Topographic Study of $Fe_{70}co_{30}$and $Ni_{80}fe_{20}$of Various Thickness for Spin Valve Application

D. Dhanalakshmi[a], Mani GMK[a1]
{dgd.apsc@psgtech.ac.in[1], manigmk7396@gmail.com}

a. Spintronics and Functional Materials Laboratory, Department of Applied Sciences, PSG College of Technology, Coimbatore 641004, India.[1]

Abstract. FeCo and NiFe thin films of various thickness were prepared on silicon substrate using UHV DC Magnetron Sputtering. The thickness of the film was studied using stylus profilometer.Topography of the surface was studied by AFM which confirms roughness of the film, increases with increasein film thickness. Magnetic properties of the film were studied using VSM analysis.We observe that the magnetic properties of FeCo and NiFe thin filmvaries with film thickness. SEM-EDS analysis confirms purity of the films.

Keywords: FeCo, NiFe, UHV DC Sputtering, Vacuum.

1 Introduction

Many researchers are very much interested to use FeCo alloy for many applications such as MRI, Nano fluids, magnetic sensor, drug delivery, biomedical application[1–4]. In the past two decades spintronics people also very much interested to use FeCo based nano-film for device applications like spin injector in spin-valve device structure. Due to FeCo magnetic properties such as magnetic stability, magnetic coercivity, spin polarization (55%), and Curie temperature (Tc-720) was high enough to be considered for various application[5–8]. In literature its reported that the alloy with the atomic ratio 50:50, 65:35, 70:30of Fe and Co content ($Fe_{100-X}Co_X$)possesses different magnetic moment atoms. Magnetic saturation of FeCo alloy was reduced by adding cobalt content[9].

Due to addition of cobalt the magnetic anisotropy is decreased. Magnetic moment was higher for Fe than Co atom due to magnetic coercivity higher for highest cobalt content.Physical vapor deposition methods are helpful for making device application due to their purity of the film. In high vacuum condition, the atmosphere molecule such as oxygen and carbon reaction at the top of the film was reduced.

Magnetic film properties depends on various factors such as substrate temperature, post annealing, different substrate, film thickness and preparation method. The change in magnetic properties was confirmed by hysteresis loop. In room temperature FeCo has polycrystalline with BCC crystal structure and the above critical temperature the structure was changed to FCC. FeCo spin injector based spin valveGMR devices were fabricated. Dhana et al prepared organic spin valve device with $Fe_{50}Co_{50}$ (40nm) as a spin injector with work function (4.9eV) was close to the organic semiconductor homo level[10]. T. Moriyama et al prepared MTJs device with FeCo as the spin injector and detector[6].

ICCAP 2021, December 07-08, Chennai, India

DOI 10.4108/eai.7-12-2021.2314738

In this paper we prepared $Fe_{70}Co_{30}$ and $Ni_{80}fe_{20}$electrode of various thickness (d= 10,20, 30,40, and 50nm) by using UHV dc magnetron sputtering and studied topography and magnetic property of the film.

2 Experimental Technique

$Ni_{80}Fe_{20}$ and $Fe_{70}Co_{30}$thin film was deposited on thermally oxidized Si (100) substrate under the following conditions. The Sputtering target of $Fe_{70}Co_{30}$and $Ni_{80}Fe_{20}$alloy was 2 inch dia., with 99.9% purity. The substrate used was Si (100)/SiO_2 wafer. The film was sputtered with Ar gas pressure of 4Sccm, DC power 50W. The sputtering parameters such as target to substrate distance, substrate temperature (RT) were kept constant. For this set of experiment, the sputtering pressure was maintained at 3 mTorr.

The base pressure was 10^{-7} Torr. The deposition rate increases with constant sputtering power and increasing time. The various characterization techniques were used to study various parameters such as film thickness, composition and soft magnetic properties of $Ni_{80}Fe_{20}$and $Fe_{70}Co_{30}$ thin films deposited. To estimate the thickness of the films, surface profilometer was used. The elemental analysis was carried out using EDS. The Vibrating sample magnetometer (VSM) was used to study and quantify the magnetic properties of Ni-Fe and Fe-Co thin films. The roughness of the film was studied using AFM.

3 Result And Discussion

For calibrating the thickness of film, NiFe and FeCo films were deposited on Si wafer with grid marking for different sputtering conditions. After deposition, the marker was removed by washing in iso-propyl alcohol. The thickness of all these films was determined using a Stylus profilometer and thus found out the sputtering time required for getting a film of 10 nm thicknessis shown in fig 1. From plotting a graph of sputtering time vs. film thickness, we find out that the sputtering time should be 3 min 20sec for NiFe and 10 mins for FeCo to obtain a 10 nm film.

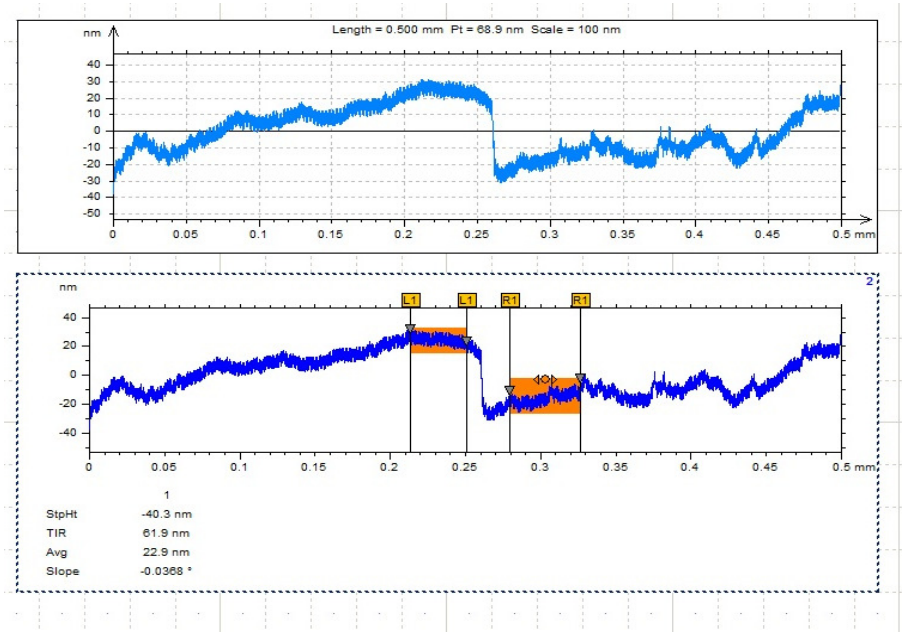

Fig 1. Thickness analysis of FeCo and NiFe film on the Silicon substrate

The surface topography also depends on thickness and grain size. If uniform grain size is maintained and thickness is increased, then surfaces becomes smooth. But as the grain size increases surface becomes rougher shown in fig 2 &3.

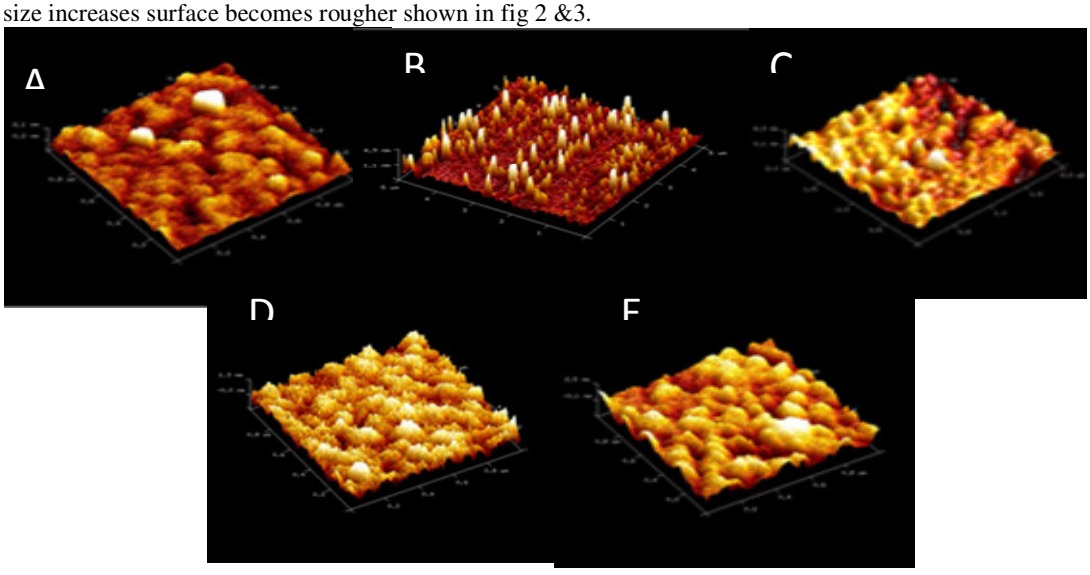

Fig 2. Topographic 3D image of FeCo A) 10nm B) 20nm C) 30nm D) 40nm E) 50nm

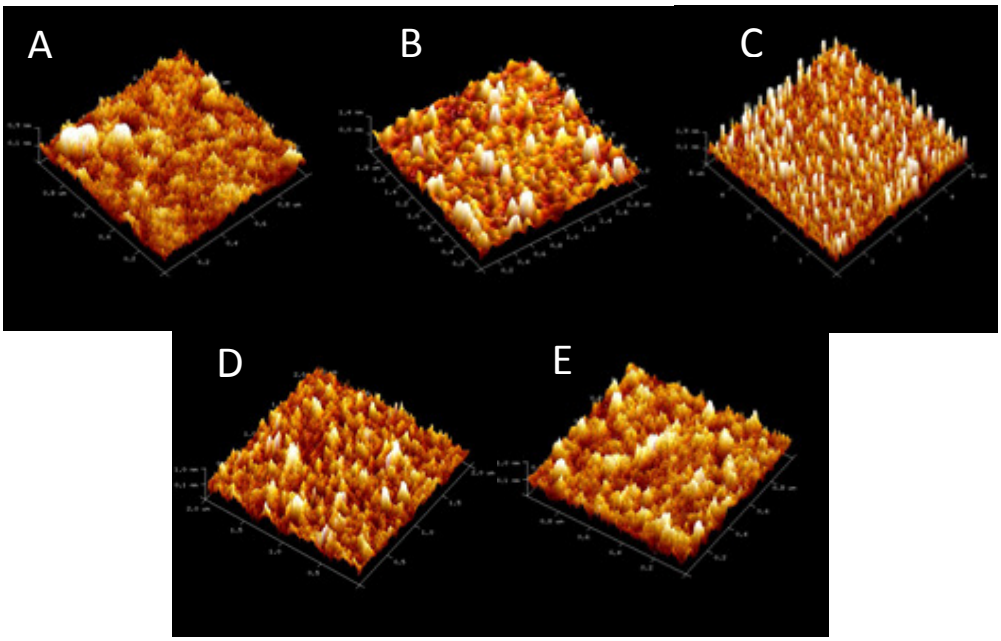

Fig 3. Topographic 3D image of NiFe A) 10nm B) 20nm C) 30nm D) 40nm E) 50nm

Vibrating sample magnetometer was used to find the magnetic properties of the films. A sample size of 5x5 mm was taken to carry out these measurements. A room temperature the magnetic characterization was carried out, the corresponding M-H loop was obtained. The sample holders are high purity and free from any metallic impurity which were used for measurement. Sample measurement process was done with bare sample (without deposited thin film) and equivalent M-H loop was obtained. The magnetization data of the bare sample were deducted from the measured magnetic signal of the sample. VSM has magnetic high sensitivityoftheorderof10^{-6} emu. Parameters extracted from the hysteresis loop are saturation magnetization Ms, remanence Mr, coercivity Hc. The magnetization and M_r/M_s value often used for explaining magnetic properties of materials. As the thickness of the films is increasing the magnetization value is increasing. Highest magnetization value was obtained at 50 nm shown in fig 4 &5. Main purpose of depositing the different thickness films is to find out the optimum magnetic characteristics which are necessary for sensor application. As in sensors the switching of the magnetic field should be very fast, i.e. the coercivity H_c should be as low as possible with optimum magnetization. As we compare the above results the lowest coercivity is obtained for 10 nm thickness film and its magnetization is very low but with least coercivity which is not suitable for sensor application. The optimum magnetic characteristics are observed at 50 nm with highest magnetization and better coercivity shown in table (1&2).

Table (1 &2)clearly indicates that FeCo and NiFe of various thickness, the magnetic coercivity of the film increased with increasing roughness of the film. Which was clearly indicates that roughness of the film and magnetic properties of the film are directly related.

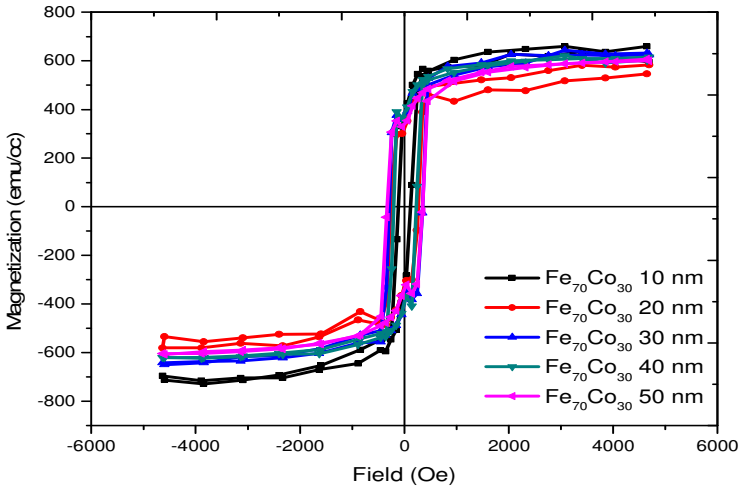

Fig 4. $Fe_{70}Co_{30}$film various thickness of the film VSM results

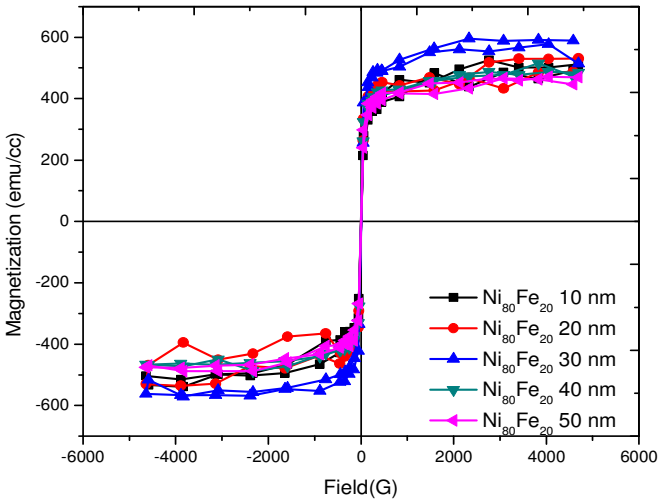

Fig 5. $Ni_{80}Fe_{20}$ film various thickness of the film VSM results

Table 1: FeCo VSM and AFM results

FeCo	Thickness (nm)	Magnetic saturation	Coercivity	Roughness of the film (nm)
$Fe_{70}Co_{30}$	10	635.43	96.32	2.1
$Fe_{70}Co_{30}$	20	583.83	288.21	4.9
$Fe_{70}Co_{30}$	30	624.19	313.63	5.9
$Fe_{70}Co_{30}$	40	616.11	210.01	1.3
$Fe_{70}Co_{30}$	50	599.93	354.23	2.5

Table 2: NiFe VSM and AFM results

NiFe	Thickness (nm)	Magnetic saturation	Coercivity	Roughness of the film (nm)
Ni80Fe20	10	511.47	6.0	1.0
Ni80Fe20	20	487.02	6.6	0.9
Ni80Fe20	30	573.12	5.6	0.6
Ni80Fe20	40	485.13	6.6	1.9
Ni80Fe20	50	469.76	7.2	1.0

The EDAX spectrum for FeCo and NiFe 50nm film studied was in shown fig 6 & 7. Result shows that Iron, Cobalt and Nickel, iron which was deposited was present in the spectrum (Fig 6 & 7) and additionally Silicon, Oxygen peaks were observed. In EDAX spectrum additionally Silicon material in high level peaks which indicates Silicon substrate was used for FeCo, NiFethin film base substrate. Unlooked Oxygen peaks indicate few concentration levels which reacts with on top surface of FeCo film.

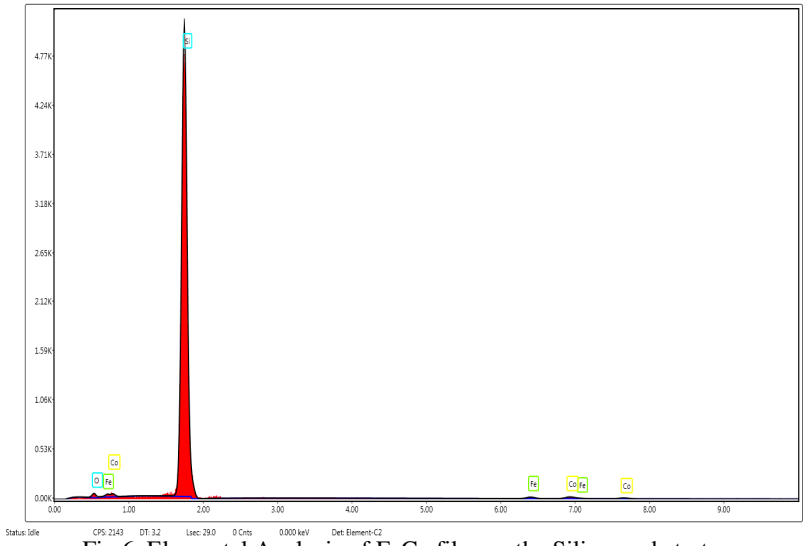

Fig 6 Elemental Analysis of FeCo film on the Silicon substrate

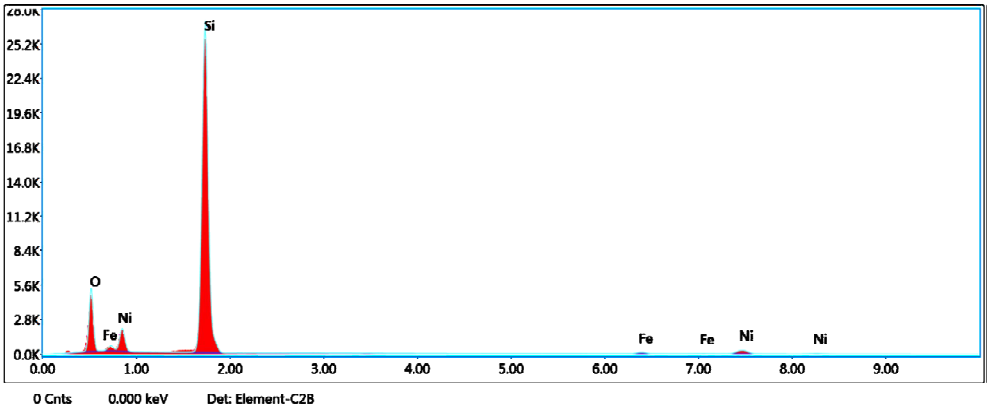

Fig 7 Elemental Analysis of NiFe film on the Silicon substrate

Conclusion

$Fe_{70}Co_{30}$ and $Ni_{80}Fe_{20}$thin film of various thickness (10, 20, 30, 40, 50nm)was prepared using UHV DC Magnetron Sputtering system. From elemental analysiswe observed only the expected elements are presented on the film. Surface analysis studies indicates that when increasing film thickness the magnetic properties also varies with surface roughness.So, from the results we conclude that FeCo and NiFe are suitable as electrode material for magnetic sensor application.

References

[1] B. Mehdaoui, J. Carrey, M. Stadler, A. Cornejo, C. Nayral, F. Delpech, B. Chaudret, M. Respaud, Influence of a transverse static magnetic field on the magnetic hyperthermia properties and high-frequency hysteresis loops of ferromagnetic FeCo nanoparticles, Appl. Phys. Lett. 100 (2012) 2012–2015. https://doi.org/10.1063/1.3681361.

[2] Ö. Çelik, T. Fırat, Synthesis of FeCo magnetic nanoalloys and investigation of heating properties for magnetic fluid hyperthermia, J. Magn. Magn. Mater. 456 (2018) 11–16. https://doi.org/10.1016/j.jmmm.2018.01.090.

[3] A. Kozlovskiy, M. Zdorovets, K. Kadyrzhanov, I. Korolkov, V. Rusakov, L. Nikolaevich, O. Fesenko, O. Budnyk, D. Yakimchuk, A. Shumskaya, E. Kaniukov, FeCo nanotubes: possible tool for targeted delivery of drugs and proteins, Appl. Nanosci. 9 (2019) 1091–1099. https://doi.org/10.1007/s13204-018-0889-3.

[4] Y. Li, A. Benchohra, B. Xu, B. Baptiste, K. Béneut, P. Parisiades, L. Delbes, A. Soyer, K. Boukheddaden, R. Lescouëzec, Pressure□Induced Conversion of a Paramagnetic FeCo Complex into a Molecular Magnetic Switch with Tuneable Hysteresis, Angew. Chemie. 132 (2020) 17425–17429. https://doi.org/10.1002/ange.202008051.

[5] M. Bowen, V. Cros, F. Petroff, A. Fert, C. Martínez Boubeta, J.L. Costa-Krämer, J. V. Anguita, A. Cebollada, F. Briones, J.M. De Teresa, L. Morellón, M.R. Ibarra, F. Güell, F. Peiró, A. Cornet, Large magnetoresistance in Fe/MgO/FeCo(001) epitaxial tunnel junctions on GaAs(001), Appl. Phys. Lett. 79 (2001) 1655–1657. https://doi.org/10.1063/1.1404125.

[6] T. Moriyama, W. Wang, J.Q. Xiao, Tunneling magnetoresistance in FeCo/MgO/FeCo tunneling junctions depending on FeCo/MgO interface state, INTERMAG 2006 - IEEE Int. Magn. Conf. 868 (2006) 866. https://doi.org/10.1109/INTMAG.2006.374897.

[7] N.A. Morley, A. Rao, D. Dhandapani, M.R.J. Gibbs, M. Grell, T. Richardson, Room temperature organic spintronics, J. Appl. Phys. 103 (2008) 101–104. https://doi.org/10.1063/1.2829245.

[8] S. M. S. S, D. S. Vijayan, M. Anand, M. Ajona, and T. Jarin, " Biodegradation of P-nitro phenol using a novel bacterium Achromobacter denitrifacians isolated from industrial effluent water ," Water Sci. Technol., vol. 00, no. 0, pp. 1–12, 2021, doi: 10.2166/wst.2021.354

[9] F.J. Yang, J. Yao, J.J. Min, J.H. Li, X.Q. Chen, Synthesis of high saturation magnetization FeCo nanoparticles by polyol reduction method, Chem. Phys. Lett. 648 (2016) 143–146. https://doi.org/10.1016/j.cplett.2016.02.022.

[10] D. Dhandapani, N.A. Morley, A. Rao, A. Das, M. Grell, M.R.J. Gibbs, Comparison of room temperature polymeric spin-valves with different organic components, IEEE Trans. Magn. 44 (2008) 2670–2673. https://doi.org/10.1109/TMAG.2008.2003060.

[11] Kiruthika, C., S. Lavanya Prabha, and M. Neelamegam. "Different aspects of polyester polymer concrete for sustainable construction." Materials Today: Proceedings 43 (2021): 1622-1625.