The areal density of hard disk drives has been increasing at 25–35% per year and now it is approaching to 1 Tbit/in\(^2\). The magnetic crystal grain volume (V) has been decreasing to several cubic nanometers which is near to the thermal instability of granular media, i.e. the superparamagnetic effect. In order to further increase the areal density thermal stability factor, \(K_u V/kT\), needs to be kept within 40–60 range. The superparamagnetic effect poses a serious challenge for continuing to increase the areal density and storage capacity of disk drives.\(^1\) In order to solve these problems the intensive research and development efforts are currently being carried out worldwide with two major concepts. The first one is to use high magnetocrystalline anisotropy (\(K_u\)) granular media, i.e. FePt or CoPt alloys, and develop a heat-assisted magnetic recording (HAMR) writer.\(^2\) The second is to use conventional perpendicular writer and develop a bit-patterned media (BPM) that effectively increase the grain volume (V).\(^3\) Both concepts need to overcome numerous technical challenges in R&D and in order to manufacture recording heads with areal density >1 Tbit/in\(^2\) and stability over 10 years of data storage.

The main idea of BPM technology is that each bit is stored in a single dimensionally defined magnetic switching volume, i.e. dot. Different methods-electron beam lithography (EBL), nanoimprint lithography (NIL), block co-polymer (BCP) for the fabrication of nano-holes with the long-range ordering and diameter of sub-20 nm corresponding to the density of ~1 Tdot/in\(^2\) have been demonstrated.\(^4,5\) A typical perpendicular media comprises of a multilayer structure including a substrate covered by a soft magnetic under layer (SUL), an interlayer (seed layer) and hard patterned magnetic layer (BPM). The hard magnetic layer can be a CoPt or FePt electrodeposited alloy of hcp-crystal structure with crystalline grains oriented along the c-axis (the magnetic easy axis) in the direction normal to the film. The important magnetic property at the thickness of interest in BPM (15–20 nm) is high out-of-plane coercivity \(H_c\) which is largely determined by magnetocrystalline anisotropy and to a lesser extent by shape anisotropy of magnetic grains (dots). Additional requirements include high magnetic anisotropy (\(K_u\)), the remanence squareness of the hysteresis loop (\(M_r/M_s\sim 1\)), and small grains within the thermal stability limit.

The electrodeposition of CoPt alloys has been studied intensively as a possible method for fabrication of BPM and MEMS devices. The CoPt alloys obtained in as-deposited state showed relatively low perpendicular coercivity at room temperature (\(H_c=200–1500\) Oe).\(^6,7\) Very high coercivity (\(H_c=10000–13800\) Oe) was achieved by electrodeposition of CoPt and FePt alloys-with near equiaxometric composition—which were transformed from as-deposited cubic to the high anisotropy L1o phase upon annealing at temperatures 400–900 C.\(^8–12\) The major disadvantage for use of these materials in BPM is the high annealing temperature which can deteriorate the thermal stability of the whole stack in BPM, i.e. substrate, SUL, under layer and magnetic layer. Textured films of hcp CoPt alloys—without post-annealing—have been obtained with high perpendicular coercivities up to 6000 Oe at thickness >100 nm.\(^13–18\) However, these studies show that the perpendicular coercivities at the thickness of interest for BPM application (15–20 nm) appeared to be relatively low. Importantly, the formation of 10 nm thin CoPt nanodot arrays-deposited inside the nanopores with 10 nm diameters and moderate coercivities (1500–1700 Oe) for application in ultra-high magnetic BPM was demonstrated recently.\(^19\)

This work presents the results on electrodeposition of hcp CoPt films with thicknesses of 15–20 nm from a new designed stable hexachloroplatinate solution.\(^20\) It will be demonstrated that a Ru electrode substrate provides an interface for the epitaxial growth of hcp phase exhibiting a perpendicular anisotropy of CoPt films as observed before in literature.\(^16,17,19,21\) It will be shown also that the addition of saccharin, as an organic additive, into the plating solution dramatically improves the epitaxial growth of CoPt film on Ru substrate. At the film thickness of interest for BPM (15–20 nm) the out-of-plane coercivity reached as high as 6700 Oe and the squarness \(M_r/M_s\sim 1\).

**Experimental**

A stable aqueous hexachloroplatinate CoPt-solution at pH 2.5 containing 0.4 M H\(_2\)BO\(_3\), 0.3 M NH\(_4\)Cl, 0.1 M CoSO\(_4\), 7H\(_2\)O, 0.00386M H\(_3\)PtCl\(_6\) and 0.00389 M Saccharin as Na-salt, was prepared according to the recently published procedure.\(^20\)

The voltammetric measurements were performed in a 100 ml closed three electrode cell with a graphite rode anode and a saturated calomel electrode (SCE) as a reference electrode in the chosen solution, i.e. with and without addition of saccharin. Some experiments were carried out in three electrode cell described in Ref. 22; Fig. 1. The potential-current curves were recorded using a Gamry Instrument PC3 potentiosat. Three kinds of electrode substrates, i.e. Pt, Cu, Ru and glassy carbon electrode (GCE) were employed for cyclic voltammetry (CV) and linear sweep voltammetry (LSV). The experiments with rotating disc electrode (RDE) were carried out with Pt (0.2 cm\(^2\) area), and GCE (0.2 cm\(^2\) area) disc. Prior to each experiment the Pt disc was polished on felt cloth with alumina powder, washed with water, immersed in acetone and rinsed sequentially in ethanol and water.

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The controlled potential electrodeposition (CPE) on sputtered Cu and Ru films (200 nm) onto oxidized Si wafers with a 5 nm Ta adhesion layer, were done by exposing the substrate (1 cm² area) to the quiescent plating solution adjusted at pH 5.5. The cyclic voltammetry on sputtered Ru and Cu seed layer (0.754 cm² area) was performed within an electrochemical cell described recently. Experiments were performed in a sealed cell under nitrogen after purging 25 min. The average thickness of the CoPt films were obtained from two point measurements, i.e. center and edge. A Dek Tek profilometer was used to take the step height as thickness. The plating rate is expressed as a ratio thickness (nm)/time (s). The film structure of CoPt films were determined by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The magnetic properties of the samples were measured using a vibrating sample magnetometer (VSM).

The elemental composition and total weights of the CoPt films were determined by inductively coupled plasma optical emission spectroscopy (ICP-OES) using a Teledyne Leeman Labs “Prodigy” ICP spectrometer. The deposited films were dissolved into approximately 5 ml solution of 50% (v/v) nitric acid and 1% (v/v) hydrochloric acid. The solutions were then diluted as necessary for analysis into 5 ml solution of 50% (v/v) nitric acid and 1% (v/v) hydrochloric acid. The solutions were determined using dynamic secondary-ion mass spectrometry (SIMS) depth prophile analysis. The SIMS analysis was obtained from Charles Evans & Associates through their in-house system. SIMS results were calibrated using the sample where major elements were determined by X-ray fluorescence (XRF). The chemical state of elements was determined using X-ray photoelectron spectroscopy (XPS) technique.

Results and Discussion

Voltammetry study.—Figure 1 shows the results of RDE voltammetry obtained at the Pt electrode in the following solutions (specified in Ref. 20): H₂PtCl₆ (waves A, B, C); CoPt (waves A, B, C, D); supporting electrolyte (wave E). Three RDE voltammograms obtained without the presence of Sacc were taken from Ref. 20 in order to compare with the new RDE voltammogram obtained in CoPt solution with Sacc additive present, which was added to Fig. 1. The overall reactions occurring under the waves A-E were expressed as a ratio thickness (nm)/time (s). The film structure of CoPt alloys were determined by inductively coupled plasma optical emission spectroscopy (ICP-OES) using a Teledyne Leeman Labs “Prodigy” ICP spectrometer. The deposited films were dissolved into approximately 5 ml solution of 50% (v/v) nitric acid and 1% (v/v) hydrochloric acid. The solutions were then diluted as necessary for analysis into 5 ml solution of 50% (v/v) nitric acid and 1% (v/v) hydrochloric acid. The solutions were determined using dynamic secondary-ion mass spectrometry (SIMS) depth prophile analysis. The SIMS analysis was obtained from Charles Evans & Associates through their in-house system. SIMS results were calibrated using the sample where major elements were determined by X-ray fluorescence (XRF). The chemical state of elements was determined using X-ray photoelectron spectroscopy (XPS) technique.

Effect of electrode substrate and saccharin additive on crystal structure and magnetic properties of CoPt films.—Figure 3 shows the XRD scans of CoPt films obtained by the potentiostatic deposition of Co₈₀Pt₂₀ films at −0.8 V/SCE on Cu (Fig. 3-left) and Ru at −0.9 V/SCE (Fig. 3-right) using the plating solution without Sacc. The thickness of both films was ~20 nm. The XRD diffraction peaks for CoPt film grown on Cu seed layer are identified as an fcc CoPt (10.0), (00.2), and (10.1), at 41.2°, 43.4° and 46.4° 2Θ values, respectively. The peaks at hcp (10.0), (00.2) and (10.1)-reported earlier in electrodeposition of CoPt on Cu seed layer and Cr seed layer have been assigned to hcp. The absence of fcc (200) peak around 50° ruled out the possibility that the observed peaks might be fcc phase. The peak at 2Θ = 43.4° is difficult to index from XRD measurements since fcc (111) and hcp (00.2) peaks have the same peak position. The XRD data for Co₈₀Pt₂₀ film grown on Ru substrate (Fig. 3-right)
Figure 2. Cyclic voltammograms (CV) at Ru electrode (0.785 cm² area); Sweep rate: 50 mV/s; (Left) CV in CoPt solution without Sacc. (Right) Overlay of CV in CoPt solution without Sacc (black curve) and with Sacc (red curve).

Figure 3. XRD patterns of Co₈₀Pt₂₀ films with thickness of 15–20 nm deposited at −0.8 V/SCE on Cu electrode; 2θ, ω = 1°, (Left) and Ru electrode; 2θ − θ, (Right).

revealed that the (10.0) and (00.2) peaks had a hcp structure with the (00.2) phase parallel to the film plane. This conclusion was confirmed by TEM measurements.

The comparison of hysteresis loops (Fig. 4) recorded in the plane (parallel) and out-of-plane (perpendicular) direction clearly show that the CoPt film deposited on Ru seed layer favors hcp phase formation resulting in higher perpendicular coercivity (Hc = 1220 Oe) compared to the CoPt film deposited on Cu seed layer (Hc = 254 Oe). This result is expected since it is known that a Ru underlayer exhibits an improvement of the microstructure and enhancement of perpendicular anisotropy of CoPt films obtained either by vacuum deposition or electrodeposition.

The dramatic improvement of crystal structure and perpendicular coercivity is illustrated in Fig. 5-left for a Co₇₁Pt₂₉ film produced by potentiostatic deposition at −0.8 V/SCE in a solution containing Sacc additive. The XRD scan of the film produced in the presence of Sacc showed only hcp (00.2) peak, while hcp (10.0) peak-observed without Sacc-was absent due to the specific influence of Sacc additive. Saccharin presumably adsorbs preferentially at the (10.0) plane hindering its growth and promotes the hetero-epitaxial growth of (00.2)

Figure 4. Hysteresis loops of Co₈₀Pt₂₀ films deposited without Sacc on Cu electrode (Left) and Ru electrode (Right).
Figure 5. (Left) Overlay of XRD patterns of CoPt films deposited at −0.8 V/SCE without Sacc on Cu substrate with composition of Co80Pt20 and with Sacc on Ru substrate with composition of Co71Pt29; (Right) Overlay of the perpendicular hysteresis loops of the ∼15 nm CoPt thin films deposited with and without Sacc on Ru seed layer.

$hcp$ CoPt on (00.2) $hcp$ Ru. Notably, two films obtained by potentiostatic deposition at $E = −0.8$ V/SCE with and without Sacc have different elemental compositions, i.e. Sacc favors the codeposition of Pt in CoPt film.

The improvement of $hcp$ crystal structure in Co71Pt29 film deposited on Ru seed layer in the presence of Sacc resulted in improved perpendicular coercivity. Figure 5-right illustrates this dramatic effect of Sacc additive on perpendicular coercivity of the ∼15 nm thin CoPt films, obtained on Ru seed layer, with ($H_c = 6700$ Oe) and without ($H_c = 1220$ Oe) Sacc. Our results clearly demonstrate that the electrodeposited CoPt films with the $hcp$ (00.2) plane –parallel to the film plane and good c-axis orientation perpendicular to the film plane—are due to the epitaxial growth of CoPt on Ru seed layer and even more due to the specific adsorption of Sacc which hinders growth of $hcp$ (10.0) plane. Figure 6 shows the magnetic hysteresis loop of as-deposited ∼15 nm Co71Pt29 thin film obtained in parallel and perpendicular direction. According to the best knowledge of literature, the hysteresis loop exemplifies the highest perpendicular coercivity ($H_c = 6700$ Oe) observed for CoPt films obtained by electrodeposition. The other magnetic properties of the ∼15 nm Co71Pt29 film like parallel coercivity ($H_c < 300$ Oe), negative nucleation field ($H_n = −440$ Oe) and high saturation field ($H_k = 9400$ Oe) are almost ideal for application as a material in BPM at the thickness of interest (15–20 nm). It is worth to point out that these samples are continuous films and their perpendicular coercivity can be significantly higher once patterned into isolated islands.

**Chemical composition, morphology and TEM structural characterization of CoPt films.**—The EDS analysis of CoPt films produced with and without Sacc additive at the controlled potential of $E = −0.8$ V/SCE indicated that the presence of Sacc favors the codeposition of Pt. Analysis of light elements (L = O, H, C, N, S, Cl and B) in the bulk of CoPt films with thickness of ∼150 nm was carried out by means of SIMS analysis (Table I).

![](image-url)

### Chemical composition, morphology and TEM structural characterization of CoPt films

- **Chemical composition.** The EDS analysis of CoPt films produced with and without Sacc additive at the controlled potential of $E = −0.8$ V/SCE indicated that the presence of Sacc favors the codeposition of Pt. Analysis of light elements (L = O, H, C, N, S, Cl and B) in the bulk of CoPt films with thickness of ∼150 nm was carried out by means of SIMS analysis (Table I).

- **Morphology and TEM structural characterization.** The chemical composition of CoPt films with a thickness of ∼150 nm, obtained by electrodeposition at the controlled potential ($E = −0.8$ V/SCE) in the presence of Sacc, was determined by X-ray photoelectron spectroscopy (XPS). The high resolution XPS spectra for Co 2p, Pt 4f, C 1s, and O 1s are shown in Fig. 7. The samples were sputtered for 12 min using 1 kV Ar⁺ beam and 5 min 500 eV beam. The sputtering removed about 30 nm of material, which is much higher than the thickness of surface oxides and hydroxides species (1–2 nm) at the CoPt surface. The samples were tilted and analysis was

### Table I. SIMS analysis of light elements of CoPt films in atom %.

| CoPt alloy | O  | H  | C  | N  | S  | Cl  | B  |
|------------|----|----|----|----|----|-----|----|
| Co71Pt29+  | 0.50 | 0.86 | 0.035 | 0.0024 | 0.073 | 0.21 | 0.002 |
| Co80Pt20** | 0.14 | 0.28 | Traces | Traces | Traces | 0.11 | 0.001 |

+ Deposited with Sacc
** Deposited without Sacc

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**Figure 6.** Normalized hysteresis loop of ∼15 nm thin Co71Pt29 film on Ru measured in-plane (parallel) and out-of-plane (perpendicular) to the film plane.
performed at take-off angle of 75° to analyze material damaged by ion beam. The standard binding energy of different chemical states of each element were analyzed according to the literature data. The Co spectra exhibit a doublet with the binding energy at 778 and 793 eV corresponding to the Co 2p3/2 and Co 2p1/2 in metallic state. The Pt 4f peaks located at 71.5 and 74.6 eV are very close to the values reported for metallic Pt. The C 1s spectrum shows intense peak around 284 eV which can be attributed to the carbon no matter what hybridization. Oxygen bonded to carbon in saccharin molecule or its reduction by products-shifts the peak to the higher binding energy by 1.5 eV per one C-O bond. The O 1s spectrum shows peaks typical of metal hydroxides (CoOH+, Pt (OH)2) at 532 eV and metal oxides (CoO, PtO) at 530 eV. The metal oxides are formed possibly from the corresponding hydroxides through acid-base reactions according to Eqs. 8 and 9.

\[
\text{CoOH}^+ + \text{OH}^- \rightarrow \text{CoO} + \text{H}_2\text{O} \quad [8]
\]

\[
\text{Pt(OH)}_2^+ + \text{H}^+ \rightarrow \text{PtO} + \text{H}_2\text{O}^+ \quad [9]
\]

Saccharin additive is known as a smoothening and stress relieving agent. Figure 8 shows SEM images of two CoPt films with thickness ~150 nm deposited at the controlled potential (E = −0.9 V/SCE) without Sacc (Fig. 8-left)-exhibiting a rough surface and the cracks due to the high tensile stress and with Sacc showing a smooth surface without cracks (Fig. 8-right).

Figure 9 shows the cross-sectional and planar bright field (BF) TEM images of CoPt films grown on Ru substrate in the presence of Sacc. The cross-sectional BF image (Fig. 9-left) shows columnar growth in which CoPt hcp (00.2) lattice plane grows continuously on Ru hcp (00.2) plane-indicating the epitaxial growth with the oxide/hydroxide material segregating to the grain boundaries. The columnar CoPt diameters are ~18 nm with the median value of 10 nm.

The qualitative detection of oxygen at the grain boundaries was determined by EDS elemental profile analysis across the grain boundary (18 nm) between the grains (Fig. 10). It was demonstrated that the content of both Co and Pt metals decreases across the grain boundary and O-content increases.

The plan-view of BF TEM image (Fig. 9-right) shows well isolated grains by non-ferromagnetic or weakly ferromagnetic Pt-rich phase localized at the grain boundaries. Such structure of CoPt nano grains would pin domain motion and also inhibit exchange interactions among the grains, which would enhance the perpendicular magnetic anisotropy and increase the coercivity of the CoPt film deposited in the presence of Sacc on Ru substrate.

Figure 11A shows a high resolution bright-field transmission electron microscopy (BF-TEM) image of the selected area diffraction (SADs)-about 200 nm diameters-from a region of the CoPt/Ru interface. The Co71Pt29 hcp (002) layer grows continuously on Ru hcp (00.2) seed layer, indicating the epitaxial growth. The SAD of CoPt patterns shown in Fig. 11B is consistent with a strong (00.2) reflection. The diffraction from Ru seed (not shown here) and the CoPt film show a good epitaxial alignment of (00.2) planes with growth direction. Figure 11C shows transmission high-energy electron diffraction (THEED)-obtained from the CoPt region of cross-section SAD region-revealed &hcp structure with a strong (00.2) and weak (01.1) diffraction patterns. The same patterns were observed by XRD with the Co71Pt29 film obtained in the presence of saccharin (see Fig. 5-left).

**Effect of electrode potential on elemental composition and magnetic properties of ~15 nm CoPt films.**—The potentiostatic depositions of CoPt films-obtained from the quiescent plating solution with Sacc at potentials ranging from −0.4 V/SCE to −1.1 V/SCE, were carried out at the fixed time changing from 9.0 s to 220 s depending on the controlled potential in order to achieve the nominal thickness of 15 nm for CoPt films (Fig. 12). The plating rate (nm/min) was determined for each potential in separate experiments measuring the thickness of CoPt films after the electrodeposition. By varying the electrode potential from less negative (−0.4 V/SCE) to more negative (−1.1 V/SCE) Co-content in CoPt films increases from 9.7 to 91 at %. The shape of potential - at. % Co curve shown in Fig. 12, obtained for electrodeposition of CoPt alloys in the the quiescence solution in the presence of Sacc is very similar to the curve without Sacc, which we have discussed in more detail in our recent paper.
The increase of Co-content in CoPt films is expected to increase their magnetic saturation, $M_s$, and cause the change in coercivity. The selected out-of-plane hysteresis curves in Fig. 13, obtained at different potentials, illustrate the changes of magnetic properties. The magnetic properties of CoPt films with 9.7–91 at % Co are summarized in Fig. 14. There are several important points regarding the magnetic properties of CoPt films which need to be noted. First, the CoPt film...
with 9.7 at% Co is nonmagnetic, i.e. $M = 0.0$ memu, indicating that the ferromagnetic-paramagnetic transition for electrodeposited CoPt alloys occurs at $<10$ at% Co. Second, the in-plane coercivity is relatively low (85–242 Oe) throughout all CoPt compositions. Third, the highest out-of-plane coercivity is in the range of 5800–6800 Oe inside composition range 71–80 at% Co. The similar composition-dependent phenomena was observed recently$^{19}$ for Co$_{70}$Pt$_{30}$ ($H_c = 1700$ Oe) and Co$_{50}$Pt$_{50}$ ($H_c = 1300$ Oe) alloys, respectively. Fourth, the squareness ($M_r/M_s$) increases with increase of Co-content in the CoPt deposit, reaching the highest values, i.e. $M_r/M_s$ ~1.0, in the composition range 71–80 at% Co and decrease at Co $>80$ at% Co. The out-of-plane coercivity dependence on CoPt composition follows the same trend as $M_r/M_s$.

The in-plane hysteresis loop of CoPt film with 71 at% Co (Fig. 6) exhibited a linear hysteresis behavior of hard axis anisotropy field ($H_K$). The magnetocrystalline anisotropy constant $K_u$ of the Co$_{71}$Pt$_{29}$ film is calculated according to the Equations 10–12.

$$K_{eff} = H_K M_s / 2$$

$$K' = K_{eff} + 1/2 N_d M_s^2$$

$$K_u = (K_{eff} + K') / 2$$

where $K_{eff}$ is the effective anisotropy energy, $M_s$ is the saturation magnetization, $N_d$ is demagnetization factor taken as $N_d = 4\pi N_2 / 2$ $N_2 M_s^2$ is the maximum possible shape anisotropy in the perpendicular direction, and $K'$ is an upper bound of anisotropy energy.$^{18}$

The estimated values of $K_u$ for $\sim 15$ nm thin CoPt films with 71 at% Co are shown in Table II, together with out-of-plane coercivity ($H_{c\perp}$) and saturation magnetization ($M_s$) which was determined experimentally from measured magnetization and volume of CoPt films. The values of the uniaxial anisotropy constant $K_u$ and saturation magnetization of the Co$_{60}$Pt$_{30}$ films shown in Table II are very close to the values for 20 nm thin Co$_{60}$Pt$_{30}$ film obtained by cosputtering at the room temperature.$^{21}$

### Table II. $H_c$, $M_s$, and $K_u$ values for Co$_{71}$Pt$_{29}$ film.

| $H_c$ (Oe) | $M_s$ (emu/cm$^3$) | $K_u$ (erg/cm$^3$) |
|------------|-----------------|------------------|
| 6700       | 760             | $5.4 \times 10^6$ |

**Conclusions**

The CoPt films with 9.7–91 at% Co and thicknesses of 15–20 nm were obtained from new designed stable hexachloroplatinate solution at a controlled potential deposition. The CoPt film with 9.7 at% Co is nonmagnetic, i.e. $M = 0.0$ memu, indicating that the ferromagnetic-paramagnetic transition for electrodeposited CoPt alloys occurs at $<10$ at% Co. The increase of Co-content in CoPt films achieved through the increase of the cathodic potentials-results in the increase of their magnetic saturation, $M_s$, and cause the change in coercivity.

The cross-sectional BF TEM image shows columnar growth in which CoPt hcp (00.2) lattice plane grows continuously on the Ru hcp (00.2) plane-indicating epitaxial growth-with the oxide/hydroxide material segregating to the grain boundaries. The plan-view of the BF TEM image shows well isolated grains by non-ferromagnetic or weakly ferromagnetic Pt-rich phase localized at the grain boundaries.

The comparison of hysteresis loops (Fig. 6) recorded in the plane (parallel) and out-of-plane (perpendicular) direction clearly show that the CoPt film deposited on Ru seed layer favors hcp phase formation resulting in higher perpendicular coercivity ($H_K = 1220$ Oe).

The dramatic improvement of $H_c$ crystal structure in $\sim 15$ nm Co$_{70}$Pt$_{30}$ film-deposited on Ru seed layer in the presence of Sacc resulted in the improved perpendicular coercivity. Our results clearly demonstrate that the electrodeposited CoPt films with the hcp (00.2) plane—parallel to the film plane and good c-axis orientation perpendicular to the film plane—are due to the epitaxial growth of CoPt on Ru seed layer and even more due to the specific adsorption of Sacc which hinders growth of hcp (10.0) plane. According to the best knowledge of literature, the hysteresis loop exemplifies the highest perpendicular coercivity ($H_K = 6700$ Oe) observed for $\sim 15$ nm CoPt films obtained by electrodeposition. The other magnetic properties of $\sim 15$ nm Co$_{70}$Pt$_{30}$ film like parallel coercivity ($H_c = 220$ Oe), negative nucleation field ($H_n = -440$ Oe), and high saturation field ($H_s = 9400$ Oe) are almost ideal for application as a material at the film thickness of interest for BPM (15–20 nm).

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