshold voltage and an off-switching threshold voltage.
3. The memory cell of claim 2, wherein the off-switching threshold voltage is lower than the on-switching threshold voltage.
4. The memory cell of claim 1, wherein the memristor can be switched between at least two resistance states in response to an applied electrical stimulus.
5. The memory cell of claim 1, wherein the resistor is nonlinear.
6. The memory cell of claim 1, wherein the resistance of the volatile conducting bridge selector in an off state is higher than the resistance of the memristor in an off-state.
7. The memory cell of claim 1, wherein the resistance of the resistor is smaller than the resistance of the volatile conducting bridge selector in an off state and greater than the resistance of the volatile conducting bridge selector in an on state.
8. The memory cell of claim 1, wherein the solid electrolyte layer includes a metal oxide.

9. The memory cell of claim 8, wherein the mobile ions form a conducting channel across the solid electrolyte layer to switch the volatile conducting bridge selector from an off-state to an on-state.
10. A crossbar array, including:
a plurality of row lines;
a plurality of column lines; and
a plurality of memory cells coupled between a unique combination of one row line and one column line, wherein each memory cell includes:
a memristor, wherein the memristor can be switched between at least two resistance states in response to an applied electrical stimulus;
a volatile conducting bridge selector coupled with the memristor, wherein the volatile conducting bridge selector includes a solid electrolyte layer and a plurality of ions that are mobile within the solid electrolyte layer, and wherein the volatile conducting bridge has an on-switching threshold voltage and an off-switching threshold voltage; and
a resistor coupled in series with the volatile conducting bridge selector.
11. The crossbar array of claim 10, wherein the resistor is nonlinear.
12. The crossbar array of claim 10, wherein the resistor prevents unintended switching of the memristor in response to a voltage larger than the on-switching voltage of the selector being applied across the memory cell.
13. The crossbar array of claim 10, wherein the solid electrolyte layer includes a metal oxide, and wherein the mobile ions form a conducting channel across the solid electrolyte layer to switch the volatile conducting bridge selector from an off-state to an on-state.
14. A memory cell, including:
a memristor, wherein the memristor can be switched between at least two

resistance states in response to an applied electrical stimulus;

a volatile conducting bridge selector coupled with the memristor, wherein the volatile conducting bridge selector includes a solid electrolyte layer and a plurality of ions that are mobile within the solid electrolyte layer, and wherein the volatile conducting bridge has an on-switching threshold voltage and an off-switching threshold voltage; and
a nonlinear resistor coupled in series with the volatile conducting bridge selector.

15. The memory cell of claim 14, wherein the nonlinear resistor prevents unintended switching of the memristor in response to a voltage larger than the on-switching voltage of the selector being applied across the memory cell.

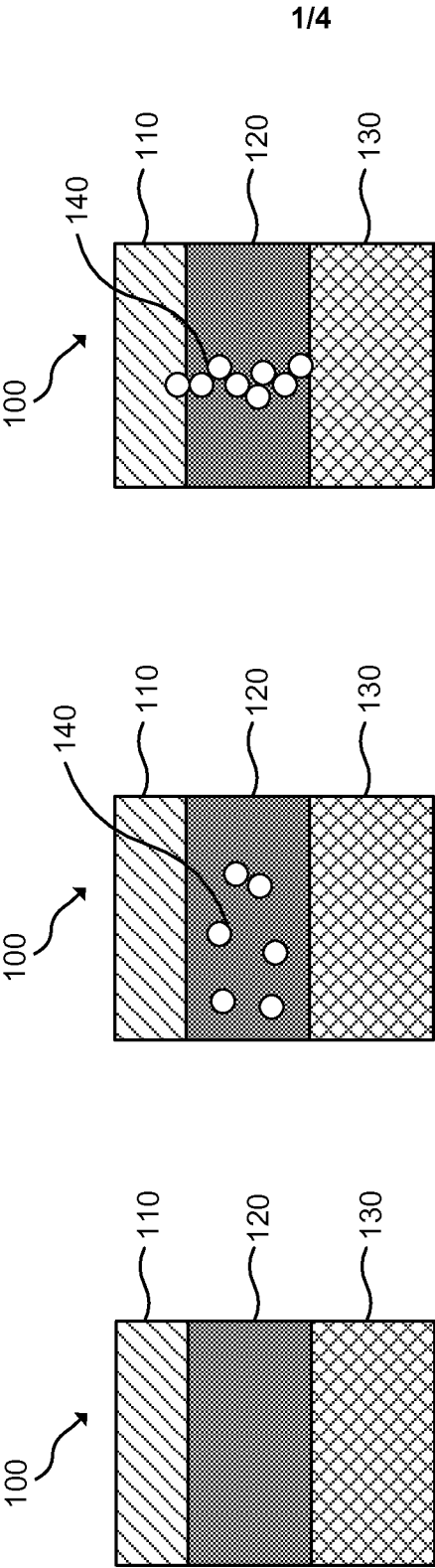


FIG. 1C

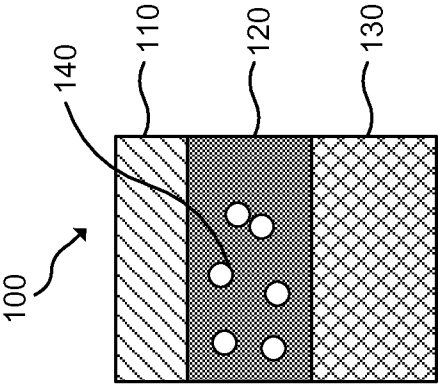


FIG. 1B

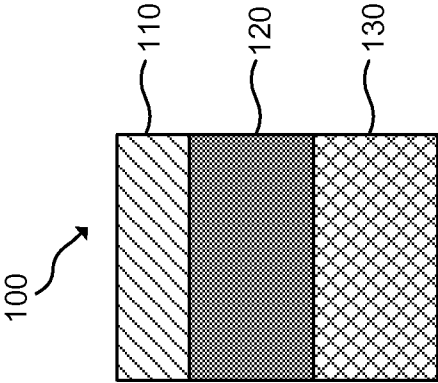


FIG. 1A

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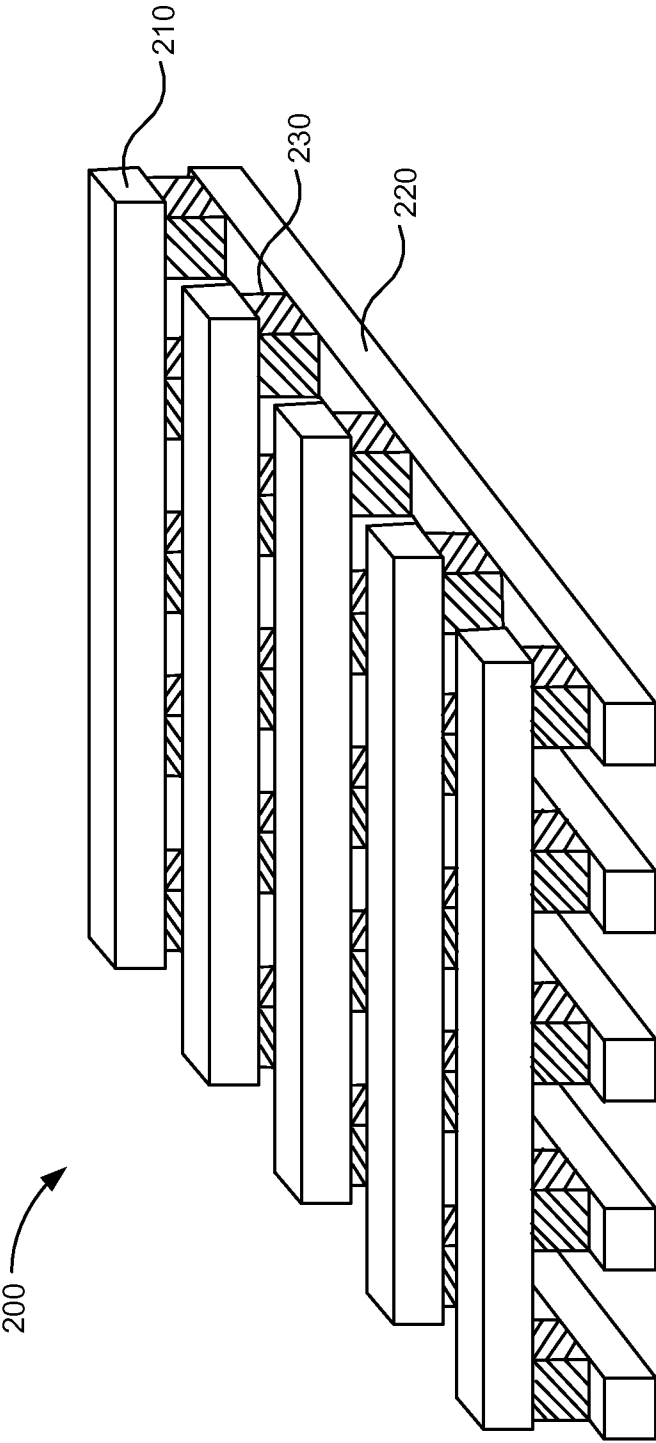


FIG. 2

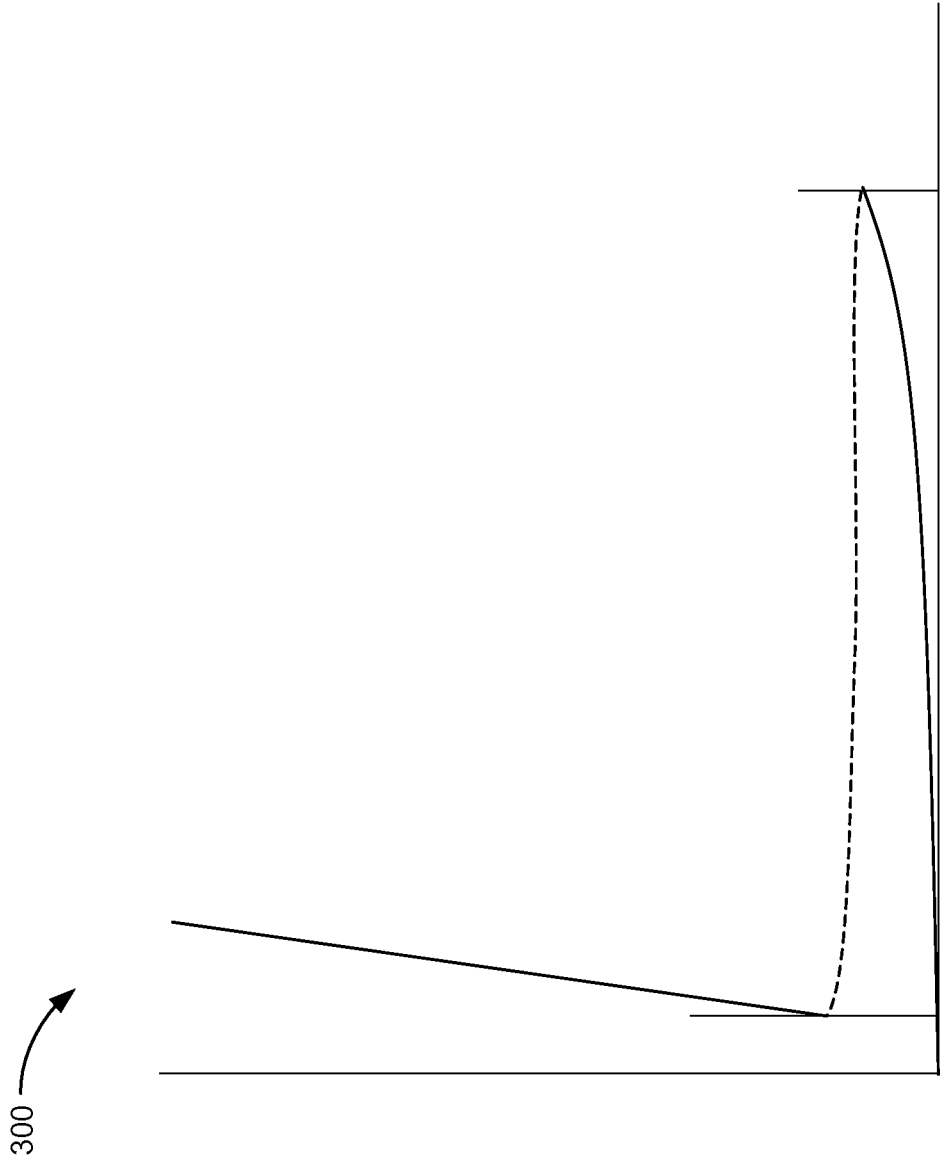


FIG. 3

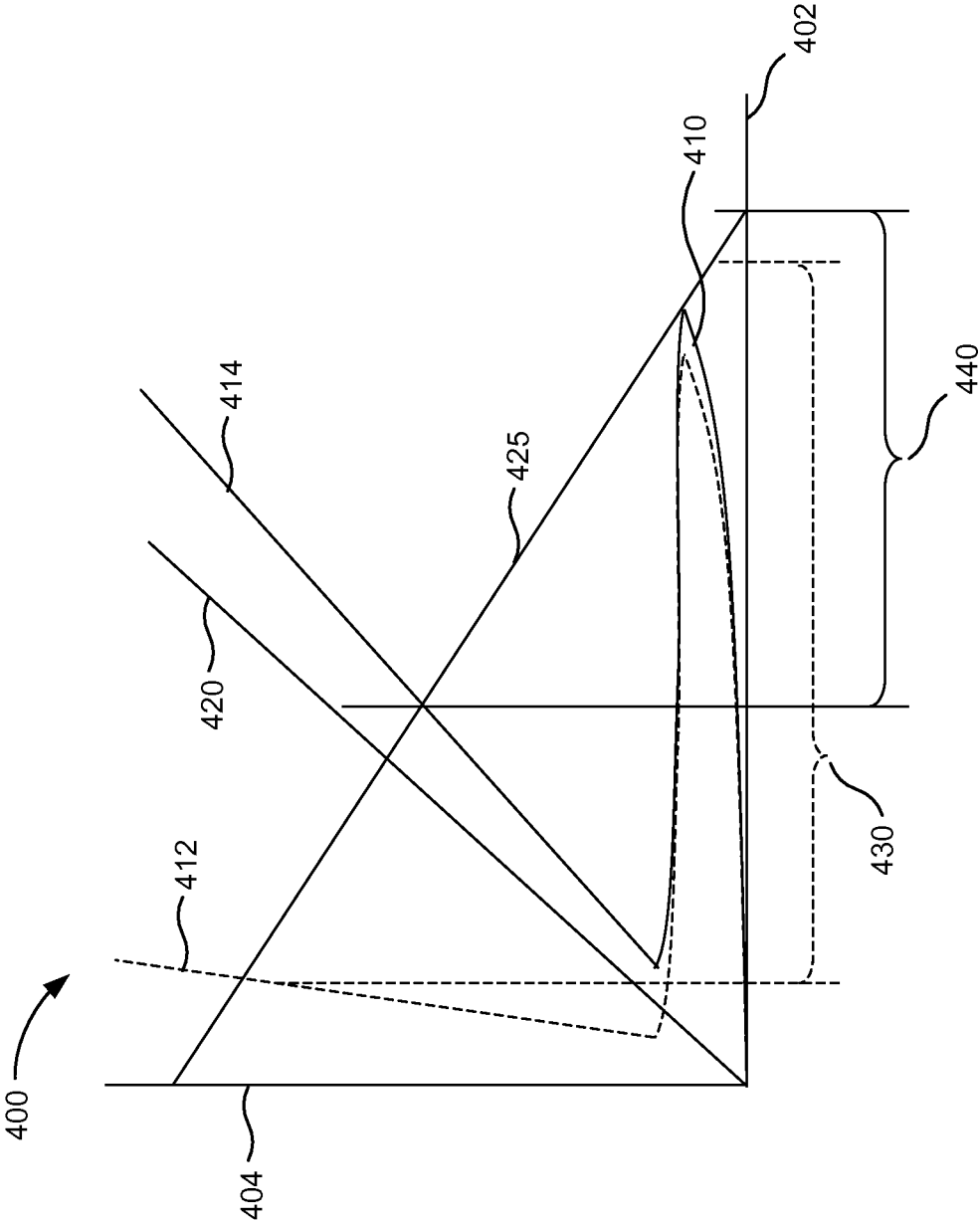


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/037604**A. CLASSIFICATION OF SUBJECT MATTER****H01L 27/115(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
H01L 27/115; H01L 45/00; G11C 11/00; H01L 27/24Documentation 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 modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: memristor, selector, solid electrolyte, resistor**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012-0250395 A1 (JEAN-FRANCOIS NODIN) 04 October 2012 See abstract, paragraphs [0088]-[0159] and figures 8-16.	1-15
Y	US 2014-0299834 A1 (INTERMOLECULAR INC. et al.) 09 October 2014 See abstract, paragraphs [0045]-[0078], [0137]-[0140] and figures 1A-4, 8.	1-15
A	US 2011-0002161 A1 (INSIK JIN et al.) 06 January 2011 See abstract, paragraphs [0026]-[0039] and figures 1-5.	1-15
A	US 2014-0264223 A1 (INTERMOLECULAR INC. et al.) 18 September 2014 See abstract, paragraphs [0043]-[0060] and figure 3.	1-15
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Information on patent family members

International application No.

PCT/US2015/037604

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