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STRUCTURAL AND MAGNETIC PROPERTIES OF $CO_{90}FE_{10}$ THIN FILMS EFFECTED BY UNDERLAYER

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ABSTRACT

In this essay we are study on structural and magnetic characteristics of CO and FE. In the current work, the single layer Co90Fe10 and X/Co90Fe10 (X = Cu, Cr, Au, Ni80Fe20) double layer films were examined. Films were produced by DC magnetron sputtering at room temperature on Si substrates. In order to improve the soft magnetic characteristics of Co Fe films, four alternative underlayers were explored. The coercivity values of the films were determined by employing a laboratory design magneto-optic Kerr effect (MOKE) magnetometry. Magnetic force microscopy and x-ray diffraction studies demonstrate that the crystalline structure and magnetic domains of Co Fe films are sensitive to the first layer. It was discovered that the soft magnetic characteristics of Co Fe films were enhanced by underlayers. Particularly, the Au underlayer proved successful in lowering coercivity Hc from 37 to 5 Oe. In this work, soft magnetic Co90Fe10 sheets were produced by DC magnetron sputtering. The 40 nm Co Fe film development over a magnetic underlayer (Ni80Fe20) and three distinct nonmagnetic underlayers (Cu, Cr, Au) were explored and compared with the Co Fe single layer film. All underlayers have a 6 nm thickness to permit comparing the nature of underlayers.

Keywords:CoFealloys,sputteredfilms,softmagneticmaterials

1. INTRODUCTION

Due to their potential in storage device applications like magnetic recording heads and magnetic sensors, soft magnetic materials based on Fe Co alloys are of great interest. Head materials for high-density recording devices require thin films that have soft magnetic characteristics and strong saturation magnetization. As a result of its extremely low magnetostriction constant, poly-crystalline Ni81Fe19 is commonly used for magnetic recording heads. Saturation magnetic flux density Bs of the Co Fe alloy is well-known. Co35Fe65 has a Bs of roughly 24 kilogrammes, which is quite near to the upper limit for ferromagnetic alloys. Studies show that conventional sputtering may produce soft magnetic, Co Fe alloy thin films with high Bs of 24 kg, such as single-layer Co Fe films, trilayer Ni Fe/Fe-Co-N/Ni Fe films, and bilayer films made of Co N/Ni F, as well as granular films of Fe Co Al O. In contrast, the Co Fe alloys made by a traditional sputtering process have a coercivity of roughly 50–100 Oe. For soft magnetic material applications, a high-Hc film is not suited. To increase the soft magnetic characteristics of Co Fe alloy films, it is important to produce low coercivity with a high Bs. Low-coercivity Fe-Co alloys, which have soft magnetic characteristics, have received a lot of attention recently. Coercivity can be reduced by employing underlayers, adding additives, and using alternative deposition procedures. In these experiments, the decrease in coercivity was commonly interpreted as a result of either a reduction in grain size or a change in preferred crystal orientation. Lowering film coercivity and enhancing film soft magnetic characteristics may be achieved by selecting an appropriate underlayer for Fe Co alloy films. Structural changes are common when an underlayer is used in these experiments. Magnetic anisotropy, which affects soft magnetic characteristics, is also affected by structural changes. Atoms placed on the surface of a thin (perhaps amorphous) underlayer are thought to be more mobile because of this. The film's energetically preferred texture is achieved by the application of a suitable underlayer. The development of layers, in turn, impacts the characteristics of films like magnetic softness, which may be influenced by the underlayer's composition.

Fe Co alloys have been used in several successful investigations to produce soft magnetic films. Fewer studies have been conducted on the use of Co Fe alloy films, particularly Co90Fe10. In addition, underlayer materials like as Au and Cr are rarely employed with Co90Fe10. Recently, the vibrating sample magnetometer (VSM) was commonly employed to investigate the magnetic characteristics of films. A good knowledge of the magnetic characteristics of thin films necessitates the use of alternating methods like a magneto-optic Kerr effect (MOKE) magnetometer. DC magnetron sputtering was used to create Co90Fe10 films with a soft magnetic core. Three alternatives nonmagnetic underlayers were tested and compared to the Co Fe single layer film, all of which grew to a thickness of 40 nm, including Ni80Fe20, Cu, Cr, and Au. The thickness of the underlayers was set at 6 nm in order to allow for an accurate comparison of their characteristics. Co90Fe10 was employed as a composite target for the fabrication of all films. Co Fe films showed a shift in magnetic characteristics and an improvement in soft magnetism. Coercivity Hc and magnetic anisotropy in the Co90Fe10 film with the Au underlayer were significantly reduced in our experiment, whereas all underlayers were successful in decreasing coercivity. To demonstrate the creation of Co90Fe10 soft magnetic thin films by means of a suitable thin underlayer, this research's goal is to demonstrate Soft magnetic Fe Co alloys with varied Ni Fe and Cu underlayer thicknesses have recently been shown to be successful in trials. Making a comparison between soft magnetic Co90Fe10 films deposited on different underlayers and those that were made with the 6 nm Au underlayer is the novelty of this paper.

2. LITERATURE REVIEW

SukruCakmaktepe(2013) There was a focus on the Co90Fe10 single layer and X/Co90Fe10 double layer films (X = Cu, Cr, Au, Ni80Fe20). Films were created using DC magnetron sputtering on Si substrates at room temperature. Four different underlayers were investigated in order to improve the soft magnetic properties of Co Fe films. Magneto-optic Kerr effect (MOKE) magnetometry was used to measure the coercivity of the films. Co Fe films' crystalline structure and magnetic domains are shown to be sensitive to the initial layer by magnetic force microscopy and x-ray diffraction. Co Fe films' soft magnetic properties were found to be enhanced by the addition of underlayers. Coercivity Hc decreased from 37 to 5 Oe as a result of the use of the Au underlayer.

Yujie Fu (2007)A thin Co underlayer was used to create soft magnetic Fe Co films with high saturation magnetization (=Fe65Co35). In-plane uniaxial anisotropy (Hce) of 10Oe and Hch of 3Oe were observed in the Fe Co/Co films, and a half decrease in Hc was achieved when the composition was altered to 25 percent Co... At frequencies between 250 and 800 MHz, the effective permeability of the films stays constant. In a single layer of Fe Co, the saturation magnetostriction was 5.2 x 105 and the intrinsic stress was 0.8 GPa; the Co underlayer lowered these values marginally. From (200) to (110) and from 74 to 8.2 nanometers, the grain size of the FeCo films was decreased dramatically by an underlayer of Co that was added to the FeCo layer. In addition, the surface roughness was decreased from 2.351 to 0.751nm as a result of this process. TEM and XPS were used to explore the early stages and the characteristics of interface diffusion in more detail.

Caruana Finkel (2014) In order to generate soft fcc Co90Fe10 films with high magnetostriction constants, the structure and magnetic properties of thin Co90Fe10 films have been examined to understand how different soft magnetic underlayers (Metglas and Ni81Fe19) impact these features. There was a 15-to-to 35-nanometer variation in the thickness of the magnetic underlayer in the Co90Fe10 films. We also looked at the impact of running a magnetic field during the process of growing both layers. According to X-ray diffraction results, the Ni Fe-grown Co90Fe10 films had lower in-plane stresses than the silicon- and Metglas-grown counterparts. The magnetostriction constants were highly dependent on the underlayer on which the Co90Fe10 films were formed, even though their coercive fields were less than those of the monolithic Co90Fe10 film. As a result, by selecting the proper soft magnetic underlayer, the magnetostriction constant of the Co90Fe10 film may be tuned to be positive or negative.

Geetha Pookat (2013) Thermal evaporation was used to create ultrathin films based on Co and Fe from a composite target. Thermal annealing changed the film microstructure. Techniques such as glancing angle X-ray diffraction (GXRD), transmission electron microscopy (TEM), and vibrating sample magnetometry were used to examine the link between the films' microstructure and magnetic characteristics (VSM). Investigations using the GXRD and TEM revealed that Co Fe crystallisation began at at 373 K. With thermal annealing, the magnetic softness of the films improved, but it deteriorated at higher temperatures. The alloy thin films were studied using atomic force microscopy after annealing, which resulted in changes in their surface shape (AFM). Thermal annealing smoothed the surface, and the magnetic characteristics were shown to be closely related to the surface alterations caused by thermal annealing.

Wenyu Jiang(2018) Electromagnetic equipment is in high demand as the power sector continues to grow. An essential part of electrical equipment design is simulating the magnetic characteristics of magnetic materials under varying external circumstances, such as frequencies and pressures, in high detail. To begin, a brief history of electrical magnetic materials research is provided in this paper. Using the Epstein square technique and the ring sample method, the magnetic characteristics of the silicon steel sheet under the impact of frequency and pressure may be recorded and tested in this work. A summary of magnetic characteristics is presented here, based on data processing and analysis, in order to demonstrate why magnetic materials may be useful in industrial settings.

3. RESEARCH METHODOLOGY

DC magnetron sputtering was used to create the samples, which were then deposited on (110) oriented Si wafers. All Si wafers were subjected to a 40 W dc sputter pre-clean procedure that included bias plasma (at a pressure of 20–200 mTorr). In most cases, the pre-clean operation removes 20–30 angstroms of surface atoms from Si. A 6-target sputtering system was used to sputter the Co Fe and underlayers in the same chamber without removing the vacuum. Before depositions, the pressure was 1.7 10–7 Torr. It was found that magnetic anisotropy may be introduced into the sputtering system using a magnetic holder. Ar depositions were carried out with an Ar background pressure of 3 mTorr at 300 W DC at all 40 nm Co90Fe10 layers. The 150 W sputter power and 1 mTorrAr pressure were used to deposit the 6 nm Au layer. A Ni80Fe20 composite target was used to deposit the 6 nm layer at 400 W sputter power and 3 mTorrAr pressure. An Ar pressure of 3 mTorr was used to deposit the 6 nm Cr layer, using a 300 W sputter power. A 300 W sputter power and a 2 mTorrAr pressure were used to deposit the 6 nm Cu layer. Using a He-Ne (630 nm) polarised laser source, MOKE magnetometry was used to identify the film's M-H loops. The MOKE magnetometer measures the reflected laser beam's longitudinal intensity. Because the samples were so thin, grazing incidence x-ray diffraction (GI-XRD) was used to analyse the crystal structure (Rigaku Ultimate IV with Cu-K radiation). Magnetic force microscopy (Park Systems' XE-100E) was used to examine the films' micromagnetic structure. It's important to keep in mind that the samples used in magnetic domain analysis are still magnetised.

4. RESULTSANDDISCUSSION

There were five different films examined: a 40 nm Co Fe single layer, an Au/40 nm Co Fe double layer, a NiFe/40 nm Co Fe double layer, a Cr/40 nm Co Fe double layer, and a Cu/40 nm Co Fe double layer, all of which were applied on Si (110) wafers at room temperature. The films' M-H loops are shown in Figure 1. Double layer films exhibit lower coercivity than single layer Co Fe films, as seen in the figure (see below). The easy axis coercivity (Hce) of a single-layer Co Fe film is 49 Oe, whereas the hard axis coercivity (Hch) is 37 Oe. The hard axis coercivity (Hch) of the Co Fe film dropped from 37 Oe to 5 Oe with the Au underlayer. There was also a finding of a uniaxial magnetic anisotropy. The Ni80Fe20 under-layer significantly reduced the coercivity of the Co Fe film. The Ni Fe/Co Fe film has a coercitivity of 8.5 Oe along the hard axis.

The Co Fe film's magnetic hysteresis was altered by the Cu underlayer in the same way. Coercivity along the hard axis of the Cu/Co Fe film was found to be 9 Oe, a significant decrease. Magnetic hysteresis in the Co-Fe film is limited by the Cr underlayer. In terms of coercivity, the Cr/Co Fe film is 28 Oe on the hard axis. Magnetic hysteresis differs significantly across four types of underlayers because of the material's influence on magnetic layers [24]. Ni Fe's contribution to the system's magnetic characteristics explains the decrease in coercivity when combined with the Ni Fe underlayer. The reduction in grain size and

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texture chance found in the XRD studies below are thought to be responsible for the improved soft magnetic characteristics with nonmagnetic underlayers.

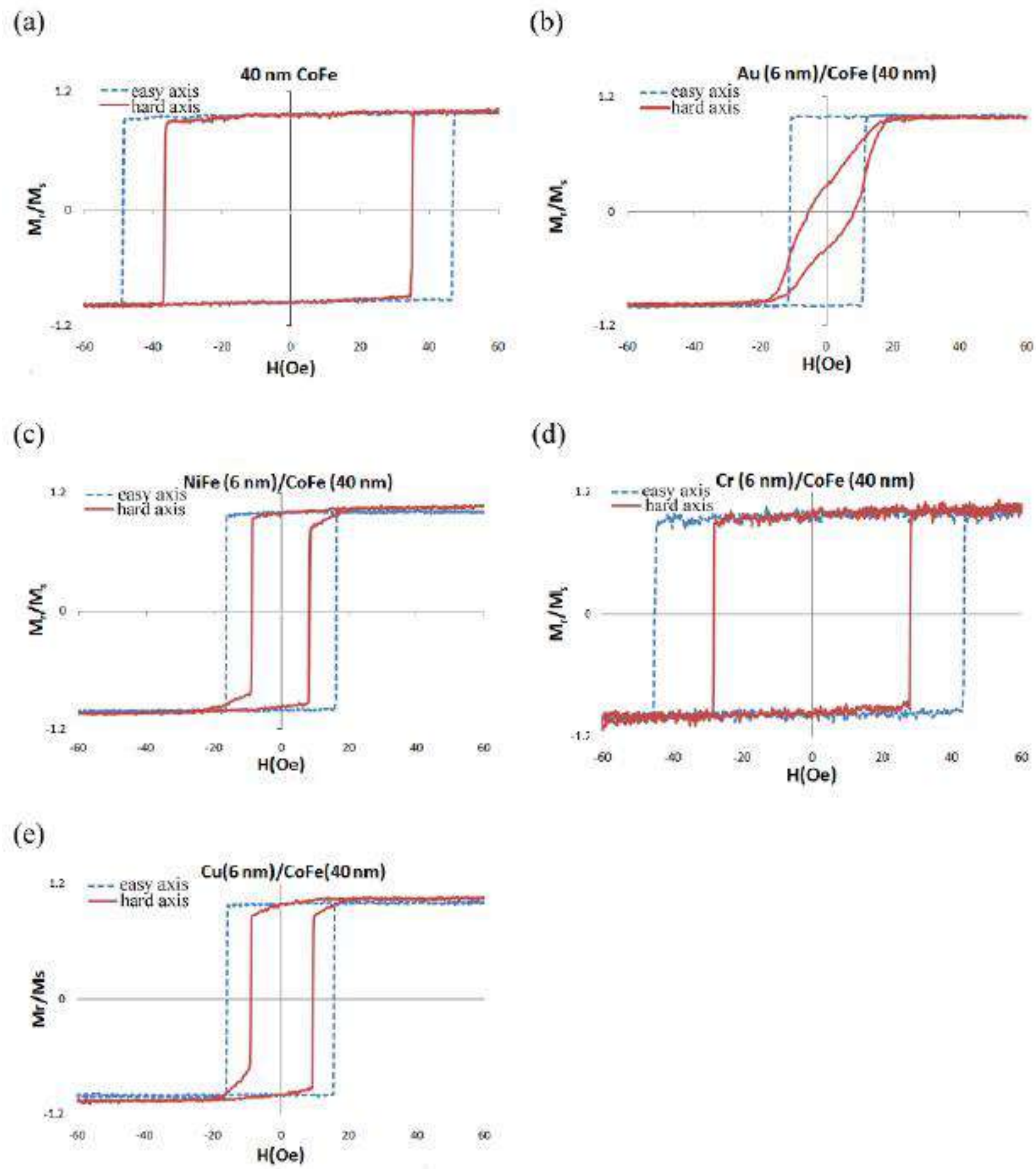

Fig. 1. Typical hysteresis loops for (a) Co Fe, (b) Au/Co Fe, (c) NiFe/Co Fe, (d) Cr/Co Fe, and (e) Cu/Co Fe films.

Figure 2 depicts MFM pictures of films that are still in the process of being degraded. It was found that the precise magnetic domain development was not observed in Au/Co Fe, Ni Fe/Co Fe, or Cu/Fe Co double layer films. These films have coercivity values of 5, 8.5, and 9 Oe along the hard axis. The lack of magnetic domains in these films is due to their low coercivity (10 Oe). In contrast, the high coercivity value of a single layer Co Fe film clearly demonstrates a magnetic domain arrangement. Magnetic domains were seen in the MFM picture of the Cr/Co Fe film, which is similar to a single layer of Co Fe. Coercivity along the hard axis of the film is around 28 Oe, which may account for the observed domain arrangement. Due to films that were in the residual condition, the stripe domain configuration was not seen in all series of films. It's extremely similar to the experiment done by Kong et al. in terms of the magnetic domains and hysteresis curves. It seems from these findings that the underlayers had an essential role to play in the creation of magnetic domains and the decrease in coercivity. In addition, these findings reveal that films' magnetic characteristics are highly dependent on the underlayers.

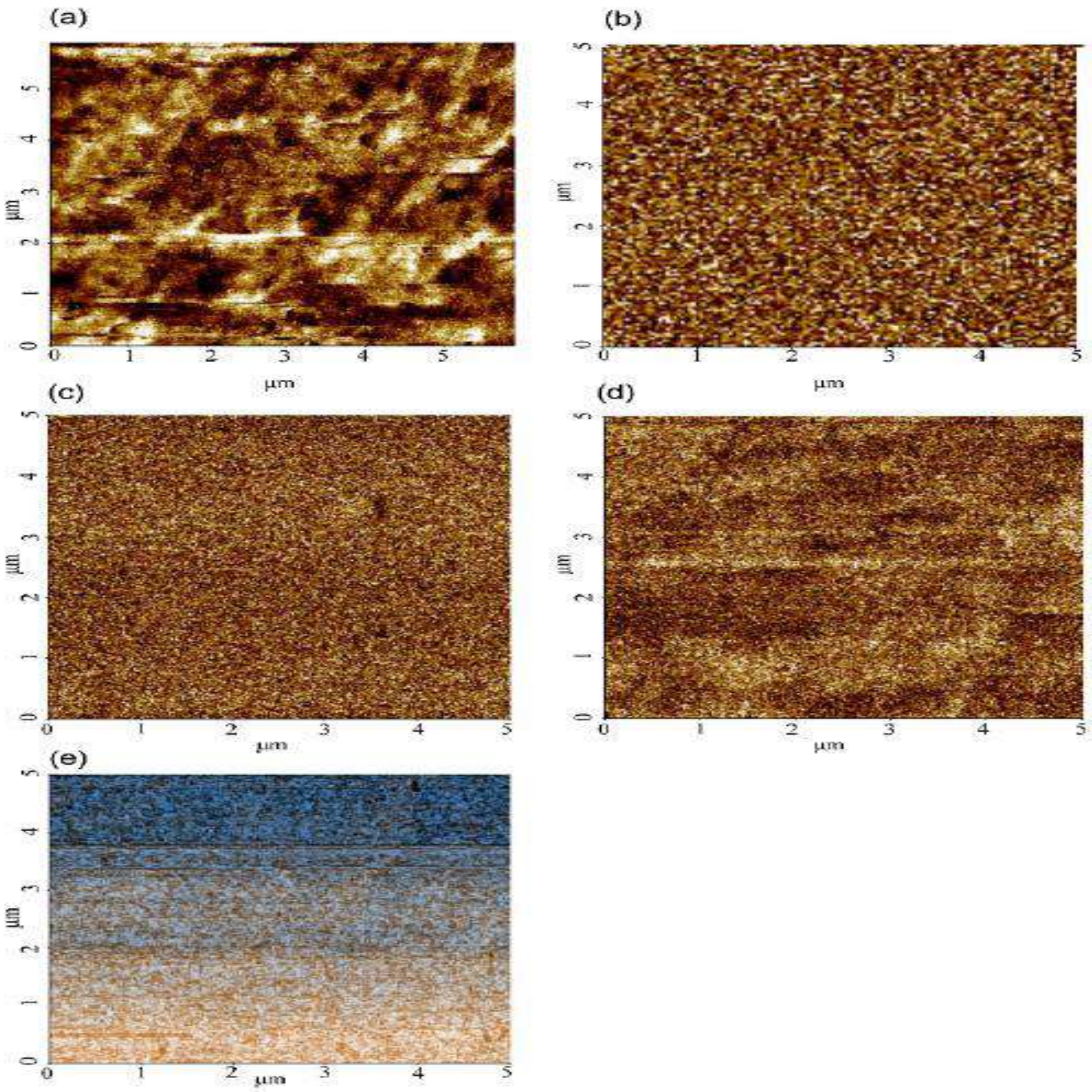

Fig. 2. MFM images of (a) Co Fe, (b) Au/Co Fe, (c) NiFe/Co Fe, (d) Cr/Co Fe, and (e) Cu/Co Fe films.

GI-XRD patterns for five films are shown in Figure 3. Underlayers have a significant impact on the crystal-line structure of Co Fe films, according to GI-XRD patterns. Structure of the single-layer Co Fe film is shown to be bcc, with the major (110) and weak (220) peaks. The primary diffraction peak of the Ni Fe/Co Fe film altered from (110) to (120). (220). Film made from Au/Co Fe reveals sluggish di fracttion lines (200 and 220). The Scherrer equation shows that XRD peak width is inversely proportional to grain size. In contrast to the Au underlayer, the (220) diffraction peak of Co Fe is significantly larger and shifts to lower angles, suggesting a substantially smaller particle size. Hoffman's ripple hypothesis predicts that the Au/Co Fe film's reduced coercivity is caused by a drop in grain size. A faint (220) diffraction line may be seen in the Cu/Co Fe film. These films' magnetic hysteresis differs greatly from that of single Co Fe, hence the GI-XRD patterns of Au/Co Fe, Ni Fe/Co Fe, and Cu/Co Fe films exhibit distinct crystalline structures. The primary (110) and weak (220) diffraction lines in the Cr/Co Fe film are identical to those in the Co Fe film with a single layer, which is encouraging. The diffraction order increased the magnetic softness, as shown by GIXRD studies of films. For our samples, it ranges from 110 to 220. Grain size decrease has been linked to a textural change in a recent research by Jung et al. You could feel less stressed as a result of this shift in texture. This is consistent with previous findings showing that the roughness of crystal structure changes as coercivity decreases. In general, the GI-

XRD results show that underlayers modify the film texture. Despite this, the fundamental reason remains a mystery and is now being investigated.

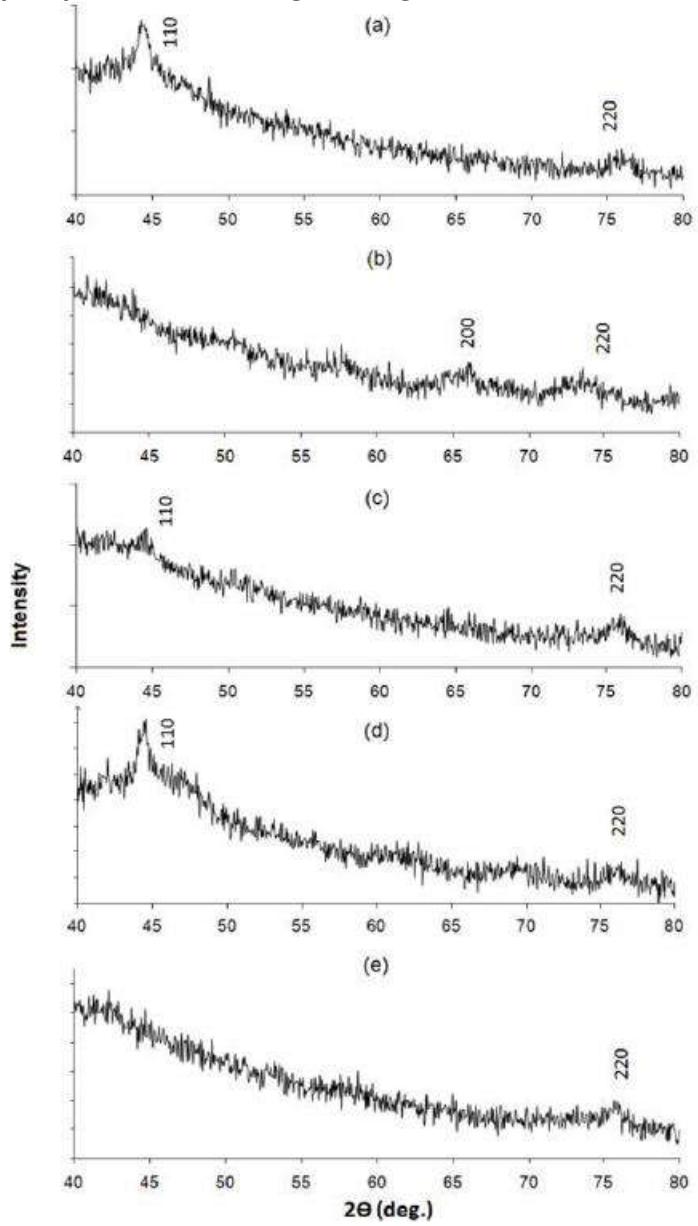

Fig. 3. GI-XRD patterns of (a) Co Fe, (b) Au/Co Fe, (c) NiFe/Co Fe, (d) Cr/Co Fe, and (e) Cu/Co Fe films.

5. CONCLUSION

On four distinct underlayers, we successfully deposited magnetic Co Fe films. The soft magnetic characteristics of Co Fe thin films were improved by using Au, Co, Cu, and Ni Fe as an underlayer. Underlayers have been shown to improve film texture and magnetic hysteresis in experiments. The drop in coercivity was shown to be linked to the change in crystal structure. The crystalline texture was altered by the presence of Au, Ni Fe, and Cu underlayers. We propose that nonmagnetic underlayers supply the Co Fe layer with a crystal structure with smaller grains that is energetically preferred. Coercivity was reduced as a result of these changes in crystal structure. Double layer Co Fe films have smaller grains according to GI-XRD findings than single layer films. In the hypothesis of Hoffman's ripples, this is the key element in reducing coercivity. Due to their ability to reduce the coercivity of Co Fe films, we recommend using 6 nm Au, NiFe, and Cu as underlayers for soft magnetic films. Soft magnetic Co Fe films cannot be prepared with a 6 nm Cr layer because of the inadequate coercivity decrease. We found that films with poor coercivity don't create a distinct magnetic domain as expected. As a result of an underlayer effect, which decreases grain size and changes domain development in the films, coercivity has been reduced in recent research. Underlayer materials for the production of soft magnetic Co Fe thin films include NiFe, Cu, and notably Au, according to our results. Further research is being done on several types of Au/Co Fe films because the Au/Co Fe film demonstrated the greatest soft magnetic characteristics in our experiment.

REFERENCES

1. Cakmaktepe, Sukru&Coşkun, M.ibrahim&Yıldız, Abdulkadir. (2013). Underlayer effect on structural and magnetic properties of Co90Fe10 thin films. Lithuanian Journal of Physics. 53. 112-118. 10.3952/lithjphys.53205.
2. Finkel, A. & Reeves-McLaren, Nik & Morley, Nicola. (2014). Influence of soft magnetic underlayers on the magnetic properties of Co90Fe10 films. Journal of Magnetism and Magnetic Materials. 357. 87–92. 10.1016/j.jmmm.2014.01.030.
3. Jiang, Wenyu & Li, Weiye& Lou, Jianyong& Wu, Shidong. (2018). Study on Magnetic Properties of Magnetic Materials with Multiple Factors. Journal of Physics: Conference Series. 1087. 052026. 10.1088/1742-6596/1087/5/052026.
4. Finkel, A. & Reeves-McLaren, Nik & Morley, Nicola. (2014). Influence of soft magnetic underlayers on the magnetic properties of Co90Fe10 films. Journal of Magnetism and Magnetic Materials. 357. 87–92. 10.1016/j.jmmm.2014.01.030.
5. Pookat, Geetha & Thomas, Hysen& Thomas, Senoy& Al-Harthi, S.H. & Raghavan, Lisha & Al-Omari, Imaddin&Sakthikumar, D. & Ramanujan, Raju &Anantharamaniyer, Maliemadom. (2013). Evolution of structural and magnetic properties of Co–Fe based metallic glass thin films with thermal annealing. Surface and Coatings Technology. 236. 246-251. 10.1016/j.surfcoat.2013.09.055.
6. Offi, F. &Kuch, Wolfgang. (2002). Structural and magnetic properties of Fe_ {x} Mn_ {1-x} thin films on Cu (001) and on Co/Cu (001). Phys. Rev. B. 66. 10.1103/PhysRevB.66.064419.
7. Fu, Yujie&Miyao, T. & Cao, Jiangwei& Yang, Zhang & Matsumoto, M. & Liu, Xiaoxi&Morisako, Akimitsu. (2007). Effect of Co underlayer on soft magnetic properties and microstructure of Fe Co thin films. Journal of Magnetism and Magnetic Materials - J MAGN MAGN MATER. 308. 165-169. 10.1016/j.jmmm.2006.05.007.
8. S. Thomas, S.H. Al-Harthi, I.A. Al-Omari, R.V. Ramanujan, V. Swaminathan, and M.R. Anantharaman, J. Phys. D. 42, 215005 (2009).
9. G. Chai, D. Guo, X. Li, J. Zhu, W. Sui, and D. Xue, J. Phys. D: Appl. Phys. 42, 205006 (2009).
10. T. Yokoshima, K. Imai, T. Hiraiwa, and T. Osaka, IEEE Trans. Magn. 40, 2332 (2004).
11. Y. Fu, T. Miyao, T. Yamakami, Z. Yang, M. Matsumoto, X. Liu, and A. Morisako, IEEE Trans. Magn. 41, 2905 (2005).
12. M. Vopsaroiu, M. Georgieva, P.J. Grundy, G.V. Fernandez, S. Manzoor, M.J. Thwaites, and K. O' Grady, J. Appl. Phys. 97, 10N303 (2005).
13. C. Mathieu, V.R. Inturi, and M.J. Hadley, IEEE Trans. Magn. 44, 431 (2008).
14. R. Law, R. Shiaa, T. Liew, and T.C. Chong, IEEE Trans. Magn. 44, 2612 (2008).