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METHOD OF FABRICATING L1₀ ORDERED FePt FILM AS A MAGNETIC
RECORDING MEDIA

TECHNICAL FIELD

5 This invention relates generally to magnetic recording media for ultra-high density magnetic recording and other applications requiring thin film hard magnet with well-controlled preferred orientation such as micro-electromechanical systems (MEMS). More particularly, the present invention relates to the method and process for in-situ deposition of face centered tetragonal structured (FCT or L1₀) ordered iron platinum (FePt) thin films with controlled
10 anisotropy by magnetron sputtering technology.

BACKGROUND OF THE INVENTION

 The current state of the art has experienced tremendous growth in demand for faster storage devices and for higher data storage density. This demand has brought about research and
15 development (R&D) to increase the areal density of magnetic hard disks. Recently, Fujitsu and Seagate laboratories have demonstrated magnetic recording media with a density as high as around 100 Gbit/in².

 Recording media possessing such a high areal density must have an average grain and magnetic cluster domain size below 10 nanometers (nm) and high coercivity to resist bit
20 demagnetization. However, when grain size is reduced, the magnetization of recorded bits becomes destabilized due to a super-paramagnetic effect. The effect, which sets in when grain size becomes too small and thermal energy becomes sufficient to allow their magnetization to reverse spontaneously, leads to the consequent loss of the recorded signal.

 It has been discovered that chemically ordered iron platinum (FePt) and cobalt platinum



(CoPt) with a face centered tetragonal structure (FCT or L1₀) possess very high magnetic anisotropy energy density, which is about 7×10^7 erg/cm³ for FePt and 5×10^7 erg/cm³ for CoPt.

This high anisotropy energy density allows for magnetically stable FePt alloy grains to be as small as about 2.6 nm and that of CoPt to be about 3.6 nm. As such the two alloys appear to be most suitable for use in ultra-high areal density recording media.

Conventionally, chemically ordered L1₀ FePt or CoPt thin films used for longitudinal media are synthesized by in-situ sputtering deposition or post-annealing at elevated substrate temperature. The following references disclose current methods for synthesis: US Patent 6,139,907, "*High Coercivity Longitudinal Recording Media And Method For Its Preparation*" (Sellmyer et al); US Patent No. 6,183,606, "*Manufacture Method Of High Coercivity FePt-Si₃N₄ Granular Composite Thin Films*" (Po-Chen Kuo, Chih-Ming Kuo); and US Patent No. 6,007,623, "*Method For Making Horizontal Magnetic Recording Media Having Grains Of Chemically-Ordered FePt or CoPt*" (Jan-Ulrich Thiele, Dieter Klaus Weller). In these prior art methods, composite films with doping are usually sputter deposited on the substrate and then post-annealed at high temperature above 550°C, which unfortunately are undesirable for industrial applications. The crystallographic orientation is random or (111) textured with a c-axis angled at 36°C above film plane, which do not provide effective magnetic properties for recording.

In the IEEE Trans.Magn. publication, "*High-Anisotropy Nanocomposite Films For Magnetic Recording*"; Vol 37, pg. (1286-1291) (July 2001) and IEEE Trans.Magn publication, "*Magnetic Recording On FePt And FePtB Intermetallic Compound Media*", Vol. 35, pg. (1077-1081), methods for providing L1₀ ordered FePt films are disclosed. However, the synthesis of the chemically ordered L1₀ FePt and CoPt thin films requires high deposition temperature or post-annealing temperature (higher than 450°C) which is not available for practical industrial

applications. Moreover, face centered tetragonal (FCT)-FePt films produced by the above methods are (111) or (001) textured. . Though a publications in Appl. Phys. Lett, in "*Reduction Of Ordering Temperature Of An FePt-Ordered Alloy By Addition Of Cu*", 80, 2147-2149 (2002) and IEEE Trans.Magn. issue on "*Low Temperature In-Situ Growth Of High Coercivity FePt Films*" Vol. 37 (2001) pg. (1280-1282), suggest that the ordering temperature of FePt films can be reduced by the addition of Cu or deposition on a CrMo underlayer, the FePt films formed in these methods are mainly (111) textured or have a random orientation. In other recent developments, there have been a few reports describing the growth of FCT-structured FePt film with C axis parallel to the plane of the film. Though (110) textured face centered tetragonal (FCT)-FePt film was obtained on SrTiO₃ (110) and MgO (110) substrate by MBE disclosed in "*Control Of The Axis Of Chemical Ordering And Magnetic Anisotropy In Epitaxial FePt Films*" J.Appl.Phys.79, 5967 (1996), and "*Magnetic Anisotropy And Microstructure In Molecular Beam Epitaxial FePt (110)/ MgO (110)*" J.Appl.Phys. 84, 934 (1998), the methods require complex MBE technology and MgO or SrTiO₃ single crystal substrates.

To provide for an application using ultrahigh recording density, it is desirable to develop a simpler method and process to produce L1₀ chemical ordered FePt film with its magnetic easy axis parallel to the plane of the films.

SUMMARY OF THE INVENTION

The present invention is about a magnetic recording media that uses iron platinum of small grain sizes with a preferred orientation to provide optimal performance for recording of data.

The invention provides a method of fabricating an iron platinum film on a substrate which require the deposition of a chromium alloy layer on the substrate as an underlayer followed by

deposition of an intermediate layer over the underlayer. The magnetic layer of iron platinum is then deposited on the intermediate layer. This deposition takes place in a magnetron sputtering system. The chromium in the underlayer has a (002) preferred orientation and the intermediate layer is selected from alloys or elements that matches the underlayer or the magnetic layer either
5 with respect to their lattice constant or their crystal structure. The iron platinum in the magnetic layer is of a face-centered-tetragonal structure and the grains have a (200) preferred orientation.

The base pressure of the magnetic sputtering system is preferably at a pressure of 1×10^{-8} or lower and uses a direct current (DC) or a radio frequency (RF) power source. At a lower base pressure, it provides control of the deposition conditions to achieve the preferred crystallographic
10 orientation desired on the films. This base pressure also allows ease in investigating the factors that affect the change in the structure of the films, which may include the presence of impurities. Pressure may be adjusted by introducing gases into the system. Oxygen, nitrogen and air are introduced as impurities and kept at a partial pressure ranging from 5×10^{-5} to 2×10^{-5} Torr during the sputtering.

15 In an embodiment of the present invention, the chromium alloy is selected from a group of alloys consisting of chromium ruthenium (CrRu), chromium molybdenum (CrMo), chromium magnesium (CrMn), chromium tungsten (CrW), chromium titanium (CrTi) and chromium vanadium (CrV) where the percentage of chromium by atomic weight in the alloy ranges from 80 to 100. Preferably, the percentage range of the chromium in the alloy is 90 to 94.

20 Preferably, the underlayer of chromium alloy has a thickness that range from 5nm to 100nm. It is preferred that a temperature range from 100 °C to 500°C is maintained during sputtering of the underlayer and intermediate layer. In another embodiment of the present invention, the intermediate layer has a thickness that ranges from 0.5 nm to 10 nm. Preferably, the thickness ranges from 1 nm to 4 nm.

Another embodiment has the intermediate layer with a lattice constant and structure that matches either that of the underlayer or the magnetic layer. Such an intermediate layer may be formed by selecting from a group having a B2 structure consisting of NiAl and FeAl or a group having a face-centered-cubic (FCC) structure consisting of Pt, Cu and Pd.

5 An alternative embodiment requires the intermediate layer has a lattice constant that matches that of the underlayer or the magnetic layer and a structure that matches that of the underlayer or magnetic layer. The intermediate layer may be formed by selecting from a group with a face centered cubic structure consisting of Ag, Au and Al.

10 In another alternative embodiment, the intermediate layer has a lattice constant that matches that of the magnetic layer where the intermediate layer can be formed by selecting from a group having body centered cubic (BCC) structure consisting of iron (Fe).

15 In yet another embodiment, the magnetic layer is formed by magnetron co-sputtering of iron platinum alloy with silver (Ag) where the iron platinum in the magnetic layer has a formula of $(\text{FePt})_{100-x}\text{Ag}_x$. Preferably, x is an integer ranging from 0 to 40 in atomic percentage. It is preferred that a temperature range of 300°C to 500°C is maintained during sputtering of the iron platinum magnetic layer. Preferably, the magnetic layer has a thickness ranging from 5nm to 100nm. More preferably, the magnetic layer has a thickness ranging from 10nm to 20nm.

20 In yet a further embodiment, the substrate is selected from a group consisting of Ni-P coated aluminum magnesium (AlMg), glass, glass ceramic, and glassy carbon and is pre-coated with a seed layer to decrease grain size of the underlayer and magnetic layer. Preferably, the seed layer is selected from a group consisting of tantalum (Ta), nickel aluminum (NiAl), and carbon (C).

The invention also provides a magnetic recording media having a layered structure on a substrate with first, a chromium alloy layer deposited on the substrate; a second layer deposited

on the first layer and a third layer deposited on the second layer such that the second layer matches the first and third layer either in lattice constant or structure or both. The third layer of the magnetic recording media has magnetic properties with a (200) preferred orientation in a faced-centered tetragonal structure.

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In an embodiment of the present invention, oxygen, nitrogen and air are introduced as impurities in the magnetic recording media. In one embodiment of the invention, the chromium alloy is selected from a group of alloys consisting of chromium ruthenium (CrRu), chromium molybdenum (CrMo), chromium magnesium (CrMn), chromium tungsten (CrW), chromium
10 titanium (CrTi) and chromium vanadium (CrV) where the chromium in the first layer has a percentage range of 80 to 100.

Preferably, the chromium in the first layer has a percentage range of 90 to 94. Preferably, the first layer has a thickness that ranges from 5nm to 100nm. In yet another embodiment of the present invention, the second layer has a lattice constant and structure that matches either that of
15 the first layer or the third layer. Such second layer is selected from a group having a B2 structure consisting of nickel aluminum (NiAl) and iron aluminum (FeAl) or a group having a face – centered cubic structure consisting of platinum (Pt), copper (Cu) and palladium (Pd).

Another embodiment has the second layer with a lattice constant that matches that of the first layer or third layer and a structure that matches that of the first layer or third layer where the
20 second layer is selected from a group with a face centered cubic structure consisting of silver (Ag), gold (Au) and aluminum (Al).

An alternative embodiment has the second layer with a lattice constant that matches that of the third layer and is selected from a group having body centered cubic structure consisting of iron (Fe). Preferably, the second layer of the magnetic recording media has a thickness in the

range from 0.5nm to 10nm. More preferably, the second layer has a thickness in the range from 1nm to 4nm.

In yet a further embodiment, wherein the third layer of the magnetic recording media is formed by magnetron co-sputtering of iron platinum alloy with silver (Ag) where the iron platinum alloy in the third layer has a formula of $(\text{FePt})_{100-x}\text{Ag}_x$. Preferably, x is an integer ranging from 0 to 40 in atomic percentage. Preferably, the third layer has a thickness ranging from 5 nm to 100 nm. More preferably, the third layer has a thickness ranging from 10 nm to 20 nm.

In a preferred embodiment, the substrate is selected from a group consisting of Ni-P coated aluminum magnesium (AlMg), glass, glass ceramic and glassy carbon, pre-coated with a seed layer to decrease grain size of the underlayer and magnetic layer. Preferably, the seed layer is selected from a group consisting of Ta, NiAl and C.

BRIEF DESCRIPTION OF THE DRAWINGS

The details of the present invention will become apparent with reference to the following description and accompanying drawings wherein:

FIG. 1 is a sectional view of the layered structure of the recording media according to an exemplary embodiment of the invention;

FIG. 2 is a series of XRD spectra of $\text{Cr}_{92}\text{Ru}_8$ (80nm) /Pt (4nm)/ $\text{Fe}_{52}\text{Pt}_{48}$ (20nm) films deposited with air partial pressure at (a) 4×10^{-6} Torr, (b) 9×10^{-7} Torr and (c) 0 Torr;

FIG. 3(a) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{92}\text{Ru}_8$ (80nm) /Pt (4nm)/ $\text{Fe}_{52}\text{Pt}_{48}$ (20nm) films deposited with air partial pressure of 4×10^{-6} Torr;

FIG. 3(b) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{92}\text{Ru}_8$ (80nm) /Pt (4nm)/ $\text{Fe}_{52}\text{Pt}_{48}$ (20nm) films deposited with air partial pressure of 9×10^{-7} Torr;

FIG. 3(c) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{92}\text{Ru}_8$ (80nm) /Pt (4nm)/ $\text{Fe}_{52}\text{Pt}_{48}$ (20nm) films deposited with air partial pressure of 0 Torr;

FIG. 4 is a graph depicting the θ -2 θ XRD spectrum of $\text{Cr}_{92}\text{Ru}_8$ (80nm) /Pt (4nm)/ $\text{Fe}_{61}\text{Pt}_{39}$ (20nm) films deposited at air partial pressure of 4×10^{-6} Torr;

5 FIG. 5 is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{92}\text{Ru}_8$ (80nm) /Pt (4nm)/ $\text{Fe}_{61}\text{Pt}_{39}$ (20nm) films deposited at air partial pressure of 4×10^{-6} Torr;

FIG. 6 is a series of XRD spectra of $\text{Cr}_{90}\text{Ru}_{10}$ (30nm)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{100-x}\text{Ag}_x$ (20nm) films, where CrRu is deposited as underlayer at air partial pressure of (a) 0 Torr, $x=20$; (b) 2×10^{-6} Torr, $x=20$ and (c) 2×10^{-6} Torr, $x=40$;

10 FIG. 7(a) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$ (30nm)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{100-x}\text{Ag}_x$ (20nm) films, $x=20$ with CrRu as underlayer at air partial pressure of 0 Torr;

FIG. 7(b) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$ (30nm)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{100-x}\text{Ag}_x$ (20nm) films, $x=20$ with CrRu as underlayer at air partial
15 pressure of 2×10^{-6} Torr;

FIG. 7(c) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$ (30nm)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{100-x}\text{Ag}_x$ (20nm) films, $x=40$ with CrRu as underlayer at air partial pressure of 2×10^{-6} Torr;

FIG. 8 is a series of XRD spectra of $\text{Cr}_{90}\text{Ru}_{10}$ (t)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{70}\text{Ag}_{30}$ (20nm) films, where the thickness, t, of the CrRu underlayer is (a) $t=30$ nm; (b) $t=15$ nm; (c) $t=8$ nm and (d) 0nm;

FIG. 9(a) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$ (t)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{70}\text{Ag}_{30}$ (20nm) films, where the thickness of the CrRu underlayer, $t=30$ nm;

FIG. 9(b) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$

(t)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{70}\text{Ag}_{30}$ (20nm) films, where the thickness of the CrRu underlayer, $t=15$ nm;

FIG. 9(c) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$

(t)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{70}\text{Ag}_{30}$ (20nm) films, where the thickness of the CrRu underlayer, $t=8$ nm;

FIG. 9(d) is a graph depicting the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{90}\text{Ru}_{10}$

5 (t)/Pt (4nm) /($\text{Fe}_{50}\text{Pt}_{50}$) $_{70}\text{Ag}_{30}$ (20nm) films, where the thickness of the CrRu underlayer, $t=0$ nm;

The drawings will be described with the following detailed description of the most preferred embodiment.

10 DETAILED DESCRIPTION OF PREFERRED EMBODIMENT OF THE INVENTION.

FIG. 1 shows an embodiment of the present invention, a magnetic recording media 10 in a layered structure. The layers include a disk 12 as a substrate on top of which is deposited with an underlayer 14 of chromium alloy followed by an intermediate layer 16 before a magnetic layer 18 of iron platinum (FePt) is coated with a coating layer 20. The disk 12 substrate may be
15 formed from glass, ceramic, glassy carbon, or nickel phosphorous coated aluminum magnesium.

The chromium alloy in the underlayer 14 is preferably at least about 80 percent chromium (Cr) in atomic weight of the alloy where the preferred orientation of the chromium grain in the alloy is (002). The chromium alloy may also include ruthenium (Ru), molybdenum (Mo), magnesium (Mn), tungsten (W), titanium (Ti), or vanadium (V). It is preferred that these
20 elements do not exceed the percentage in weight of 10%.

The intermediate layer 16 is a matrix structure taking form of a B2 structure, face centered cubic (FCC) structure or body centered cubic (BCC) structure. With a B2 structure, such as that of NiAl or FeAl, the lattice constant and the structure of the intermediate layer 16 is compatible with the lattice constant and structure of the underlayer 14 chromium alloy. If the

intermediate layer 16 is in a matrix structure of a FCC structure such as Au, Ag or Al, the lattice constant would match that of the underlayer 14 and the structure of the magnetic layer of iron platinum (FePt). If the intermediate layer 16 has a FCC structure of platinum (Pt), copper (Cu) or palladium (Pd), the lattice constant and structure will match that of the iron platinum magnetic layer 18. In the case where a BCC structure such as Fe is used as intermediate layer, the lattice constant will be suitably matched with the lattice constant of the (FePt) magnetic layer. The intermediate layer 16 preferably has a thickness from about 0.5 nm to about 10 nm and most preferably from about 1 nm to about 4 nm in thickness. The thickness of the underlayer 14 can be controlled to be from about 5 nm to about 100 nm.

The iron platinum (FePt) magnetic layer 18 has a face centered tetragonal (FCT or $L1_0$) structure and the grains of the alloy have (200) preferred orientation providing a longitudinally ordered recording media.

The method of the present invention involves the use of a magnetron sputtering system in depositing each layer on the disk substrate 12 where the base pressure of the system is preferably lower than 1×10^{-8} Torr. During the deposition of chromium alloy underlayer 14, intermediate layer 16 and iron platinum (FePt) magnetic layer 18, gas, namely oxygen, nitrogen or air, is fed into the system. The partial pressure of the feeding gas is in the range from about 5×10^{-5} Torr to about 2×10^{-6} Torr. A $L1_0$ ordered (FePt) magnetic layer 18 with grain (200) preferred orientation is thus formed.

The growth of films with preferred orientation is closely related to surface free energy, interface energy and strain energy, where strain energy includes growth strain, epitaxial strain and thermal strain energies. The growth strain energy arises from various defects such as working gas atoms, impurity atoms or dislocation etc., while epitaxial strain arises from lattice mismatch and thermal strain from different thermal expansion coefficient. It is difficult to obtain the

growth of FCT-FePt with (200) preferred orientation on Cr (002) underlayer due to the large epitaxial strain energy between the Cr underlayer and the FePt layer. However, when the partial pressure of the feeding gas is in the range from about 5×10^{-5} Torr to about 2×10^{-6} Torr, it is believed that the impurities from the feeding gas induce changes in the grain growth strain in FePt film, such that the interface energy between CrRu underlayer and FePt film promotes the growth of FCT-FePt (200) preferred orientation.

At the time of deposition of the underlayer 14 and intermediate layer 16, the substrate temperature is kept in a temperature in the range from about 100°C to about 500°C and more preferably from about 200°C to about 400°C. The substrate temperature is then altered to a different range from 300°C to 500°C for the deposition of the magnetic layer 18.

The following FIGs. 2, 3, 4, and 5 illustrate the properties of a magnetic recording media under different conditions as a result of the above method.

FIG. 2 illustrates the result of a θ -2 θ X-ray diffraction (XRD) scan spectra, of Cr₉₂Ru₈ (80nm)/Pt (4nm)/Fe₅₂Pt₄₈ (20nm) magnetic recording media films deposited in the magnetron system with various air partial pressure where the substrate temperature is set at 400°C. For a sample prepared at air partial pressure of 4×10^{-6} Torr, the XRD spectra is depicted in curve (a). Similarly, the XRD spectra in curve (b) depicts the XRD spectra of a sample prepared at air partial pressure of 9×10^{-7} Torr, and curve (c) depicts the XRD spectra of a sample prepared at air partial pressure 0 Torr.

The FCT-structured FePt(001) peak 20 is very weak and broad, which indicates that (001)-preferred oriented FCT-structured FePt grains in the film are fewer and smaller than the (200) and (002)-preferred oriented FCT-FePt grains 22. With the decrease of the air partial pressure (below 9×10^{-7} Torr), the intensity of FCT-FePt (001) peak increases gradually as can be seen in the peaks 20' and 20". Therefore, the ideal pressure is represented by curve (a) with a

pressure of 4×10^{-6} Torr.

One of the problems with relying solely on the information provided by Fig. 2 is that with regard to peaks 22, 22', and 22'' between 46° and 50° , it is difficult to be sure that the material is FCT-structured FePt phase and not FCC structured FePt phase. This is because the lattice parameter, a , of disordered and ordered FePt are very close, where $a=0.384$ nm for FCT-structured FePt, and $a=0.386$ nm for FCC-structured FePt. Thus, the possibility that the material has a FCC-structure instead of the desired FCT-structure still exists.

However, because there is a difference in the magnetic properties between FCC-structured iron platinum (FePt) and FCT-structured (FePt), another battery of magnetic tests, the results of which are illustrated by Figs. 3(a) – 3(c) are helpful in identifying the structure. FCC-structured iron platinum (FePt) is magnetically soft and FCT-structured (FePt) is magnetically hard. This difference is illustrated in the in-plane and out-of plane coercivity graphs of FIGs. 3(a) - 3(c).

From Fig. 2, it was observed that as air partial pressure increases, the intensity of the Cr (002) decreases, as can be seen from the decrease in peaks 24'', 24' and 24. A peak 21 for FePt(112) preferred orientation is also observed that with the decrease in the air partial pressure, however, this is insignificant. As the base pressure increases, the grain growth strain energy and the interface energy between FePt film and CrRu underlayer may decrease while epitaxial strain energy dominates. Under such a condition, the growth of FCT-structured FePt with (001) becomes diminished. The decrease of the intensity of Cr (002) peak may also be due to the change in the grain growth strain energy. Usually, FePt films deposited on a glass substrate are magnetically soft, however if the FePt is deposited in the presence of a Cr alloy layer like CrRu, the growth of the FCT-FePt (200) or (001) preferred orientation is improved.

FIGs. 3(a) - 3(c) show the out-of-plane and in-plane hysteresis loops of $\text{Cr}_{92}\text{Ru}_8$ (80nm)

/Pt (4nm)/Fe₅₂Pt₄₈ (20nm) films deposited under various air partial pressures. The in-plane coercivity 28 of the sample prepared at air partial pressure of 4×10^{-6} Torr in FIG. 3(a) is as large as 2760 Oe, suggesting that the peak 22, 22' and 22'' between 46° and 50° is dominated by FCT-FePt (200) and not FCC-FePt (200) peak. The peaks 22, 22', and 22'' between 46° and 50° shift to higher angles as the air partial pressure decreases. The shift of the peak between 46° and 50° is due to the shift of FCT-structured FePt (200) to FCT-structured FePt (002) and the films are dominated by FCT-structured FePt (001) preferred orientation.

This phenomenon can be explained by the dominant out-of-plane coercivity. The hysteresis loops 26 and 28 of a sample prepared at air partial pressure of 4×10^{-6} Torr in FIG. 3(a) shows that it has longitudinal anisotropy, where the loop 28 shows high in-plane orientation of the magnetic grains of FePt and a relatively low out-of plane orientation. With the decrease of the air partial pressure, the magnetic grains in the film become more perpendicularly orientated shown in trend observed in FIG 3(a) - 3(c). The perpendicular anisotropy improves in the samples prepared at air partial pressure of 9×10^{-7} Torr in FIG 3(b) over the samples at air partial pressure of 0 Torr in FIG. 3(c). The out-of-plane coercivity also decreases with the gradual change in the air partial pressures. This may be ascribed to the less pinning sites resulting from impurities and grain defects.

FIG. 4 illustrates the θ -2 θ XRD spectrum and FIG. 5 illustrates the out-of-plane 31 and in-plane 33 hysteresis loops of Cr₉₂Ru₈ (80nm) /Pt (4nm)/Fe₆₁Pt₃₉ (20nm) films deposited at air partial pressure of 4×10^{-6} Torr. In FIG. 4, a sharp peak 30 of FCT-FePt (200) preferred orientation occurs at the angle between 46° and 50° and another sharp peak 32 of Cr (002) preferred orientation occurs at the angle between 62° and 67°. The results illustrated in FIG. 4 and FIG. 5 show that the film is of FCT-structured FePt having the (200) preferred orientation with longitudinal anisotropy. As compared to that in FIG 3(a), the in-plane coercivity increased

from 2760 Oe to 2930 Oe and the saturation magnetization increased from 417 emu/cc to 520 emu/cc, respectively. This result indicates that the excess Fe may compensate the Fe consumed by the reaction with impurities such as oxygen and nitrogen and thus the saturation magnetization increases.

5 In another preferred embodiment of the present invention the iron platinum magnetic layer 18 with $L1_0$ ordered FePt (200) preferred orientation can be deposited on the intermediate layer by DC or RF magnetron co-sputtering of iron platinum (FePt) target and silver (Ag) target to produce the iron platinum alloy of the formula $(Fe_{50}Pt_{50})_{100-x}Ag_x$, with traces of silver (Ag). The substrate temperature for FePt magnetic layer deposition is set to fall within the range from
10 300°C to 500°C. The silver (Ag) doping in the magnetic layer improves the bond energy between the iron platinum grains in the magnetic film and also prevents grain growth. This is illustrated in the following discussion.

FIG. 6 illustrates the θ -2 θ XRD spectra of $Cr_{90}Ru_{10}$ (30nm)/Pt (4nm) / $(Fe_{50}Pt_{50})_{100-x}Ag_x$ (20nm) films with various silver (Ag) content and various air partial pressure where chromium
15 ruthenium (CrRu) is deposited as the underlayer 14. In the spectra demarcated as (a) where the underlayer 14 was deposited at air partial pressure 0 Torr and the percentage of silver (Ag) in the iron platinum alloy is at a 20% ($x=20$), the $L1_0$ iron platinum (FePt) (001) peak 34 and Cr (002) peak 36 are found to be very strong.

This suggests that many $L1_0$ FePt grains with (001) preferred orientation exist in the film.
20 The peak 38 between 45°C and 50°C can be ascribed to the overlap of peaks for $L1_0$ iron platinum (FePt) with preferred orientation (002), $L1_0$ iron platinum (FePt) with preferred orientation (200) and Ag with preferred orientation (002). With the introduction of air (at an air partial pressure of 2×10^{-6} Torr) during deposition of the chromium alloy underlayer 14, it is observed that the intensity of chromium (Cr) (002) peaks 36' and 36'' and $L1_0$ FePt (001) peaks

34' and 34'' decrease significantly as seen in the XRD spectra of (b) and (c).

The peaks 38' and 38'' between 45°C and 50°C shift to a low angle, which is due to the shift of L1₀ FePt (002) peak to L1₀ FePt (200) peak. In this example of (Fe₅₀Pt₅₀)₈₀Ag₂₀, the iron platinum magnetic layer 18 is dominated by the L1₀ FePt grains of (200) preferred orientation.

5 In the (c) spectrum, it is observed that an increase in the silver (Ag) from x=20 to x=40 lead to a decrease in the FePt content peak 34'' and 38''. It is further observed that with an increase in Ag, a Ag (002) peak 39 appears in the XRD spectrum and the intensity of L1₀ FePt (200) decreases due to the decrease of FePt content, where the thickness of the magnetic film is maintained constant at 20 nm.

10 FIGs .7(a) - 7(c) illustrate the respective in-plane and out-of-plane hysteresis loops 40 and 42, 40' and 42', and 40'' and 42'' of Cr₉₀Ru₁₀ (30nm)/Pt (4nm) /(Fe₅₀Pt₅₀)_{100-x}Ag_x (20nm) films with various percentage of silver Ag where x=20 to x=40 in the iron platinum alloy of the magnetic layer 18, where the chromium ruthenium alloy (CrRu) is deposited at various air partial pressure to form the underlayer 14. The loops 40 and 42, 40' and 42', and 40'' and 42'', indicate
15 that all magnetic layers prepared in the presence of silver (Ag) exhibit longitudinal anisotropy.

It is further observed that when air is introduced during the deposition of the CrRu underlayer 14, where the air partial pressure is gradually increased, the perpendicular coercivity decreases and the longitudinal anisotropy improves. This is observed in all the out-of-plane and in-plane hysteresis loops from 0 Torr in FIG. 7(a) to 2x10⁻⁶ Torr in FIG. 7(b). An increase in the
20 percentage of Ag in the FePt alloy magnetic layer 18, from x = 20 to x = 40, leads to a decrease in the magnetization in each pair of in-plane loops and out-of-plane loops 40'/42' and 40''/42''.

This re-enforces the observation in FIG. 6, that decrease in the (200) orientated FePt grains is due to increase in silver content in the magnetic layer.

FIG. 8 illustrates the θ -2 θ XRD spectra of Cr₉₀Ru₁₀ (t)/Pt (4nm) /(Fe₅₀Pt₅₀)₇₀Ag₃₀ (20nm)

films with various thickness of CrRu as underlayer 14 deposited with air partial pressure at 0 Torr. In the XRD spectrum (a) where the CrRu underlayer 14 is of a thickness, $t = 30$ nm, a strong $L1_0$ FePt (001) peak 44 is observed. The peak 46 between 45°C and 50°C is due to overlap of $L1_0$ FePt (002) and (200) peaks. In addition, a peak 43 of Ag (002) is also observed.

5 The peak 48 for Cr is also clearly evident. With the decrease of the CrRu underlayer thickness to $t = 15$ nm and then to $t = 8$ nm, the $L1_0$ FePt (001) peak disappears from the XRD spectra (b) and (c). The peak 46' between 45°C and 50°C shifts to a low angle at peak 46'', which is due to the shift of $L1_0$ FePt (002) peak to $L1_0$ FePt (200) peak. Therefore, the peak 46'' is dominated by the $L1_0$ FePt (200) component. The chromium peak 48' and 48'' is also less
10 evident in the XRD spectra (b) and (c). When no CrRu underlayer 14 is deposited, the XRD spectrum (d) shows only a small broad FePt (111) peak 45, which indicates that the magnetic layer is dominated by FCC-structured FePt (111) orientated grains which is confirmed by its low coercivity as observed in the out-of-plane and in-plane hysteresis loops in FIGs. 9(a) - 9(d).

In FIG 9(a), where the thickness of the CrRu underlayer is 30 nm, a very large
15 perpendicular coercivity is observed in the loop 52 because many FePt grains are (001) oriented.

With the decrease of the CrRu underlayer 14 thickness from $t = 30$ nm to $t = 15$ nm and then to $t = 8$ nm, the perpendicular coercivity decreases and the longitudinal anisotropy improves as shown in the change in relationship of the respective pairs of in-plane and out-of-plane loops 50/52; 50'/52', and 50''/52'' in FIGs. 9(a), 9(b), and 9(c). For the sample without CrRu
20 underlayer, as shown in FIG. 9(d), the film is magnetically soft since the magnetic layer is dominated by the FCC-structured FePt grains of (111) preferred orientation, which indicates CrRu underlayer is necessary for the growth of FCT-FePt (200) or (001) preferred orientation.

These results are consistent with the XRD results in FIG. 8.

It is to be noted that the above description is only illustrative to the present invention and

those skilled in the art will recognize that the magnetic properties of the FePt films can be adjusted by altering the thickness of the various layers, the composition of FePt and the conditions for the deposition of the different layers. Various other embodiments of the invention provide advantages complementary to those already described and hence the spirit and scope of

5 the present invention should not be limited to that as described above.

We claim:

1. A method of fabricating an iron platinum film on a substrate, comprising:

depositing a chromium alloy underlayer on the substrate wherein the chromium in the underlayer has a (002) orientation;

5 depositing an intermediate layer on the underlayer; and

depositing an iron platinum magnetic layer on the intermediate layer by using a magnetron sputtering system, wherein the intermediate layer matches one of a group consisting of the underlayer and the magnetic layer; and wherein the iron platinum in the magnetic layer is a face-centered-tetragonal structure with a (200) orientation.

10

2. The method according to claim 1, wherein the magnetic sputtering uses a direct current (DC) power source.

3. The method according to claim 1, wherein the magnetic sputtering uses a radio frequency (RF) power source.

15

4. The method according to claim 1, wherein oxygen, nitrogen, and air are introduced during the sputtering of the respective layers.

20 5. The method according to claim 4, wherein the oxygen, nitrogen and air is kept at a partial pressure ranging from about 5×10^{-5} to about 2×10^{-5} Torr.

6. The method according to claim 1, wherein the magnetron sputtering system has a base pressure of less than 1×10^{-8} Torr.

7. The method according to claim 1, wherein the chromium alloy is selected from a group of alloys consisting of CrRu, CrMo, CrMn, CrW, CrTi and CrV.

5 8. The method according to claim 7, wherein the percentage of the chromium in the alloy is 80% to 100%.

9. The method according to claim 8, wherein the percentage of the chromium in the alloy is 90% to 94%.

10

10. The method according to claim 1, wherein the underlayer has a thickness that ranges from 5 nm to 100 nm.

11. The method according to claim 1, wherein a temperature range from about 100 °C to about 15 500°C is maintained during depositing of the underlayer and intermediate layer.

12. The method according to claim 1, wherein the intermediate layer has a thickness in the range from about 0.5 nm to about 10 nm.

20 13. The method according to claim 12, wherein the intermediate layer has a thickness in the range from about 1 nm to about 4 nm.

14. The method according to claim 1, wherein the intermediate layer has a lattice constant and structure that matches the lattice constant and structure of one of a group consisting of the

underlayer and the magnetic layer.

15. The method according to claim 1, wherein the intermediate layer has a lattice constant that matches that of one of a group consisting of the underlayer and the magnetic layer.

5

16. The method according to claim 1, wherein the intermediate layer has a structure that matches that of one of a group consisting of the underlayer and magnetic layer.

17. The method according to claim 15 or 16, wherein the intermediate layer is selected from a group having a face centered cubic structure consisting of Ag, Au, and Al.

10

18. The method according to claim 14, wherein the intermediate layer is selected from a group having a B2 structure consisting of NiAl and FeAl.

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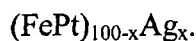
19. The method according to claim 14, wherein the intermediate layer is selected from a group having a face-centered-cubic structure consisting of Pt, Cu and Pd.

20. The method according to claim 15, wherein the intermediate layer has a body centered cubic structure comprising iron.

20

21. The method according to claim 1, wherein the magnetic layer is formed by magnetron co-sputtering of iron platinum alloy with Ag.

22. The method according to claim 21, wherein the iron platinum in the magnetic layer is



23. The method according to claim 22, wherein x is an integer ranging from 0 to 40.

5 24. The method according to claim 1, wherein a temperature range from about 300°C to about 500°C is maintained during depositing of the iron platinum magnetic layer.

25. The method according to claim 1, wherein the magnetic layer has a thickness ranging from about 5 nm to about 100 nm.

10

26. The method according to claim 25, wherein the magnetic layer has a thickness ranging from about 10 nm to about 20 nm.

27. The method according to claim 1, wherein the substrate is selected from a group consisting
15 of Ni-P coated AlMg, glass, glass ceramic, and glassy carbon.

28. The method according to claim 27, further comprising pre-coating the substrate to decrease a grain size of the underlayer and magnetic layer.

20 29. The method according to claim 28, wherein the seed layer is selected from a group consisting of Ta, NiAl and C.

30. A magnetic recording media having a layered structure on a substrate with a first layer of chromium alloy deposited on the substrate;

a second layer deposited on the first layer;

a third layer deposited on the second layer;

wherein the second layer matches the first and third layer in lattice constant and structure and

wherein the third layer has a (200) orientation in a faced centered tetragonal structure.

5

31. The magnetic recording media of claim 30, wherein the chromium alloy is selected from a group of alloys consisting of CrRu, CrMo, CrMn, CrW, CrTi and CrV.

32. The magnetic recording media of claim 31, wherein the percentage of chromium in the first
10 layer is from about 80% to about 100%.

33. The magnetic recording media of claim 32, wherein the percentage of chromium in the first layer is from about 90% to about 94%.

15 34. The magnetic recording media of claim 30, wherein oxygen, nitrogen and air are introduced.

35. The magnetic recording media of claim 31, wherein the underlayer has a thickness that ranges from 5 nm to 100 nm.

20 36. The magnetic recording media of claim 30, wherein the intermediate layer has a lattice constant and structure that matches that of one of a group consisting of the underlayer and the magnetic layer.

37. The magnetic recording media of claim 30, wherein the intermediate layer has a lattice

constant that matches that of one of a group consisting of the underlayer and the magnetic layer.

38. The magnetic recording media of claim 30, wherein the intermediate layer has a structure that
5 matches that of one of a group consisting of the underlayer and magnetic layer.

39. The magnetic recording media of claim 37 or 38, wherein the intermediate layer is selected from a group with a face centered cubic structure consisting of Ag, Au and Al.

10 40. The magnetic recording media of claim 36, wherein the intermediate layer is selected from a group having a B2 structure consisting of NiAl and FeAl.

41. The magnetic recording media of claim 37, wherein the intermediate layer is selected from a group having a face centered cubic structure consisting of Pt, Cu and Pd.

15

42. The magnetic recording media of claim 38, wherein the intermediate layer is a body centered cubic structure comprising iron.

43. The magnetic recording media of claim 30, wherein the intermediate layer has a thickness in
20 the range from about 0.5 nm to about 10 nm.

44. The magnetic recording media of claim 43, wherein the intermediate layer has a thickness in the range from about 1 nm to about 4 nm.

45. The magnetic recording media of claim 30, wherein the magnetic layer is formed by co-magnetron sputtering of iron platinum alloy with Ag.

46. The magnetic recording media of claim 45, wherein the iron platinum in the magnetic layer
5 is $(\text{FePt})_{100-x}\text{Ag}_x$.

47. The magnetic recording media of claim 46, wherein x is an integer ranging from 0 to 40.

48. The magnetic recording media of claim 30, wherein the magnetic layer has a thickness
10 ranging from about 5 nm to about 100 nm.

49. The magnetic recording media of claim 48, wherein the magnetic layer has a thickness ranging from about 10 nm to about 20 nm.

15 50. The magnetic recording media of claim 30, wherein the substrate is selected from a group consisting of Ni-P coated AlMg, glass, glass ceramic, and glassy carbon.

51. The magnetic recording media of claim 30, wherein the substrate is pre-coated with a seed layer to decrease grain size of the underlayer and magnetic layer.

20 52. The magnetic recording media of claim 51, wherein the seed layer is selected from a group consisting of Ta, NiAl, and C.