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(54) MAGNETIC MEMORY DEVICE

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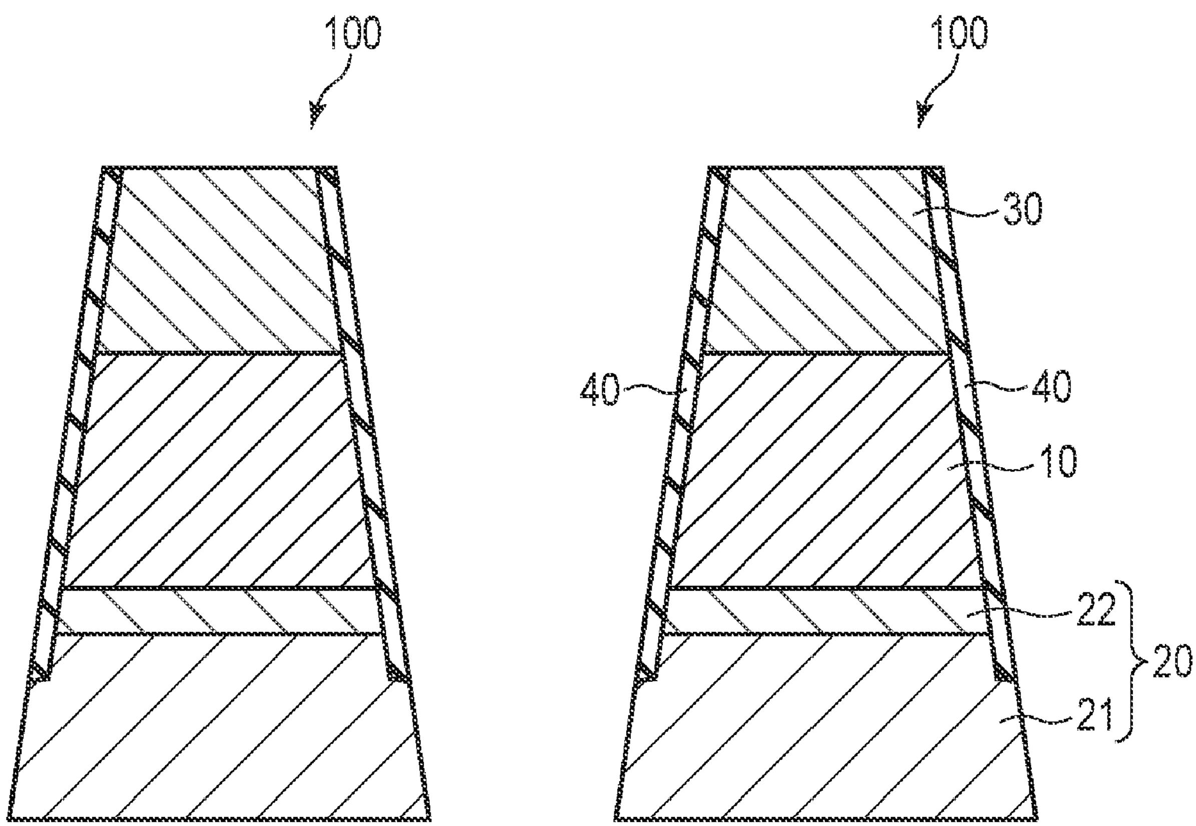
(57) **ABSTRACT**

According to one embodiment, a magnetic memory device includes an electrode, and a magnetoresistance effect element provided on the electrode. The electrode includes a first electrode portion and a second electrode portion provided between the magnetoresistance effect element and the first electrode portion and containing a metal element selected from molybdenum (Mo) and ruthenium (Ru).



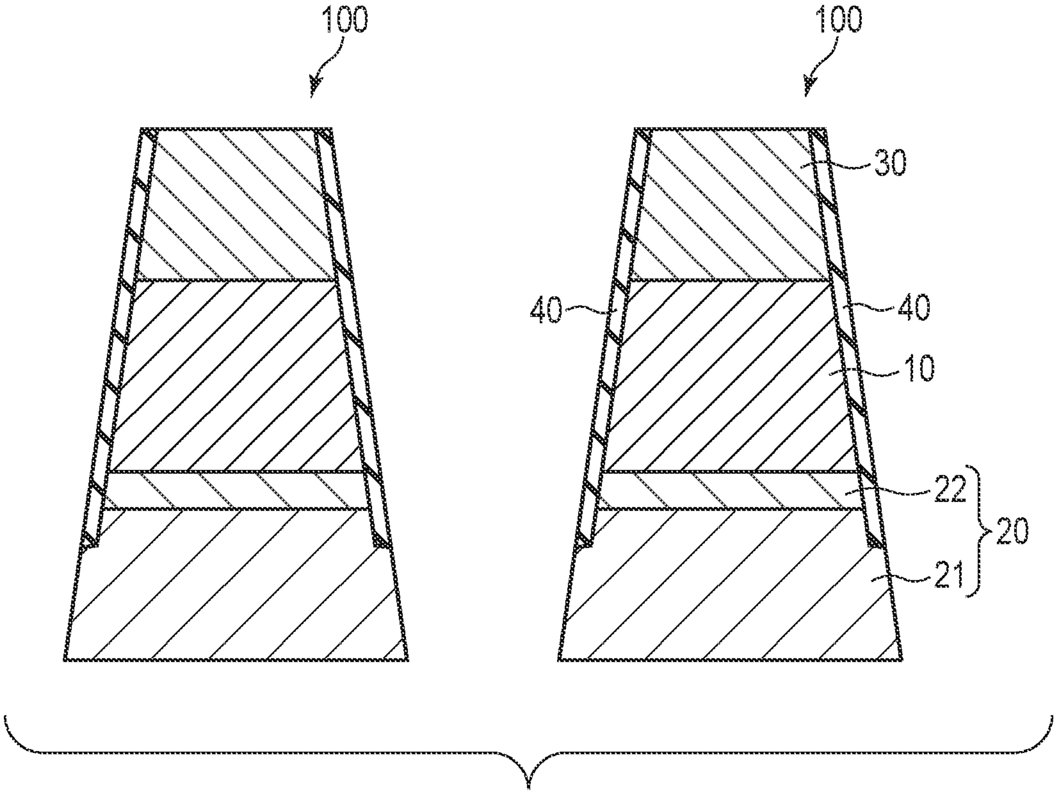


FIG. 1

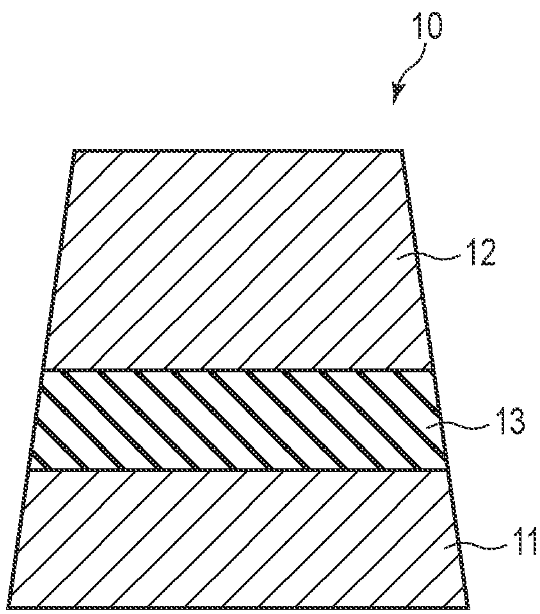


FIG. 2

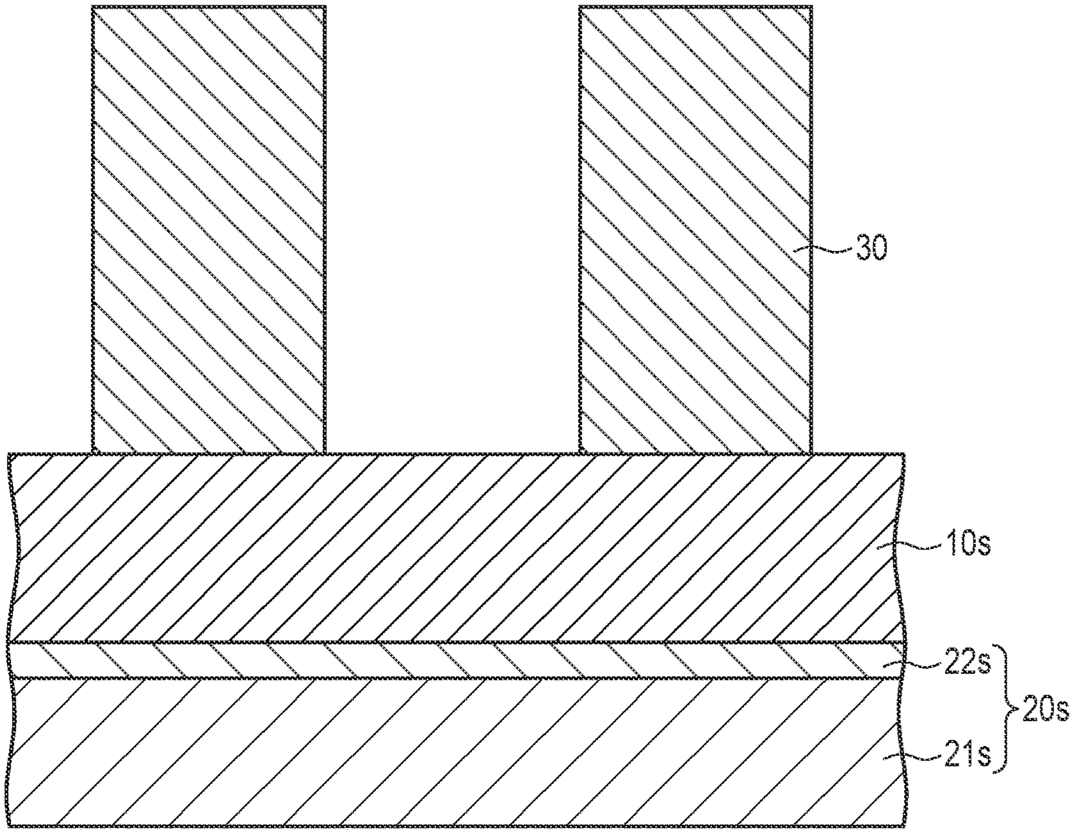


FIG. 3

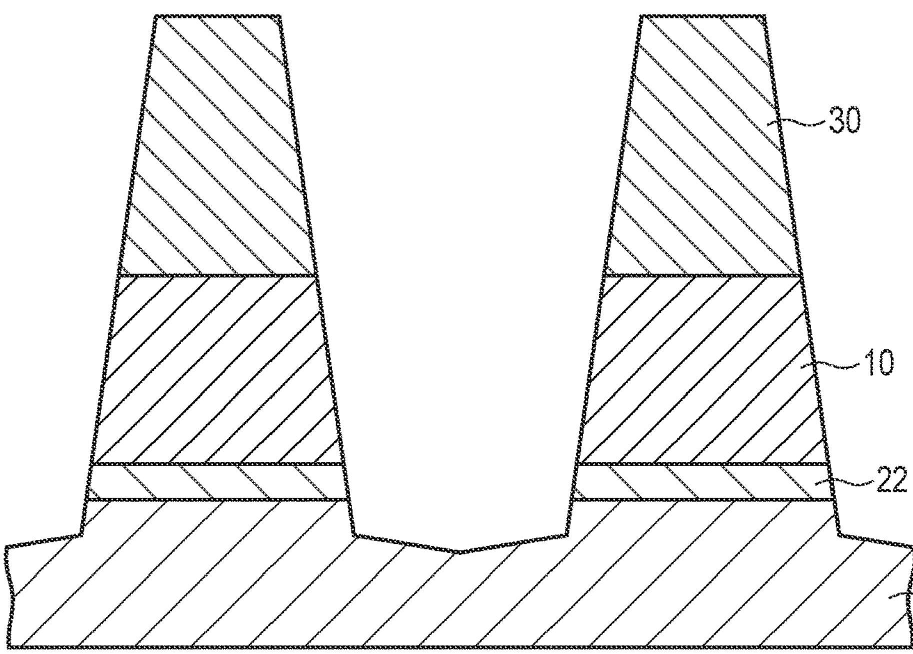
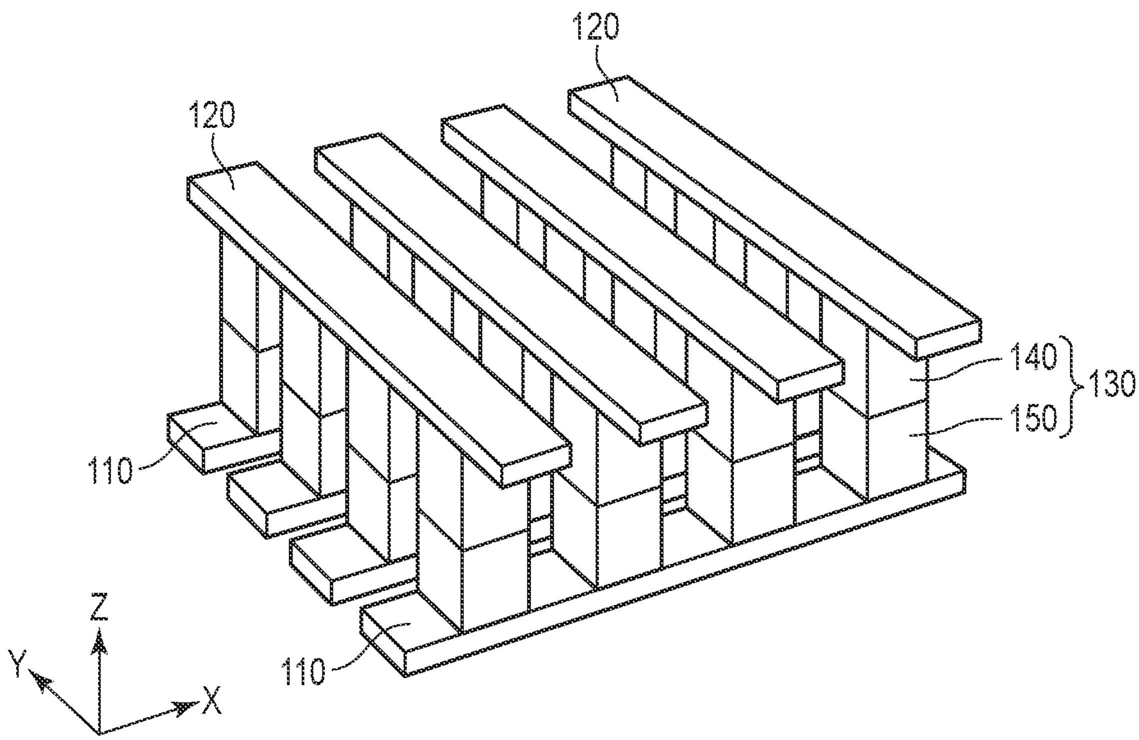


FIG. 4



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MAGNETIC MEMORY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2022-148039, filed Sep. 16, 2022, the entire contents of which are incorporated herein by reference.

FIELD

[0002] Embodiments described herein relate generally to a magnetic memory device.

BACKGROUND

[0003] A magnetic memory device has been proposed in which magnetoresistance effect elements are integrated on a semiconductor substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** is a cross-sectional view schematically showing a configuration of a magnetic memory device according to an embodiment.

[0005] FIG. **2** is a cross-sectional view schematically showing a configuration of a magnetoresistance effect element contained in the magnetic memory device according to the embodiment.

[0006] FIG. **3** is a cross-sectional view schematically illustrating a part of a method of manufacturing the magnetic memory device according to the embodiment.

[0007] FIG. **4** is a cross-sectional view schematically illustrating a part of a method of manufacturing the magnetic memory device according to the embodiment.

[0008] FIG. **5** is a perspective view schematically showing a brief configuration of an applied example of the magnetic memory device according to the embodiment.

DETAILED DESCRIPTION

[0009] In general, according to one embodiment, a magnetic memory device includes: an electrode; and a magnetoresistance effect element provided on the electrode, wherein the electrode includes a first electrode portion and a second electrode portion provided between the magnetoresistance effect element and the first electrode portion and containing a metal element selected from molybdenum (Mo) and ruthenium (Ru).

[0010] Embodiments will be described hereinafter with reference to the accompanying drawings.

[0011] FIG. **1** is a cross-sectional view schematically showing a configuration of a magnetic memory device according to the embodiment.

[0012] The magnetic memory device of this embodiment has a configuration in which a plurality of stacked structures **100** are provided on a lower structure (not shown) that includes a semiconductor substrate.

[0013] The stacked structures **100** each include a magnetoresistance effect element **10**, an electrode **20**, a hard mask **30**, and a sidewall insulating layer **40**.

[0014] FIG. **2** shows a schematic cross-sectional view of the magnetoresistance effect element **10**.

[0015] The magnetoresistance effect element **10** is a magnetic tunnel junction (MTJ) device and is provided on the electrode **20**. The magnetoresistance effect element **10** has a stacked structure including a storage layer (first magnetic layer) **11**, a reference layer (second magnetic layer) **12** and a tunnel barrier layer (nonmagnetic layer) **13**.

[0016] The storage layer **11** is a ferromagnetic layer having a variable magnetization direction and includes, for example, a CoFeB layer containing cobalt (Co), iron (Fe) and boron (B). The term "variable magnetization direction" means that the magnetization direction changes for a given write current.

[0017] The reference layer **12** is a ferromagnetic layer having a fixed magnetization direction and includes, for example, a CoFeB layer containing cobalt (Co), iron (Fe) and boron (B). The term "fixed magnetization direction" means that the magnetization direction does not change for a given write current.

[0018] The tunnel barrier layer **13** is an insulating layer provided between the storage layer **11** and the reference layer **12**, and includes, for example, an MgO layer containing magnesium (Mg) and oxygen (O).

[0019] When the magnetization direction of the storage layer **11** is parallel to the magnetization direction of the reference layer **12**, the magnetoresistance effect element **10** exhibits a low resistance state. When the magnetization direction of the storage layer **11** is antiparallel to the magnetization direction of the reference layer **12**, the magnetoresistance effect element **10** exhibits a high resistance state. Therefore, the magnetoresistance effect element **10** can store binary data according to its resistance state (low resistance state and high resistance state).

[0020] The magnetoresistance effect element **10** is constituted by a spin transfer torque (STT) type magnetoresistance effect element and has perpendicular magnetization. That is, the magnetization direction of the storage layer **11** is perpendicular to its main surface, and the magnetization direction of the reference layer **12** is perpendicular to its main surface.

[0021] Note that FIG. **2** shows a bottom-free type magnetoresistance effect element in which the storage layer **11** is located on a lower layer side of the reference layer **12**, but a top-free type magnetoresistance effect element in which the storage layer **11** is located on an upper layer side of the reference layer **12** may be used.

[0022] Let us now return to the explanation of FIG. **1**. The electrode **20** functions as a bottom electrode of the magnetoresistance effect element **10** and includes a first electrode portion **21** and a second electrode portion **22**.

[0023] The first electrode portion **21** contains carbon (C). Specifically, the first electrode portion **21** contains carbon as a major component and is formed from a carbon layer that contains substantially no elements other than carbon.

[0024] The second electrode portion **22** is provided between the magnetoresistance effect element **10** and the first electrode portion **21** and contains a metal element selected from molybdenum (Mo) and ruthenium (Ru). Specifically, the second electrode portion **22** is formed from a molybdenum layer or ruthenium layer that contains a metal element selected from molybdenum and ruthenium as a main component and substantially contains no elements other than molybdenum and ruthenium. The upper surface of the second electrode portion **22** is in contact with the lower surface of the magnetoresistance effect element **10**, and the lower surface of the second electrode portion **22** is in contact with the upper surface of the first electrode portion **21**.

[0025] The hard mask **30** is provided on the magnetoresistance effect element **10** and is formed of a conductive material. The hard mask **30** functions as a mask used to form the pattern of the magnetoresistance effect element **10** and the pattern of the electrode **20**. The hard mask **30** functions as the top electrode of the magnetoresistance effect element **10** as well.

[0026] The sidewall insulating layer **40** is provided along a side surface of the magnetoresistance effect element **10**, a side surface of the second electrode portion **22**, and an upper portion of a side surface of the first electrode portion **21**. The sidewall insulating layer **40** has the function of protecting the magnetoresistance effect element **10**.

[0027] Next, with reference to FIGS. **3**, **4** and **1**, a method of manufacturing the magnetic memory device according to the embodiment will be described.

[0028] First, as shown in FIG. **3**, an electrode layer **20***s* including a first electrode layer **21***s* and a second electrode layer **22***s* located on the first electrode layer **21***s* is formed on a lower structure (not shown) including a semiconductor substrate. The first electrode layer **21***s* is formed from a carbon layer and the second electrode layer **22***s* is formed from a molybdenum layer or a ruthenium layer. Subsequently, a magnetoresistance effect element layer **10***s* including a storage layer, a reference layer, and a tunnel barrier layer is formed on an electrode layer **20***s*. Further, a hard mask **30** is formed on the magnetoresistance effect element layer **10***s*.

[0029] Next, as shown in FIG. **4**, the magnetoresistance effect element layer **10***s* and the second electrode layer **22***s* are etched using the hard mask **30** as a mask. More specifically, the etching is performed by ion beam etching (IBE). In this etching process, the upper portion of the first electrode layer **21***s* is etched as well. Here, a portion of the hard mask **30** is etched as well. With this etching process, the pattern of the magnetoresistance effect element **10** and the pattern of the second electrode portion **22** can be obtained.

[0030] Next, as shown in FIG. **1**, the sidewall insulating layer **40** is formed on a side surface of the pattern obtained in the etching process of FIG. **4**. Subsequently, the first electrode layer **21***s* is etched using the hard mask **30** as a mask to form the first electrode portion **21**. More specifically, the etching is performed by reactive ion etching (RIE). At this time, the magnetoresistance effect element **10** is protected by the sidewall insulating layer **40**.

[0031] In this manner, the magnetic memory device shown in FIG. **1** is formed.

[0032] As described above, in this embodiment, the electrode **20** includes a second electrode portion **22** provided between the magnetoresistance effect element **10** and the first electrode portion **21**, and the second electrode portion **22** contains a metal element selected from molybdenum and ruthenium. With this configuration, according to this embodiment, proper patterning as described below can be carried out.

[0033] In the case where the second electrode portion **22** is not provided, the material component of the magnetoresistance effect element layer **10***s* generated in the IBE process of FIG. **4** may undesirably remain on the surface of the first electrode layer **21***s* by knocking. That is, the material component of the magnetoresistance effect element layer **10***s* may undesirably remain on the surface of the first electrode layer **21***s* as residue. Therefore, when etching the first electrode layer **21***s* in the RIE process after the process shown in FIG. **4**, the etching of the first electrode layer **21***s* may be inhibited by the residue remaining on the surface of the first electrode layer **21***s*. As a result, a portion of the first electrode layer **21***s* may remain between adjacent stacked structures **100**, and the first electrode layer **21***s* may not be sufficiently separated between adjacent stacked structures **100**. In particular, as the magnetic memory device is miniaturized and the distance between adjacent stacked structures **100** becomes smaller, there rises an increasing possibility that the first electrode layer **21***s* cannot be sufficiently separated.

[0034] In this embodiment, a second electrode layer **22***s* containing a metal element selected from molybdenum and ruthenium is provided between the magnetoresistance effect element layer **10***s* and the first electrode layer **21***s*. Molybdenum and ruthenium are less likely to remain on the surface of the first electrode layer **21***s* due to knocking. Further, in the IBE process shown in FIG. **4**, since the second electrode layer **22***s* is etched after the magnetoresistance effect element layer **10***s* is etched, the material components of the magnetoresistance effect element layer **10***s* generated by IBE are removed when the second electrode layer **22** is etched. Therefore, there is no substantial residue remaining on the surface of the first electrode layer **21***s* that would inhibit RIE. In this manner, the first electrode layer **21***s* can be etched reliably in the RIE process, and the first electrode layer **21***s* can be reliably separated between adjacent stacked structures **100**.

[0035] FIG. **5** is a perspective view schematically showing a brief structure of a magnetic memory device to which the stacked structure **100** described above is applied. Note here that X, Y, and Z directions shown in FIG. **5** are intersect each other, and more specifically, the X, Y, and Z directions are orthogonal to each other.

[0036] The magnetic memory device shown in FIG. **5** includes a plurality of first wiring lines **110** each extending in the X direction, a plurality of second wiring lines **120** each extending in the Y direction, and a plurality of memory cells **130** each provided between each respective one of the plurality of first wiring lines **110** and each respective one of the plurality of second wiring lines **120**. The first wiring lines **110** correspond to word lines, whereas the second wiring lines **120** correspond to bit lines, or vice versa.

[0037] The memory cells **130** each includes a magnetoresistance effect element **140** and a selector (switching element) **150** connected in series to the magnetoresistance effect element **140**, and the magnetoresistance effect element **140** and the selector **150** are provided between the respective first wiring line **110** and the respective second wiring line **120**. The memory cell **130** includes the stacked structure **100** described above, and in FIG. **5**, the magnetoresistance effect element **140** substantially corresponds to the stacked structure **100** described above.

[0038] The selector **150** is a 2-terminal type switching device including a bottom electrode, a top electrode, and a selector material layer provided between the bottom electrode and the top electrode, and has characteristics in which it changes from an off state to an on state when the voltage applied between the two terminals reaches or exceeds a threshold voltage.

[0039] That is, by applying a voltage between a first wiring line **110** and a second wiring line **120** to set the respective selector **150** to the on state, a current flows to the magnetoresistance effect element **140**, thus making it possible to write to or read from the magnetoresistance effect element **140**.

[0040] Note that as a material for the selector **150**, for example, a material having such properties (snap-back properties) that the resistance value drops sharply at a predetermined voltage and the applied voltage drops sharply therewith and the current increases can as well be applied.

[0041] Further, the electrode **20** shown in FIG. **1** may as well be used as the bottom electrode of the magnetoresistance effect element **140** and the top electrode of the selector **150**.

[0042] By applying the above-described stacked structure **100** to a magnetic memory device as shown in FIG. **5**, an excellent magnetic memory device can be obtained.

[0043] Note that in FIG. **5**, the magnetoresistance effect element **140** is provided on the upper layer side of the selector, but the magnetoresistance effect element **140** may as well be provided on the lower layer side of the selector.

[0044] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel devices and methods described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modification as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A magnetic memory device comprising:

an electrode; and

a magnetoresistance effect element provided on the electrode,

wherein

the electrode includes a first electrode portion and a second electrode portion provided between the magnetoresistance effect element and the first electrode portion and containing a metal element selected from molybdenum (Mo) and ruthenium (Ru).

2. The device of claim **1**, wherein

the first electrode portion contains carbon (C).

3. The device of claim **1**, further comprising:

a hard mask provided on the magnetoresistance effect element.

4. The device of claim **1**, further comprising:

a sidewall insulating layer provided along a side surface of the magnetoresistance effect element and a side surface of the second electrode portion.

5. The device of claim **1**, wherein

the magnetoresistance effect element includes a first magnetic layer having a variable magnetization direction, a second magnetic layer having a fixed magnetization direction, and a nonmagnetic layer provided between the first magnetic layer and the second magnetic layer.

6. The device of claim **1**, further comprising:

a switching element connected in series to the magnetoresistance effect element.

7. The device of claim **6**, further comprising:

a first wiring line extending in a first direction; and

a second wiring line extending in a second direction intersecting the first direction,

wherein

the magnetoresistance effect element and the switching element are provided between the first wiring line and the second wiring line.

8. A method of manufacturing a magnetic memory device, comprising:

forming an electrode layer including a first electrode layer and a second electrode layer on the first electrode layer;

forming a magnetoresistance effect element layer on the electrode layer;

forming a hard mask on the magnetoresistance effect element layer;

etching the magnetoresistance effect element layer and the second electrode layer using the hard mask as a mask,

wherein

the second electrode layer contains a metal element selected from molybdenum (Mo) and ruthenium (Ru).

9. The method of claim **8**, wherein

the first electrode layer contains carbon (C).

10. The method of claim **8**, wherein

etching the magnetoresistance effect element layer and the second electrode layer is performed by ion beam etching (IBE).

11. The method of claim **8**, further comprising:

forming a sidewall insulating layer on a side surface of a pattern obtained by etching the magnetoresistance effect element layer and the second electrode layer; and

etching the first electrode layer using the hard mask as a mask after forming the sidewall insulating layer.

12. The method of claim **11**, wherein

etching the first electrode layer is performed by reactive ion etching (RIE).

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