

A MAGNETIC STRUCTURE AND A MAGNETIC RECORDING MEDIUM COMPRISING THE SAME

Cross-Reference to Related Application

[0001] This application claims the benefit of priority of Singapore Patent Application No. 201000386-1, filed 19 January 2010, the contents of which being hereby incorporated by reference in its entirety for all purposes.

Technical Field

[0002] The invention relates to a magnetic recording medium, and in particular, to a heat-assisted magnetic recording medium comprising a switchable coupling layer.

Background

[0003] In conventional magnetic recording media, high magnetic anisotropy is required to overcome the so-called super-paramagnetic effect. However, high magnetic anisotropy places a tremendous burden on the write requirements and the current write pole material is unable to generate fields that are sufficiently strong to enable recordings on such materials. Heat-assisted magnetic recording (HAMR) and composite media including exchange-coupled hard/soft magnetic layers are attractive approaches to attain high-areal density. The use of alloys such as iron platinum (FePt)/iron rhodium (FeRh) bilayer composite media for heat-assisted recording (composite HAMR media) has been proposed. Unlike conventional composite media composition, FeRh was chosen because it exhibits meta-magnetic transition. FeRh is anti-ferromagnetic at room temperature and undergoes a transition to the ferromagnetic state at temperatures around 150-200 °C. Therefore, the FePt/FeRh bilayer can provide additional thermal stability at

room temperature while the coupling between the FePt recording layer and the FeRh coupling layer may reduce the switching field after the meta-magnetic transition.

[0004] However, for composite HAMR media, a FeRh layer having a thickness of more than 30 nm is often needed and the entire FeRh layer has to be heated above the transition temperature which may require higher heating power for writing purposes. Moreover, a thick FeRh layer renders the control of the microstructure of the FePt recording layer for recording purposes difficult.

Summary

[0005] Various embodiments provide for a HAMR medium with a reduced switching field, which overcomes, or at least alleviates, the above problems.

[0006] Various embodiments provide for a magnetic structure that allows a low switching field by use of a coupling layer having a thickness less than 30 nm, and preferably less than 10 nm.

[0007] Various embodiments provide a magnetic structure. The magnetic structure may include:

a first magnetic layer including a soft magnetic material;

a second magnetic layer including a hard magnetic material; and

a coupling layer between the first magnetic layer and the second magnetic layer, wherein the coupling layer includes a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature.

[0008] Various embodiments provide a magnetic recording medium. The magnetic recording medium may include:

a substrate; and

a magnetic structure including a first magnetic layer comprising a soft magnetic material; a second magnetic layer including a hard magnetic material; and a coupling layer between the first magnetic layer and the second magnetic layer, wherein the coupling layer includes a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature, wherein the first magnetic layer is formed on the substrate.

[0009] Various embodiments provide a method of manufacturing a magnetic recording medium. The method may include:

forming a first magnetic layer on a substrate, wherein the first magnetic layer includes a soft magnetic material;

forming a coupling layer on the first magnetic layer, wherein the coupling layer includes a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature; and

forming a second magnetic layer on the coupling layer, wherein the second magnetic layer includes a hard magnetic material.

Brief Description of the Drawings

[0010] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily drawn to scale, emphasis instead generally being placed upon illustrating the principles of various

embodiments. In the following description, various embodiments of the invention are described with reference to the following drawings.

[0011] **Fig. 1** shows a magnetic structure in accordance with various embodiments.

[0012] **Fig. 2** shows a magnetic recording medium in accordance with various embodiments.

[0013] **Fig. 3** shows a graph showing hysteresis loops at 300 K (dashed line) and 473 K (solid line) for the magnetic recording medium of **Fig. 2**.

[0014] **Fig. 4** shows a graph showing the coercivity as a function of exchange-coupling in the magnetic recording medium of **Fig. 2**.

[0015] **Fig. 5** shows a graph showing the coercivity as a function of the FeCo layer thickness in the magnetic recording medium of **Fig. 2**.

Description

[0016] The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the invention may be practised. These embodiments are described in sufficient detail to enable those skilled in the art to practise the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the invention. The various embodiments are not necessarily mutually exclusive, as

some embodiments can be combined with one or more other embodiments to form new embodiments.

[0017] An exemplary embodiment of one aspect of the present invention relates to a magnetic structure **12** having a basic structure composed of three layers **12a**, **12b**, **12c** as shown in **Fig. 1**. A coupling layer **12b** is formed and sandwiched between a first magnetic layer **12c** and a second magnetic layer **12a**. Advantageously, each respective layer **12a**, **12b**, **12c** has a different magnetic property.

[0018] In various embodiments, the first magnetic layer **12c** may include a soft magnetic material having a high magnetization saturation, and functions both as an assist writing layer and a soft magnetic underlayer in a magnetic recording medium. Suitable soft magnetic materials include, but are not limited to, Fe materials and alloys such as Fe, FeCo, FeNi, FeNiCo, and FeCrCo. Other suitable materials will depend on the materials included in the second magnetic layer **12a** and will be apparent to a person skilled in the art. In one embodiment, the magnetic material included in the second magnetic layer **12a** has a (001) orientation and Fe alloys with Body-Centered Cubic (BCC) structures are suitable materials for the first magnetic layer **12c** since (002) oriented BCC structure has a similar atomic arrangement with that of a (001) oriented structure in the second magnetic layer **12a**, which is essential to induce the (001) orientation in the second magnetic layer **12a**. In various embodiments, the first magnetic layer **12c** may have a layer thickness in the range from about 10 nm to about 100 nm, e.g. a layer thickness in the range from about 10 nm to about 80 nm, e.g. a layer thickness in the range from about 10 nm to about 50 nm.

[0019] In various embodiments, the second magnetic layer **12a** may include a hard magnetic material having small and magnetically isolated grains, and functions as a recording layer in a magnetic recording medium. The hard magnetic material is a high anisotropy material with a room temperature coercivity so high that it is incapable of being written by a conventional write head, and may be perpendicular type recording material. Suitable hard magnetic materials include, but are not limited to, FePt or CoPt with its c-axis substantially out-of-plane with respect to a magnetic recording medium substrate for perpendicular recording. Chemically-ordered alloys of FePt and CoPt, in their bulk form, are known as tetragonal L1₀-ordered phase materials (also called CuAu(I) materials). Such L1₀ phase materials are known for their high magneto-crystalline anisotropy and magnetic moment, properties that are desirable for high density magnetic recording materials. The hard magnetic materials may also include alloys based on the FePt and CoPt L1₀ phase, i.e. FePt-Y and CoPt-Y where Y may be Ni, Au, Cu, Pd, or Ag, as well as with composite oxide materials such as TiO₂, SiO₂, Ta₂O₅, ZrO₂, ZrO, MgO, and B₂O₃, or with elemental Ag, Cu, Ta, and C. While these materials in general have similar high anisotropy as the binary alloy FePt and CoPt, they allow additional control over the magnetic and structural properties of the magnetic recording medium. Other materials with perpendicular magnetic anisotropy include CoPt, Co-Pd, Fe-Pt, and Fe-Pd multi-layers. In various embodiments, the second magnetic layer **12a** may have a layer thickness in the range from about 7 nm to about 20 nm, e.g. a layer thickness in the range from about 7 nm to about 15 nm, e.g. a layer thickness in the range from about 7 nm to about 12 nm.

[0020] In various embodiments, a coupling layer **12b** may be sandwiched between the first magnetic layer **12c** and the second magnetic layer **12a** and may include a

material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature. The coupling layer **12b** is anti-ferromagnetic and magnetically isolates the first magnetic layer **12c** from the second magnetic layer **12a** at temperatures below the transition temperature. The coupling layer **12b** is ferromagnetic and magnetically exchange-couples the first magnetic layer **12c** and the second magnetic layer **12a** at temperatures above the transition temperature. Suitable phase switchable materials for the coupling layer **12b** include, but are not limited to, FeRh and FeRhX where X is an element selected from the group consisting of Ir, Pt, Pd, Ru, Re, and Os and X is present at less than about 10 at.% based on the total number of atoms present in FeRhX. Other possible phase switchable materials include MnZn, SmZn, GdZn, TbZn, DyZn, HoZn, and ErZn. In various embodiments, the coupling layer **12b** may have a layer thickness in the range from about 3 nm to about 10 nm, e.g. a layer thickness in the range from about 3 nm to about 8 nm, e.g. a layer thickness in the range from about 3 nm to about 5 nm.

[0021] In one embodiment, the magnetic structure may include FeCo included in the first magnetic layer **12c**; FePt included in the second magnetic layer **12a**; and FeRh included in the coupling layer **12b**. In **Fig. 1**, the orientations of moments (spins) in each respective layer **12a**, **12b**, **12c** are shown by respective arrows **22a**, **22b**, **22c**. Prior to heating, the FeCo layer **12c** is an in-plane magnetization film in which the magnetization direction is in parallel to the major plane thereof whereas the FePt layer **12a** is a perpendicular magnetization film in which the magnetization direction is perpendicular to the major plane. The spins **22c**, **22a** in the FeCo layer **12c** and the FePt layer **12a** are shown to be orientated substantially orthogonal to each other. The FeRh alloy material in the coupling layer **12b** is in anti-ferromagnetic state at room

temperature but the state changes to ferromagnetic state when heated above a transition temperature. Thus, at room temperature prior to heating, the FePt recording layer **12a** and the FeCo assist writing layer **12c** are magnetically isolated from each other by the anti-ferromagnetic FeRh coupling layer **12b**. After meta-magnetic transition of the FeRh coupling layer **12b** by heating to 150-200 °C, the FePt recording layer **12a** and the FeCo assist writing layer **12c** are exchange-coupled together through the ferromagnetic FeRh coupling layer **12b**. The spins **22c**, **22a** in the FeCo layer **12c** and the FePt layer **12a** are shown to have changed orientation and to align in a common general direction. As a result, the switching field to reverse a magnetized bit in the FePt recording layer **12a** can be greatly reduced. With a lower switching field in the recording layer **12a**, the heating power for writing information in the recording layer **12a** can be as low as 150-200 °C. The reduction of the switching field is attributed to the exchange-spring effects and the demagnetizing effects of FeCo due to its high magnetization value of 2.45 Tesla. The heating may be provided by a heating element such as a laser. The heat may be removed and the FeRh coupling layer **12b** may cool to a temperature below the transition temperature, with the magnetization of the FePt recording layer **12a** remaining in its reversed state. In this way, the magnetic structure **12** can be used for recording binary data. In various embodiments, the transition temperature may be in the range from about 100 °C to about 300 °C, e.g. in the range from about 100 °C to about 250 °C, e.g. a transition temperature in the range from about 100 °C to about 200 °C.

[0022] Various embodiments relate to a magnetic recording medium **10** including a substrate **16** and the magnetic structure **12** of **Fig. 1** as shown in **Fig. 2**.

[0023] As outlined above, the magnetic structure **12** may include the first magnetic layer **12a** including a soft magnetic material; the second magnetic layer **12c** including the hard magnetic material; and the coupling layer **12b** between the first magnetic layer **12c** and the second magnetic layer **12a**, wherein the coupling layer **12b** may include a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature. The first magnetic layer **12c** may be formed directly or indirectly on (in general may be disposed over) the substrate **16**.

[0024] The substrate **16** may be a disk substrate and is typically glass, although any conventional disk substrate material may also be suitable.

[0025] An adhesion control layer **14** may optionally be formed on and positioned adjacent to a disk substrate **16**. Suitable materials for the adhesion control layer **14** include, but are not limited to, Ti and Ta with a thickness of approximately 3 to 5 nm. Conventional thin film deposition techniques such as RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy may be used to form the adhesion control layer **14**.

[0026] A seed layer or underlayer **18** of a small grain size may optionally be formed on and positioned adjacent to the adhesion control layer **14** for the purpose of downsizing and/or for orientation control of the crystal grains of the second magnetic layer **12a** (i.e. the recording layer). Suitable seed layer or underlayer **18** materials include, but are not limited to, Cr alloys such as CrRu, CrMo, CrW, RuAl, TiN and MgO with a thickness of about 30 to about 100 nm, e.g. a layer thickness in the range from about 30 nm to about 60 nm. Conventional thin film deposition techniques such as

RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy may be used to form the seed layer or underlayer **18**.

[0027] The first magnetic layer **12c** including the soft magnetic material may be formed and positioned adjacent to the seed or underlayer **18**. In various embodiments, the first magnetic layer **12c** functions both as an assist writing layer and a soft magnetic underlayer. Thickness of the first magnetic layer **12c** may be in the range from about 10 nm to about 100 nm, e.g. a layer thickness in the range from about 10 nm to about 80 nm, e.g. a layer thickness in the range from about 10 nm to about 50 nm. Conventional thin film deposition techniques such as RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy may be used to form the first magnetic layer **12c**.

[0028] The coupling layer **12b** including the material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature may be formed and positioned adjacent to the first magnetic layer **12c**. The thickness of the coupling layer **12b** may be in the range from about 3 nm to about 10 nm, e.g. a layer thickness in the range from about 3 nm to about 8 nm, e.g. a layer thickness in the range from about 3 nm to about 5 nm. Conventional thin film deposition techniques such as RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy may be used to form the coupling layer **12b**.

[0029] The second magnetic layer **12a** including the hard magnetic material may be formed and positioned adjacent to the coupling layer **12b**. The second magnetic layer **12a** forms a recording layer of the magnetic recording medium **10**. The thickness of the recording layer **12a** may be in the range from about 7 nm to about 20 nm, e.g. a layer

thickness in the range from about 7 nm to about 15 nm, e.g. a layer thickness in the range from about 7 nm to about 12 nm. For recording purpose, the recording layer **12a** may be FePt and should preferably have a (001) orientation. The seed or underlayer **18** may optionally be provided to control and/or induce the (001) orientation in the FePt recording layer **12a** so as to render the FePt recording layer **12a** suitable for magnetic recording. Conventional thin film deposition techniques such as RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy may be used to form the second magnetic layer **12a**.

[0030] A protective overcoat **20**, which may include a lubricant layer, may be formed and positioned adjacent to the second magnetic layer **12a**. The overcoat **20** may be diamond-like amorphous carbon or nitrogenated carbon, or any other conventional disk overcoat. Conventional thin film deposition techniques such as RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy may be used to form the overcoat **20**.

[0031] In one embodiment (not shown), a layer of MgO, Pt, Ru, Ta, or TiN having a thickness in the range from about 0.3 nm to about 0.8 nm, e.g. a layer thickness in the range from about 0.3 nm to about 0.6 nm, e.g. a layer thickness in the range from about 0.3 nm to about 0.5 nm, may be formed and sandwiched between the coupling and first magnetic layers **12b**, **12c** to control the magnetic coupling and to reduce interlayer diffusion between between the two layers **12b**, **12c**.

[0032] In another embodiment (not shown), a layer of MgO, Pt, Ru, Ta, or TiN having a thickness in the range from about 0.3 nm to about 0.8 nm, e.g. a layer thickness

in the range from about 0.3 nm to about 0.6 nm, e.g. a layer thickness in the range from about 0.3 nm to about 0.5 nm, may be formed and sandwiched between the coupling and second magnetic layers **12b**, **12a** to control the magnetic coupling and to reduce the interlayer diffusion between the two layers **12b**, **12a**.

[0033] In a further embodiment (not shown), two separate layers of MgO, Pt, Ru, Ta, or TiN each having a thickness in the range from about 0.3 nm to about 0.8 nm, e.g. a layer thickness in the range from about 0.3 nm to about 0.6 nm, e.g. a layer thickness in the range from about 0.3 nm to about 0.5 nm, may be provided. The first MgO, Pt, Ru, Ta, or TiN layer may be sandwiched between the coupling and first magnetic layers **12b**, **12c** to control the magnetic coupling and to reduce interlayer diffusion between the two layers **12b**, **12c**, while the second MgO, Pt, Ru, Ta, or TiN layer may be sandwiched between the coupling and second magnetic layers layers to control the magnetic coupling and to reduce the interlayer diffusion between the two layers **12b**, **12a**. The MgO, Pt, Ru, Ta, or TiN layer may be formed by conventional thin film deposition techniques such as RF or DC magnetron sputtering, ion beam deposition, or molecular beam epitaxy.

[0034] An advantage of using the present magnetic structure in a magnetic recording medium is that a higher heating efficiency may be achieved since only a very thin (3-10 nm) coupling layer **12b** of FeRh is needed to be heated above the meta-magnetic transition temperature. In addition, the first magnetic layer **12c** of FeCo provides a higher magnetic moment which further reduces the switching field as compared to conventional FePt/FeRh bilayer. The first magnetic layer **12c** of FeCo also functions as a soft magnetic underlayer to enhance writing. Moreover, the present

magnetic structure has the same thermal stability at room temperature as conventional FePt/FeRh bilayer and yet the present magnetic structure is considerably cheaper as compared to conventional FePt/FeRh bilayer since Rh is more expensive than Co.

[0035] Various embodiments relate to a method of manufacturing a magnetic recording medium, comprising forming a first magnetic layer on a substrate, wherein the first magnetic layer includes a soft magnetic material; forming a coupling layer on the first magnetic layer, wherein the coupling layer includes a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature; and forming a second magnetic layer on the coupling layer, wherein the second magnetic layer includes a hard magnetic material.

[0036] In one embodiment, a thin layer of Ti of approximately 3 to 5 nm, which may act as an adhesion control layer **14**, may be deposited onto a glass substrate **16** at room temperature using magnetron sputtering. On the adhesion control layer **14**, a seed/underlayer **18** of CrRu having a thickness in the range from about 30 nm to about 100 nm, e.g. a layer thickness in the range from about 30 nm to about 70 nm, e.g. a layer thickness in the range from about 30 nm to about 50 nm, may be deposited at 250 to 350 °C. This is an interlayer used for orientation control. After that, a first magnetic layer **12c** of FeCo having a thickness in the range from about 10 nm to about 100 nm, e.g. a layer thickness in the range from about 10 nm to about 80 nm, e.g. a layer thickness in the range from about 10 nm to about 50 nm may be deposited at 300 °C or above using magnetron sputtering. This layer may work both as a soft underlayer and an assist writing layer. On top of the first magnetic layer **12c**, the coupling layer **12b** of FeRh for phase transition temperature control having a thickness in the range from

about 3 nm to about 10 nm, e.g. a layer thickness in the range from about 3 nm to about 8 nm, e.g. a layer thickness in the range from about 3 nm to about 5 nm may be deposited at 350 to 500 °C. This is an exchange switching layer (on/off) coupling between the FeCo soft underlayer **12c** and the FePt recording layer **12a**. Then the recording layer **12a** of FePt having a thickness in the range from about 7 nm to about 20 nm, e.g. a layer thickness in the range from about 7 nm to about 15 nm, e.g. a layer thickness in the range from about 7 nm to about 12 nm may be deposited at a temperature in the range from about 300 °C to about 400 °C. This layer is for the recording of information. Finally, an overcoat **20** of diamond-like carbon with variable thickness and temperature may be deposited on the recording layer to protect the layers underneath it.

[0037] Hysteresis loops for the magnetic recording medium **10** with the magnetic structure **12** in accordance with various embodiments at 300 K and 473 K are shown in **Fig. 3**. The magnetic structure **12** may include a first magnetic layer **12c** of FeCo; a coupling layer **12b** of FeRh; and a second magnetic layer **12a** of FePt. Magnetic reversal starts in the soft magnetic layer, forming a Neel-type domain wall when an external field is applied. This wall propagates towards and penetrates the hard magnetic layer, assisting in the switching. At 300 K, the FeRh layer **12b** is still anti-ferromagnetic and the magnetic structure **12** exhibits two distinct switching states. The FeRh layer **12b** is ferromagnetic at elevated temperature of 473 K and allows the propagation of the domain wall into the FePt layer **12a**, facilitating a single state reversal at lower switching fields.

[0038] **Fig. 4** shows the coercivity as a function of exchange coupling. Initial increment of exchange constant C^* (normalized exchange coupling strength between the FeCo and FePt layers) from 0.25 to 0.5 reduces the coercivity by a factor of 2. Subsequent increase of exchange coupling only yields smaller changes to the coercivity. Therefore, a sufficiently strong coupling between layers 12a and 12b, and between layers 12b and 12c, would be required to significantly reduce the switching field of the recording layer 12a.

[0039] **Fig. 5** shows the coercivity as a function of FeCo layer thickness. Substantial reduction of the coercivity can be achieved with increasing FeCo layer thickness. However, when the FeCo layer reaches about 20 nm or thicker, the impact on the reduction of the switching field becomes increasingly small, indicating that the FeCo layer need not be too thick.

[0040] The inventions illustratively described herein may suitably be practiced in the absence of any element or elements, limitation or limitations, not specifically disclosed herein. Thus, for example, the terms "comprising", "including", "containing", etc. shall be read expansively and without limitation. Additionally, the terms and expressions employed herein have been used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by specific embodiments and optional features, modification and variation of the inventions embodied therein herein disclosed may be resorted to by

those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention.

[0041] The invention has been described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the invention. This includes the generic description of the invention with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

[0042] Other embodiments are in the following claims. In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognize that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group.

Claims

1. A magnetic structure comprising:

a first magnetic layer comprising a soft magnetic material;

a second magnetic layer comprising a hard magnetic material; and

a coupling layer between the first magnetic layer and the second magnetic layer,

wherein the coupling layer comprises a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature.
2. The structure of claim 1, wherein the coupling layer is anti-ferromagnetic and magnetically isolates the first magnetic layer from the second magnetic layer at temperatures below the transition temperature.
3. The structure of claim 1, wherein the coupling layer is ferromagnetic and magnetically exchange-couples the first magnetic layer and the second magnetic layer at temperatures above the transition temperature.
4. The structure of any one of claims 1 to 3, wherein the coupling layer comprises FeRh.
5. The structure of any one of claims 1 to 3, wherein the coupling layer comprises FeRhX, where X is an element selected from the group consisting of Ir, Pt, Pd, Ru, Re, and Os.
6. The structure of claim 5, wherein element X is present at less than about 10 at.% based on the total number of atoms present in FeRhX.

7. The structure of any one of claims 1 to 6, wherein the soft magnetic material comprises an alloy of Fe.
8. The structure of claim 7, wherein the soft magnetic material comprises FeCo.
9. The structure of claim 7, wherein the soft magnetic material comprises FeNiCo.
10. The structure of any one of claims 1 to 9, wherein the hard magnetic material comprises FePt.
11. The structure of any one of claims 1 to 9, wherein the hard magnet material comprises CoPt.
12. The structure of claim 10 or 11, wherein the hard magnetic material further comprises a material selected from the group consisting of TiO₂, SiO₂, Ta₂O₅, ZrO₂, ZrO, MgO, B₂O₃, Ni, Au, Ag, Cu, Pd, Ta, and C.
13. The structure of any one of claims 1 to 12, further comprising a first interlayer between the first magnetic layer and the coupling layer.
14. The structure of claim 13, wherein the first interlayer comprises a material selected from the group consisting of MgO, Pt, Ru, Ta, and TiN.

15. The structure of any one of claims 1 to 14, further comprising a second interlayer between the coupling layer and the second magnetic layer.
16. The structure of claim 15, wherein the second interlayer comprises a material selected from the group consisting of MgO, Pt, Ru, Ta, and TiN.
17. The structure of any one of claims 1 to 16, wherein the coupling layer has a thickness of between 3 and 10 nm.
18. The structure of any one of claims 1 to 17, wherein the first magnetic layer has a thickness of between 10 and 100 nm.
19. The structure of any one of claims 1 to 18, wherein the second magnetic layer has a thickness of between 7 and 20 nm.
20. The structure of any one of claims 1 to 19, wherein the transition temperature is above room temperature.
21. The structure of claim 20, wherein the transition temperature is between 100 and 300 °C.
22. A magnetic recording medium comprising:
a substrate; and
the magnetic structure of any one of claims 1 to 21, wherein the first magnetic layer is formed on the substrate.

23. The medium of claim 22, further comprising a seed layer between the substrate and the first magnetic layer.

24. The medium of claim 23, wherein the seed layer comprises a material selected from the group consisting of CrRu, CrMo, CrW, RuAl, TiN and MgO.

25. The medium of claim 23 or 24, wherein the seed layer has a thickness of between 30 and 100 nm.

26. The medium of any one of claims 23 to 25, further comprising an adhesion control layer between the substrate and the seed layer.

27. The medium of claim 26, wherein the adhesion control layer comprises Ti or Ta.

28. The medium of claim 26 or 27, wherein the adhesion control layer has a thickness of between 3 and 5 nm.

29. A method of manufacturing a magnetic recording medium, comprising:
forming a first magnetic layer on a substrate, wherein the first magnetic layer comprises a soft magnetic material;
forming a coupling layer on the first magnetic layer, wherein the coupling layer comprises a material that switches from an anti-ferromagnetic state to a ferromagnetic state upon heating above a transition temperature; and

forming a second magnetic layer on the coupling layer, wherein the second magnetic layer comprises a hard magnetic material.