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[Continued on next page]

(54) **Title:** LAYER ARRANGEMENT AND METHOD FOR FABRICATING THEREOF

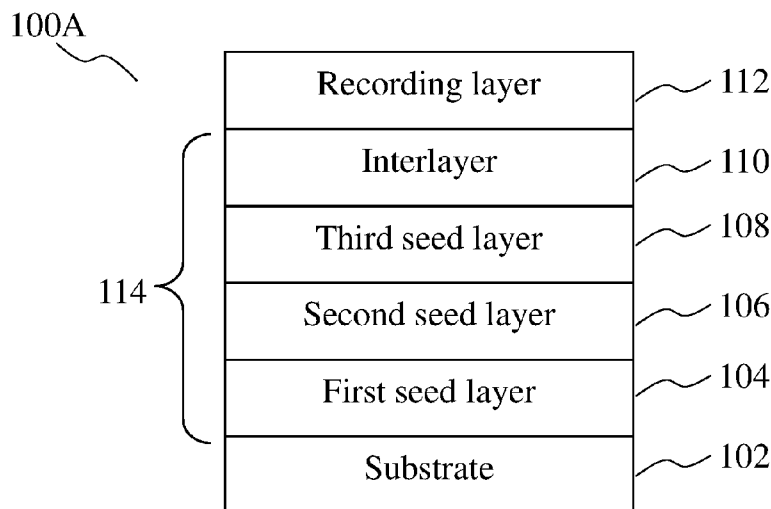


FIG. 1A

(57) **Abstract:** According to various embodiments, there is provided a layer arrangement including a substrate; a first seed layer arranged over the substrate, the first seed layer including an alloy of Ta; a second seed layer arranged over the first seed layer, the second seed layer including Ta; a third seed layer arranged over the second seed layer, the third seed layer including an alloy of Ni; an interlayer arranged over the third seed layer; and a recording layer arranged over the interlayer, the recording layer including a plurality of magnetic materials.

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LAYER ARRANGEMENT AND METHOD FOR FABRICATING THEREOF**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of Singapore Patent Application number 10201500464Y filed 21 January 2015, the entire contents of which are incorporated herein by reference for all purposes.

TECHNICAL FIELD

[0002] The present invention relates to layer arrangements and methods for fabricating thereof.

BACKGROUND

[0003] Perpendicular Magnetic Recording (PMR), also commonly referred to as Perpendicular recording, is a technology for data recording on hard disks. The PMR technology in its existing form appears to be reaching its limits in recording density. In order to achieve high recording density, the recording medium needs to have high anisotropy energy, in other words, highly directional specific energy, so as to support small grain size. Cobalt-platinum (CoPt) alloys may be used as magnetic recording medium. However, an obstacle to achieving high anisotropy energy in CoPt-X alloys is the stacking faults found in CoPt-X alloys. These stacking faults may also be a main source of noise in PMR media. While cobalt materials such as L_{11} -CoPt and Co_3Pt typically have high magnetic anisotropies, their coercivities may be too low for them to be used as recording media.

[0004] Therefore, there is a need to develop a CoPt-X recording medium that can be free of stacking faults, in order to improve the recording density of PMR technology.

SUMMARY

[0005] According to various embodiments, there may be provided a layer arrangement including a substrate; a first seed layer arranged over the substrate, the first seed layer including an alloy of Ta; a second seed layer arranged over the first seed layer, the second seed layer including Ta; a third seed layer arranged over the second seed layer, the third seed

layer including an alloy of Ni; an interlayer arranged over the third seed layer; and a recording layer arranged over the interlayer, the recording layer including a plurality of magnetic materials.

[0006] According to various embodiments, there may be provided a method for fabricating a layer arrangement, the method including providing a substrate; providing a first seed layer over the substrate, the first seed layer including an alloy of Ta; providing a second seed layer over the first seed layer, the second seed layer including Ta; providing a third seed layer over the second seed layer, the third seed layer including an alloy of Ni; providing an interlayer over the third seed layer; and providing a recording layer over the interlayer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

[0008] FIG. 1A shows a conceptual diagram of a layer arrangement according to various embodiments.

[0009] FIG. 1B shows a conceptual diagram of a layer arrangement according to various embodiments.

[0010] FIG. 2 shows a flow diagram showing a method for fabricating a layer arrangement, according to various embodiments.

[0011] FIG. 3 shows a conceptual diagram showing a layer arrangement according to various embodiments.

[0012] FIG. 4 shows the effect of atomic content of Co on the coercivity of CoPt for the layer arrangement of FIG. 3; the magnetic hysteresis loop of $\text{Co}_{64.3}\text{Pt}_{35.7}$; and the magnetic Kerr rotation loop of $\text{Co}_{74.8}\text{Pt}_{25.2}$.

[0013] FIG. 5 shows a graph showing the effect of sputter pressure on coercivity of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIG. 3.

[0014] FIG. 6 shows a graph showing the effect of Co content on coercivity of CoPt of the layer arrangement of FIG. 3 at two different sputter pressures.

[0015] FIG. 7 shows a conceptual diagram of a layer arrangement according to various embodiments.

[0016] FIG. 8 shows a graph showing the perpendicular coercivity of CoPt deposited on two different structures, in relation to the atomic composition of Co.

[0017] FIG. 9 shows a graph showing the effect of sputter pressure on the coercivity of $\text{Co}_{64.3}\text{Pt}_{35.7}$.

[0018] FIG. 10 shows a graph showing the variation of $\text{Co}_{64.3}\text{Pt}_{35.7}$ thickness and its effect on coercivity.

[0019] FIG. 11 shows a graph showing the effect of temperature on the deposition of $\text{Co}_{64.3}\text{Pt}_{35.7}$.

[0020] FIG. 12 shows a graph showing the effect of sputter power on the coercivity of the CoPt of the layer arrangement of FIG. 7.

[0021] FIG. 13 shows a graph showing the magnetic hysteresis loops of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIG. 7 for various thicknesses of the third seed layer.

[0022] FIG. 14 shows a graph summarising the coercivity of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIG. 7, for various thicknesses of the third seed layer.

[0023] FIG. 15 shows a graph showing the in-plane and out-of-plane components of the magnetic hysteresis loop of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIG. 7.

[0024] FIG. 16 is a graph showing the XRD patterns of the layer arrangement of FIG. 7 with different NiW thickness.

[0025] FIG. 17 shows a graph showing the summary of mosaic distribution, i.e. textures of the third seed layer, the recording layer and the interlayer, with respect to the thickness of the third seed layer.

[0026] FIG. 18 shows a graph showing the saturation magnetization and magnetic anisotropy of $\text{Co}_{64.3}\text{Pt}_{35.7}$ deposited as the recording layer of the layer arrangement of FIG. 7, with respect to the thickness of the third seed layer.

[0027] FIG. 19A shows an illustration of hexagonal close-pack structure (HCP) structure and a face centred cubic (FCC) structure.

[0028] FIG. 19B shows an illustration of a stacking fault within a HCP structure.

[0029] FIG. 20 shows a High Resolution Transmission Electron Microscopy (HRTEM) image of the recording layer of a layer arrangement according to various embodiments.

[0030] FIG. 21A shows a cross-sectional HRTEM image of the recording layer of FIG. 20.

[0031] FIG. 21B shows a magnified view of the HRTEM image of FIG. 21A.

[0032] FIG. 22 shows a layer arrangement according to various embodiments.

[0033] FIG. 23A shows a cross-sectional HRTEM image of the recording layer of the layer arrangement of FIG. 22.

[0034] FIG. 23B shows a magnified view of the HRTEM image of FIG. 23A.

[0035] FIG. 24A shows a cross-sectional HRTEM image of the recording layer of the layer arrangement of FIG. 22.

[0036] FIG. 24B shows a magnified view of the HRTEM image of FIG. 24A.

[0037] FIG. 25A shows a cross-sectional HRTEM image of the layer arrangement of FIG. 22 wherein the third seed layer is a 86 nm-thick layer of NiW.

[0038] FIG. 25B shows a magnified view of the HRTEM image of FIG. 25A.

[0039] FIG. 25C shows a plan view of the recording layer of the layer arrangement of FIG. 22 wherein the third seed layer is an 86nm-thick layer of NiW.

[0040] FIG. 26A shows a graph showing plane (100) X-ray powder diffraction (XRD) data obtained for the layer arrangement of FIG. 22 for various thicknesses for the third seed layer.

[0041] FIG. 26B shows a graph showing plane (110) X-ray powder diffraction (XRD) data obtained for the layer arrangement of FIG. 22 for various thicknesses for the third seed layer.

[0042] FIG. 27 shows a table summarising the XRD data for the layer arrangement of FIG. 22 for various thicknesses for the third seed layer.

[0043] FIG. 28 shows a layer arrangement according to various embodiments.

[0044] FIG. 29 shows a graph showing the in-plane and out-of-plane components of the magnetic hysteresis loop of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement according to various embodiments.

[0045] FIGS. 30A-30B show cross-sectional HRTEM images of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of a layer arrangement according to various embodiments.

[0046] FIGS. 30C-30D show selected area electron diffraction (SAED) images of the $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIGS. 30A-30B.

[0047] FIG. 31 shows a layer arrangement according to various embodiments.

[0048] FIG. 32 shows a layer arrangement according to various embodiments.

[0049] FIG. 33 shows a graph showing a summary of coercivity of CoPt deposited on two different structures.

[0050] FIG. 34 shows a graph showing the effect of the interlayer thickness on the coercivity of the recording layer, for the layer arrangement of FIG. 32.

[0051] FIG. 35 shows a conceptual diagram of a layer arrangement according to various embodiments.

[0052] FIG. 36 shows a graph showing the effect of the second interlayer thickness on the coercivity of the recording layer, for the layer arrangement of FIG. 35 wherein the first interlayer thickness is 5nm.

[0053] FIG. 37 shows a graph showing the Kerr rotation loops of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIG. 35 for various thicknesses of the second interlayer.

[0054] FIG. 38 shows two HRTEM images, showing a plan view and a cross-sectional view of the recording layer of a layer arrangement according to various embodiments.

[0055] FIG. 39 shows a graph showing the Kerr rotation loop of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement of FIG. 35.

DESCRIPTION

[0056] Embodiments described below in context of the devices are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

[0057] In order that the invention may be readily understood and put into practical effect, particular embodiments will now be described by way of examples and not limitations, and with reference to the figures.

[0058] Various embodiments are provided for devices, and various embodiments are provided for methods. It will be understood that basic properties of the devices also hold for the methods and vice versa. Therefore, for sake of brevity, duplicate description of such properties may be omitted.

[0059] It will be understood that any property described herein for a specific device may also hold for any device described herein. It will be understood that any property described herein for a specific method may also hold for any method described herein. Furthermore, it will be understood that for any device or method described herein, not necessarily all the components or steps described must be enclosed in the device or method, but only some (but not all) components or steps may be enclosed.

[0060] In the context of various embodiments, elements, compounds and alloys may be stated in their chemical formula, for example “cobalt” may be interchangeably referred to as “Co”, “platinum” may be interchangeably referred to as “Pt”, “tungsten” may be interchangeably referred to as “W”, “nickel” may be interchangeably referred to as “Ni”, “iron” may be interchangeably referred to as “Fe”, “aluminum” may be interchangeably referred to as “Al”, “rubidium” may be interchangeably referred to as “Ru”.

[0061] In the context of various embodiments, the first interlayer may be interchangeably referred to as “low pressure Ru layer” or “Ru (low p.)”.

[0062] In the context of various embodiments, the second interlayer may be interchangeably referred to as “high pressure Ru layer” or “Ru (high p.)”.

[0063] In the context of various embodiments, the recording layer may be interchangeably referred to as “magnetic medium” or “recording medium”.

[0064] Perpendicular Magnetic Recording (PMR), also commonly referred to as Perpendicular recording, is a technology for data recording on hard disks. The PMR technology in its existing form appears to be reaching its limits in recording density. In order to achieve high recording density, the recording medium needs to have high anisotropy energy, in other words, highly directional specific energy, so as to support small grain size. Cobalt-platinum (CoPt) alloys may be used as magnetic recording medium. However, an obstacle to achieving high anisotropy energy in CoPt-X alloys is the stacking faults found in CoPt-X alloys. These stacking faults may also be a main source of noise in PMR media. While cobalt materials such as L_{11} -CoPt and Co_3Pt typically have high magnetic anisotropies, their coercivities may be too low for them to be used as recording media. Therefore, there is a need to develop a CoPt-X recording medium that can be free of stacking faults, in order to improve the recording density of PMR technology.

[0065] FIG. 1A shows a conceptual diagram of a layer arrangement 100A according to various embodiments. The layer arrangement 100A may include a substrate 102; a first seed layer 104 arranged over the substrate 102; a second seed layer 106 arranged over the first seed layer 104; a third seed layer 108 arranged over the second seed layer 106; an interlayer 110 arranged over the third seed layer 108; and a recording layer 112 arranged over the interlayer 110. The first seed layer 104 may include an alloy of tantalum (Ta). The second seed layer 106 may include Ta. The third seed layer 108 may include an alloy of nickel (Ni). The recording layer 112 may include a magnetic material which includes a plurality of magnetic materials.

[0066] In other words, according to various embodiments, a layer arrangement 100A may include a substrate 102; a first seed layer 104; a second seed layer 106; a third seed layer 108; an interlayer 110 and a recording layer 112. All of the layers underneath the recording layer 112 except the substrate 102, may be collectively referred herein as the underlying structure 114. For example, the underlying structure of the layer arrangement 100A may include the substrate 102, the first seed layer 104, the second seed layer 106, the third seed layer 108 and the interlayer 110. Each layer within the underlying structure may be provided by deposition. The deposition may be carried out by sputtering.

[0067] The substrate 102 may include an inert or non-magnetic material, such as glass. The first seed layer 104 may be arranged over the substrate 102, and may include a Ta alloy, such as NiTa. The atomic content of the NiTa may be about 40-60% Ni with the remaining content being Ta. The first seed layer 104 may be about 5 to 10nm in thickness. The first seed layer 104 may serve to enhance adhesion. The second seed layer 106 may be arranged over the first seed layer 104, and may include Ta. The second seed layer 106 may be about 3nm in thickness. The second seed layer 106 may be a bridge layer between the first seed layer 104 and the third seed layer 108. At least one of the first seed layer 104 or the second seed layer 106 may include amorphous materials. The third seed layer 108 may be arranged over the second seed layer 106 and may include a Ni alloy, such as NiW or NiFeAlW. The interlayer 110 may be arranged over the third seed layer 108 and may include Ru. The recording layer 112 may be arranged over the interlayer 110 and may include a plurality of magnetic materials.

[0068] The third seed layer 108 may be configured to induce growth of a crystalline structure of the interlayer. The third seed layer 108 may include at least one of a non-magnetic seed layer, or a magnetic seed layer. The Ni alloy of the third seed layer 108 may include tungsten (W), i.e. the alloy may be one of NiW or NiW-XY. The non-magnetic seed layer may be arranged over the magnetic seed layer. Alternatively, the magnetic seed layer may be arranged over the non-magnetic seed layer. The non-magnetic seed layer may include NiW or other Ni alloys. The non-magnetic seed layer may have a thickness at least substantially in a range of less than 10nm or 5-10nm. The non-magnetic seed layer may include a polycrystalline material with face-centered cubic structure. The atomic ratio of tungsten in the non-magnetic seed layer may be about 10%, while the remaining content may be entirely Ni. The magnetic seed layer may include a Ni alloy, such as but not limited to NiFeAlW. The magnetic seed layer may include a polycrystalline material with face-centered cubic structure. The magnetic seed layer may be magnetically soft and may be part of a soft underlayer for enhancing the writing field. The atomic ratio of Ni in the magnetic seed layer may be about 60-70%, the atomic ratio of Fe may be about 30-20% while the atomic ratio of Al and W may be about 5%. The magnetic seed layer may have a thickness at least substantially in a range of 15nm to 25nm. Each of the magnetic seed layer and the non-magnetic seed layer may serve as bases for deposition of the interlayer 110. The thickness of the magnetic seed layer may be at least substantially equal to four times the thickness of the non-magnetic seed layer. The interlayer 110 may include a first interlayer and a second interlayer, wherein the second interlayer may be arranged over the first interlayer. Each of the first interlayer and the second interlayer may

include Ru. The first interlayer may be fabricated at a low pressure while the second interlayer may be fabricated at a high pressure, for texture and grain size control respectively. Ru films deposited at low pressure, for example at less than 10 mT, may exhibit low roughness and large grain size; while Ru films deposited at high pressure, for example more than 60 mT, may exhibit high roughness and small grain size. The interlayer 110 may have a crystalline structure, such as hexagonal close-packed (HCP) structure. The interlayer 110 may be deposited to induce heteroepitaxial growth of the recording layer. The thickness of each of the first interlayer and the second interlayer may be about 10-15nm. The first interlayer may serve to provide orientation control for the growth of the recording layer while the second interlayer may serve to provide control over the grain size and uniformity of the recording layer.

[0069] The recording layer 112 may include a cobalt (Co) alloy having a formula of $\text{Co}_x\text{-X}_{100-x}$, where x indicates atomic content. The X in the alloy may be platinum (Pt), i.e. the cobalt alloy may be CoPt. The atomic content of Co in the Co alloy may be at least substantially in the range of 60% to 70%. The atomic content of Co may be at least substantially equal to 64.3%. The recording layer may be formed from $\text{Co}_{64.3}\text{Pt}_{35.7}$. A ratio of an atomic content of Co to an atomic content of Pt may be at least substantially equal to 3:5. The Co alloy may further include chromium (Cr); and may further include an oxide. The oxide may be one from the group consisting of TiO_2 , SiO_2 , Ta_2O_5 and CuO . The oxide may also be a combination of at least one from the group consisting of TiO_2 , SiO_2 , Ta_2O_5 and CuO . The recording layer 112 may have a granular structure. The interlayer 110 may be configured to induce growth of the granular structure of the recording layer 112. A grain size of the granular structure may be at least substantially in a range of 7nm to 10nm. An easy axis of each magnetic material of the plurality of magnetic materials in the recording layer 112 may be at least substantially perpendicular to a surface of the recording layer 112. The recording layer 112 may have a thickness at least substantially in a range of 7nm to 10nm, such as at least substantially equal to 8nm.

[0070] FIG. 1B shows a conceptual diagram of a layer arrangement 100B according to various embodiments. The layer arrangement 100B may be similar to the layer arrangement 100A of FIG. 1A, in that it includes a substrate 102, a first seed layer 104, a second seed layer 106, a third seed layer 108, an interlayer 110 and a recording layer 112. As compared to the layer arrangement 100A, the layer arrangement 100B may further include a nucleation control layer 114. The nucleation control layer 114 may be arranged between the interlayer 110 and the recording layer 112. Alternatively, wherein the interlayer 110 includes a first

interlayer and a second interlayer, the nucleation control layer 114 or a further nucleation control layer may be arranged between the first interlayer and the second interlayer. The nucleation control layer 114 may be configured to induce at least one of a desired grain size or a desired grain isolation parameter in a layer above the nucleation control layer. In other words, the nucleation control layer 114 arranged beneath the recording layer may influence the growth of the recording layer to achieve a desired grain size or to achieve a desired grain isolation in the crystalline structure of the recording layer. The nucleation control layer 114 may include Co. The nucleation control layer 114 may be a Co alloy including Cr and may further include an oxide. The oxide may be one from the group consisting of TiO_2 , SiO_2 , Ta_2O_5 and CuO . The oxide may also be a combination of at least one from the group consisting of TiO_2 , SiO_2 , Ta_2O_5 and CuO . The layer arrangement 100B may also include a magnetically soft underlayer, the magnetically soft underlayer configured to conduct magnetic flux from the recording head.

[0071] FIG. 2 shows a flow diagram 200 showing a method for fabricating a layer arrangement according to various embodiments. In 222, a substrate may be provided. In 224, a first seed layer may be provided over the substrate, the first seed layer including an alloy of Ta. In 226, a second seed layer may be provided over the first seed layer, the second seed layer including Ta. In 228, a third seed layer may be provided over the second seed layer, the third seed layer including an alloy of Ni. In 230, an interlayer may be provided over the third seed layer. In 232, a recording layer may be provided over the interlayer. Providing the interlayer may include forming a first interlayer under a first pressure; and forming a second interlayer under a second pressure. The second pressure may be higher than the first pressure. Providing a recording layer over the interlayer may include depositing Co alloy over the interlayer by sputtering. The sputtering may be conducted at a predetermined sputter pressure and at a predetermined temperature. The predetermined sputter pressure may be at least substantially in a range of 90mTorr to 100mTorr. The predetermined temperature may be equal to or less than 280°C . The recording layer may be provided at room temperature. Each of the substrate, the first seed layer, the second seed layer, the third seed layer, the interlayer and the recording layer, may also be provided by deposition at room temperature. Each of the substrate, the first seed layer, the second seed layer and the third seed layer may be provided by deposition at a low pressure of less than 10mT. The recording layer and the second interlayer may be deposited at high pressure of more than 60 mT.

[0072] A layer arrangement according to various embodiments may include a stacking-fault free magnetic medium. The stacking-fault free magnetic medium may be the recording layer

of the layer arrangement. A stacking fault is a defect characterizing the disordering of crystallographic planes. The magnetic medium, i.e. the recording layer, may be based on CoPt alloys.

[0073] A layer arrangement according to various embodiments may include a magnetic medium which possesses high anisotropy energy K_u , for example 1.5×10^7 erg/cc. The magnetic medium may be the recording layer of the layer arrangement. The magnetic medium may include magnetically anisotropic materials, in other words, the magnetic medium may include materials with directionally specific magnetic moment. Anisotropy energy is a measure of the amount of energy required to change the direction of the magnetic moment of the materials. A material with high anisotropy energy can better retain its magnetic anisotropy when exposed to an external magnetic field.

[0074] A layer arrangement according to various embodiments may include a magnetic medium which possesses high coercivity, for example the perpendicular coercivity may be beyond 16 kOe. The magnetic medium may be the recording layer of the layer arrangement. Coercivity is a measure of the ability of a magnetic material to withstand an external magnetic field without becoming demagnetized. A magnetic medium having a high coercivity is inherently thermally more stable, as stability is proportional to the product of magnetic grain volume times the uniaxial anisotropy constant K_u , which in turn is higher for a material with a higher magnetic coercivity.

[0075] A layer arrangement according to various embodiments may include a magnetic medium which has small grain sizes, for example 6-7nm.

[0076] A layer arrangement according to various embodiments may include a magnetic medium which has a small damping constant. A damping constant is a measure of the dissipation of magnetic energy due to eddy currents induced in the magnetic medium. A material with a small damping constant will be able to store a larger amount of magnetic energy.

[0077] A layer arrangement according to various embodiments may be suitable to be used as a recording media for at least one of PMR or Microwave-Assisted Magnetic Recording (MAMR).

[0078] A method for fabricating a layer arrangement, according to various embodiments, may be able to suppress the formation of stacking faults in a recording layer of the layer arrangement at room temperature. The method may include carrying out deposition of the recording layer at room temperature. The recording layer may be a CoPt alloy film.

[0079] A method for fabricating a layer arrangement according to various embodiments may be able to fabricate a layer arrangement including a recording layer which has a high K_u . The K_u of the recording layer may be at least substantially in a range of more than 10^7 erg/cc. The method may be able to achieve a recording layer having saturation magnetization, M_s of at least substantially in the range of 700-900 electromagnetic units per cubic centimeter (emu/cc), so that the layer arrangement may be able to provide a sufficient level of read-back signal. The layer materials, layer structure, film compositions and processes for the fabrication of the stacking-fault free magnetic medium, such as CoPt-X, is described in the subsequent paragraphs.

[0080] FIG. 3 shows a layer arrangement 300 according to various embodiments. The layer arrangement 300 may include a substrate 302, a first seed layer 304, a second seed layer 306, an interlayer 310 and a recording layer 312. The substrate 302 may be at least substantially identical to or similar to the substrate 102 of the layer arrangement 100, and may include glass. The first seed layer 304 may be at least substantially identical to or similar to the first seed layer 104 of the layer arrangement 100. The first seed layer 304 may include NiTa, and may be at least substantially about 35nm in thickness. The second seed layer 306 may be at least substantially identical to or similar to the second seed layer 106 of the layer arrangement 100. The second seed layer 306 may include Ta, and may be at least substantially about 3nm in thickness. The interlayer 310 may be at least substantially identical to or similar to the interlayer 110 of the layer arrangement 100. The interlayer 310 may include Ru and may be at least substantially about 20nm in thickness. The interlayer 310 may be formed under low pressure. The recording layer 312 may at least substantially identical to or similar to the recording layer 112 of the layer arrangement 100. The recording layer 312 may include a CoPt alloy having a formula $\text{Co}_x\text{Pt}_{100-x}$, and may be at least substantially about 7nm in thickness. The recording layer 312 may have a HCP structure. The layers underneath the recording layer 312, less the substrate 302, may be collectively referred herein as the underlying structure 314 of the layer arrangement 300.

[0081] FIG. 4A shows a graph 400A showing the effect of content of Co in a $\text{Co}_x\text{Pt}_{100-x}$ alloy, on the coercivity of the recording layer 312 of the layer arrangement 300 of FIG. 3, wherein the recording layer 312 is a layer of $\text{Co}_x\text{Pt}_{100-x}$ alloy. The graph 400A includes a horizontal axis 440 indicating the atomic percentage of Co, i.e. value of x in $\text{Co}_x\text{Pt}_{100-x}$; and a vertical axis 442 indicating the coercivity of the CoPt alloy in Oestereds (Oe). The graph 400A was plotted using data obtained by making compositional adjustments to the CoPt alloy. The CoPt alloy may be deposited on the underlying structure 314 which is arranged over the substrate

302, using an Intevac 200 Lean system. In other words, the CoPt alloy was deposited to form the recording layer 312. The composition of the CoPt alloy was adjusted using a Triatron station co-sputtering $\text{Co}_{52}\text{Pt}_{48}$ with a Co target. A window of CoPt compositions were fabricated at room temperature. From the data plotted in the graph 400A, it can be seen that the optimal composition which yielded the highest coercivity of the recording layer 312, is $\text{Co}_{64.3}\text{Pt}_{35.7}$ which achieved coercivity of 6kOe.

[0082] FIG. 4B shows a graph 400B showing the magnetic hysteresis loop of the recording layer 312 of the layer arrangement 300 of FIG. 3, wherein the recording layer 312 is a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$. The graph 400B includes a horizontal axis 444 indicating applied field in kOe; and a vertical axis 446 indicating magnetization in emu/cc. The graph 400B further includes a plot 448 representing in-plane magnetization and a plot 450 representing out-of-plane magnetization. The in-plane magnetization component is smaller than the out-of-plane magnetization component, suggesting the dominance of perpendicular magnetization.

[0083] FIG. 4C shows a graph 400C shows the Kerr rotation loop of the recording layer 312 of the layer arrangement 300 of FIG. 3, wherein the recording layer 312 is a layer of $\text{Co}_{74.8}\text{Pt}_{25.2}$. The graph 400C includes a horizontal axis 452 indicating applied field in kOe; and a vertical axis 454 indicating Kerr rotation in millidegrees (m°). The graph 400C shows the hysteresis loop of $\text{Co}_{74.8}\text{Pt}_{25.2}$ film deposited at low pressure.

[0084] FIG. 5 shows a graph 500 showing the effect of sputter pressure on the coercivity of the recording layer 312 of the layer arrangement 300 of FIG. 3, wherein the recording layer 312 is a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$ alloy. The graph 500 includes a horizontal axis 550 indicating the pressure used for depositing the $\text{Co}_{64.3}\text{Pt}_{35.7}$ alloy over the underlying structure 314, in other words, the sputter pressure, in milliTorrs (mT); and a vertical axis 552 indicating coercivity of the recording layer 314, in Oe. The graph 500 shows that the coercivity of the recording layer 312 increases monotonically from 5.5 kOe to 7.2 kOe with an increase of the sputter pressure from 75mT to 100mT.

[0085] FIG. 6 shows a graph 600 showing the effect of Co atomic content of a CoPt alloy on the coercivity of the recording layer 312 of the layer arrangement 300 wherein the recording layer 312 is a layer of CoPt alloy, at two different sputter pressures. The graph 600 includes a horizontal axis 660 indicating atomic percentage of Co; and a vertical axis 662 indicating coercivity of the recording layer 312 in Oe. The graph 600 further includes a first plot 664 and a second plot 666. The first plot 664 represents the effect of Co content on the coercivity of CoPt at sputter pressure of 76.9mT while the second plot 666 represents the effect of Co content on coercivity of CoPt at sputter pressure of 99.8mT. The graph 600 shows that the

optimal composition of CoPt does not change with differences in the sputter pressure. The optimal atomic percentage of Co is in the range of 59-68%, with the peak occurring at about 64%, regardless of the sputter pressure.

[0086] FIG. 7 shows a conceptual diagram of a layer arrangement 700 according to various embodiments. The layer arrangement 700 may be similar to the layer arrangement 300 of FIG. 3, in that it may include a substrate 702, a first seed layer 704, a second seed layer 706, an interlayer 710 and a recording layer 712. The substrate 702, the first seed layer 704, the second seed layer 706 and the recording layer 712 may be similar to the substrate 302, the first seed layer 304, the second seed layer 306 and the recording layer 312 of the layer arrangement 300, respectively. The substrate 702, the first seed layer 704, the second seed layer 706 and the recording layer 712 may also be at least substantially identical or similar to the substrate 102, the first seed layer 104, the second seed layer 106 and the recording layer 112 of the layer arrangement 100, respectively. The interlayer 710 may include Ru and may have a thickness at least substantially equal to 16nm. As compared to the layer arrangement 300, the layer arrangement 700 may further include a third seed layer 708. The third seed layer 708 may include NiW, and may have a thickness of at least substantially equal to 9nm. The third seed layer 708 may be at least substantially identical or similar to the third seed layer 108 of the layer arrangement 100. All of the layers underneath the recording layer 712 except the substrate 702, may be collectively referred herein as the underlying structure 714.

[0087] FIG. 8 shows a graph 800 showing the effect of Co atomic content of a CoPt alloy on the coercivity of the recording layers of two different layer arrangements, wherein each of the recording layers is a layer of the CoPt alloy. The percentage composition of Co in the recording layer was varied across the compositional range of 52 to 75 atomic %. The graph 800 includes a horizontal axis 880 indicating a percentage composition of Co in the recording layer; and a vertical axis 882 indicating perpendicular coercivity of the recording layer in Oe. The graph 800 further includes a first plot 884 representing the recording layer of the layer arrangement 700, i.e. the CoPt alloy is deposited over a structure of NiTa (35nm)/ Ta (3nm)/ Ni-X (25nm)/ Ru (low pressure) (30nm)/CoPt. Coercivity peaked at composition of $\text{Co}_{64.3}\text{Pt}_{35.7}$ with coercivity at 13.5 kOe. The graph 800 further includes a second plot 886 representing the recording layer of the layer arrangement 300, i.e. the CoPt alloy is deposited over a structure of NiTa (35nm) /Ta (3nm) /Ru(low pressure) (20nm) /CoPt. Similarly, the coercivity peaked at a composition of $\text{Co}_{64.3}\text{Pt}_{35.7}$ with value of 5.5kOe. This suggested that the optimal composition of $\text{Co}_{64.3}\text{Pt}_{35.7}$ was not affected by the variations in the layers underneath the CoPt recording layer.

[0088] FIGS. 9-12 depict the optimization of the sputtering parameters for forming the recording layer 712 of the layer arrangement 700, wherein the recording layer 712 is a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$ alloy.

[0089] FIG. 9 shows a graph 900 showing the effect of sputter pressure on the coercivity of a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$, wherein the layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$ is deposited onto the underlying structure 714 to form the recording layer 712. The graph 900 includes a horizontal axis 990 indicating sputter pressure in millitorr (mTorr); and a vertical axis 992 indicating coercivity in Oe. The coercivity increased monotonically with deposition pressure suggesting higher pressure is beneficial in improving coercivity.

[0090] FIG. 10 shows a graph 1000 showing the effect of $\text{Co}_{64.3}\text{Pt}_{35.7}$ layer thickness on the coercivity of the recording layer 712, wherein the $\text{Co}_{64.3}\text{Pt}_{35.7}$ layer is deposited onto the underlying structure 714 to form the recording layer 712. The graph 1000 includes a horizontal axis 1010 indicating thickness of the $\text{Co}_{64.3}\text{Pt}_{35.7}$ layer in nanometers (nm); and a vertical axis 1012 indicating coercivity of the recording layer in Oe. The graph 1000 shows that the coercivity of $\text{Co}_{64.3}\text{Pt}_{35.7}$ increases with thickness, reaching a peak at 13.9kOe with a thickness of 8nm. Subsequent increases in CoPt thickness up to 15 nm led to decreases in coercivity, indicating an optimal thickness of the CoPt layer at around 8 nm.

[0091] FIG. 11 shows a graph 1100 showing the effect of deposition temperature on the coercivity of recording layer 712 when the $\text{Co}_{64.3}\text{Pt}_{35.7}$ alloy is deposited onto the underlying structure 714 to form the recording layer 712. The graph 1100 includes a horizontal axis 1110 indicating heater power in kilowatts (kW); and a vertical axis 1112 indicating coercivity of the recording layer in Oe. The graph 1100 shows the decline in coercivity with an increase in heating power which causes an increased application of heat to the $\text{Co}_{64.3}\text{Pt}_{35.7}$ alloy. This trend of decreasing coercivity with increasing temperature is opposite to the temperature dependencies of other high K_u CoPt materials such as Co_3Pt and $\text{L1}_1\text{-CoPt}$, which show improved coercivity with higher fabrication temperatures. L1 denotes a ligand.

[0092] FIG. 12 shows a graph 1200 showing the effect of sputter power on the coercivity of the recording layer 712, wherein the recording layer 712 is a CoPt layer. The graph includes a horizontal axis 1220 indicating CoPt sputter power in kilowatts (kW); and a vertical axis 1222 indicating coercivity in Oe. As shown in the graph 1200, the coercivity decreases as the sputter power increases beyond about 0.18kW.

[0093] FIG. 13 shows a graph 1300 showing the magnetic hysteresis loops of the recording layer 712 of the layer arrangement 700, for various thicknesses of the third seed layer. The recording layer 712 is a $\text{Co}_{64.3}\text{Pt}_{35.7}$ layer. The third seed layer may include $\text{Ni}_{90}\text{W}_{10}$. The

graph 1300 includes a horizontal axis 1330 indicating applied field in kiloOestereds (kOe); and a vertical axis 1332 indicating magnetization in emu/cc. The graph 1300 includes a first plot 1334 representing the layer arrangement without the third seed layer, i.e. 0nm of $\text{Ni}_{90}\text{W}_{10}$. The graph 1300 further includes plot 1336 representing $\text{Ni}_{90}\text{W}_{10}$ layer of 2.5nm thickness; plot 1338 representing $\text{Ni}_{90}\text{W}_{10}$ layer of 8.6nm thickness; plot 1340 representing $\text{Ni}_{90}\text{W}_{10}$ layer of 25nm thickness; and plot 1342 representing $\text{Ni}_{90}\text{W}_{10}$ layer of 86nm thickness.

[0094] FIG. 14 shows a graph 1400 summarising the coercivity of the recording layer 712 of the layer arrangement 700 for various thicknesses of the third seed layer, wherein the recording layer is a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$. The third seed layer may include $\text{Ni}_{90}\text{W}_{10}$. The initial addition of 2.5 nm in thickness of Ni-W led to a decrease in coercivity. However, subsequent increases in the thickness of Ni-W resulted in a monotonic increase in coercivity up to 15 kOe with 86 nm-thick layer of Ni-W. The increase in coercivity in CoPt may be due to improvements in texture with increasing thickness of the Ni-W layer.

[0095] FIG. 15 shows a graph 1500 showing the magnetic hysteresis loop of the recording layer 712, wherein the recording layer 712 is a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$. The graph 1500 includes a horizontal axis 1550 indicating applied field in kOe; and a vertical axis 1552 indicating magnetization in emu/cc. The graph 1500 further includes the out-of-plane component 1554 and the in-plane component 1556. As can be seen from the graph 1500, the out-of-plane component 1554 is larger than the in-plane component 1556, suggesting that perpendicular magnetization dominates.

[0096] FIG. 16 shows a graph 1600 showing the XRD patterns of $\text{Co}_{64.3}\text{Pt}_{35.7}$ films with different $\text{Ni}_{90}\text{W}_{10}$ thickness.

[0097] FIG. 17 shows a graph 1700 showing the summary of mosaic distribution, i.e. textures of the third seed layer including NiW, the recording layer including CoPt and the interlayer including Ru, with respect to the thickness of the NiW layer. NiW(111) and CoPt+Ru(002) textures. The NiW layer is the third seed layer of the layer arrangement 700. The graph 1700 includes a horizontal axis 1770 and a vertical axis 1772. The horizontal axis indicates the thickness of the NiW layer in nm while the vertical axis 1772 indicates the mosaic distribution in degrees. The graph 1700 further includes a first plot 1774 representing the 111 plane of the NiW layer, i.e. the third seed layer. The graph 1700 further includes a second plot 1776 representing the 002 plane of the CoPt and Ru layers, i.e. the recording layer and the interlayer. The graph 1700 shows that the mosaic distribution decreases with increasing

thickness of the third seed layer, suggesting that the increasing coercivity with thickness of the NiW layer was a result of texture improvement.

[0098] FIG. 18 shows a graph 1800 showing the effect of the thickness of the third seed layer 708, on the saturation magnetization (M_s) and magnetic anisotropy (K_u) of the recording layer 712 of the layer arrangement 700. The recording layer 712 may be a layer of $\text{Co}_{64.3}\text{Pt}_{35.7}$. The third seed layer 708 may be a layer of NiW. The graph includes a horizontal axis 1880 indicating the thickness of the third seed layer, i.e. thickness of the NiW layer; a first vertical axis 1882 indicating M_s in emu/cc; and a second vertical axis 1884 indicating K_u in $\times 10^7$ erg/cc. The graph 1800 further includes a first plot 1886 representing M_s , which is to be read in conjunction with the first vertical axis 1882; and a second plot 1888 representing K_u , which is to be read in conjunction with the second vertical axis 1884. The magnetic anisotropy of CoPt increased as the thickness of the third seed layer 708 increased, up to a thickness of 25nm and then plateaued with thicker Ni-W films. Saturation magnetization was insensitive to the Ni-W thickness variations and was maintained at around 800 emu/cc.

[0099] FIG. 19A shows an illustration 1900A of hexagonal close-pack structure (HCP) structure and a face centred cubic (FCC) structure. A stacking fault may occur when a face-centered cubic (FCC) phase forms within a HCP structure. Both HCP and FCC structures are close-packed structures with the highest average density. The difference between these two lies in the way that the layers of atoms are stacked. HCP phase is a repetition of two closed pack layers forming a structure of A-B-A-B-A-B... where the atoms in every other layer are in the same position along the out-of-plane direction. FCC phase on the other hand, consists of the stacking of three closed packed layers forming a periodicity of A-B-C-A-B-C-... with every third layer having the same position along the out-of-plane direction. Therefore, the formation of an A-B-C stacking within an A-B-A structure typically results in the presence of defects.

[0100] FIG. 19B shows an illustration 1900B of a stacking fault within a hexagonal close-pack structure (HCP) structure. The HCP structure includes a FCC stacking below a HCP stacking.

[0101] FIG. 20 shows a High Resolution Transmission Electron Microscopy (HRTEM) image 2000 of the recording layer of the layer arrangement 300. The recording layer is a continuous $\text{Co}_{64.3}\text{Pt}_{35.7}$ film. The layer arrangement 300 does not include a third seed layer.

[0102] FIG. 21A shows a cross-sectional HRTEM image 2100A of the recording layer of FIG. 20.

[0103] FIG. 21B shows a magnified view 2100B of the HRTEM image 2100A. The interlayer includes HCP phase only, while the recording layer includes a mixture of FCC and HCP phases.

[0104] FIG. 22 shows a layer arrangement 2200 according to various embodiments. The layer arrangement 2200 may be similar to the layer arrangement 700, in that it includes a substrate 2202, a first seed layer 2204, a second seed layer 2206, an interlayer 2210 and a recording layer 2212. The substrate 2202 may include glass. The first seed layer 2204 may include NiTa, and may be about 35nm in thickness. The second seed layer 2206 may include Ta, and may be 3nm in thickness. The interlayer 2210 may include Ru, and may be about 16nm in thickness. The recording layer 2212 may include CoPt, and may be about 7nm in thickness. The layer arrangement 2200 may include a third seed layer 2208 which may include an alloy of Ni. The alloy may be NiW-XY, wherein XY may be at least one of other metals or compounds. The third seed layer 2208 may have a thickness that may be at least substantially about 86nm or less.

[0105] FIG. 23A shows a cross-sectional HRTEM image 2300A of the recording layer 2212 of the layer arrangement 2200. The recording layer 2212 which is deposited on the interlayer 2210 including Ru, is a $\text{Co}_{64.3}\text{Pt}_{35.7}$ film. The third seed layer 2208 includes an 8.6 nm-thick layer of NiW.

[0106] FIG. 23B shows a magnified view 2300B of the HRTEM image 2300A. The $\text{Co}_{64.3}\text{Pt}_{35.7}$ film exhibited granular structure but still included a mixture of HCP and FCC phases with extensive stacking faults observed. The amount of FCC within the $\text{Co}_{64.3}\text{Pt}_{35.7}$ grains however were reduced compared to samples without NiW underlayer, for example the recording layer as seen in HRTEM images 2100A and 2100B.

[0107] FIG. 24A shows a cross-sectional HRTEM image 2400A of the recording layer 2212 of the layer arrangement 2200. The recording layer 2212 which is deposited on the interlayer 2210 including Ru, is a $\text{Co}_{64.3}\text{Pt}_{35.7}$ film. The third seed layer 2208 includes a 25 nm-thick layer of NiW.

[0108] FIG. 24B shows a magnified view 2400B of the HRTEM image 2400A. The CoPt layer showed more distinct grain isolation compared to samples with 8.6 nm NiW as shown in HRTEM images 2300A and 2300B. The FCC phases and stacking faults within the CoPt layer also decreased significantly.

[0109] FIG. 25A shows a cross-sectional HRTEM image 2500A of the layer arrangement 2200 wherein the third seed layer 2208 is a 86 nm-thick layer of NiW. The recording layer

2212 which is deposited on the interlayer 2210 including Ru, is a $\text{Co}_{64.3}\text{Pt}_{35.7}$ film. Isolated grain structures can be seen in the recording layer 2212.

[0110] FIG. 25B shows a magnified view 2500B of the HRTEM image 2500A. Stacking faults and FCC phases were still present but significantly less than the CoPt films of the layer arrangement wherein the third seed layer 2208 is a 25 nm-thick layer of NiW, as shown in HRTEM images 2400A and 2400B.

[0111] FIG. 25C shows a plan view 2500C of the recording layer 2212 of the layer arrangement 2200 wherein the third seed layer 2208 is an 86nm-thick layer of NiW. As can be observed, the recording layer 2212 is generally of HCP structure.

[0112] FIG. 26A shows a graph 2600A showing in-plane (100) X-ray powder diffraction (XRD) data obtained for the layer arrangement 2200 for various thicknesses for the third seed layer 2208. The graph 2600A includes a horizontal axis 2660 indicating 2-theta angle in degrees; and a vertical axis 2662 indicating intensity in counts per second (CPS). The graph 2600A includes a first plot 2664A representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 2.5nm; a second plot 2666A representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 8.6nm; a third plot 2668A representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 25nm; and a fourth plot 2670A representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 87nm.

[0113] FIG. 26B shows a graph 2600B showing plane (110) X-ray powder diffraction (XRD) data obtained for the layer arrangement 2200 for various thicknesses for the third seed layer 2208. The graph 2600B includes a horizontal axis 2660 indicating 2-theta angle in degrees; and a vertical axis 2662 indicating intensity in counts per second (CPS). The graph 2600B includes a first plot 2664B representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 2.5nm; a second plot 2666B representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 8.6nm; a third plot 2668B representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 25nm; and a fourth plot 2670B representing the XRD data for the layer arrangement 2200 wherein the third seed layer 2208 has a thickness of 87nm.

[0114] FIG. 27 shows a table 2700 summarising the XRD data for the layer arrangement 2200 for various thicknesses for the third seed layer 2208. The table 2700 includes a first column 2770 listing the sample numbers of the various samples of layer arrangements 2200;

a second column 2772 listing the thickness of the third seed layer 2208 including NiW; a third column 2774 listing the miller indices of the crystal lattice plane of the recording layer 2212; a fourth column 2776 listing the values of the peaks in the XRD data; a fifth column 2778 listing the area underneath the XRD peaks; and a sixth column 2780 listing the ratio of the peak value corresponding to the 100 plane with respect to the peak value corresponding to the 110 plane. The table 2700 shows that there is a clear increase of the ratio of the peak value corresponding to the 100 plane with respect to the peak value corresponding to the 110 plane, indicating that the stacking faults reduces as the NiW thickness increases.

[0115] FIG. 28 shows a layer arrangement 2800 according to various embodiments. The layer arrangement 2800 may be similar to the layer arrangement 700, in that it includes a substrate 2802, a first seed layer 2804, a second seed layer 2806, a third seed layer 2808 and a recording layer 2812. The substrate 2802 may include glass. The first seed layer 2804 may include NiTa. The second seed layer 2806 may include Ta. The third seed layer 2808 may include a Ni alloy that may be non-magnetic, such as Ni-W. The recording layer 2812 may include CoPt, which may be $\text{Co}_{64.3}\text{Pt}_{35.7}$. Instead of a single interlayer, the layer arrangement 2800 may have a first interlayer 2810A; and a second interlayer 2810B. Each of the first interlayer 2810A and the second interlayer 2810B may include Ru. The second interlayer 2810B may be deposited under a higher pressure than the first interlayer 2810A.

[0116] FIG. 29 shows a graph 2900 showing the in-plane and out-of-plane components of the magnetic hysteresis loop of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement 2800 having the structure of NiTa (35nm) / Ta (3nm) / Ni-W (8.6nm) / Ru (low pressure) (20nm) / Ru (high pressure) (15nm)/ $\text{Co}_{64.3}\text{Pt}_{35.7}$. The graph 2900 includes a horizontal axis 2990 indicating applied field in Oe; and a vertical axis 2992 indicating magnetization in emu/cc. The graph 2900 further includes the out-of-plane component 2994, i.e. perpendicular component and the in-plane component 2996. Magnetic hysteresis loops for the sample showed almost zero in-plane hysteresis exhibiting excellent (0002) HCP orientation. Out-of-plane coercivity obtained was about 13.5 kOe.

[0117] FIG. 30A shows a cross-sectional HRTEM image 3000A of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement 2800 having the structure of NiTa (35nm) / Ta (3nm) / Ni-W (8.6nm) / Ru (low pressure) (20nm) / Ru (high pressure) (15nm)/ $\text{Co}_{64.3}\text{Pt}_{35.7}$. With the addition of the second interlayer 2810B which is a Ru layer sputtered at a high pressure, the $\text{Co}_{64.3}\text{Pt}_{35.7}$ recording layer 2812 exhibited small well isolated grains of between 6 to 7nm in size. However, stacking faults were visible within the $\text{Co}_{64.3}\text{Pt}_{35.7}$ grains.

[0118] FIG. 30B shows a magnified view 3000B of the HRTEM image 3000A. A section of modified Co_3Pt phase can be seen in the magnified view.

[0119] FIG. 30C shows a selected area electron diffraction (SAED) image 3000C of the $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement 2800 having the structure of NiTa (35nm) / Ta (3nm) / Ni-W (8.6nm) / Ru (low pressure) (20nm) / Ru (high pressure) (15nm)/ $\text{Co}_{64.3}\text{Pt}_{35.7}$.

[0120] FIG. 30D shows a SAED image 3000D of the $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement 2800 having the structure of NiTa (35nm) / Ta (3nm) / Ni-W (8.6nm) / Ru (low pressure) (20nm) / Ru (high pressure) (15nm)/ $\text{Co}_{64.3}\text{Pt}_{35.7}$. The SAED images 3000C and 3000D show that the lattice matching in the abc plane between $\text{Co}_{64.3}\text{Pt}_{35.7}$ layer and Ru layer is almost perfect, as indicated by the lattice zone of (01-10) having the same d-spacing of 0.233 nm for both layers. The lattice parameter along z direction, indicated by the lattice zone of (0001), is also very similar for both layers (0.438 nm for $\text{Co}_{64.3}\text{Pt}_{35.7}$ and 0.436 nm for Ru and only a 0.45% difference). Both the XRD and TEM results agree well with each other and confirm that the $\text{Co}_{64.3}\text{Pt}_{35.7}$ is a hcp phase with almost perfect lattice matching with the underneath Ru layer.

[0121] FIG. 31 shows a layer arrangement 3100 according to various embodiments. The layer arrangement 3100 may be similar to the layer arrangement 700, in that it includes a substrate 3102, a first seed layer 3104, a second seed layer 3106, an interlayer 3110 and a recording layer 3112. The substrate 3102 may include glass. The first seed layer 3104 may include NiTa and maybe about 35nm in thickness. The second seed layer 3106 may include Ta and maybe about 3nm in thickness. The interlayer 3110 may include Ru and may be about 30nm in thickness. The interlayer 3110 may be formed under low pressure. The recording layer 3112 may include CoPt, which may be $\text{Co}_{64.3}\text{Pt}_{35.7}$. The recording layer 3112 may be about 8nm in thickness. The layer arrangement 3100 may further include a third seed layer 3108 which may include a non-magnetic layer 3130 and a magnetic layer 3132. The magnetic layer 3132 may be arranged over the non-magnetic layer 3130. The third seed layer 3108 may be about 25nm in thickness.

[0122] FIG. 32 shows a layer arrangement 3200 according to various embodiments. The layer arrangement 3200 may be similar to the layer arrangement 700, in that it includes a substrate 3202, a first seed layer 3204, a second seed layer 3206, an interlayer 3210 and a recording layer 3212. The substrate 3202 may include glass. The first seed layer 3204 may include NiTa and maybe about 35nm in thickness. The second seed layer 3206 may include Ta and maybe about 3nm in thickness. The interlayer 3210 may include Ru and may be about 30nm in thickness. The interlayer 3210 may be formed under low pressure. The recording

layer 3212 may include CoPt, which may be $\text{Co}_{64.3}\text{Pt}_{35.7}$. The recording layer 3212 may be about 8nm in thickness. The layer arrangement 3200 may further include a third seed layer 3208 which may include a non-magnetic layer 3130 and a magnetic layer 3132. The non-magnetic layer 3130 may be arranged over the magnetic layer 3132. The third seed layer 3208 may be about 25nm in thickness.

[0123] FIG. 33 shows a graph 3300 showing a summary of coercivity of CoPt deposited on two structures. The first structure is NiTa (35nm) / Ta (3nm) / Ni-W (x nm) / NiFe-WAl (25nm - x nm) Ru (low pressure) (20nm) / Ru (high pressure) (15nm). The CoPt used for obtaining the data was $\text{Co}_{64.3}\text{Pt}_{35.7}$. The second structure is NiTa (35nm) / Ta (3nm) / NiFe-WAl (y nm) / NiW (25nm - y nm) Ru (low pressure) (20nm) / Ru (high pressure) (15nm). In other words, $\text{Co}_{64.3}\text{Pt}_{35.7}$ deposited on the first structure is similar to the layer arrangement 3100, while $\text{Co}_{64.3}\text{Pt}_{35.7}$ deposited on the second structure is similar to the layer arrangement 3200. The graph 3300 includes a first horizontal axis 3330 indicating a thickness of the lower layer of the third seed layer in nm; a second horizontal axis 3332 indicating a thickness of the upper layer of the third seed layer in nm; and a vertical axis 3334 indicating coercivity of the recording layer in Oe. The total thickness of the NiW layer and the NiWAlFe layer, i.e. thickness of the third seed layer, was maintained at about 25nm. A combination of 5nm of NiW arranged over 20nm of NiWAlFe yielded the highest coercivity in the CoPt. For the CoPt deposited on the first structure, i.e. the layer arrangement 3100, replacement of NiW with a NiFe-WAl underlayer and the subsequent increase in NiFe-WAl thickness led to an increase in coercivity. However, when NiW was fully replaced by NiFe-WAl, the coercivity decreased. For the second structure, with initial replacement of 5 nm NiFe-WAl with NiW, coercivity increased significantly. Subsequent increases in NiW thickness however led to decreases in coercivity. This suggests that a combination of 20nm NiFe-WAl followed by 5nm NiW yielded the optimal coercivity seen in CoPt, which is larger than if NiW (25 nm) or NiFe-WAl (25 nm) was used solely.

[0124] FIG. 34 shows a graph 3400 showing the effect of the interlayer 3210 thickness on the coercivity of the recording layer 3212, for the layer arrangement 3200 wherein the NiWAlFe thickness is 20nm and the NiW layer is 5nm. The graph 3400 includes a horizontal axis 3440 indicating thickness of the interlayer 3210 in nm; and a vertical axis 3442 indicating coercivity of the recording layer 3212 in Oe. The graph 3400 shows that the coercivity of the recording layer 3212 decreases with a reduction in the thickness of the interlayer 3210, although even with the interlayer 3210 thickness at 5nm, a coercivity of 14kOe could still be obtained.

[0125] FIG. 35 shows a conceptual diagram of a layer arrangement 3500 according to various embodiments. The layer arrangement 3500 may be similar to the layer arrangement 3200, in that it includes a substrate 3502, a first seed layer 3504, a second seed layer 3506, a third seed layer 3508 and a recording layer 3512. The substrate 3502 may include glass. The first seed layer 3504 may include NiTa and maybe about 35nm in thickness. The second seed layer 3506 may include Ta and maybe about 3nm in thickness. The third seed layer 3508 may include a non-magnetic layer 3130 and a magnetic layer 3132. The non-magnetic layer 3130 may be arranged over the magnetic layer 3132. The third seed layer 3508 may be about 25nm in thickness. The non-magnetic layer 3130 may be about 5nm in thickness and the magnetic layer 3132 may be about 20nm in thickness. The magnetic layer 3132 may be about four times as thick as the non-magnetic layer 3130. The recording layer 3512 may include CoPt, which may be $\text{Co}_{64.3}\text{Pt}_{35.7}$. The recording layer 3512 may be about 8nm in thickness. The layer arrangement 3500 may further include an interlayer 3510 which may include Ru. The interlayer 3510 may include a first interlayer 3550 formed under a low pressure; and a second interlayer 3552 formed under a high pressure. The first interlayer 3550 may have a thickness of about 5nm while the second interlayer 3552 may have a thickness of between 0 to 15nm.

[0126] FIG. 36 shows a graph 3600 showing the effect of the second interlayer 3552 thickness on the coercivity of the recording layer 3512, for the layer arrangement 3500 wherein the first interlayer 3550 thickness is 5nm. The graph 3600 includes a horizontal axis 3660 indicating thickness of the second interlayer 3552 in nm; and a vertical axis 3662 indicating coercivity of the recording layer 3512 in Oe. The graph 3600 shows that the coercivity of the recording layer 3512 increased with addition of up to 5nm of the second interlayer 3552. Further increase in the thickness of the second interlayer 3552 resulted in a decrease in the coercivity of the recording layer 3512. The layer arrangement without the dual Ni-X layers as the third seed layer 3508 may achieve high coercivity by having the third seed layer as a 25nm-thick NiW layer, the first interlayer 3550 as a 30nm-thick Ru layer and the second interlayer 3552 as a 20nm-Ru layer. With the implementation of dual Ni-X layers in the third seed layer 3508, in other words the non-magnetic layer 3130 and the magnetic layer 3132, the thickness of the first interlayer 3550 and the second interlayer 3552 may be reduced down to 5nm each.

[0127] FIG. 37 shows a graph 3700 showing the Kerr rotation loops of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement 3500 for various thicknesses of the second interlayer 3552. The graph 3700 includes a horizontal axis 3770 indicating applied field in kOe; and a vertical axis 3772 indicating magnetization in Kerr rotation in m° . The graph 3700 includes a first plot 3774

representing the layer arrangement 3500 without the second interlayer layer 3552, i.e. 0nm. The graph 3700 further includes plot 3776 representing 2.5nm-thick second interlayer 3552; plot 3778 representing 5.0nm-thick second interlayer 3552; plot 3780 representing 10.0nm-thick second interlayer 3552; and plot 3782 representing 15.0nm-thick second interlayer 3552.

[0128] FIG. 38 shows two HRTEM images, showing a plan view 3800 and a cross-sectional view 3882 of $\text{Co}_{64.3}\text{Pt}_{35.7}$ deposited on NiTa (35nm)/ Ta (3nm)/ NiWAlFe (20nm)/ NiW (5nm)/ Ru (low pressure) (5nm)/ Ru (high pressure) (5nm) layers. In other words, FIG. 38 shows the plan view and the cross-sectional view of the layer arrangement 3500. This structure uses a dual layer Ni-based third seed layer 3508 consisting of both $\text{Ni}_{90}\text{W}_{10}$ and $\text{Ni}_{64}\text{W}_5\text{Al}_1\text{Fe}_{30}$ instead of a single layer of $\text{Ni}_{90}\text{W}_{10}$. Cross-sectional TEM image shows well isolated grains with grain size of between 6 to 7 nm. Plan-view TEM images also showed distinct well-isolated CoPt grains. With the incorporation of two different Ni-based layers in the third seed layer 3508, coercivity can be increased to 16.5 kOe with excellent squareness which is better than using only NiW or NiWAlFe alone as the third seed layer 3508.

[0129] FIG. 39 shows a graph 3900 showing the Kerr rotation loop of $\text{Co}_{64.3}\text{Pt}_{35.7}$ of the layer arrangement 3500. The graph 3900 includes a horizontal axis 3990 indicating applied field in kOe; and a vertical axis 3992 indicating Kerr rotation in m° .

[0130] A layer arrangement according to various embodiments, may be fabricated without requiring any high temperature processes. The layer arrangement may be free of stacking faults. The recording layer of the layer arrangement may have a high magnetic anisotropy. The coercivity of the recording layer may be high and may be at least substantially equal to 16.5kOe. The grain size of the recording layer may be small, such as 6 to 7nm.

[0131] A layer arrangement according to various embodiments, may include a recording layer that includes Cr. The recording layer may include CoCrPt, with Co:Pt ratio of at least substantially about 1.5: 2.5.

[0132] A layer arrangement according to various embodiments, may include a recording layer that includes an oxide. The recording layer may include CoPt-X, where X may be one of TiO_2 , SiO_2 , Ta_2O_5 and CuO or any combination of TiO_2 , SiO_2 , Ta_2O_5 and CuO. The Co:Pt ratio may be at least substantially about 1.5: 2.5.

[0133] A layer arrangement according to various embodiments, may include a nucleation control layer. The nucleation control layer may include CoCr-X, where X may be one of TiO_2 , SiO_2 , Ta_2O_5 and CuO or any combination of TiO_2 , SiO_2 , Ta_2O_5 and CuO. The

nucleation control layer may be arranged between a first interlayer and a second interlayer, for grain size and grain isolation control.

[0134] A nucleation control layer according to various embodiments, may be arranged between an interlayer and a recording layer, for grain size and grain isolation control.

[0135] While embodiments of the invention have been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced. It will be appreciated that common numerals, used in the relevant drawings, refer to components that serve a similar or the same purpose.

Claims

1. A layer arrangement comprising:
 - a substrate;
 - a first seed layer arranged over the substrate, the first seed layer comprising an alloy of Ta;
 - a second seed layer arranged over the first seed layer, the second seed layer comprising Ta;
 - a third seed layer arranged over the second seed layer, the third seed layer comprising an alloy of Ni;
 - an interlayer arranged over the third seed layer; and
 - a recording layer arranged over the interlayer, the recording layer comprising a plurality of magnetic materials.
2. The layer arrangement of claim 1, wherein the first seed layer comprises NiTa.
3. The layer arrangement of claim 1, wherein the alloy of Ni comprises W.
4. The layer arrangement of claim 1, wherein the third seed layer comprises a non-magnetic seed layer.
5. The layer arrangement of claim 4, wherein the non-magnetic seed layer comprises Ni-W.
6. The layer arrangement of claim 4, wherein the non-magnetic seed layer has a thickness at least substantially in a range of less than 10nm.
7. The layer arrangement of claim 1, wherein the third seed layer comprises a magnetic seed layer.
8. The layer arrangement of claim 7, wherein the magnetic seed layer comprises Ni-Fe-Al-W.
9. The layer arrangement of claim 7, wherein the magnetic seed layer has a thickness at least substantially in a range of 15nm to 25nm.

10. The layer arrangement of claim 1, wherein the third seed layer comprises a non-magnetic seed layer arranged over a magnetic seed layer.
11. The layer arrangement of claim 10, wherein the non-magnetic seed layer has a first thickness and the magnetic seed layer has a second thickness, wherein the second thickness is at least substantially equal to four times the first thickness.
12. The layer arrangement of claim 1, wherein the interlayer comprises Ru.
13. The layer arrangement of claim 1, wherein the interlayer comprises a first interlayer and a second interlayer arranged over the first interlayer.
14. The layer arrangement of claim 13, wherein each of the first interlayer and the second interlayer comprises Ru.
15. The layer arrangement of claim 1, wherein the recording layer has a thickness, the thickness being at least substantially in a range of 7nm to 10nm.
16. The layer arrangement of claim 1, wherein the recording layer comprises cobalt alloy having a formula of $\text{Co}_x\text{-X}_{100-x}$.
17. The layer arrangement of claim 16, wherein X is Pt.
18. The layer arrangement of claim 16, wherein x is at least substantially equal to 64.3.
19. A method for fabricating a layer arrangement, the method comprising:
 - providing a substrate;
 - providing a first seed layer over the substrate, the first seed layer comprising an alloy of Ta;
 - providing a second seed layer over the first seed layer, the second seed layer comprising Ta;
 - providing a third seed layer over the second seed layer, the third seed layer comprising an alloy of Ni;

providing an interlayer over the third seed layer; and
providing a recording layer over the interlayer.

20. The method of claim 19, wherein providing the interlayer comprises forming a first interlayer under a first pressure and forming a second interlayer under a second pressure, wherein the second pressure is higher than the first pressure.

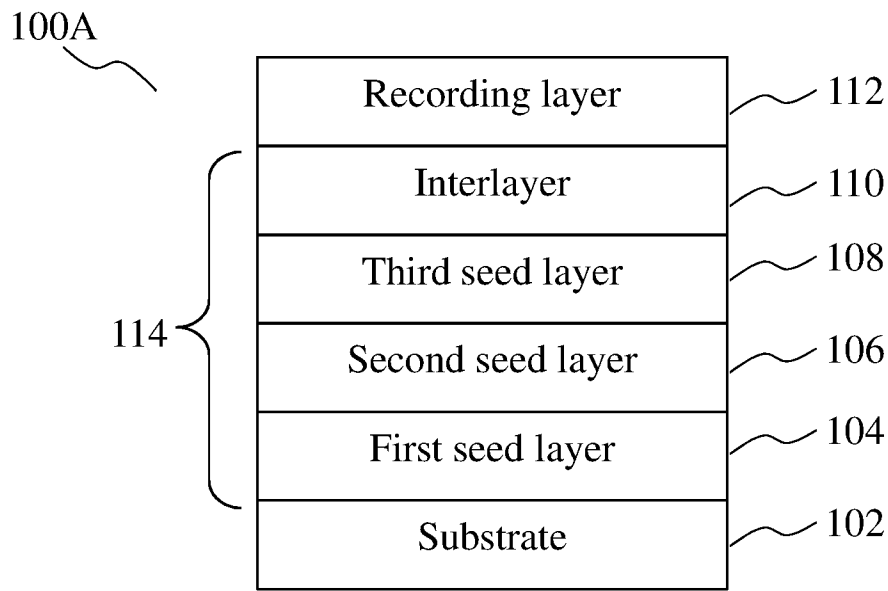


FIG. 1A

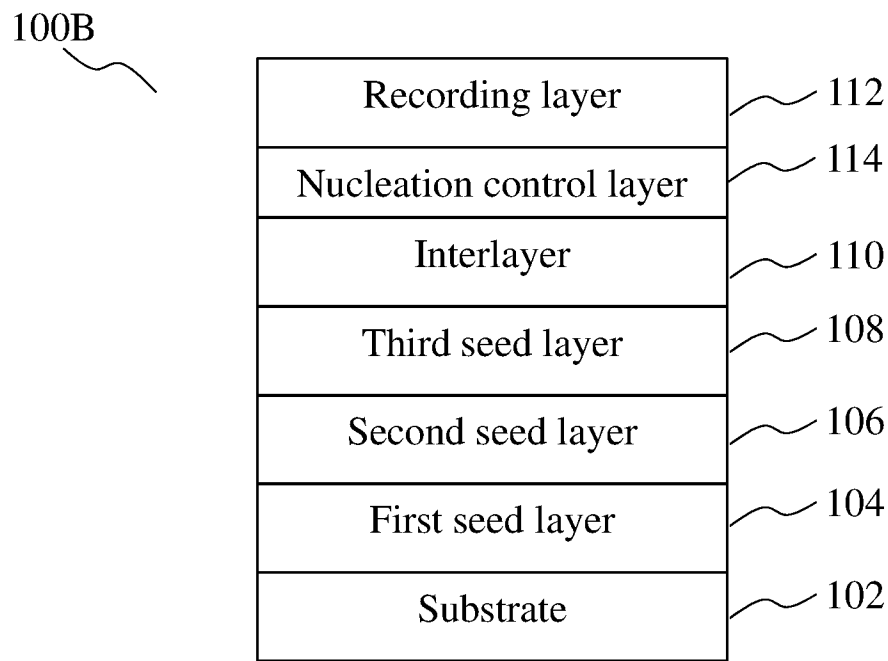
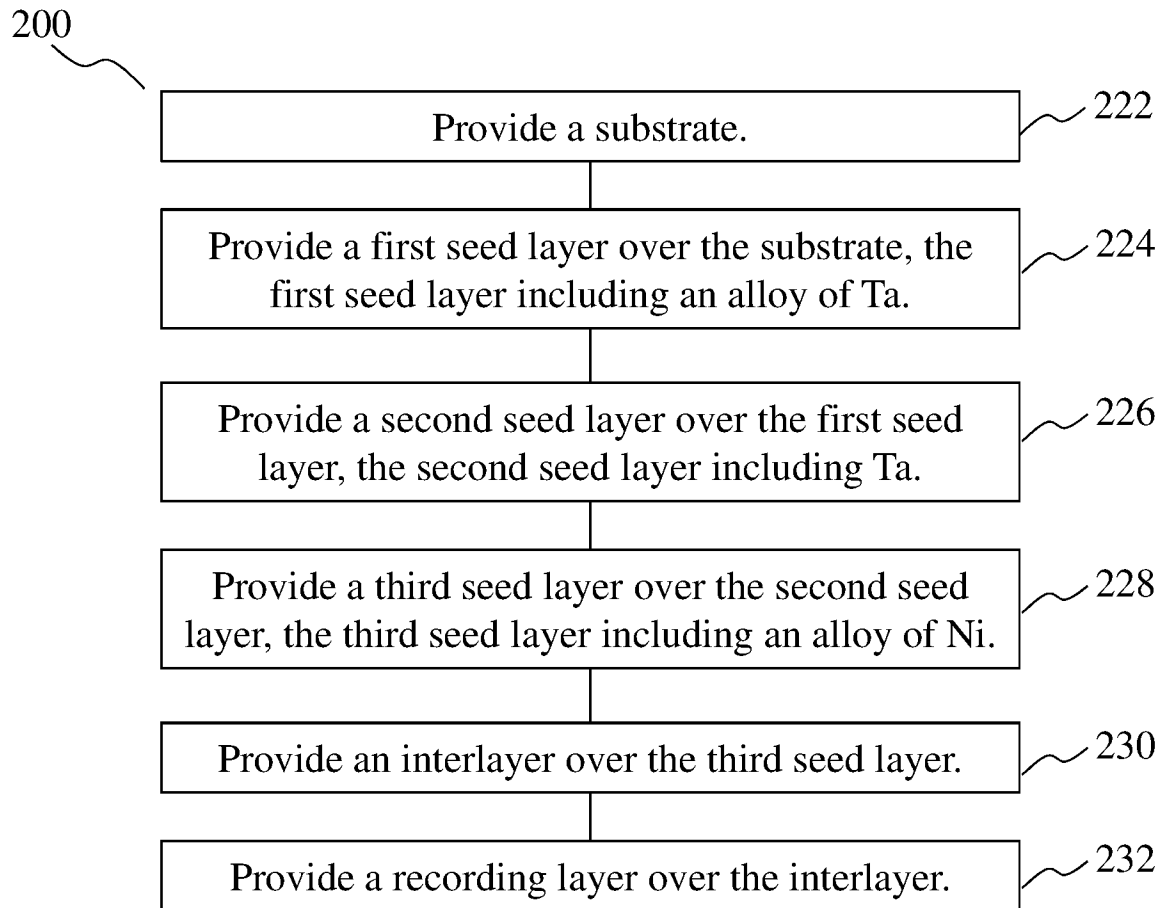
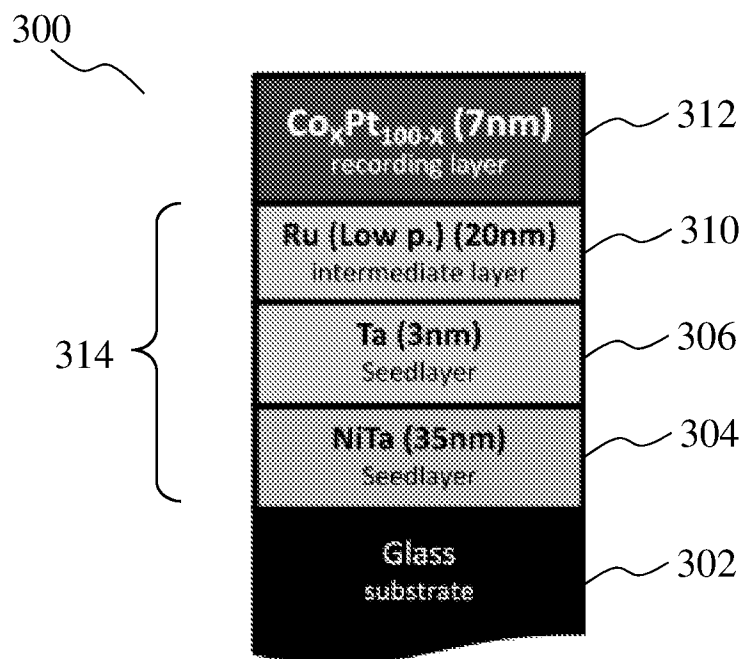


FIG. 1A

**FIG. 2****FIG. 3**

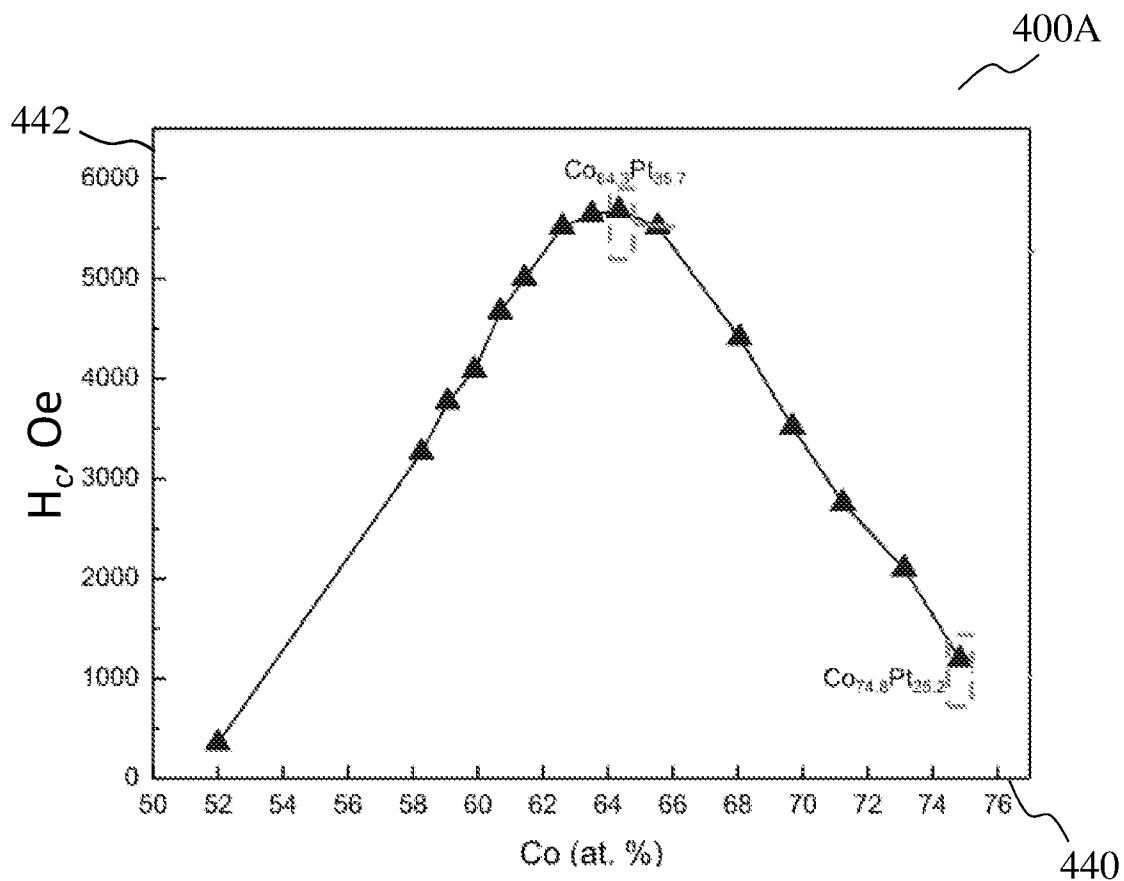


FIG. 4A

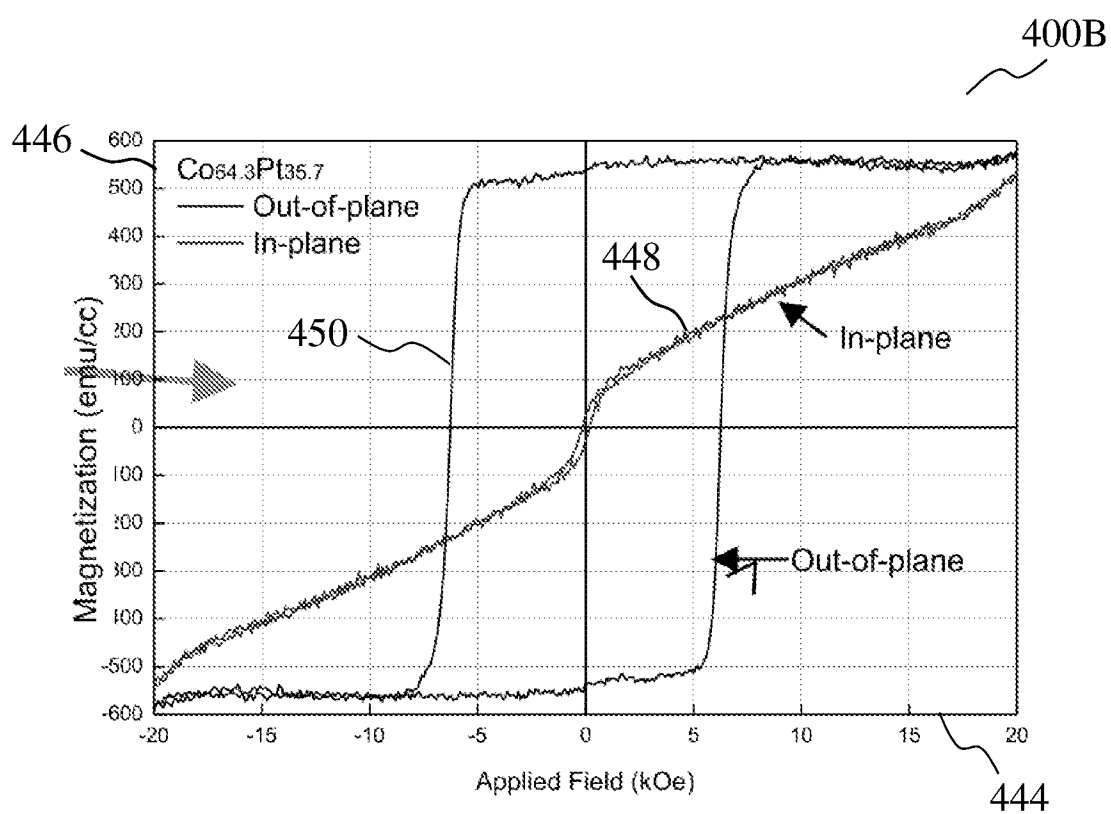
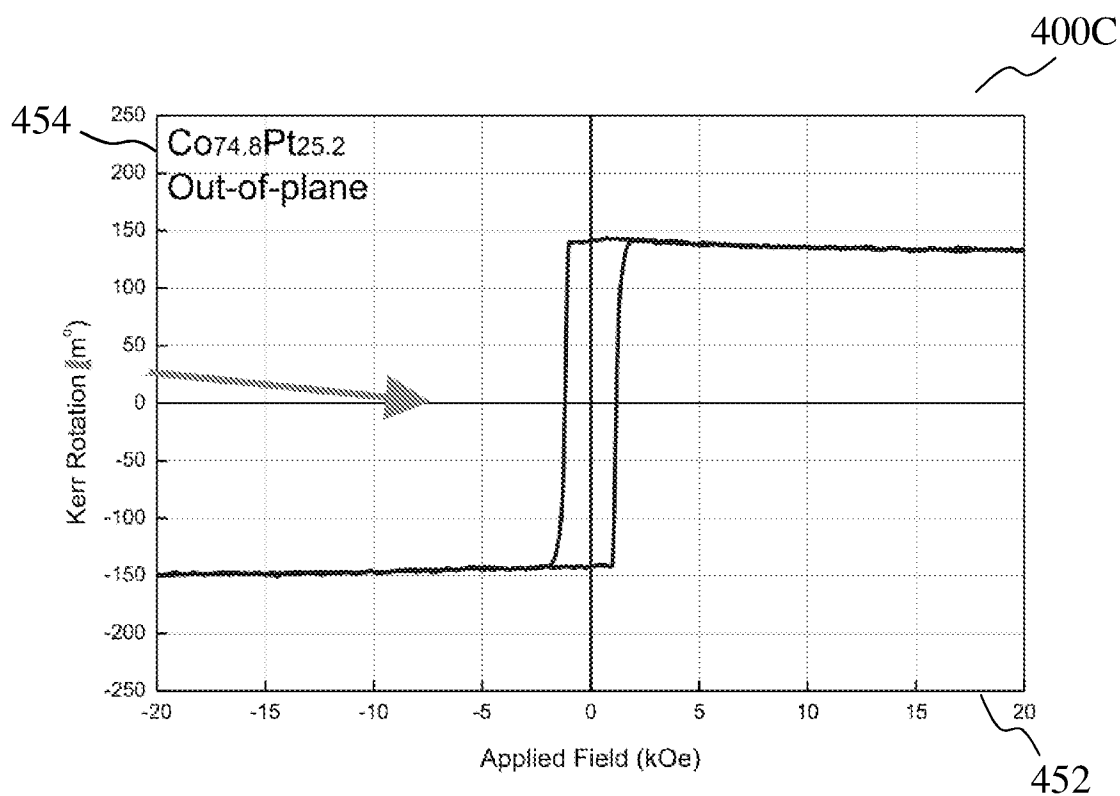
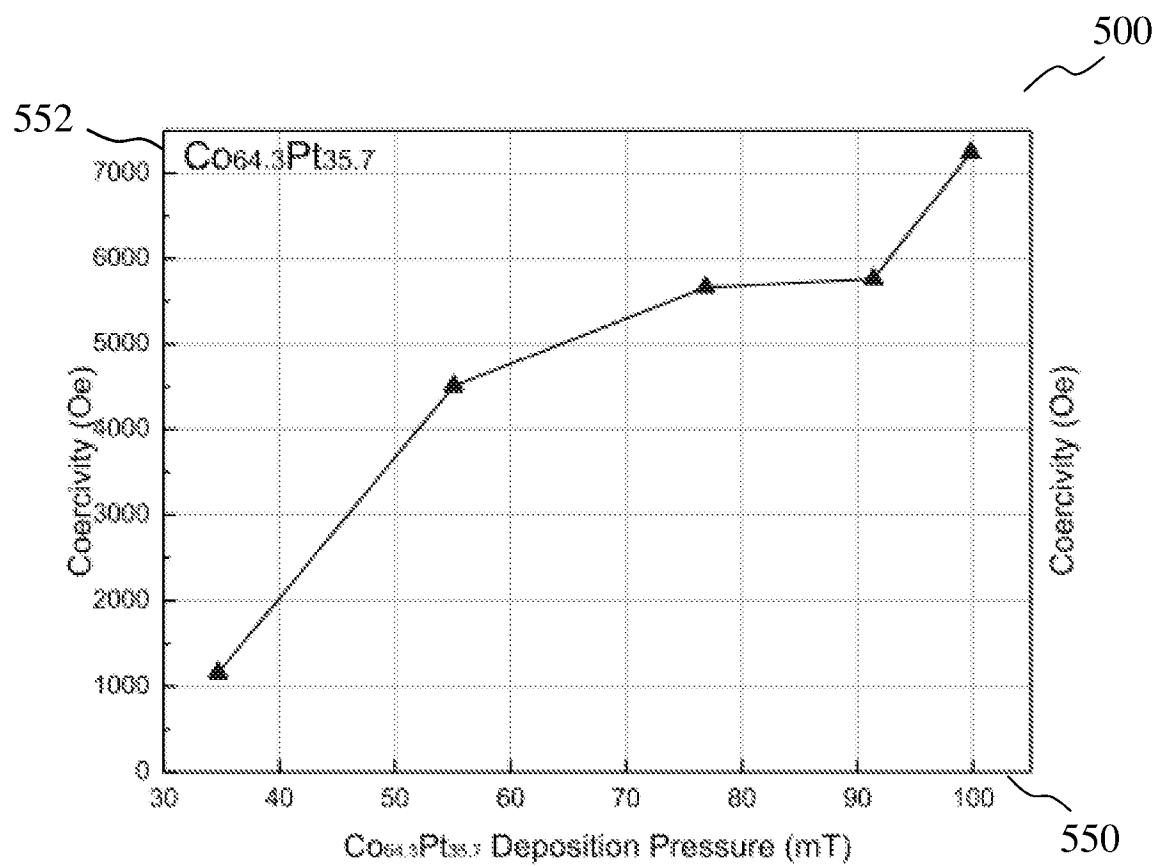
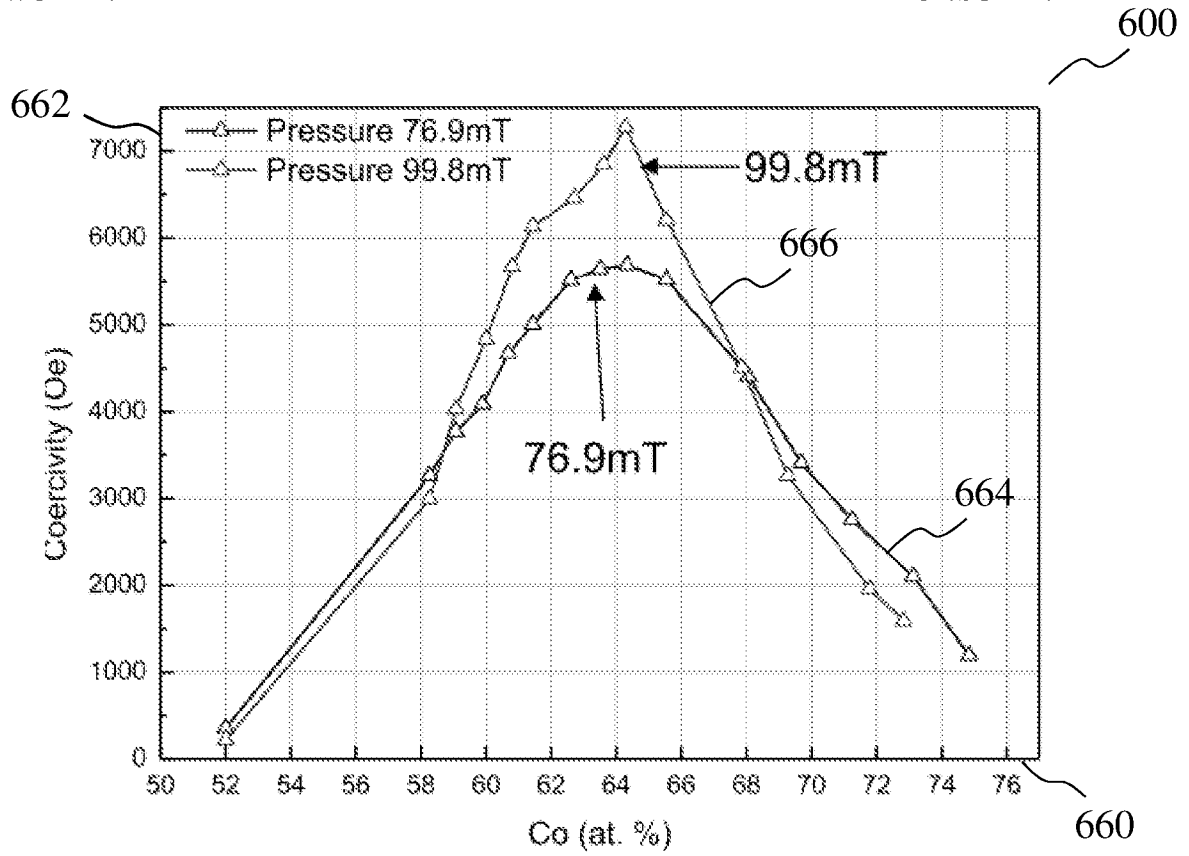
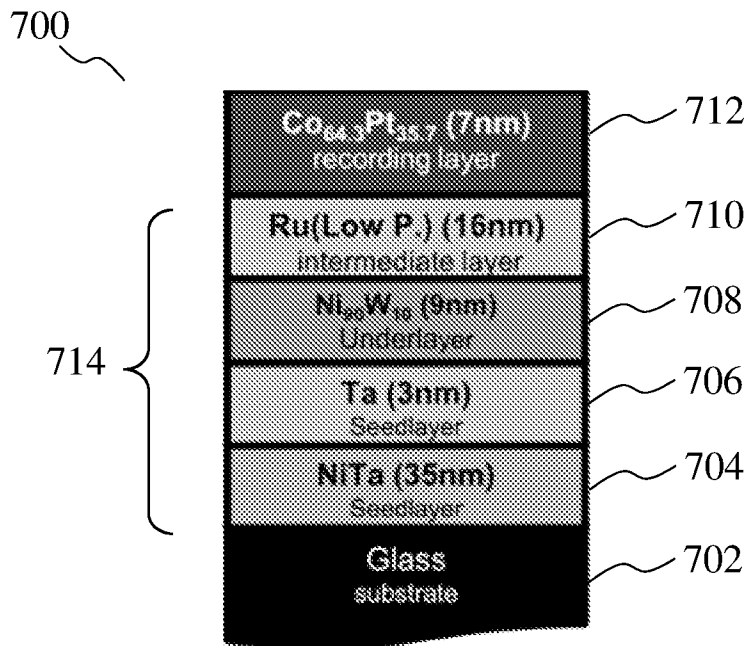


FIG. 4B

**FIG. 4C****FIG. 5**

**FIG. 6****FIG. 7**

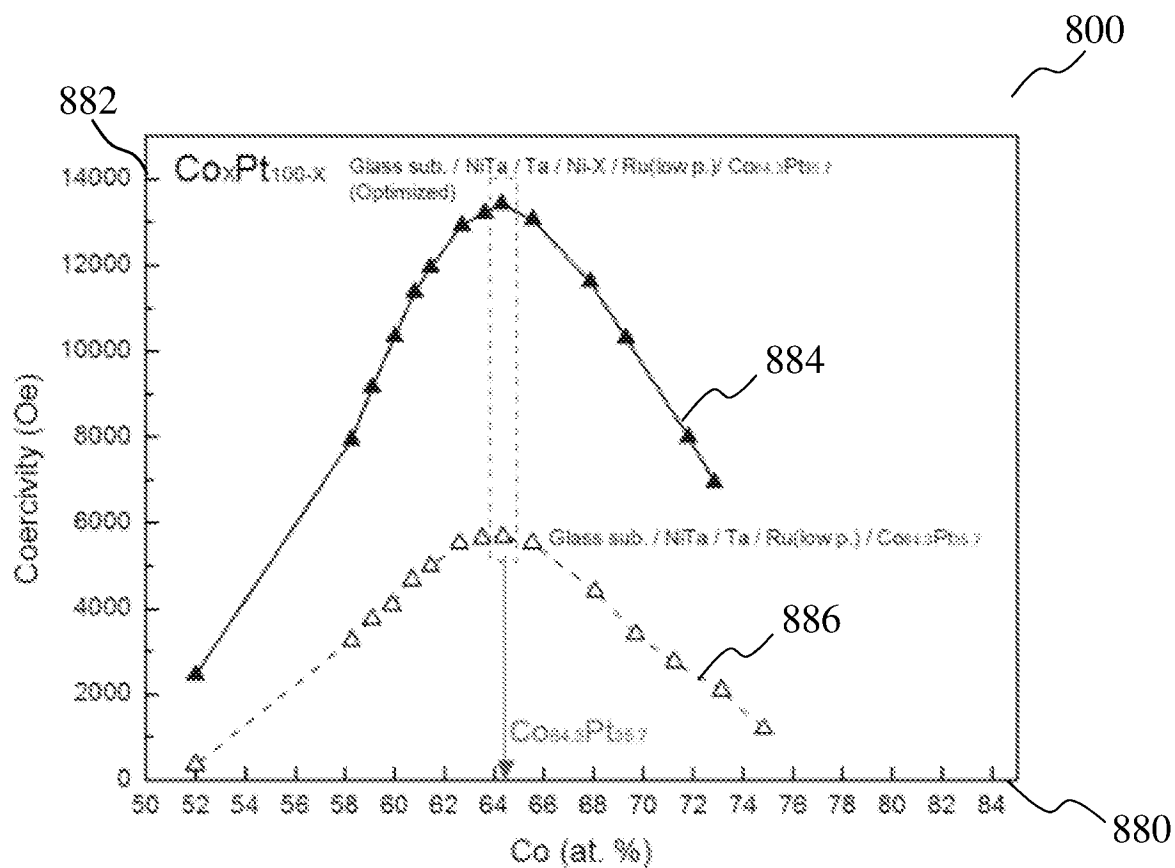


FIG. 8

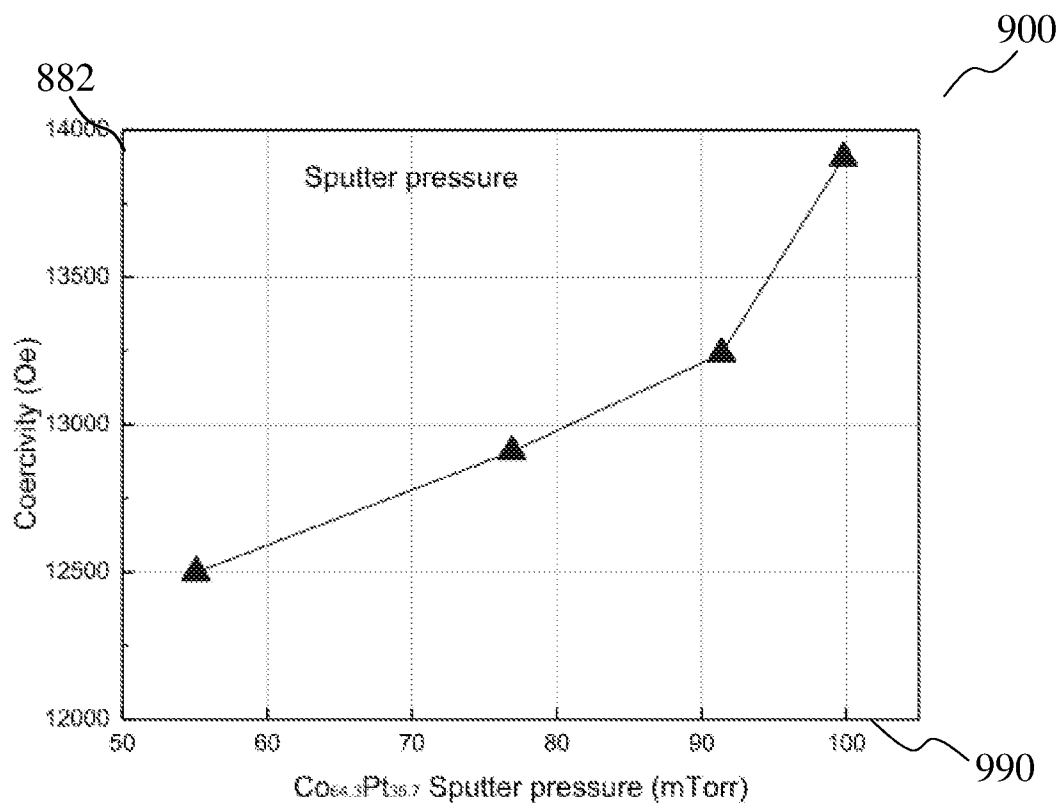
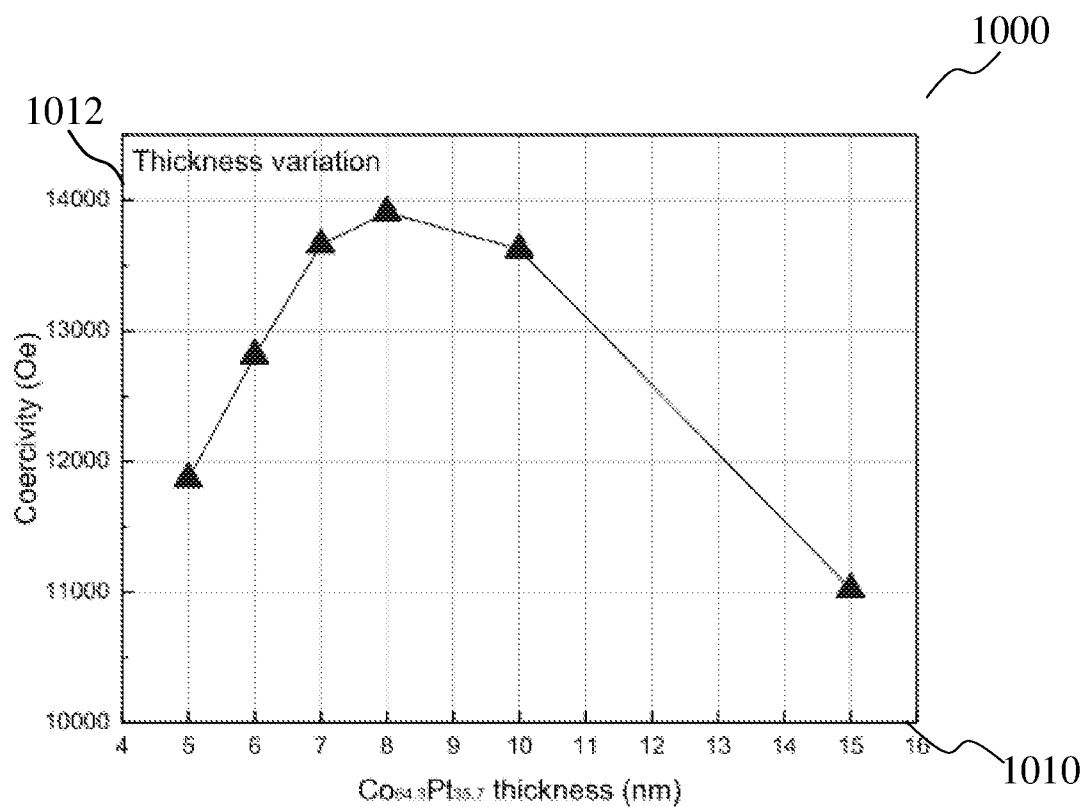
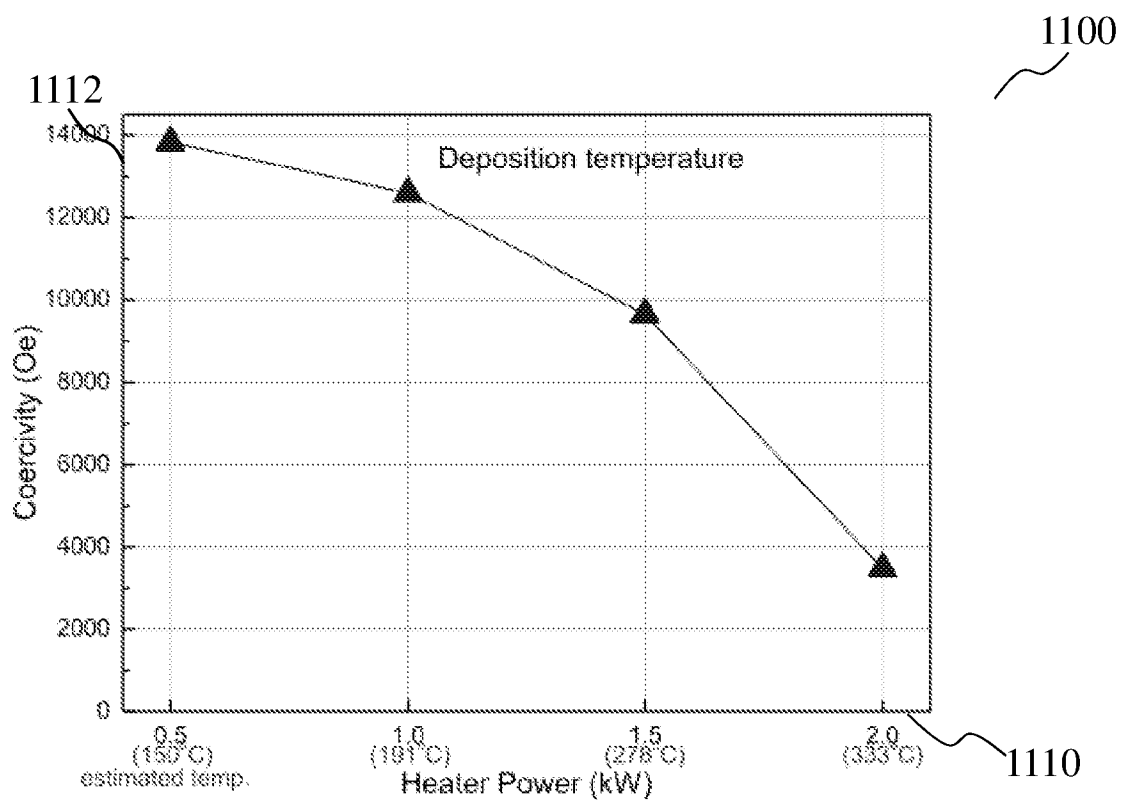
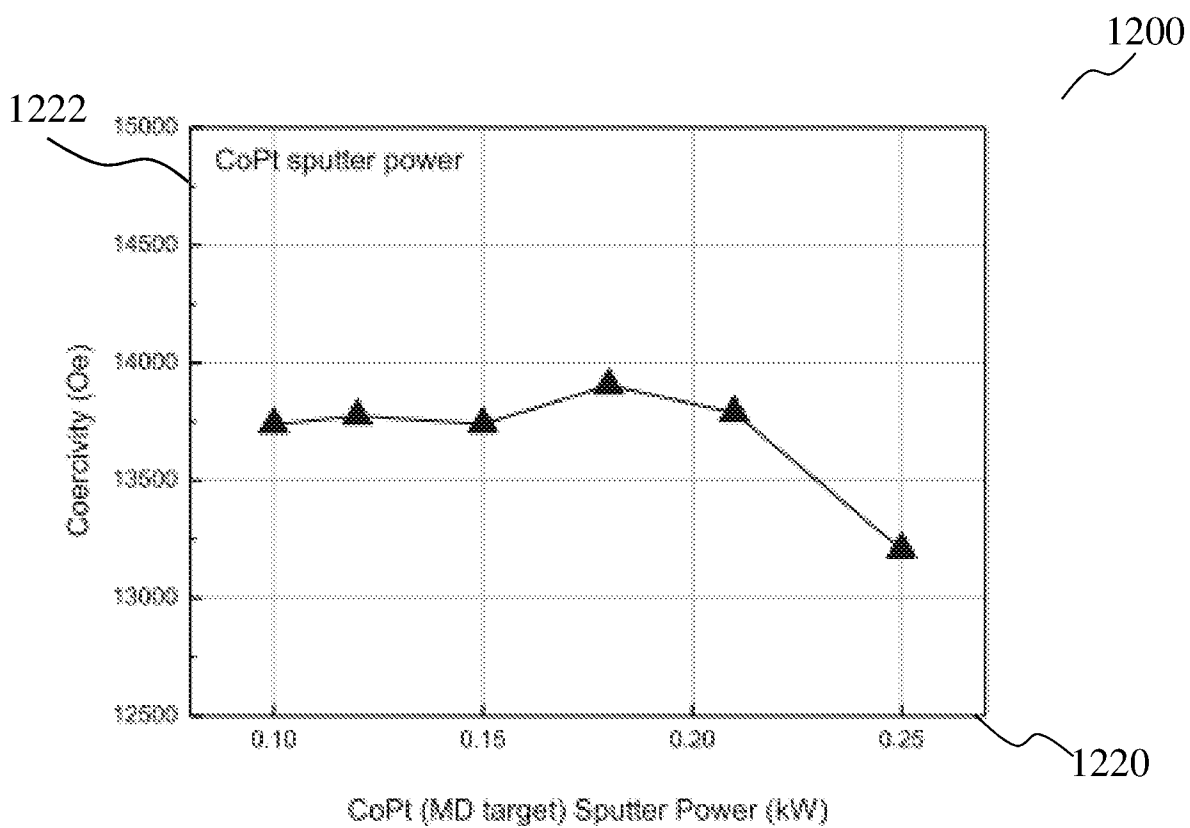
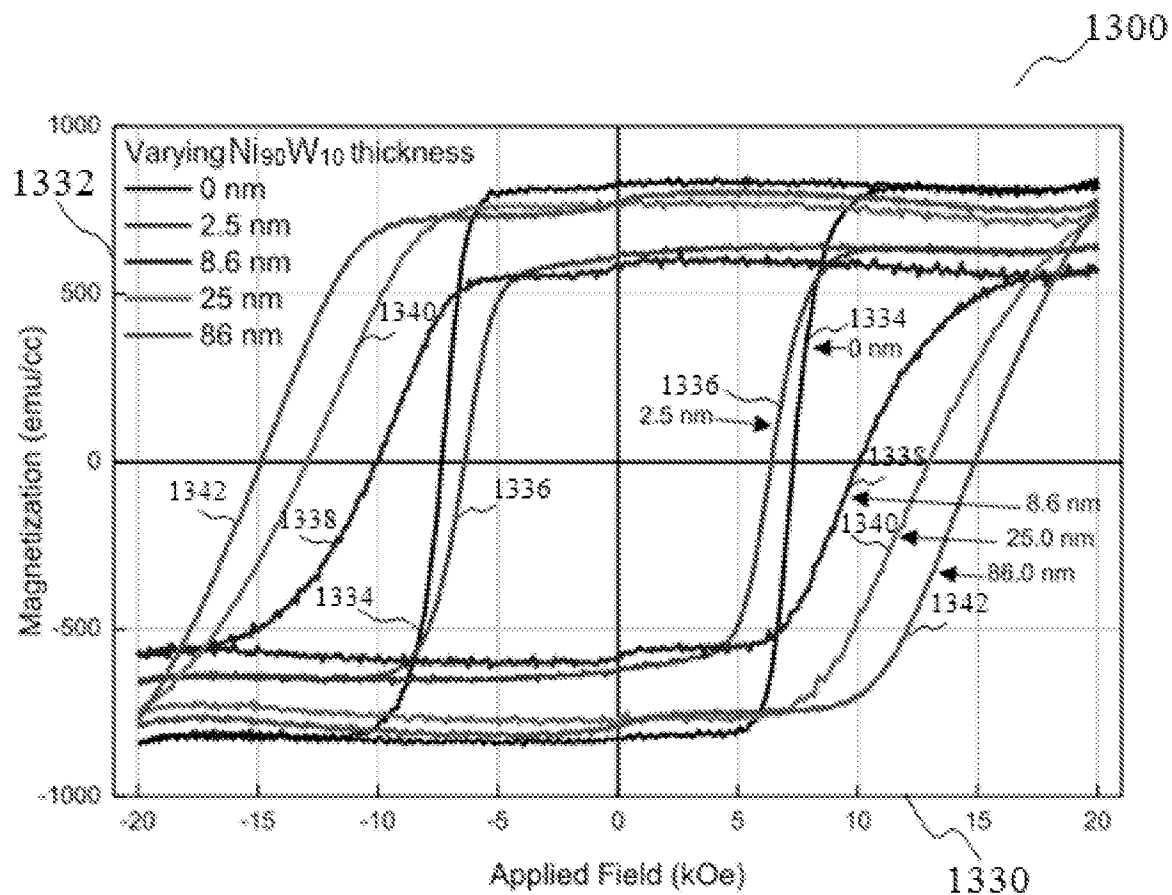
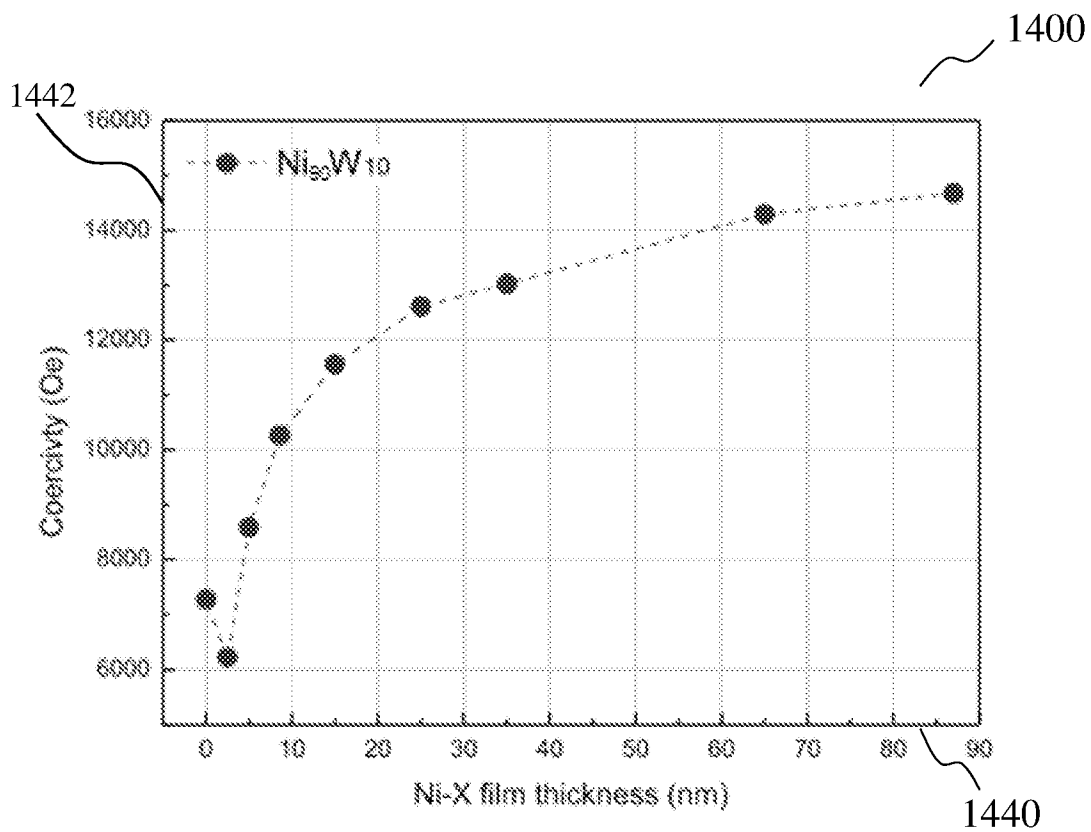
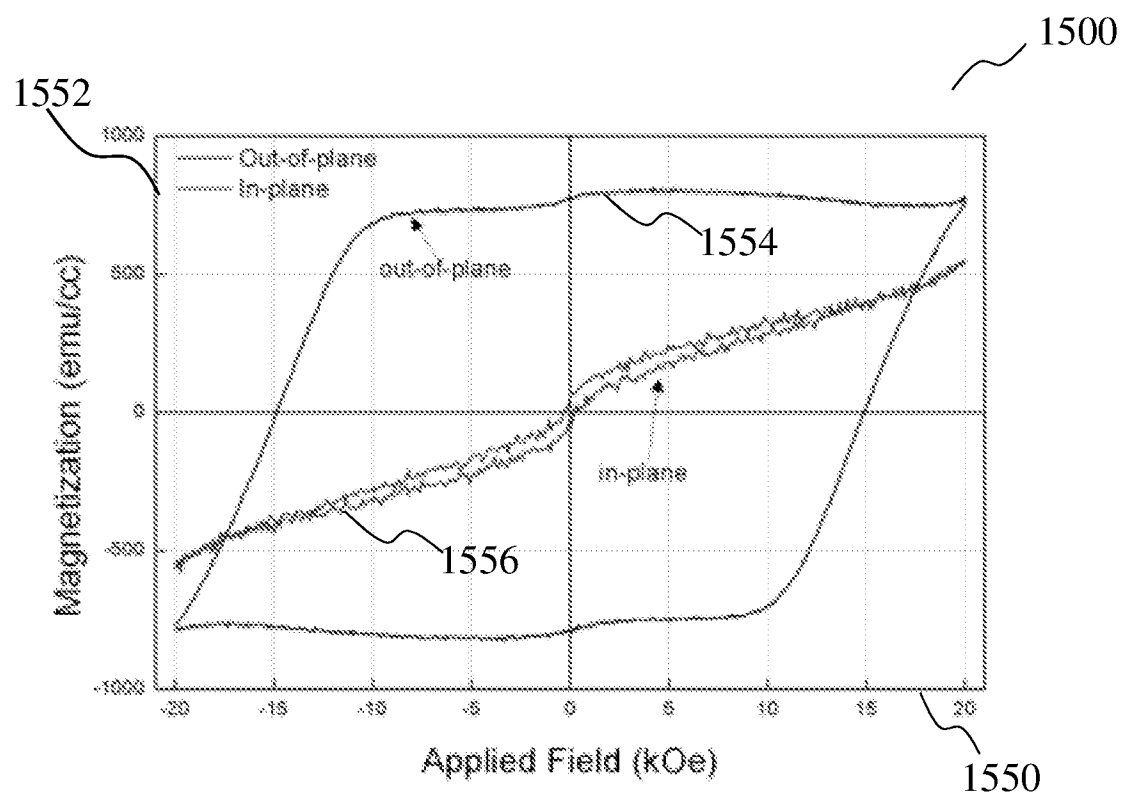


FIG. 9

**FIG. 10****FIG. 11**

**FIG. 12****FIG. 13**

**FIG. 14****FIG. 15**

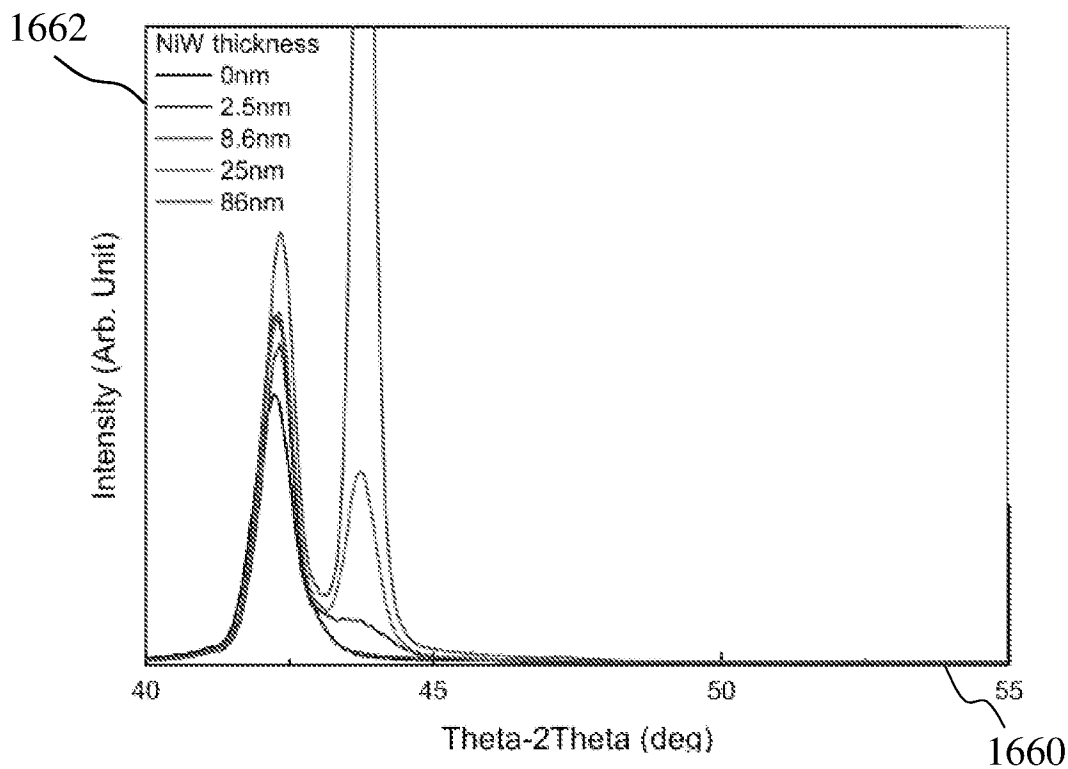


FIG. 16

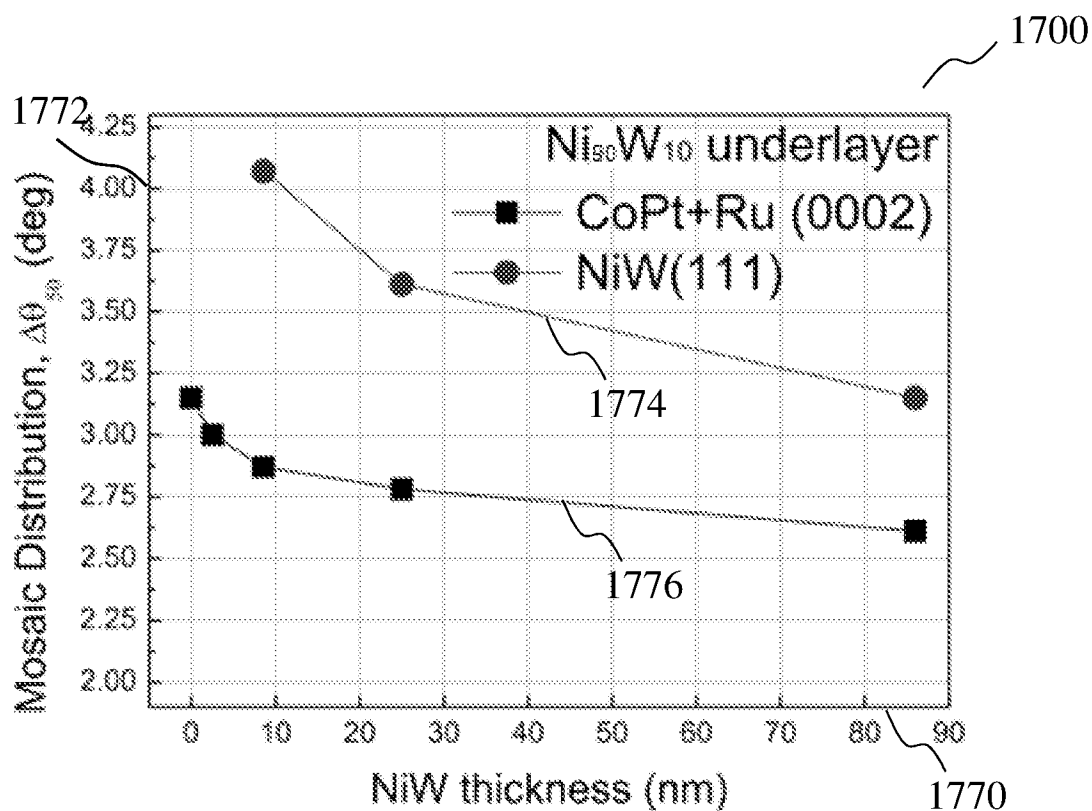


FIG. 17

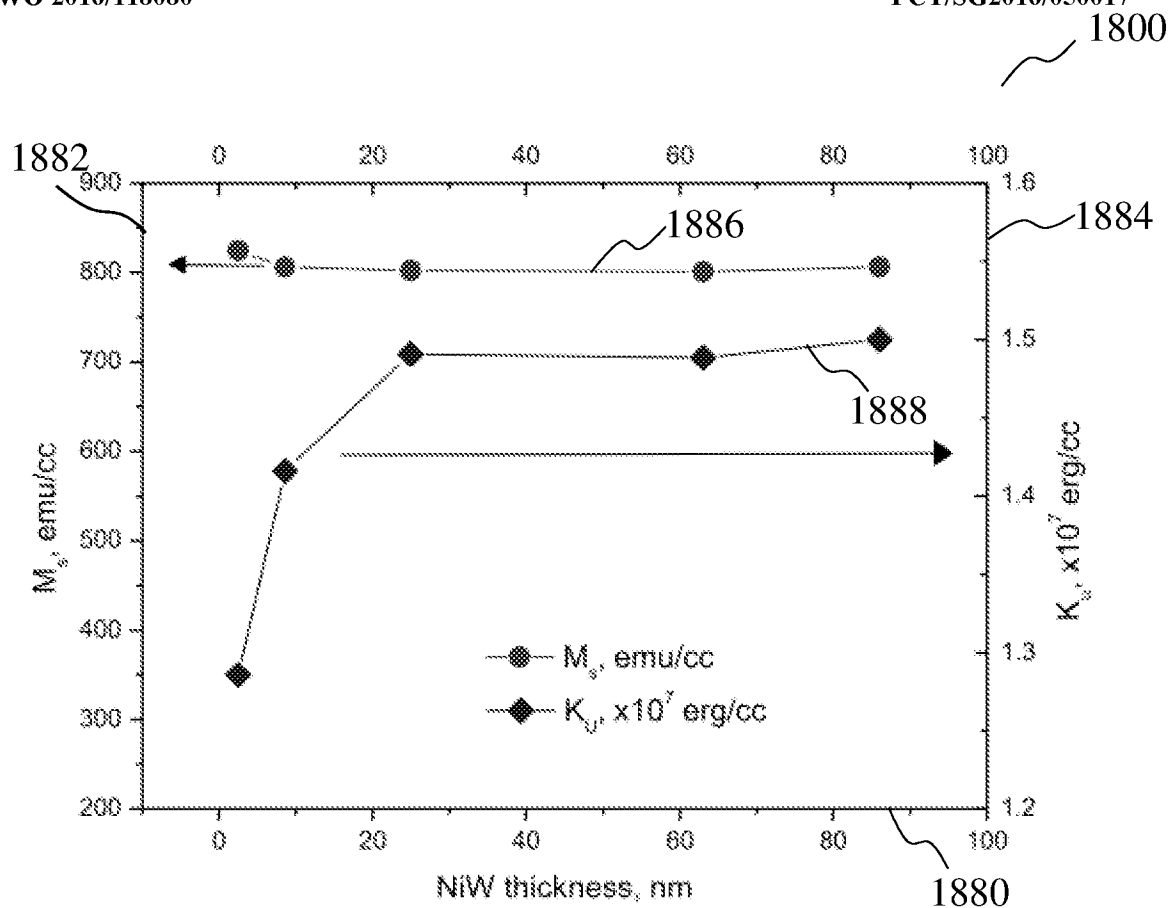


FIG. 18

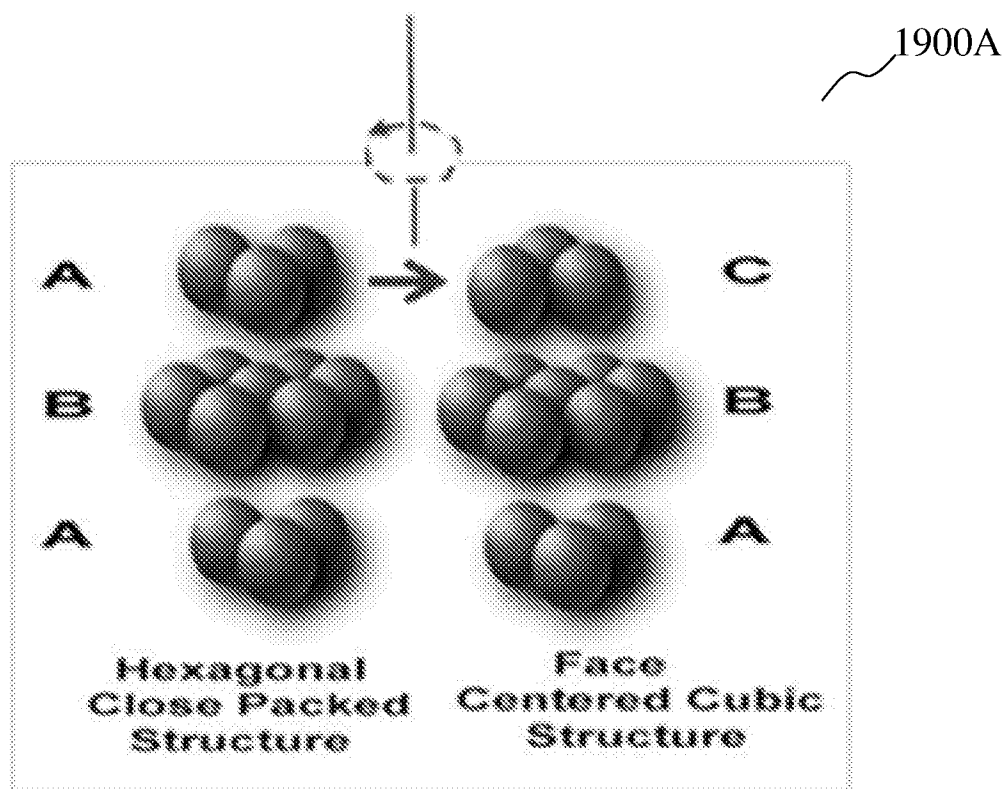


FIG. 19A

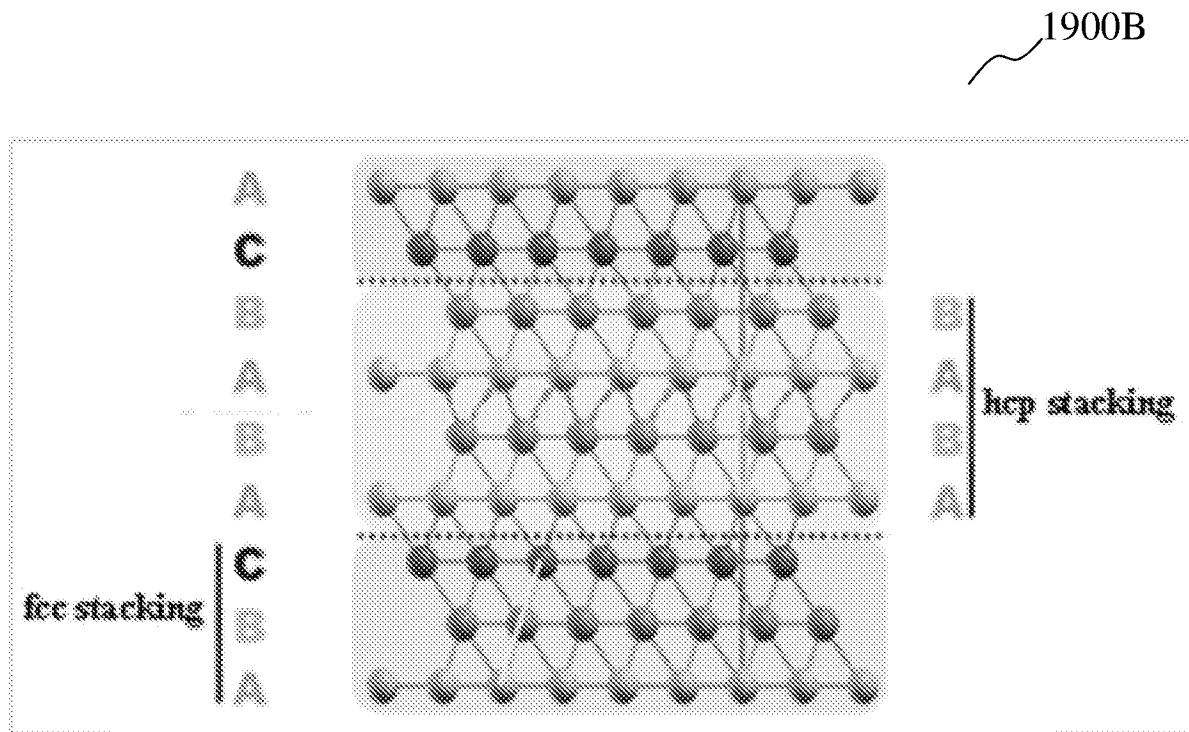


FIG. 19B

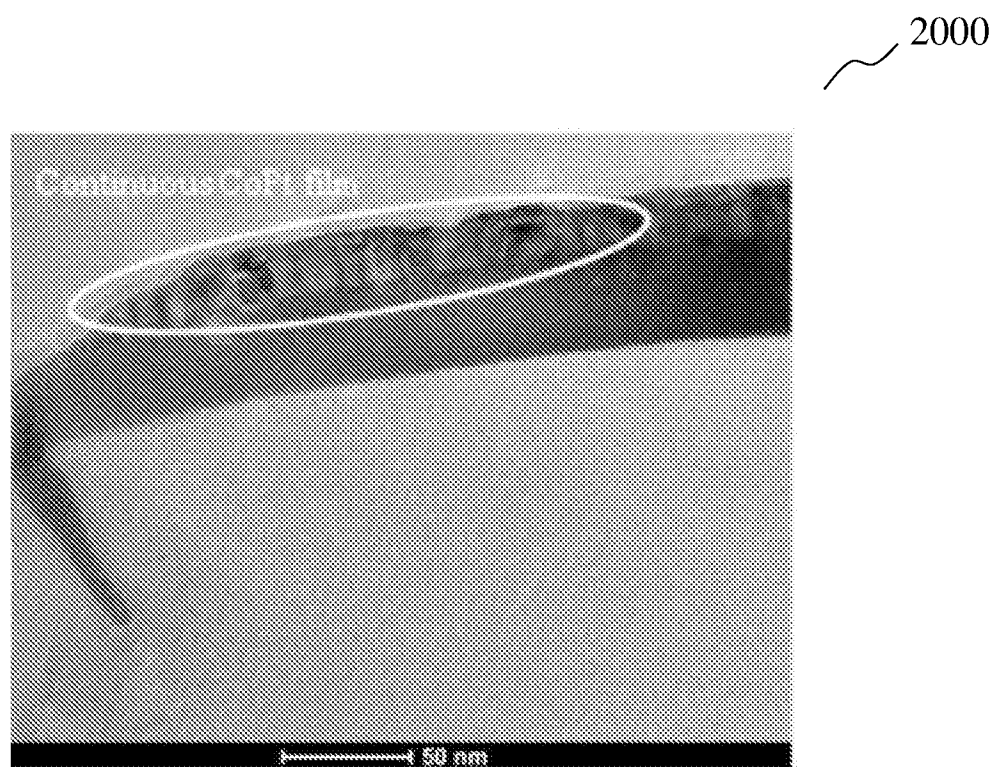


FIG. 20

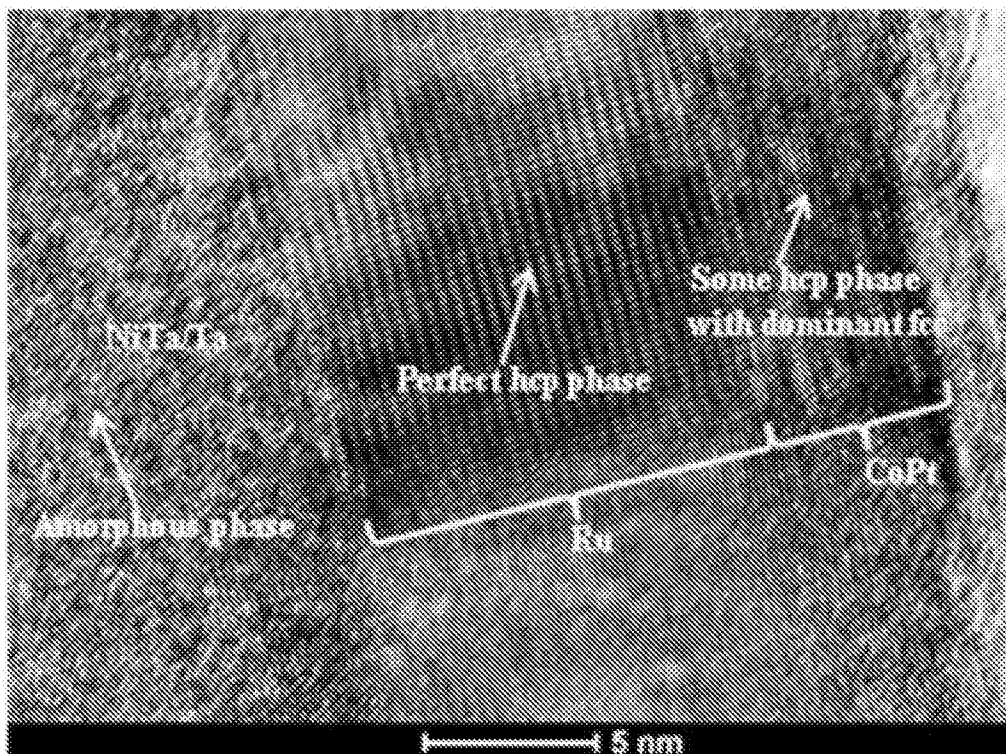


FIG. 21A

2100B

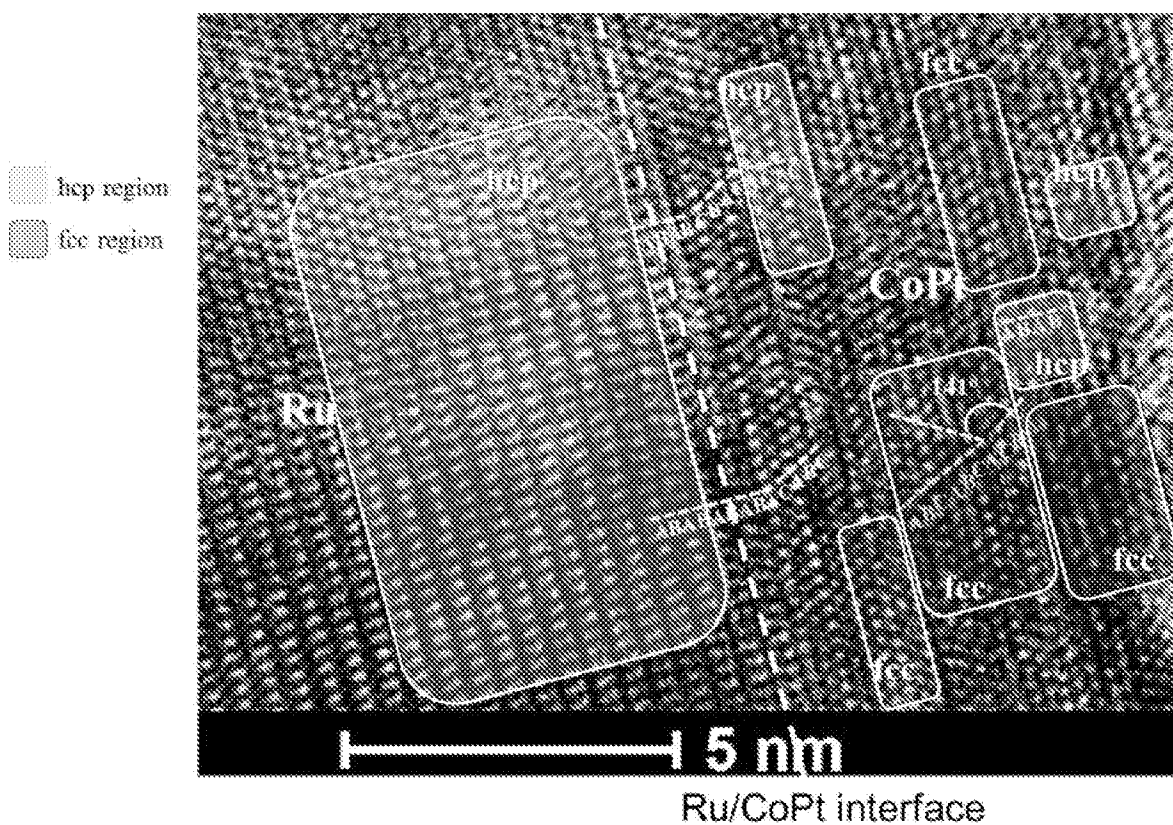
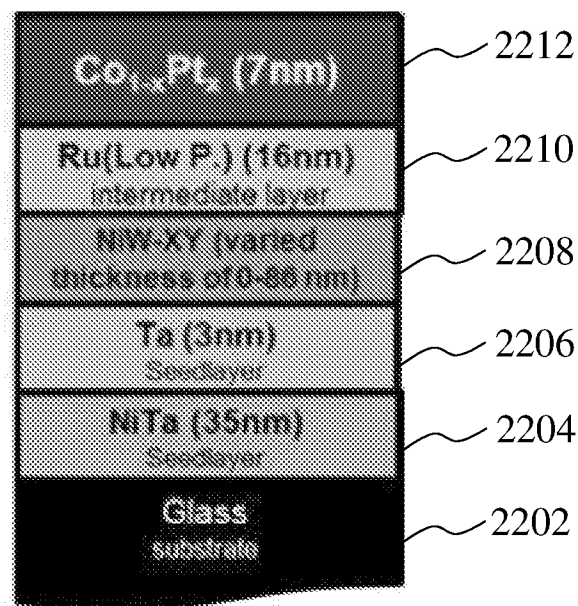
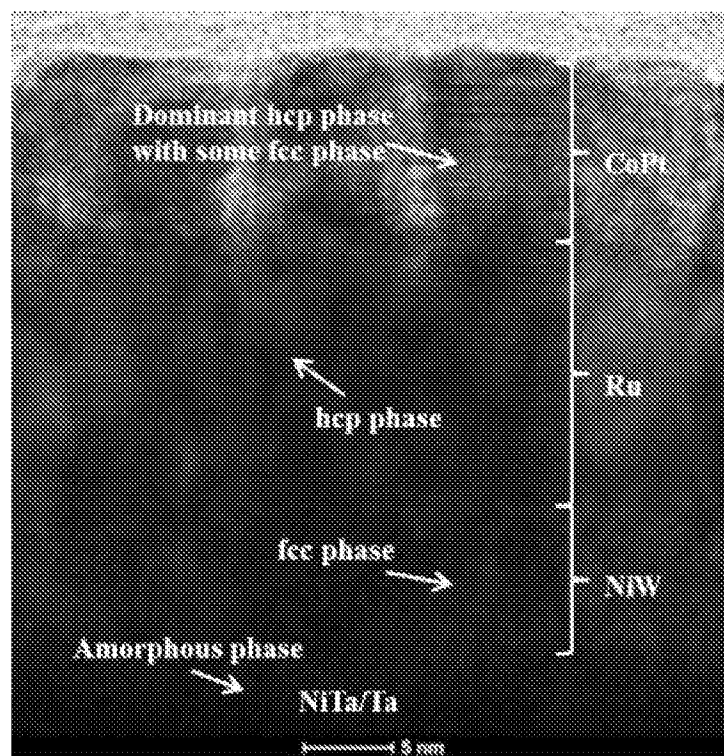


FIG. 21B

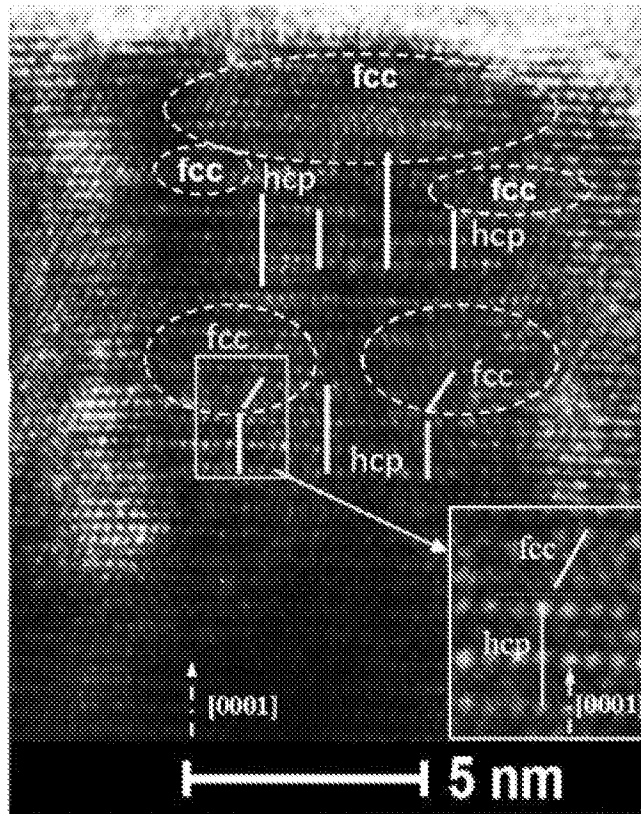
2200

**FIG. 22**

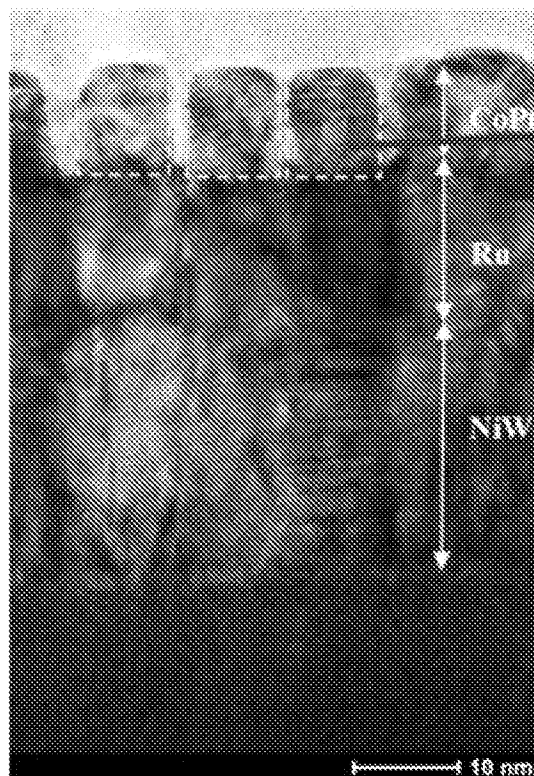
2300A

**FIG. 23A**

2300B

**FIG. 23B**

2400A

**FIG. 24A**

2400B

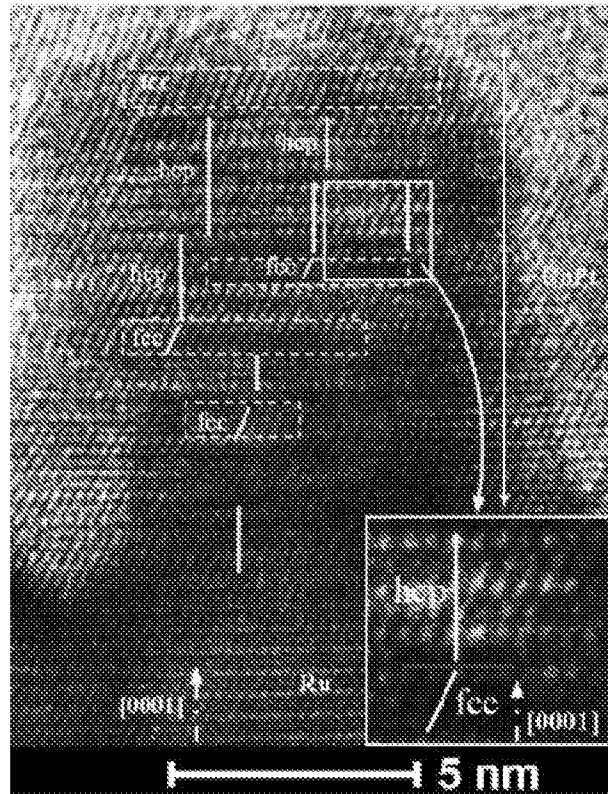


FIG. 24B

2500A

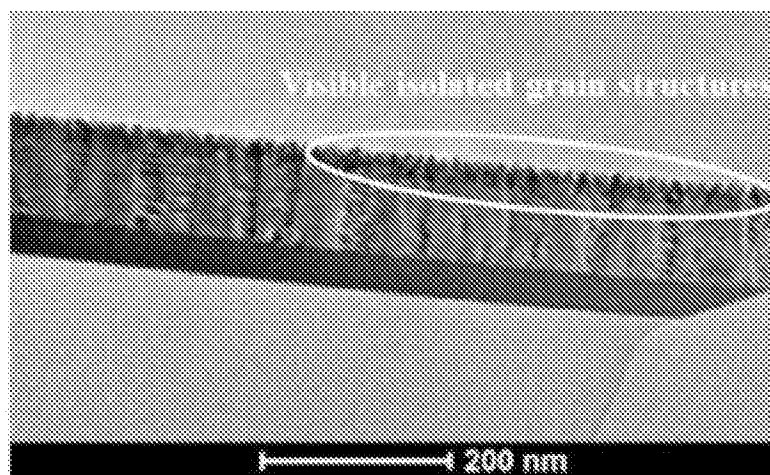


FIG. 25A

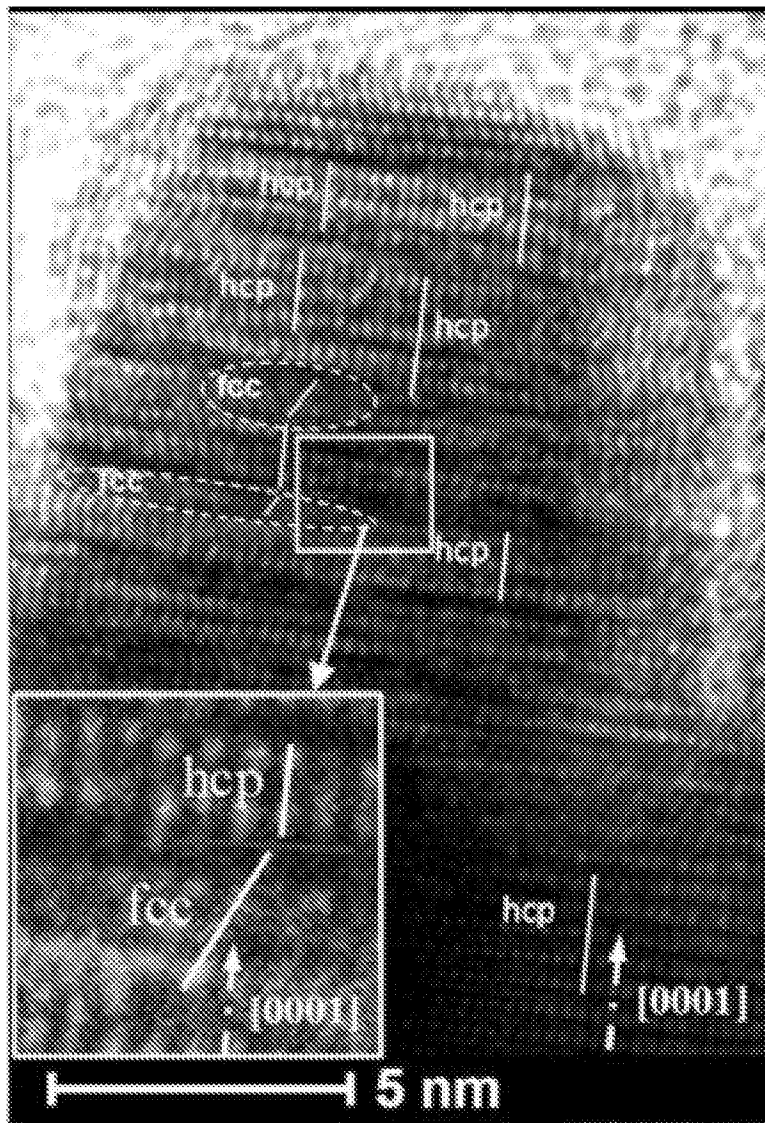


FIG. 25B

2500C

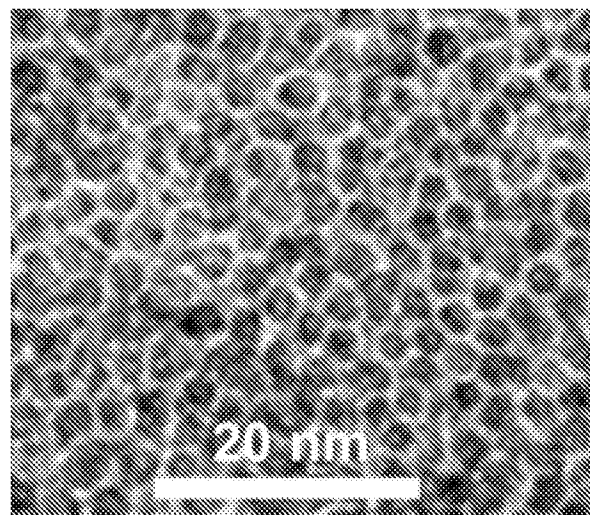


FIG. 25C

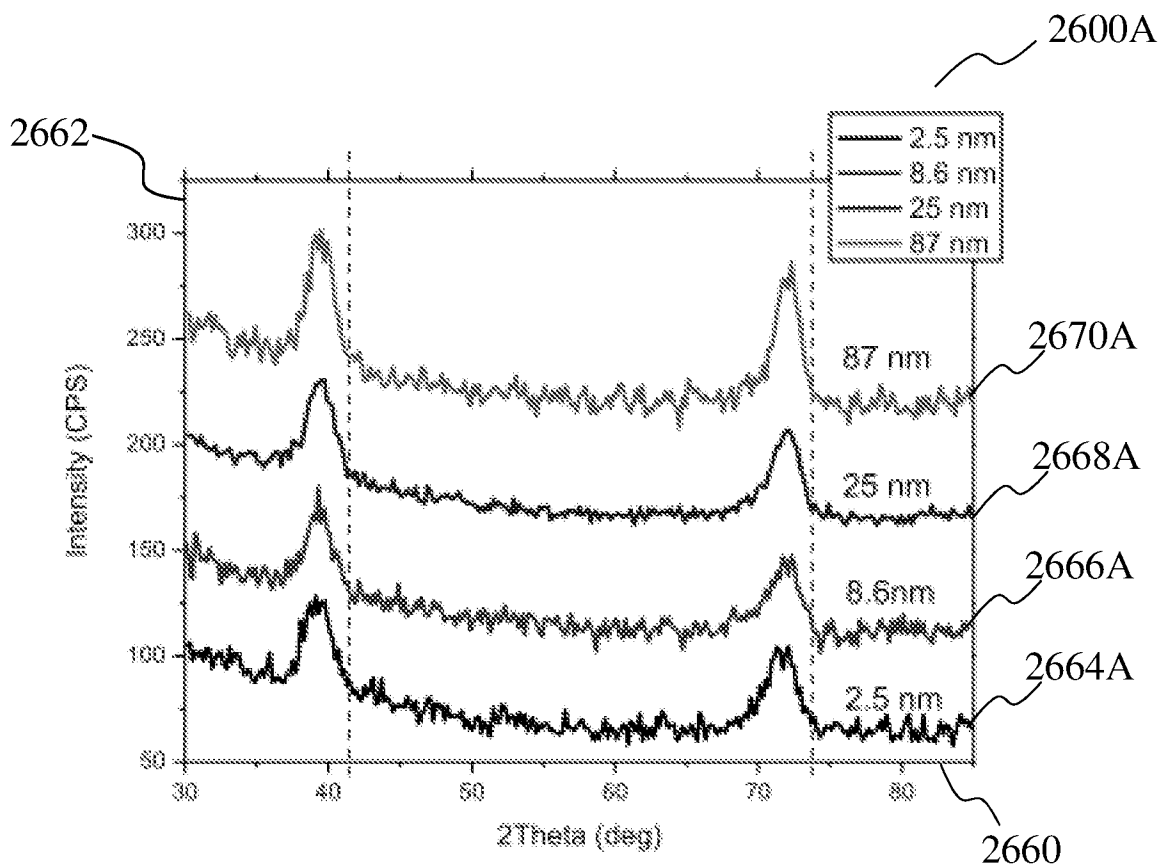


FIG. 26A

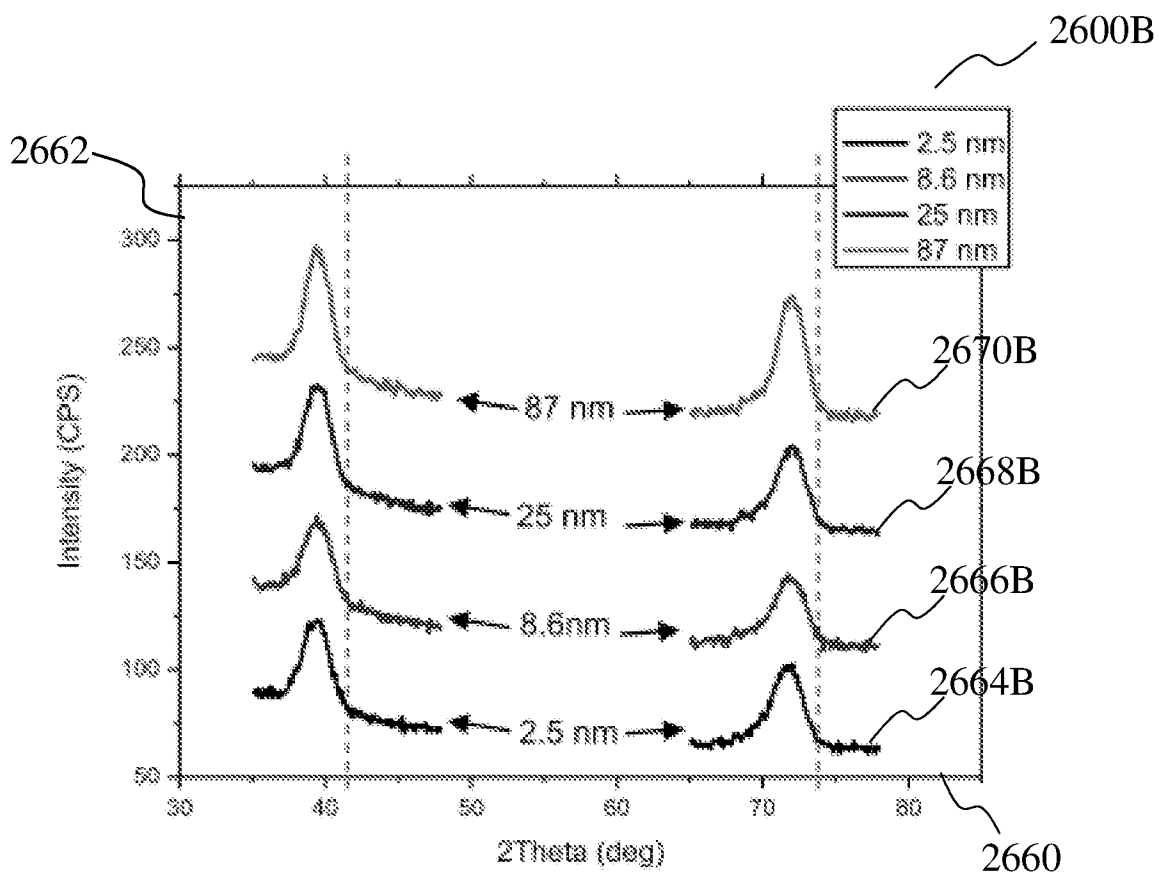
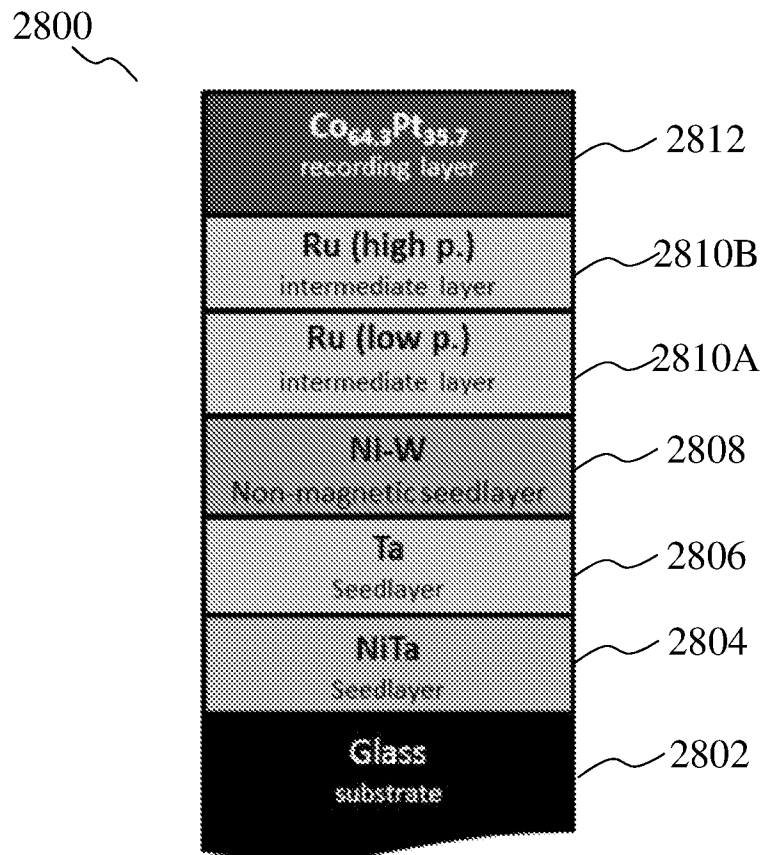


FIG. 26B

2770 2772 2774 2776 2778 2780

Sample	NiW (nm)		Peak	Area	Ratio I(100)/I(110)
20130906-05	2.5	Co (100)	39.32	2677.03	0.85
		Co (110)	71.57	3156.47	
20130905-23	8.6	Co (100)	39.43	2764.97	0.88
		Co (110)	71.69	3140	
20130906-08	25	Co (100)	39.42	3077.93	0.94
		Co (110)	71.81	3295.06	
20130906-11	87	Co (100)	39.43	3915.82	0.93
		Co (110)	71.85	4210.65	

FIG. 27**FIG. 28**

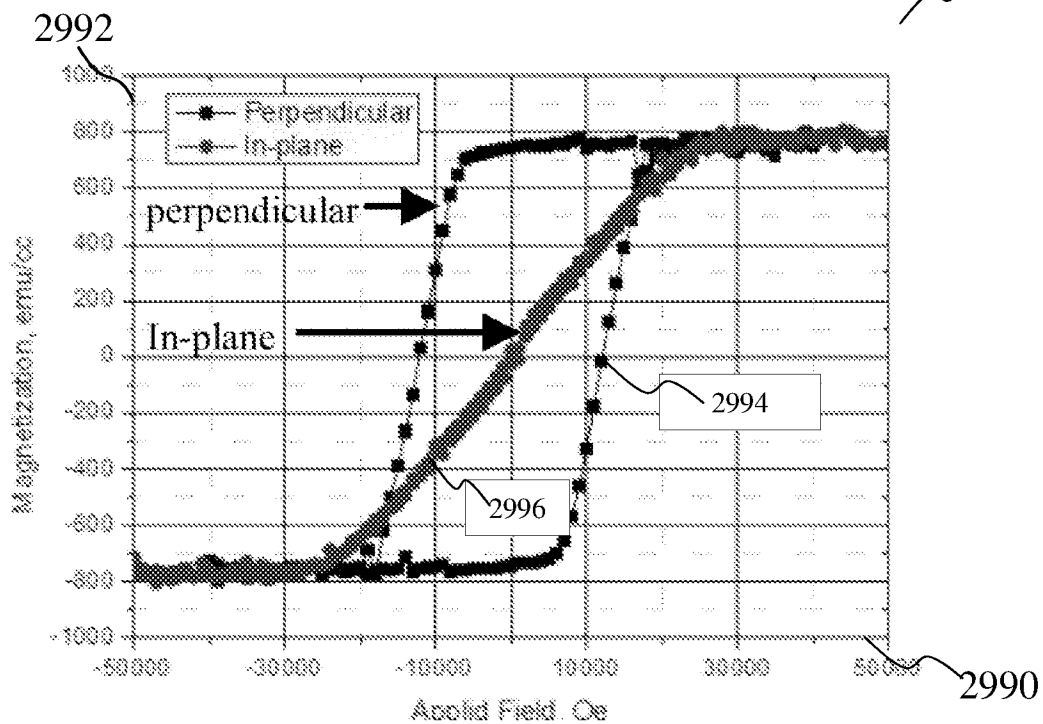


FIG. 29

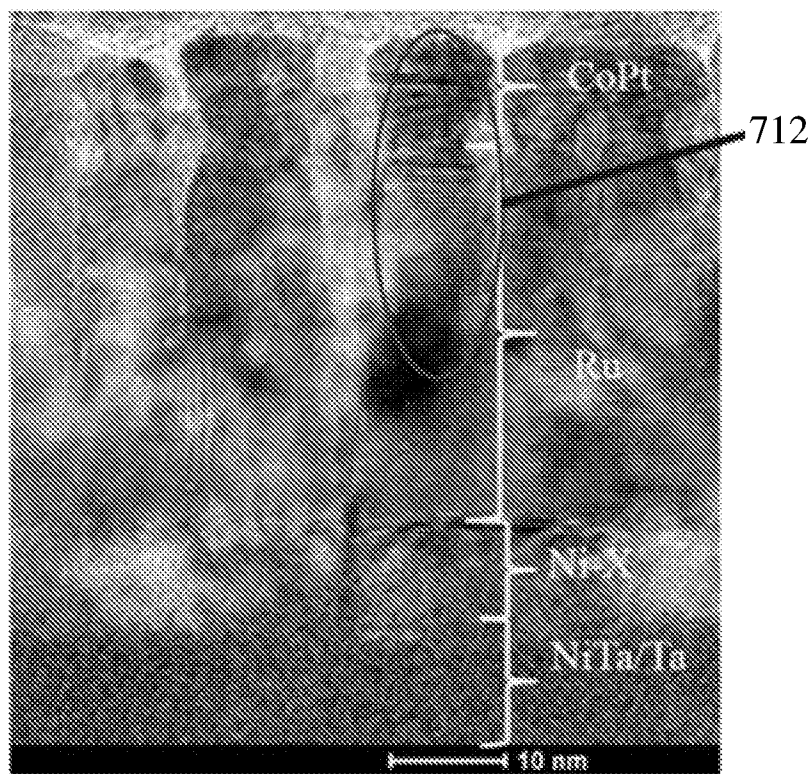
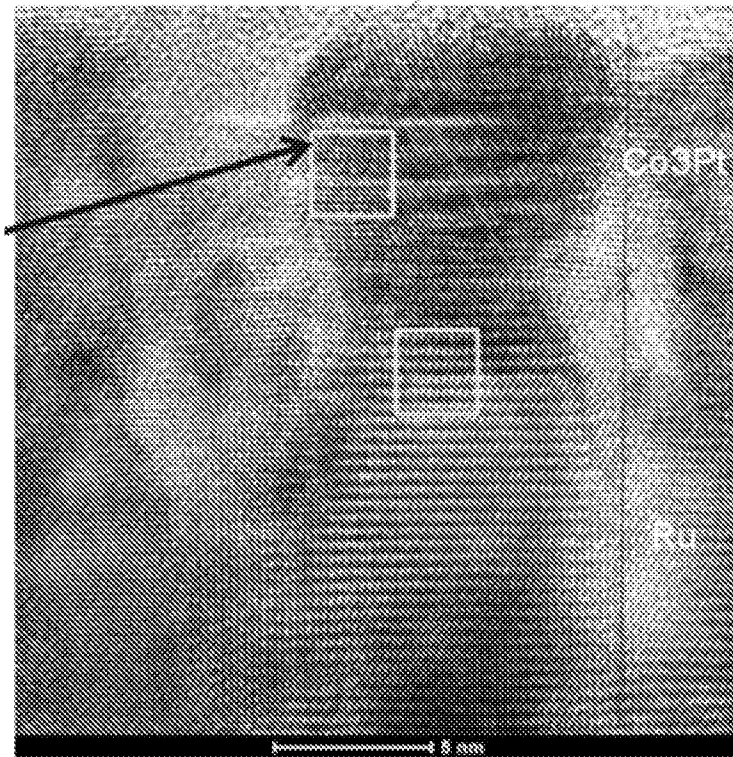


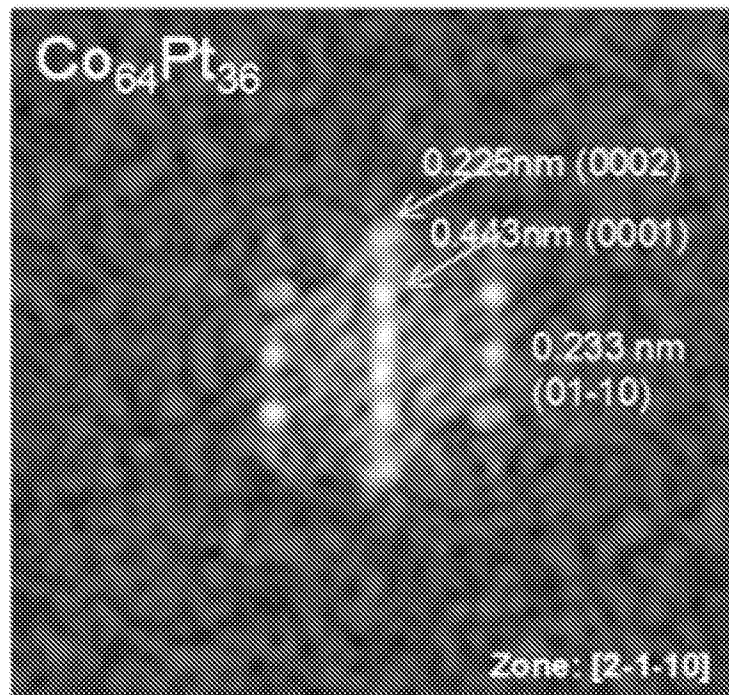
FIG. 30A

HRTEM images (01-11) plane

3000B

**FIG. 30B**

3000C

**FIG. 30C**

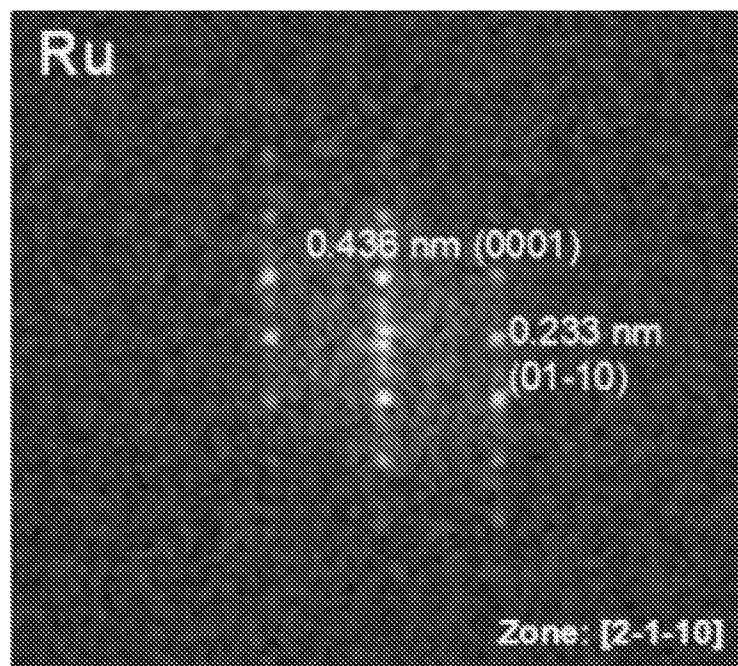


FIG. 30D

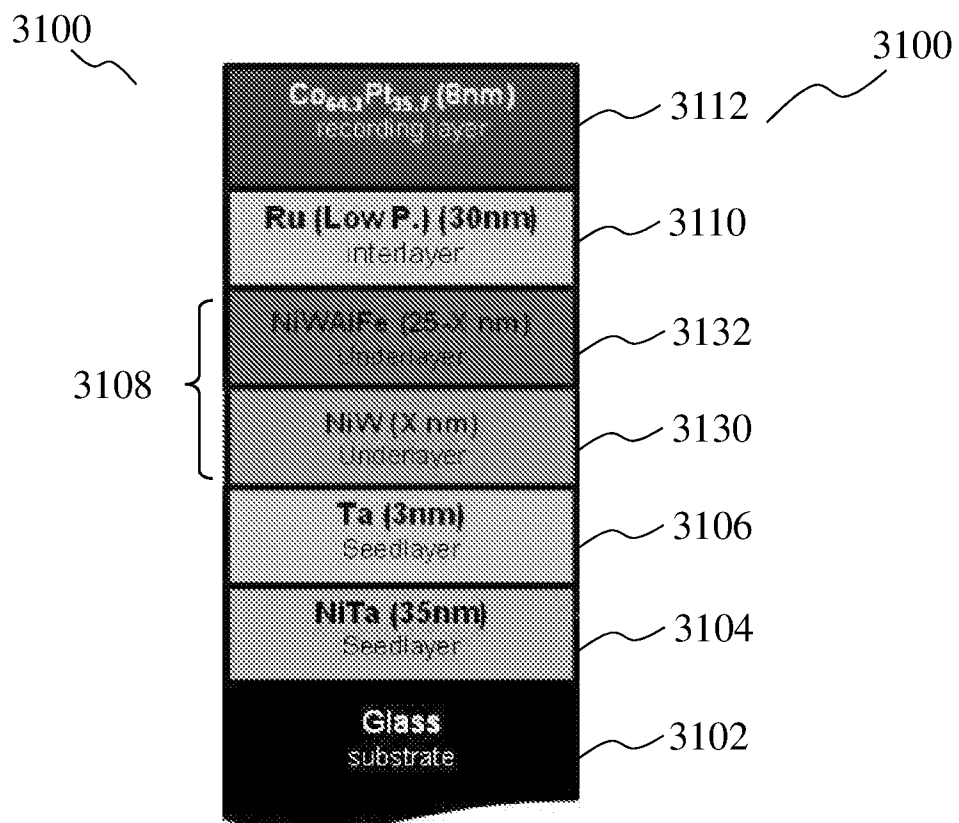
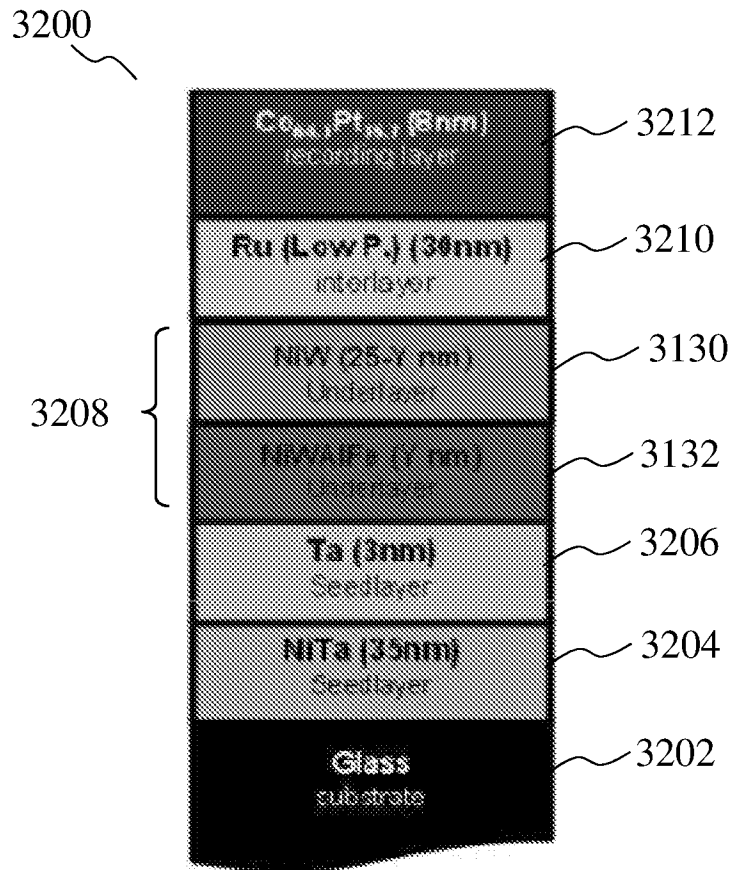
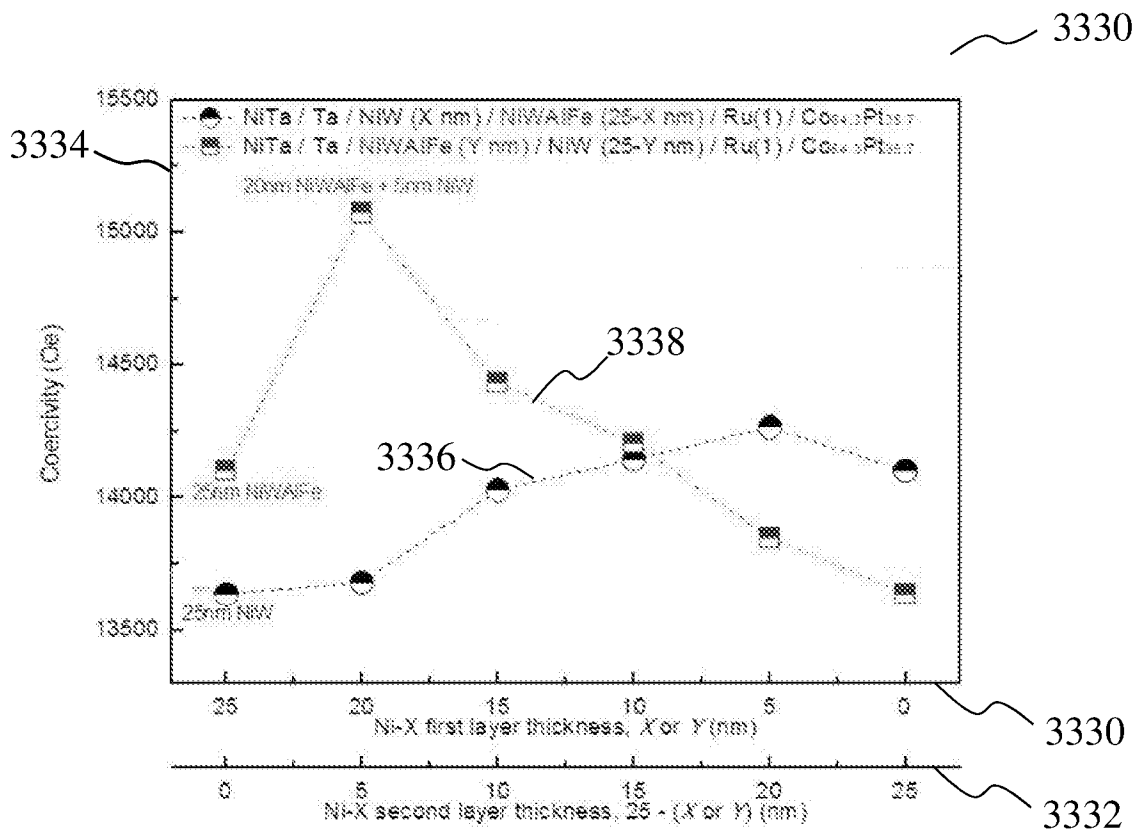


FIG. 31

**FIG. 32****FIG. 33**

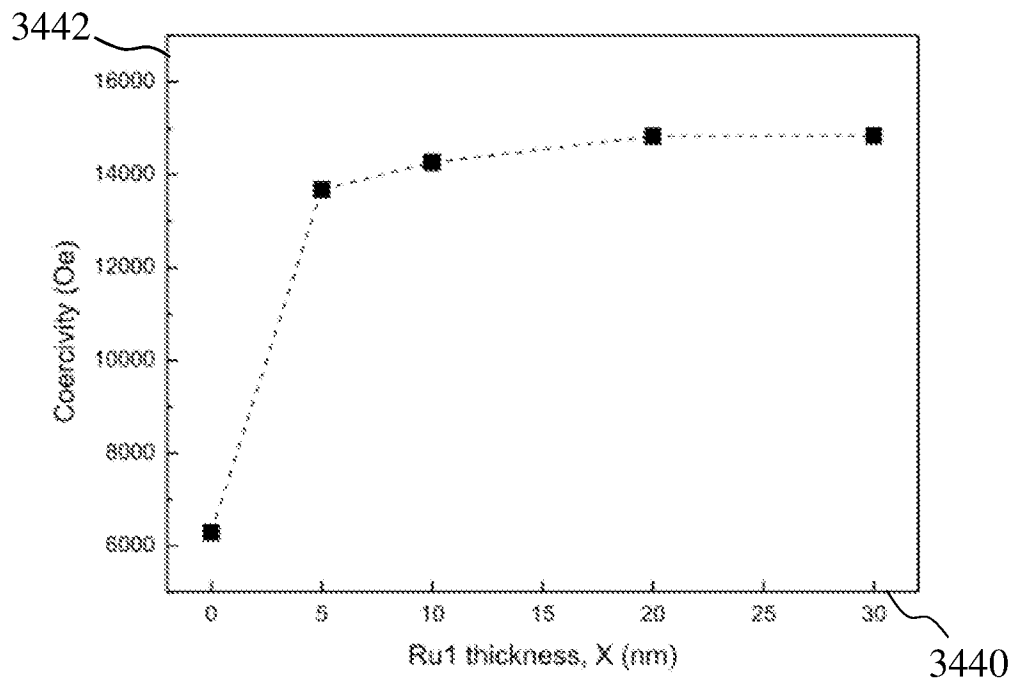


FIG. 34

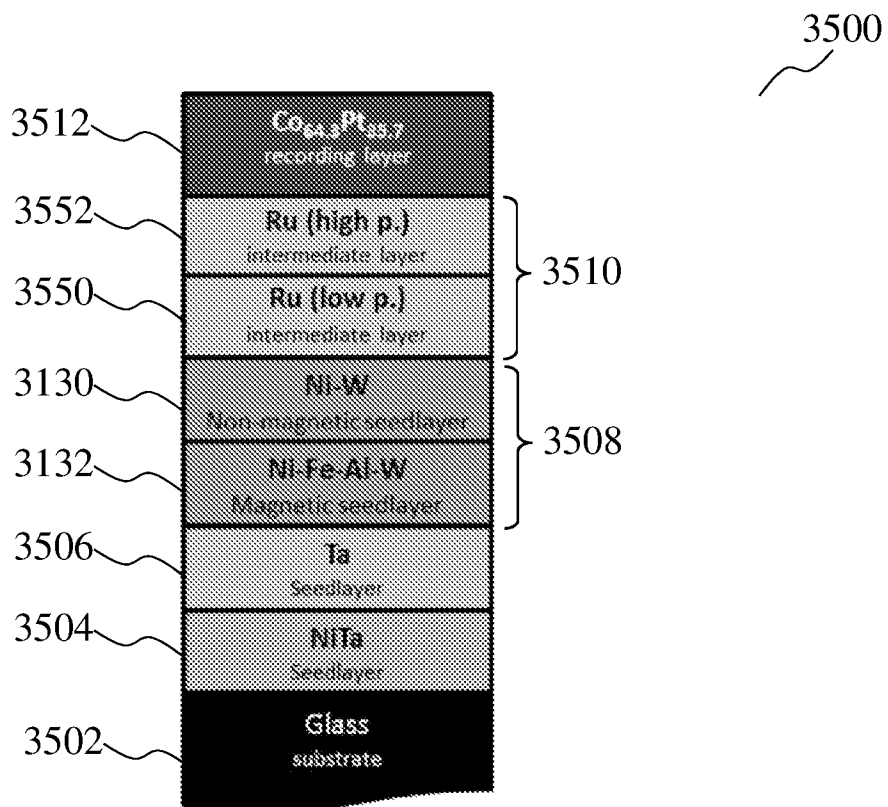
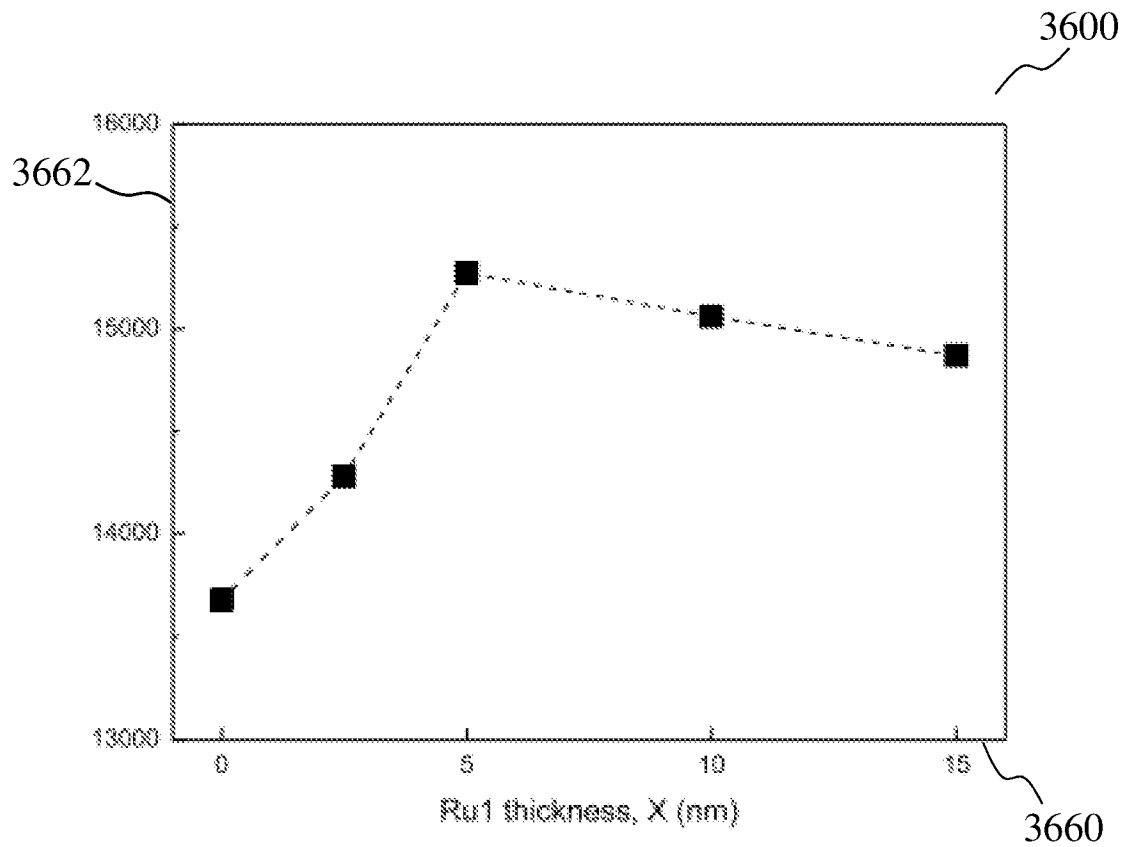
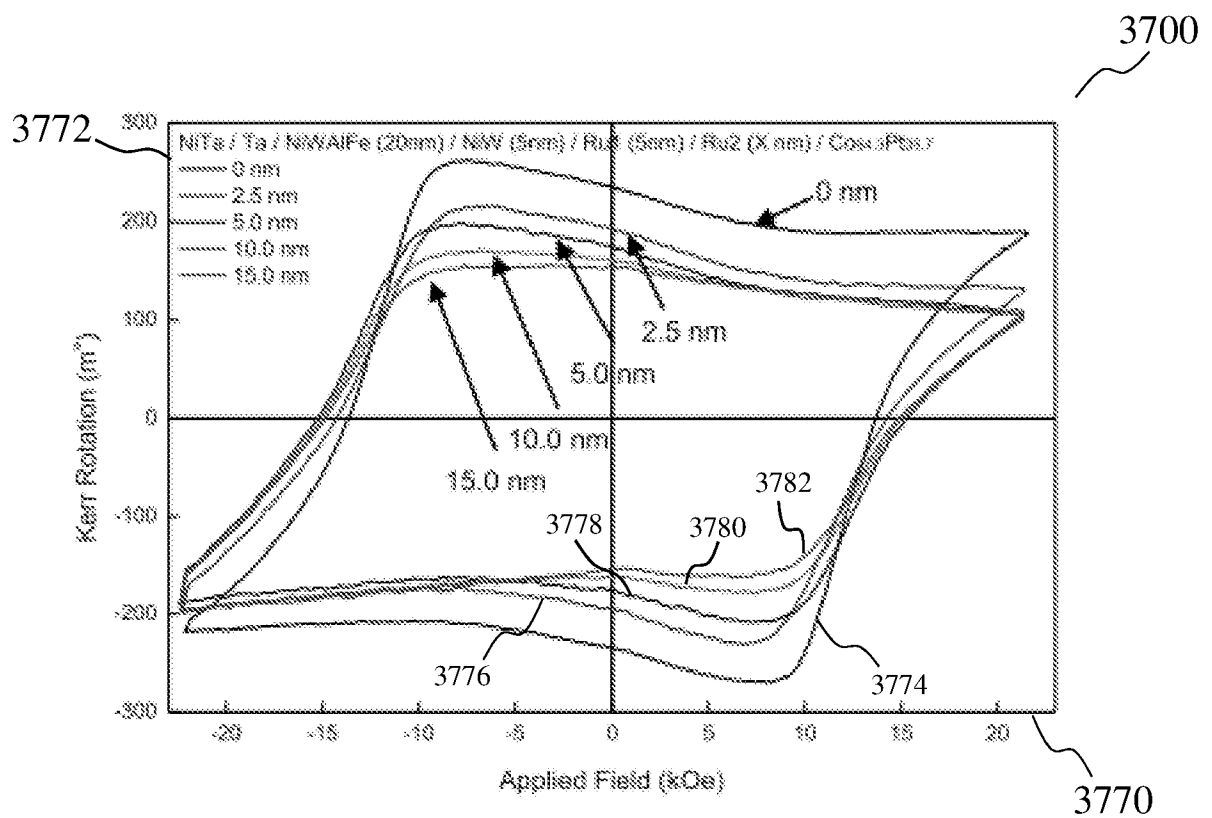


FIG. 35

**FIG. 36****FIG. 37**

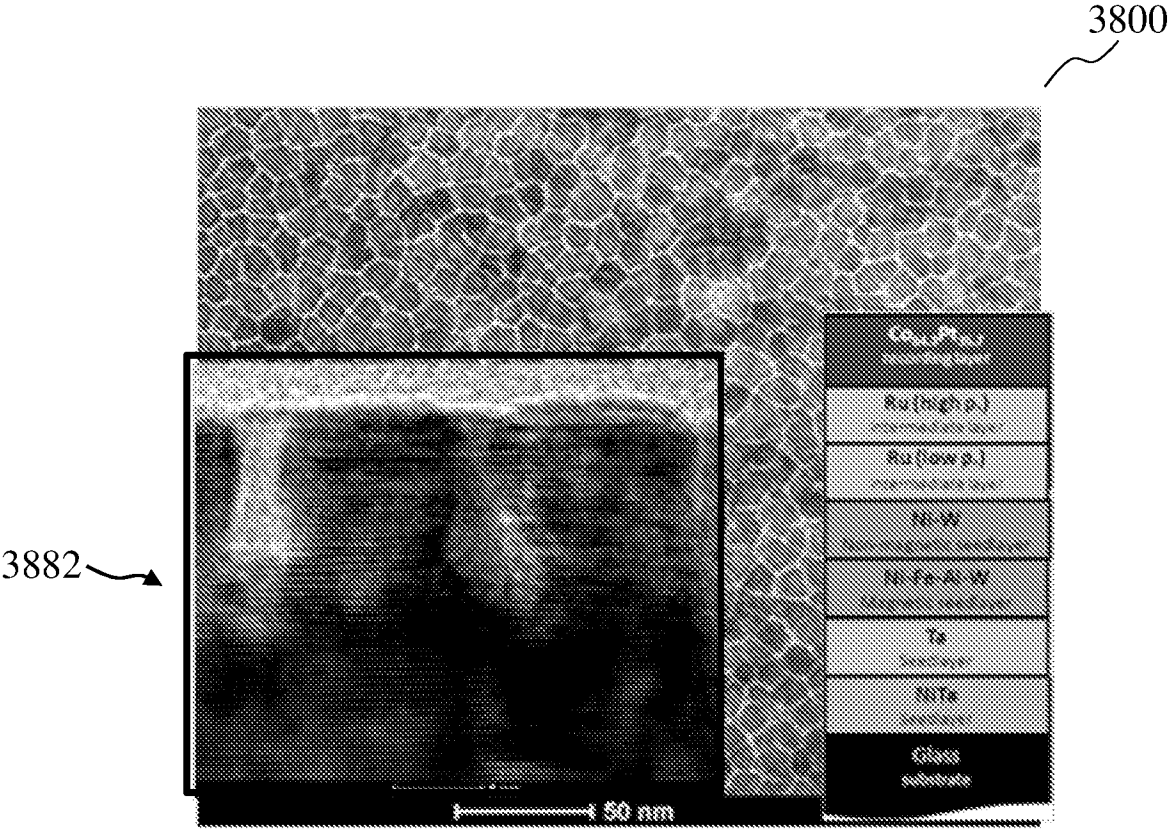


FIG. 38

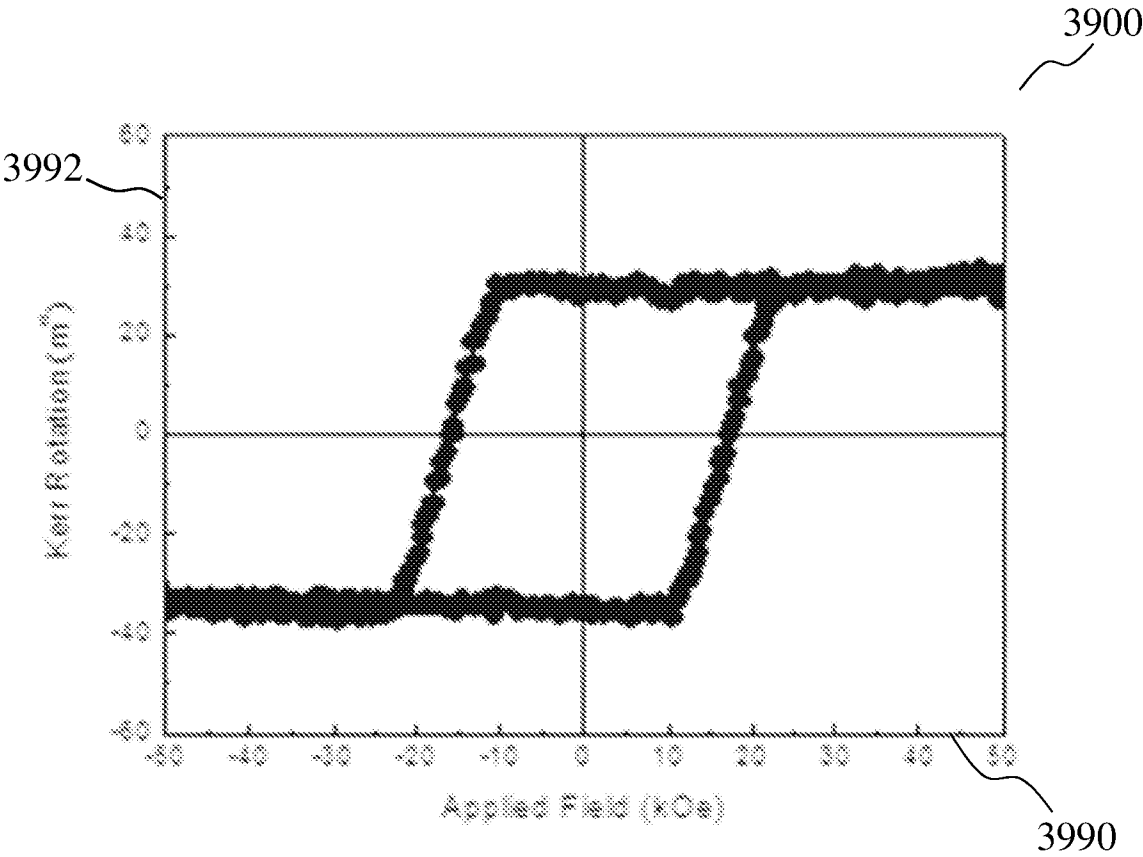


FIG. 39

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050017

A. CLASSIFICATION OF SUBJECT MATTER

G11B 5/738 (2006.01) G11B 5/84 (2006.01) G11B 5/65 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G11B 5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC; WPI: perpendicular magnetic recording, PMR, recording medium, seed layer, under layer, intermediate layer, fcc, hcp, stacking fault, nickel, tungsten, alloy, thickness, method, pressure and related search terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0309580 A1 (TONOOKA S. ET AL.) 9 December 2010 figure 1; paragraphs [0054]-[0058]	1-14 and 16-20
X	US 2012/0099220 A1 (TAMAI I. ET AL.) 26 April 2012 figure 1; paragraphs [0032]-[0049]	1-6, 12-14, 16, 19 and 20
X	US 2010/0035085 A1 (JUNG H-S. ET AL.) 11 February 2010 figure 2; paragraphs [0031]-[0038]	1, 3-6, 12, 15 and 16

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

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

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

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

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Date of the actual completion of the international search
30/03/2016 (day/month/year)

Date of mailing of the international search report
07/04/2016 (day/month/year)

Name and mailing address of the ISA/SG

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Singapore 189554

Email: pct@ipos.gov.sg

Authorized officer

Wong Chee Leong (Dr)

IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050017**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0021770 A1 (HAZANOV A. ET AL.) 28 January 2010 whole document	
A	US 2009/0116137 A1 (TAKEKUMA I. ET AL.) 7 May 2009 whole document	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2016/050017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010/0309580 A1	09/12/2010	CN 101923864 A JP 2010-287260 A	22/12/2010 24/12/2010
US 2012/0099220 A1	26/04/2012	NONE	
US 2010/0035085 A1	11/02/2010	CN 101669168 A JP 2010-518536 A WO 2008/097450 A1	10/03/2010 27/05/2010 14/08/2008
US 2010/0021770 A1	28/01/2010	NONE	
US 2009/0116137 A1	07/05/2009	JP 2009-116952 A	28/05/2009