



**HAL**  
open science

# Influence of the Cr and Ni concentration in CoCr and CoNi alloys on the structural and magnetic properties

Eric Aubry, Tao Liu, Alain Billard, Alexandre Dekens, Frederic Perry,  
Stéphane Mangin, Thomas Hauet

## ► To cite this version:

Eric Aubry, Tao Liu, Alain Billard, Alexandre Dekens, Frederic Perry, et al.. Influence of the Cr and Ni concentration in CoCr and CoNi alloys on the structural and magnetic properties. *Journal of Magnetism and Magnetic Materials*, 2017, 422, pp.391-396. 10.1016/j.jmmm.2016.09.013 . hal-01569168

**HAL Id: hal-01569168**

**<https://hal.science/hal-01569168>**

Submitted on 26 Jul 2017

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# **Influence of the Cr and Ni concentration in CoCr and CoNi alloys on the structural and magnetic properties**

E. Aubry<sup>1</sup>, T. Liu<sup>2</sup>, A. Billard<sup>3</sup>, A. Dekens<sup>2</sup>, F. Perry<sup>4</sup>, S. Mangin<sup>2</sup>, and T. Hauet<sup>2</sup>

<sup>1</sup> Nipson Technology, 12 Avenue des Trois chênes, Techn'Hom 3, 90000 Belfort

<sup>2</sup> Institut Jean Lamour, UMR 7198 CNRS-Université de Lorraine, 54506 Vandoeuvre-lès-Nancy, France

<sup>3</sup> IRTES-LERMPS EA 7274, UTBM, Site de Montbéliard, 90010 Belfort Cedex, France

<sup>4</sup> PVDco, 30 rue de Badménil, 54120 Baccarat, France

## **Abstract**

The crystalline and magnetic properties of micron thick magnetron sputtered  $\text{Co}_{1-x}\text{Cr}_x$  and  $\text{Co}_{1-x}\text{Ni}_x$  alloy films are analyzed in the view of their implementation as semi-hard magnets. All the tested films crystallize in hcp lattice, at least up to 35 atomic % of alloying elements (Cr or Ni). The structural study shows that the ratio of hcp phase with [0001] axis orientated perpendicular to the film as compared with in-plane orientation increases (resp. decreases), when Ni (resp. Cr) concentration increases independently of the post-annealing temperature. The orientation of the magnetization results from the competition between the demagnetization field which tends to align the magnetization in plane and the crystalline anisotropy which tends to maintain the magnetization along the [0001] axis. Interestingly, we find that, although Co and Ni are very similar atoms,  $\text{Co}_{1-x}\text{Ni}_x$  alloys crystalline anisotropy can be strongly increased and reach up to twice the anisotropy of the best  $\text{Co}_{1-x}\text{Cr}_x$  alloy, while maintaining a magnetization at saturation above 1200 kA/m. The thermal stability of the structural and magnetic properties of both alloys is demonstrated for annealing temperature up to 300°C.

## 1. Introduction

Semi-hard magnetic material is a class of magnets which exhibits intermediate magnetic properties between soft and hard magnets [1]. Their coercivity  $H_c$  usually ranges from 50 to 1000 Oe approximately [1]. They exhibit a relatively high magnetization at saturation  $M_s$ , a medium magnetization at remanence  $M_r$  and medium saturation field, so that the energy cost to magnetize the material is much lower than that of hard magnet. Therefore they can be easily magnetized and demagnetized to control the value of the residual magnetization and of the magnetic force which is also proportional to the thickness of the coating. For examples, thick semi-hard magnet films with high magnetic force can be used in magnetic micro-actuators [2] such as magnetic force switch [3], or magnetic microencapsulation [4], in magnetically coupled devices or in magnetic data storage used in magnetic printing [5][6][7]. Among these materials, Co-based alloy with hexagonal close-packed structure is interesting in reason of its high saturation magnetization and of its high uniaxial magneto-crystalline anisotropy. According to the positive magneto-crystalline anisotropy constants ( $K_1 = 4,5 \cdot 10^5 \text{ J m}^{-3}$ , and  $K_2 = 1,5 \cdot 10^5 \text{ J m}^{-3}$ ), the easy axis corresponds to the [0001] c-axis of the hexagonal structure.

Due to this feature, CoNi-based alloys have been especially studied, first as a media for magnetic recording or optical recording, and lately for magnetography and MEMS application. CoNi, CoNiP, CoNiFe alloys have been widely studied since the 1970s. Most of the publications report on the evolution of coercive field as a function of deposition condition [8], concentration [9], film thickness [10][11], grain size [11], post-deposition annealing under field [12], volumic magneto-elastic properties [10][13], and the ratio of hcp and fcc phases [9][12]. Nevertheless the coercive field depends on many parameters which are not intrinsic to the magnetic film and strongly depends on the growth process. There is a lack of reports on the relation between crystalline structure (hcp or fcc) and more intrinsic parameters like magnetization at saturation or anisotropy.

Moreover all the above cited references deal with electrodeposited films with thicknesses ranging from few hundreds of nanometers up to few microns mostly because physical deposition techniques have shown poor magnetic results for a perpendicular magnetic recording application [14][15][16]. Properties of micron thick films grown by magnetron sputtering deposition are

therefore rarely reported. Sputtered films thicker than 500 nm are even rarer although a thickness transition from amorphous to polycrystalline phase [17] and strong thickness dependence of coercivity [18] have been reported and unexplained.

Besides, about at the same time, introduction of Cr (instead of Ni) into Co-based film has been proposed in order to lower the magnetization value and therefore reduce the demagnetizing field below the anisotropy field [19][20][21], in the view of implementation as a media for perpendicular magnetic recording system in the 1970s. Because of its great technological potential, sputtered thin Co-Cr films were largely studied. Reports on the topic mostly focused on microstructure and Cr segregation in a few tens of nanometer thick film microstructure. Only few studies report on Co-Cr films synthesis with a thickness exceeding 1  $\mu\text{m}$ . Among them, as in the case of CoNi,  $H_c$  has been studied as a function of various parameters like film thickness [22], temperature [23][24] and stress [25]. But in addition, more attention was paid to characterize the intrinsic parameters of the CoCr layers beyond  $H_c$ . Particularly it was demonstrated that both the magnetization and the perpendicular anisotropy constant decreases when the Cr concentration increases [21][26]. Therefore CoCr thick films can be used as a test system for our study of the intrinsic magnetic parameters of micron thick CoNi films.

In this article, the magnetic behavior of 1  $\mu\text{m}$ -thick film of CoNi and CoCr alloys deposited by sputtering technique is reported. We focus on the influence of Ni or Cr concentration, as well as annealing temperature, on their structural and magnetic properties. Our results on CoCr are coherent with the literature and gives credit to our results and conclusions on thick CoNi alloys.

## **2. Experimental details**

### **2.1 Co alloys films preparation**

The sputtering device consists in a 45 L stainless steel vessel (Alcatel SCM 450). A base pressure of less than  $10^{-4}$  Pa is obtained with a turbomolecular pump unit. Co target is sputtered with a pulsed Advanced Energy Pinnacle Plus+ power supply. The current density set at  $68 \text{ A m}^{-2}$ . Cr or Ni targets are sputtered with a DC Advanced Energy MDX 500. The substrates used are  $6 \times 6 \text{ mm}^2$  Al squares. They were fixed at equal distance from the center of the rotating substrate-holder to prevent any microstructural modification linked to the impingement angle variation. The

substrate-holder is located at 70 mm from the metallic targets. Ar gas flow rates are controlled with MKS flowmeters, and MKS Baratron gauge measured the total pressure. Coatings were post-annealed from 200°C to 400°C in Ar inert atmosphere.

## 2.2 Co-based alloys films characterization

The thickness of the deposited films on glass substrate was determined by the step method with an Altysurf profilometer equipped with a tungsten micro force inductive probe allowing an accuracy of about 20 nm. The structural features of the coatings deposited on Al substrates were performed in using a Bruker D8 focus diffractometer (Co  $K_{\alpha}$  radiation) equipped with the LynxEye linear detector in Bragg Brentano configuration. The morphology of the coatings was characterized by means of a Field Emission Scanning Electron Microscope (FE-SEM JEOL JSM-7800F). The chemical composition of the film deposited on Al substrates was estimated by energy dispersive spectroscopy (Quantax Bruker with XFLASH 6|30 detector) coupled with a Field Emission Scanning Electron Microscope (FE-SEM JEOL JSM-7800 F). Magnetometry measurements were performed by vibrating sample magnetometer (Micro-sense) at room temperature with magnetic field (up to 2T) applied in the plane of the films.

## 3. Results and discussion

### 3.1 Synthesis of the Co alloys thick films by cosputtering

Co alloy films have been prepared by cosputtering from pure metallic targets. The chemical content was controlled through the current density  $I_d$  dissipated in the addition element target. Indeed as shown in Figure 1 the target voltages, the deposition rates and the atomic content in  $Co_{1-x}Cr_x$  and  $Co_{1-x}Ni_x$  sputtered films depend on  $I_d$ . The atomic content of the addition element linearly increases with  $I_d$ . For a fixed current density, the Ni atomic content in  $Co_{1-x}Ni_x$  is higher than that of Cr content in  $Co_{1-x}Cr_x$  films. This difference is ascribed to a higher sputtering yield of Ni than that of Cr ( $S_{Ni} = 0.95$  and  $S_{Cr} = 0.87$  for a bombarding  $Ar^+$  ion energy of 300 eV) [27][28], but also to the slightly higher Ni voltage and lower Co voltage with Ni addition element. Despite the difference in chemical composition, it is worth noting that the deposition rates are identical. Ferromagnetic target being sensitive to the magnetron effect, the thickness of the target was adjusted to 1 mm accelerating the aging of the target. Voltage of Co target in the

presence of Ni is lower than that of the voltage of Co with Cr because of the aging of the Co target. This effect compensates the higher Ni sputtering yield leading to identical deposition rates.

## 2.1 Structure of the CoCr and CoNi alloy films

Figure 2 shows X-ray diffractograms of cosputtered  $\text{Co}_{1-x}\text{Cr}_x$  and  $\text{Co}_{1-x}\text{Ni}_x$  coatings after annealing at different temperatures in Ar atmosphere. All films crystallised in hcp lattice ( $\text{P6}_3/\text{mmc}$  space group) along the [0002] direction, which corresponds to the easy axis of magnetization (c-axis). Presence of Co fcc lattice, which is the stable phase of pure Co for temperature higher than  $417^\circ\text{C}$ , is detected in  $\text{Co}_{1-x}\text{Ni}_x$  films for  $x$  larger than 20% after annealing at  $400^\circ\text{C}$ . Ni enrichment induces a growth along the [111] easy axis of the fcc phase. To qualitatively investigate the degree of the [0002] preferential orientation in the hcp lattice, i.e. to determine if the easy c-axis lays in-plane or out-of-plane, the Lotgering factor has been calculated [29][30]. These calculations have been performed on (0002) peaks which correspond to the hcp c-axis perpendicular to the film (see Figure 3) and on  $(10\bar{1}0)$  peaks which correspond to other directions of the c-axis in the plane of the film. Note that the  $(10\bar{1}1)$  peak is barely detectable for all alloys.  $\text{Co}_{1-x}\text{Cr}_x$  films exhibit a strong [0002] preferential orientation for a Cr content lower than 12.4 at. %. Further increase of the Cr content degrades the degree of the [0002] preferential orientation.  $\text{Co}_{1-x}\text{Cr}_x$  crystalline structure has good thermal stability since annealing does not affect the Lotgering factor of [0002] peak (see Figure 3). By contrast, the [0002] preferential orientation in  $\text{Co}_{1-x}\text{Ni}_x$  films is only favoured by increasing the Ni content, up to 0.9 for 30 at. % of Ni. At  $400^\circ\text{C}$ , we note that the increase of Ni content also leads to the growth of a [111] textured fcc phase.

## 2.2 Magnetic properties of the CoCr and CoNi alloys films

The magnetization hysteresis loops were measured with a magnetic field applied in the film plane as shown in Figure 4. The orientation of the magnetic field in plane does not affect the magnetic response which allows us to conclude that there is no significant anisotropy in-plane. However there is a clear difference between the hysteresis loops measured in-plane and out-of-

plane (see Figure 4). In Figure 5, the main magnetic features are presented (magnetization at saturation (a), anisotropy constant (b), squareness (c) and coercive field (d)) as a function of the Cr or Ni content. In Figure 5(a), magnetization at saturation ( $M_s$ ) is shown to decrease progressively with increasing Cr content in  $Co_{1-x}Cr_x$  alloy, according to the Slater-Pauling rule [1][31]. As expected, the saturation magnetization of  $Co_{1-x}Ni_x$  films slightly decreases as the Ni content is modified since the Ni magnetization is lower than Co magnetization [14][32]. The presence of the fcc phase in the 400°C-annealed  $Co_{1-x}Ni_x$  samples does not seem to affect their magnetic properties.

The magnetization orientation results from the competition between the demagnetization field ( $4\pi M_s$ ) which tends to maintain the magnetization in the film plane and the magneto-crystalline anisotropy which tends to align the magnetization along the direction perpendicular to the film [33][34]. In Figure 5(b), we present the crystalline anisotropy constant ( $K_v$ ) of  $Co_{1-x}Cr_x$  and  $Co_{1-x}Ni_x$  alloys.  $K_v$  is calculated from the saturation field ( $H_k^{eff}$ ) measured when applying the magnetic field perpendicularly to the films and defined as  $H_k^{eff} = 4\pi M_s - (2K_v/M_s)$ . A positive  $K_v$  value is extracted for all tested hcp Co-based alloys. Since we found the same value within the error bar for all annealing temperature, we plot only one point per concentration. For low concentration of Cr and Ni,  $K_v$  is similar for both alloys and is around  $2 \cdot 10^5 \text{ J m}^{-3}$ . Such value is typical of the reported values for pure hcp Cobalt [35][36][37]. Nevertheless, its amplitude varies differently for the two alloys when increasing the Cr and Ni content respectively. Increasing Cr content (resp. Ni), decreases (resp. increases)  $K_v$ . Similar results for CoCr films have been reported [21][26], but not for CoNi. From our study, it is clear that both evolutions can be directly correlated to the quality of hcp crystal orientation (Figure 3).  $K_v$  increases when the degree of orientation of hcp c-axis along the direction perpendicular to the film is improved.

The squareness of the in-plane field hysteresis loop is defined as the ratio ( $M_r/M_s$ ) with  $M_r$  the remanent magnetization and  $M_s$  the magnetization at saturation. The squareness is found to be correlated to the magnetic anisotropy. The squareness decreases in  $Co_{1-x}Ni_x$  as Ni content increases while the crystalline anisotropy, which favours out-of-plane anisotropy, is improved (Figure 5). The evolution of coercive field is more difficult to explain as many parameters (and their distribution) play significant role in the irreversible magnetization reversal process (e.g. magnetization, exchange interaction, grain structure, magnetocrystalline anisotropy, domain wall

motion and pinning). Increasing the Cr amount in  $\text{Co}_{1-x}\text{Cr}_x$  (for films annealed at 200 and 300°C) leads first to an increase and then a decrease of coercive fields with a maximum at around 16 at. %. This may originate from a competition between  $M_s$  and  $K_v$  (large  $M_s$  induces an increase of coercive field, and low  $K_v$  tends to decrease the coercive field). We also observe that the coercive field keeps increasing continuously with the Cr content even after 16% for 400°C annealed samples. As no structural modification was observed (see Figure 3), we expect this behavior to be induced by the segregation of Cr to the Co-rich grain boundary, which proceeds around this Cr content (~20 at. %) for high temperature [38]. The magnetic behavior of  $\text{Co}_{1-x}\text{Ni}_x$  films is different. There is mostly two regimes most probably related to the degree of magnetocrystalline anisotropy. For low Ni content, a lower coercive field and a larger coercive field is observed for Ni content larger than 20 at. %. Similar variations were reported by S. Armyanov for electrodeposited CoNi coatings [39].

#### **4. Conclusions**

The influence of Cr and Ni on the structural and magnetic properties of sputtered CoNi and CoCr alloy 1  $\mu\text{m}$  thick films, grown by magnetron physical vapor deposition was studied. For Ni and Cr concentration ranging from 0 to 35 at. %, all films crystallize in an hcp lattice. The structural study showed that the ratio of hcp phase with [0001] axis orientated perpendicular to the film as compared with in-plane orientation increases (resp. decreases), when Ni (resp. Cr) concentration increases independently of the post-annealing temperature. The crystalline magnetic anisotropy is found to align preferentially the magnetization along the [0001] axis and mostly opposes the demagnetization field which favors in-plane anisotropy.  $\text{Co}_{1-x}\text{Ni}_x$  alloys crystalline anisotropy constants can be up to twice larger than the best  $\text{Co}_{1-x}\text{Cr}_x$  anisotropy, while maintaining a magnetization at saturation above 1200 kA/m. Post-annealing until 300°C does not alter the magnetic features of both type of alloys, as requested for their integration in manufacturing processes for magnetic printing media.

#### **Acknowledgement**



The authors thank the Région Lorraine and the French National Agency for its grant of the research project (ANR-11-RMNP-004).

## References

- [1] B. D. Cullity, C. D. Graham, Introduction to magnetic materials, 2<sup>nd</sup> edition, Wiley, 2009.
- [2] O. Cugat, J. Delamare, G. Reyne, Magnetic Micro-actuators and systems (MAGMAS), IEEE T. Magn. 39 (2003) 3607
- [3] Z.-H. Wei, C.-P. Lee, M.-F. Lai, Magnetic particle separation using controllable magnetic force switches, J. Magn. Mater. 322 (2010) 19
- [4] A.-L. Gassner, M. Abonnenc, H.-X. Chen, J. Morandini, J. Josserand, J. S. Rossier, J.-M. Busnel, H. H. Girault, Magnetic forces produced by rectangular permanent magnets in static microsystems, Lab Chip 9 (2009) 2356
- [5] J.-J. P. Eltgen, G. Magnenet, Magnetic printer using perpendicular recording, IEEE T. Magn. 16 (1980) 961
- [6] E. Schlömann, Theory of magnetographic printing, IEEE T. Magn. 10 (1974) 60
- [7] D. Jeannot, J. C. Bouchand, G. Sache, RF sputtered CoCr for magnetography, J. Appl. Phys. 63 (1988) 3962
- [8] J. H. Kefalas, Effect of electroplating parameters on magnetic properties of Ni-Co alloys, J. Appl. Phys. 37 (1966) 1160
- [9] V. Tutovan, N. Velican, Magnetic properties of electrodeposited Ni-Co thin films, Thin Solid Films 7 (1971) 219
- [10] V. Tutovan, N. Velican, Stripe domains in electrodeposited NiCo thin films, Thin Solid Films 15 (1973) 31
- [11] Fernando M. F. Rhen, Saibal Roy, Dependence of magnetic properties on micro- to nanostructure of CoNiFe films, J. Appl. Phys. 103 (2008) 103901
- [12] Chun Wu, Kai Wang, Donggang Li, Changsheng Lou, Yue Zhao, Yang Gao, Qiang Wang, Tuning microstructure and magnetic properties of electrodeposited CoNiP films by magnetic field annealing, J. Magn. Mater. 61 (2016) 416

- [13] X. Liu, G. Zangari, Easy axis dispersion and micromagnetic structure of electrodeposited, high moment Fe-Co-Ni films, *J. Appl. Phys.* 90 (2001) 5247
- [14] H. Yamaguchi, M. Yanagisawa, Magnetic properties and structures of sputtered CoNi/Cr films, *IEEE T. Magn.* 22 (1986) 576
- [15] H. J. Lee, The crystal growth and magnetic properties of sputtered CoNi films on bcc polycrystalline underlayers 63 (1988) 3269
- [16] A. G. Spencer, R. P. Howson, The properties of magnetron sputtered CoNi thin films, *vacuum* 36 (1986) 103
- [17] Y. M. Kim, S. H. Han, H. J. Kim, D. Choi, K. H. Kim, J. Kim, Thickness effects on magnetic properties and ferromagnetic resonance in Co-Ni-Fe-N soft magnetic thin films, *J. Appl. Phys.* 91 (2002) 8462
- [18] M. R. Khan, R. D. Fisher, N. Heiman, DC-magnetron sputtered CoNiTa for high density longitudinal recording, *IEEE T. Magn.* 26 (1990) 118
- [19] S. Iwasaki, H. Nakamura, An analysis for the magnetization mode for high density magnetic recording, *IEEE T. Magn.* 13 (1977) 1272
- [20] S. Iwasaki, K. Ouchi, Co-Cr recording films with perpendicular magnetic anisotropy, *IEEE T. Magn.* 14 (1978) 849
- [21] S. Iwasaki, K. Ouchi, N. Honda, Studies of the perpendicular magnetization mode in Co-Cr sputtered films, *IEEE T. Magn.* 16 (1980) 1111
- [22] D. Ravipati, J. M. Sivertsen, J. H. Judy, Effect of substrate and deposition rate on dc magnetron sputtered Co-Cr thin films, *IEEE T. Magn.* 22 (1986) 1152
- [23] Z.-M. Li, J.F. Carolan, R.C. Thompson, B.R. Parsons, Magnetic properties of dc magnetron sputtered CoCr films, *Thin Solid Films* 154 (1987) 431
- [24] Y. Niimura, S. Nakagawa, M. Naoe, Control of coercive force of Co-Cr sputtered films, *IEEE T. Magn.* 23 (1987) 68

- [25] B. G. Demczyk, Evolution of microstructure and magnetic properties in magnetron-sputtered CoCr thin films, *Ultramicroscopy* 47 (1992) 425
- [26] H. Hoffmann, Thin film media (CoCr films with perpendicular anisotropy), *IEEE T. Magn.* 22 (1986) 472
- [27] Brian N. Chapman, *Glow Discharge Processes*, John Wiley & Sons Inc., 1980, New-York
- [28] M.P. Seah, An accurate semi-empirical equation for sputtering yields, II: for neon, argon and xenon ions, *Nucl. Instrum. Meth. B* 229 (2005) 348
- [29] R. Furushima, S. Tanaka, Z. Kato, K. Uematsu, Orientation distribution-Lotgering factor relationship in a polycrystalline material-as an example of bismuth titanate prepared by a magnetic field, *J. Ceram. Soc. Jpn.*, 118 (2010) 921
- [30] F. K. Lotgering, Topotactical reactions with ferrimagnetic oxides having hexagonal crystal structures-I, *J. Inorg. Nucl. Chem.* 9 (1959) 113
- [31] N. Zhang, J.C. Lodder, Structural and magnetic properties of CoCr ribbons, *J. Magn. Mater.* 89 (1990) 284
- [32] N. V. Myung, D.-Y. Park, B.-Y. Yoo, P. T.A. Sumodjo, Development of electroplated magnetic materials of MEMS, *J. Magn. Mater.* 265 (2003) 189
- [33] S. Girod, M. Gottwald, S. Andrieu, S. Mangin, J. McCord, J.-M. L. Beaujour, B. J. Krishnatreya, A. D. Kent, E. E. Fullerton, Strong perpendicular magnetic anisotropy in Ni/Co(111) single crystal superlattices, *Appl. Phys. Lett.* 94 (2009) 262504
- [34] C. H. Lambert, A. Rajanikanth, T. Hauet, E. E. Fullerton, S. Mangin, S. Andrieu, Quantifying perpendicular magnetic anisotropy at Fe/MgO(001) interface, *Appl. Phys. Lett.* 102 (2013) 122410
- [35] R. Skomski, *Nanomagnetics*, *J. Phys.: Condens. Matter* 15 (2003) 841
- [36] D. Weller, G. R. Harp, R. F. C. Farrow, A. Cebollada, J. Sticht, Orientation dependence of the polar Kerr effect in fcc and hcp Co, *Phys. Rev. Lett.* 72 (1994) 2097

- [37] X. Liu, M. M. Steiner, R. Sooryakumar, G. A. Prinz, R. F. C. Farrow, G. Harp, Exchange stiffness, magnetization, and spin waves in cubic and hexagonal phases of cobalt, *Phys. Rev. B* 53 (1996) 12166
- [38] J. N. Chapman, I.R. Mc Fadyen, J.P.C Bernards, Investigation of Cr segregation within rf-sputtered CoCr films, *J. Magn. Magn. Mater.* 62 (1986) 359
- [39] S. Armyanov Structure, internal stress and magnetic properties of electrodeposited Co-Ni alloys *IEEE T. Magn.* 14 (1978) 855

## Figures caption

- FIG. 1** Evolution of target voltages ( $V_{Cr}$ ,  $V_{Ni}$ ,  $V_{Co,Cr}$  and  $V_{Co,Ni}$  (Co voltages as a function of the alloying element), chemical compositions ( $C_{Cr}$  and  $C_{Ni}$ ), and deposition rates ( $V_{d,Cr}$  and  $V_{d,Ni}$ ) of cosputtered  $Co_{1-x}Cr_x$  and  $Co_{1-x}Ni_x$  films as a function the current intensity dissipated in Cr or Ni target
- FIG. 2** X-ray diffractograms of cosputtered  $Co_{1-x}Cr_x$  and  $Co_{1-x}Ni_x$  films after annealing at different temperatures
- FIG. 3** Lotgering factor of (0002) plane as a function of the Cr or Ni content in Co-base alloy film after annealing at different temperatures
- FIG. 4** Magnetization as a function of the applied magnetic field parallel to the film plane ( $H_{//}$ ) or perpendicular ( $H_{\perp}$ ) for  $Co_{92}Cr_8$ ,  $Co_{74}Cr_{26}$ ,  $Co_{93}Ni_7$  and  $Co_{75}Ni_{25}$  films.
- FIG. 5** Dependence of magnetic properties on the alloying element content for different annealing temperatures. For anisotropy  $K_v$  values all the annealing temperature lead to similar values so that only one point per concentration was plotted with an error bar (mostly due to the measurement error of saturation field)

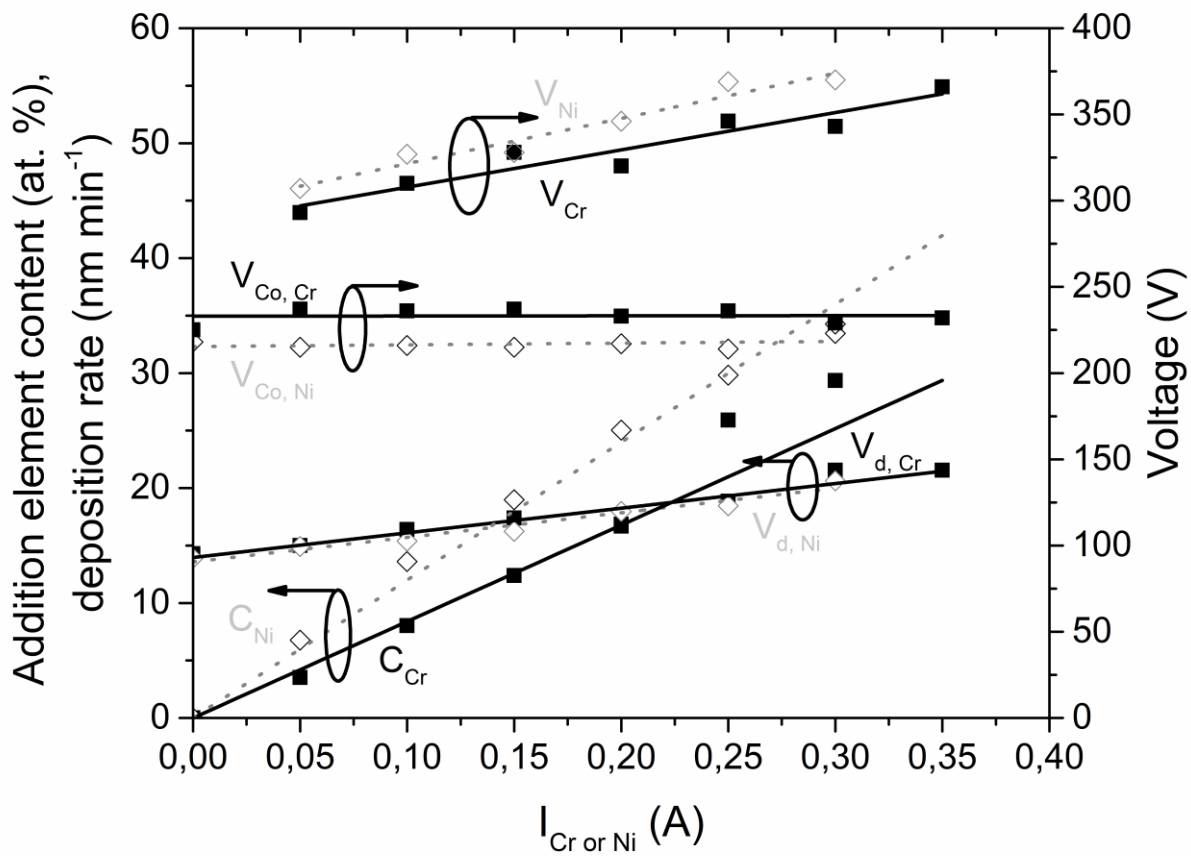


Figure 1.

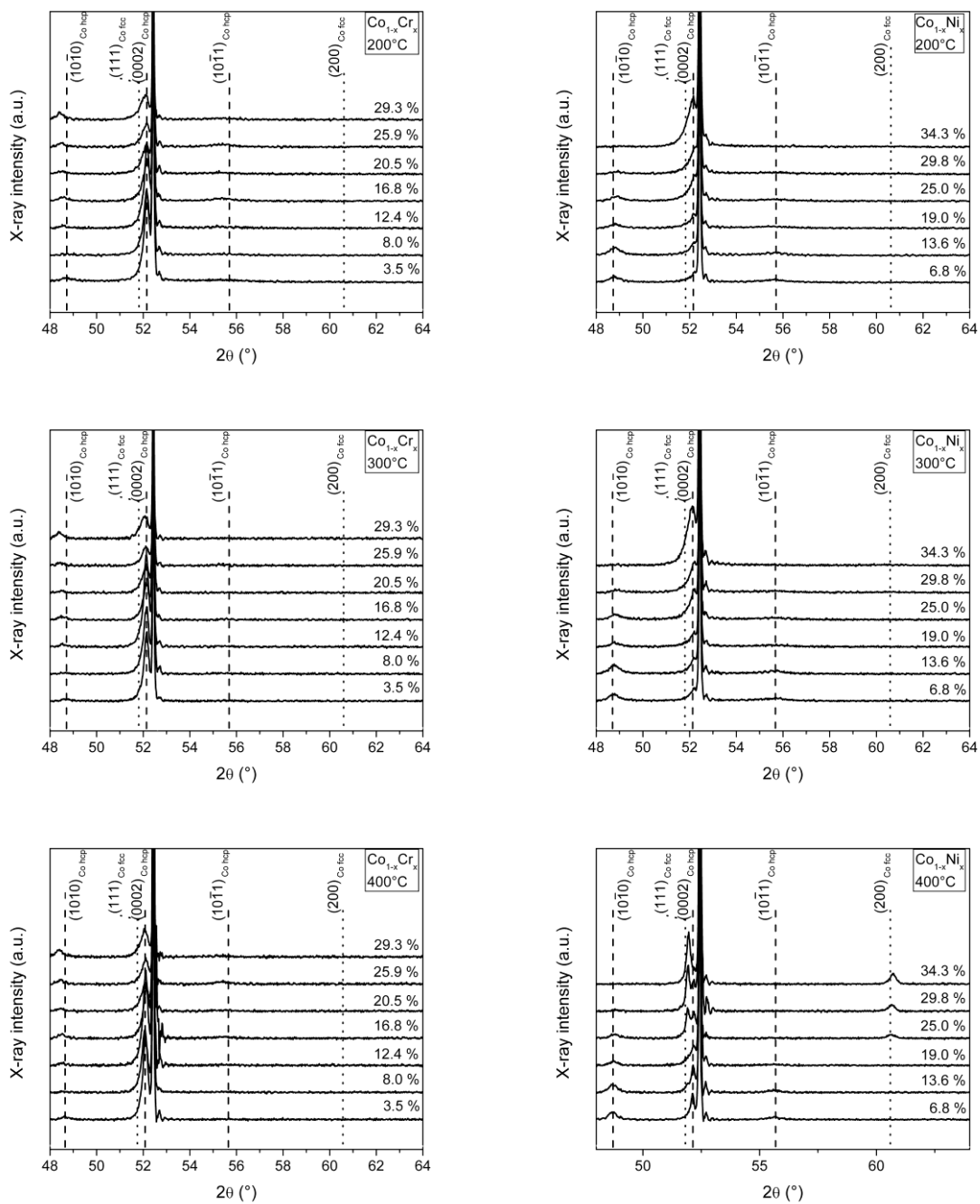


Figure 2.



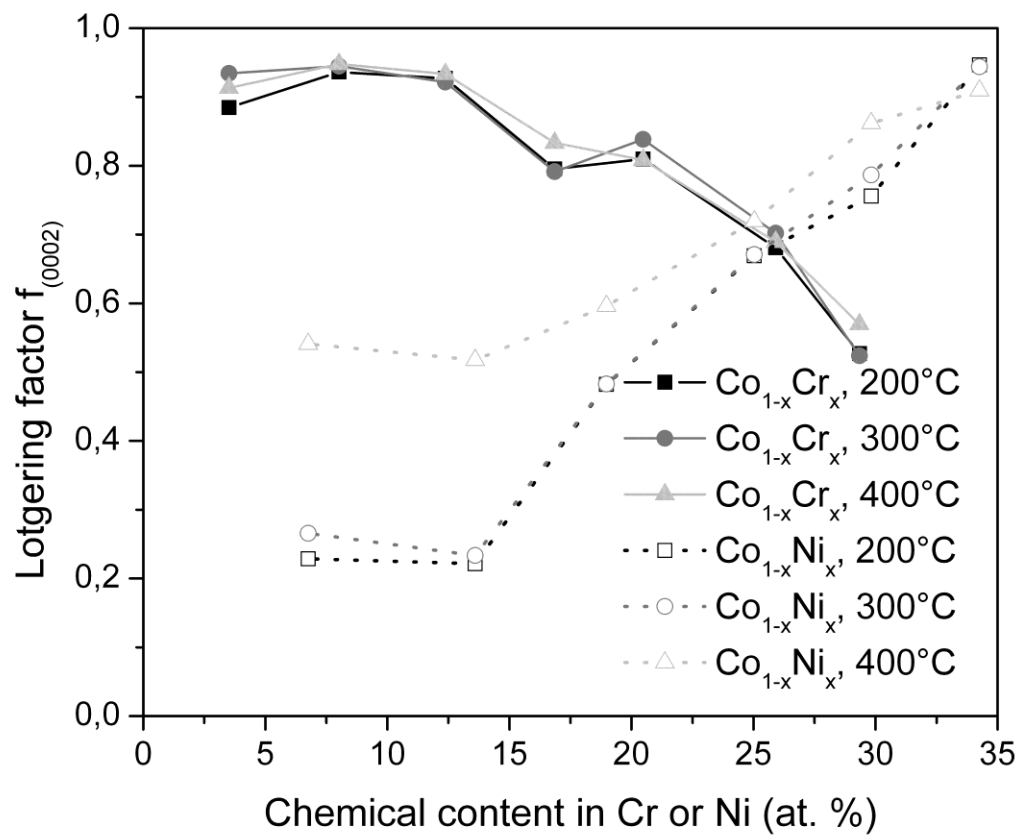


Figure 3.

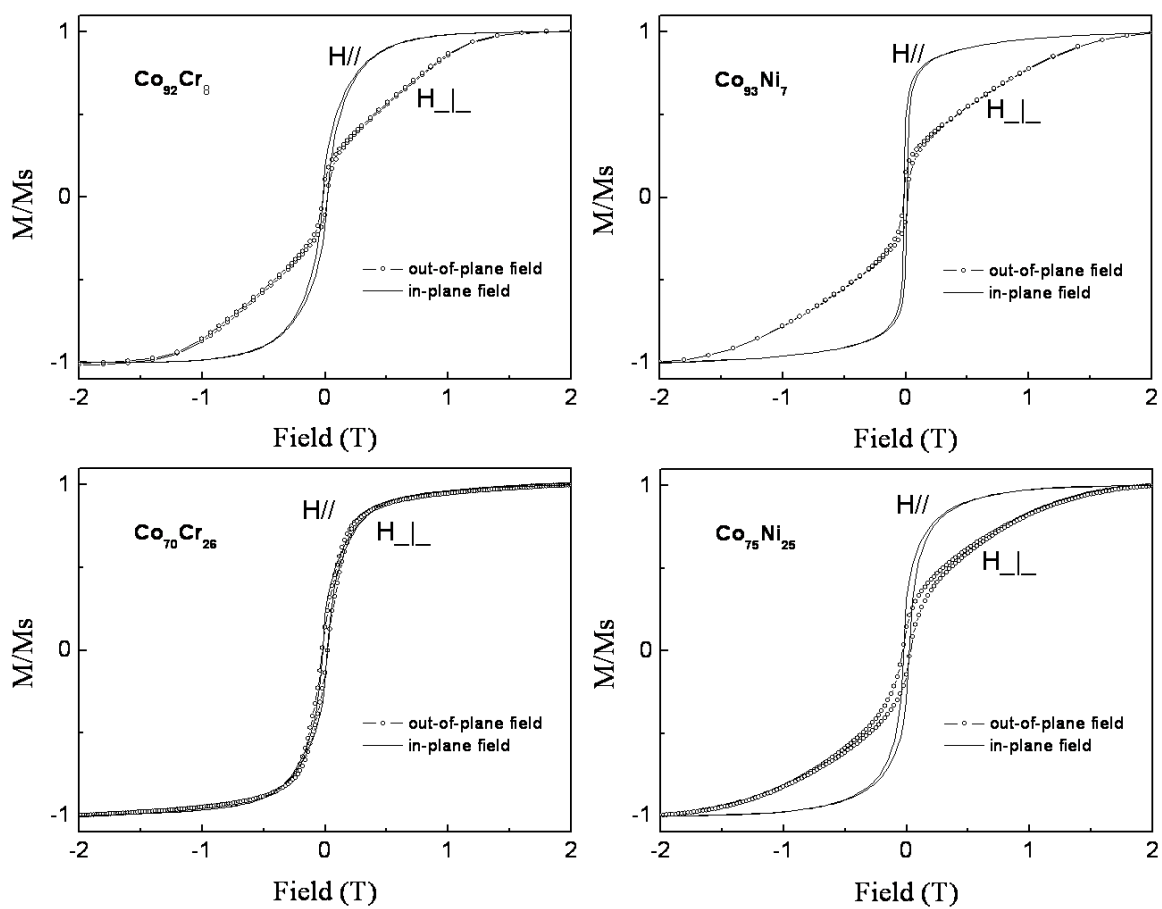


Figure 4

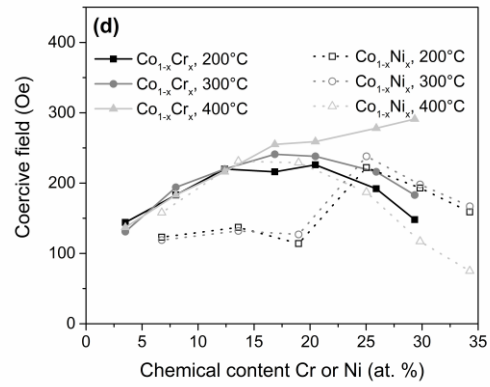
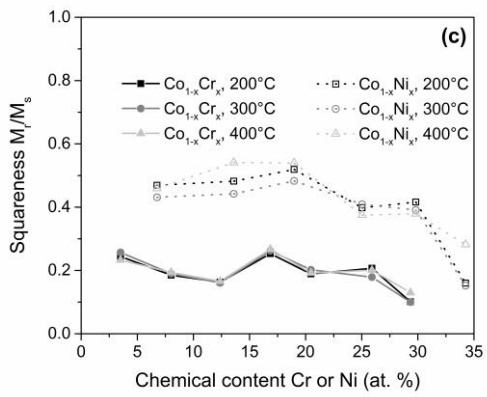
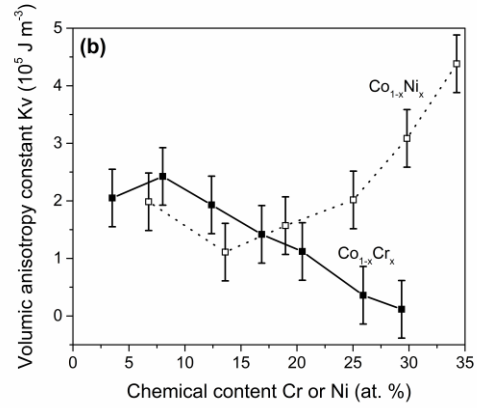
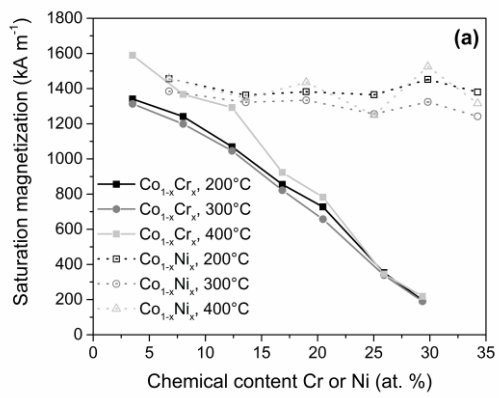


Figure 5