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SYNTHESIS AND CHARACTERISATION OF ELECTRODEPOSITED NiFeCr THIN FILMS

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NiFeCr thin films were coated on Al substrate by using electrodeposition method at 30^0C of temperature by varying the current density. In this investigation the bath pH was desired as 3.All the coated films were subjected to the structural and magnetic characterization. The wt.% of Ni, Fe and Cr were determined by using Energy-dispersive X-ray Spectroscopy (EDAX). The particle size and micro hardness of the electrodeposited NiFeCr films were calculated by using X-ray diffraction (XRD) and Vickers hardness test. The coercivity and saturation magnetization of the coated thin films were found by using Vibrating Sample Magnetometer (VSM). The Scanning Electron Microscopy (SEM) pictures of the coated films reveals that the surface morphology is uniform and it is composed with fine grains. The XRD pattern shows the crystalline nature of the film. The average particle size is 27 nm. From the VSM pattern we conclude that the electrodeposited NiFeCr films have lower coercivity 12.194G with higher magnetization value of 0.11660 emu.

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1. Introduction

In recent years electrodeposition process is widely used by the researchers because of its many advantages such as it does not need vacuum, easier handling, low cost and more efficient deposition over the other deposition method. The alloy composition is not only influenced by the bath composition but also influenced by factors such as applied current density. The electro deposited thin films have excellent physical, chemical and mechanical properties and so they are widely used in many fields such as corrosion resistance, preparation of magnetic materials and electronic materials [1-3]. Generally high Ni content possesses excellent magnetic properties. The Electro deposited NiFe films have high corrosion resistance[4-6]. From the previous researchers work, among the magnetic materials NiFe films have best magnetic properties. Generally the NiFe film has high corrosion property because of the presence of Fe which is a major issue. In order to reduce the corrosion and enhancing the magnetic properties of NiFe films Cr, P, W, Mo, Zn is added as additive content which is a hard material and highly corrosion resistant [7-12]. In this present work Cr is chosen as the third element to combine with NiFe films. Hence electrodeposited NiFeCr thin films were subjected to structural and magnetic properties.

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2. Experimental

2.1 Electrodeposition of NiFeCr thin films

The chemical composition and operating conditions of electrodeposition of NiFeCr thin films is shown in Table.1

Table 1. Chemical composition and operating conditions of the electroplating bath

Bath chemicals (g/L)		Temperature (^oC)	pH	Current density (A/dm^2)
Nickel chloride	80	30	3	0.5,1,1.5,2
Ferric chloride	65			
Chromium chloride	50			
Boric acid	30			
Glycine	50			
Ammonium formate	30			

NiFeCr thin films were deposited by using electrodeposition method at 30° C temperature. Aluminium substrate of size (7.5×1.5cm) is used as anode and cathode for electrodeposition of NiFeCr thin films. An adhesive tape was used to cover all the substrate area except the desired area of deposition. Before the electrodeposition, aluminium substrates were mechanically polished with silicon carbide emery paper, degreased in 1 M NaOH for 5 min and finally rinsed with the double distilled water and dried in air. The reagent grade chemicals which are used to prepare the baths were dissolved in double distilled water. The pH of the solution was maintained as 3. The films were deposited on aluminium substrate by varying the current densities from 0.5 A/ dm^2 to 2 A/ dm^2 for 30 minutes. The structure and morphology of the NiFeCr thin films were studied by using XRD and SEM. The magnetic properties were analyzed by using VSM. The film composition was studied with the help of EDAX. Hardness of the deposit was obtained using Vickers's hardness tester using diamond intender method.

2.2 Characterization of NiFeCr thin films

2.2.1. Determination of Composition and characterization of Ni-Fe-Cr alloy deposits

The composition of the film was determined using the EDAX analyzer attachment in JEOL 6390 scanning electron microscope and the surface morphologies of the films were analysed with the SEM. The structural analysis of the films was studied using a computer controlled Shimadzu X-ray diffractometer employing CuKα (λ=0.15418 nm) radiation.

The Crystalline size(D),Inter planar space(a),Strain and dislocation density(δ) values for the films have been calculated by using the Scherrer's formula[13].

$$D = \frac{0.94\ 5\lambda}{\beta cos\theta} \quad (1)$$

The strain (ε) was calculated using the relation

$$\varepsilon = \frac{\beta cos\theta}{4} \quad (2)$$

The dislocation density (δ) was calculated from the relation.

$$\delta = \frac{1}{D^2} \quad (3)$$

where,
β is the full width at half maximum of the peak in radians,
λ is the wavelength of CuKα target (λ=0.15418 nm),
θ is the Bragg diffraction angle at peak position in degrees.

3. Results and Discussion

3.1 Compositions of the deposits

The composition of NiFeCr thin film was obtained from the EDAX studies and shown in fig.1. The wt % of the films deposited are tabulated as shown in table.2

Table.2 Results of EDAX analysis

S.No	Current density A/dm^2	Ni Wt %	Fe Wt %	Cr Wt %
1	0.5	67.35	31.38	1.27
2	1	71.3	28.01	0.69
3	1.5	65.24	34.7	0.06
4	2	69.57	30.35	0.07

The wt% of Cr is decreasing when increasing the current density. The higher wt% of Cr is 1.27 at 0.5 A/dm^2 current density is obtained in 67.35 wt% of Ni and 31.38 wt% of Fe.

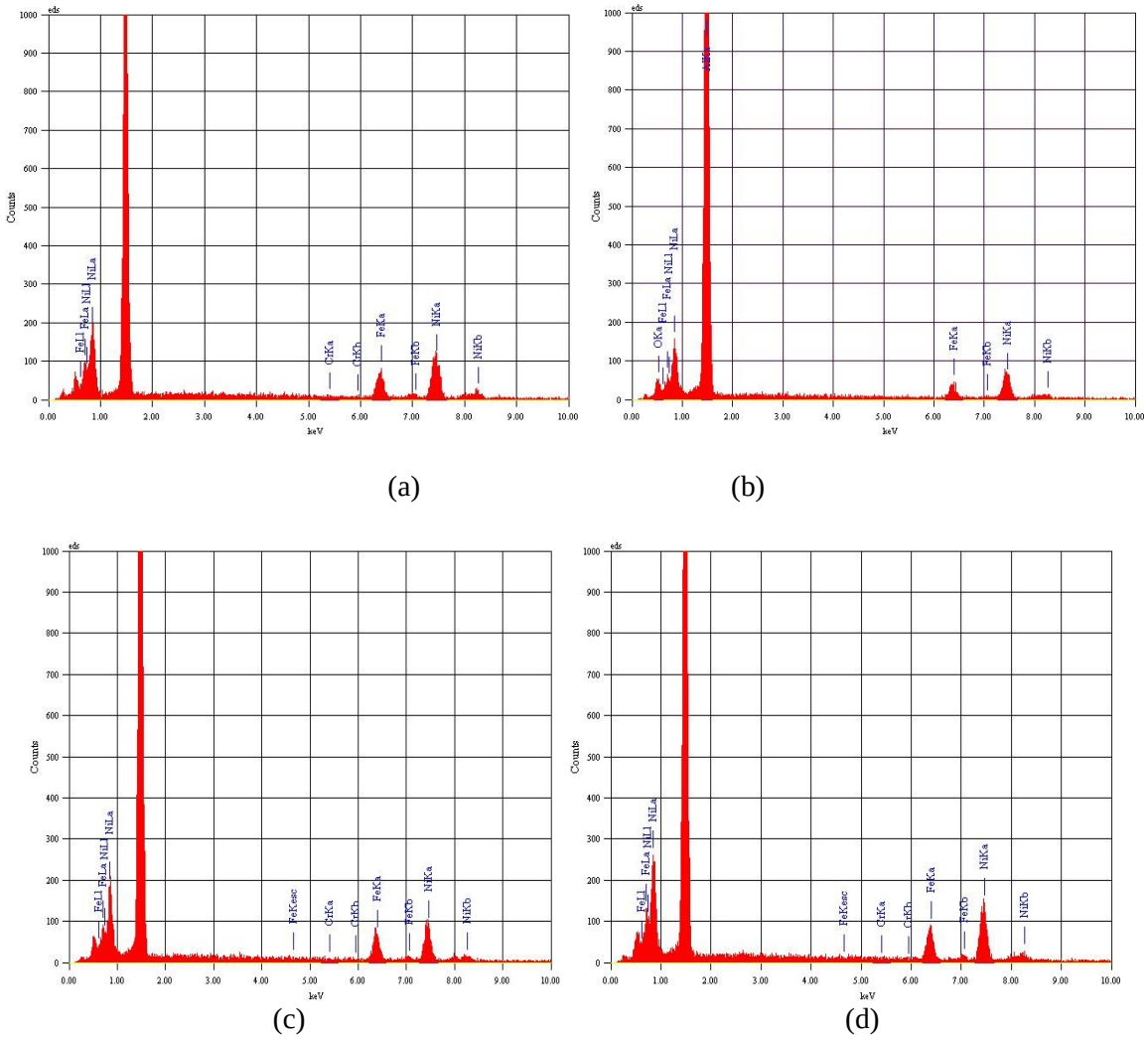
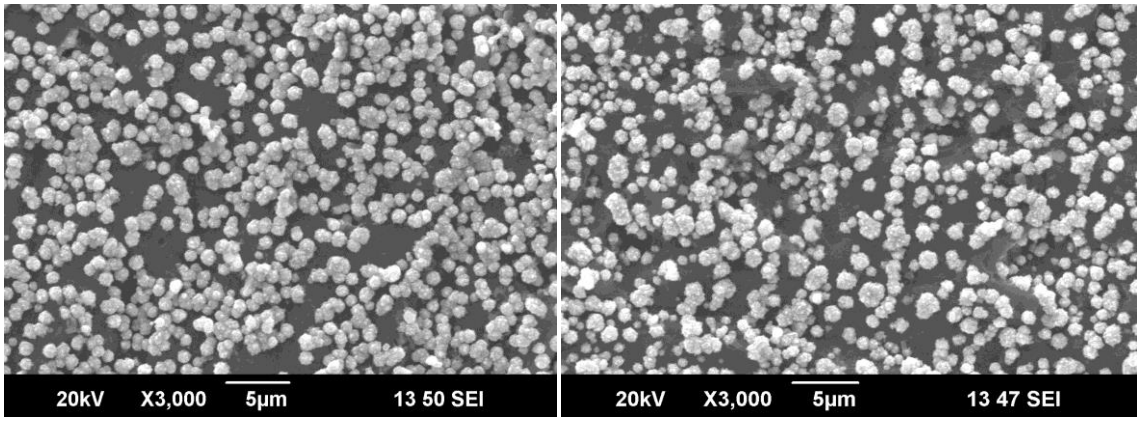


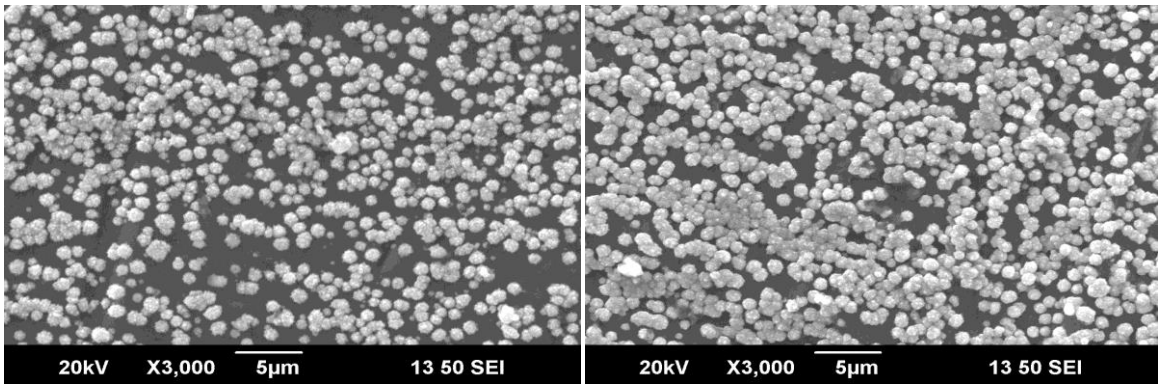
Fig.1 EDAX spectrum of NiFeCr films electrodeposited at (a)0.5 A/dm^2 (b) 1 A/dm^2 (c) 1.5 A/dm^2 (d)2 A/dm^2

3.2 Morphological observation

The surface morphologies of the films were analyzed with SEM pictures as shown in fig.2. It is observed that the deposits of the films are generally composed of uniform surface morphology with fine grains. Hydroxide particles are not present and all the deposits are bright, uniform, fine grain, metallic and smooth [14].



(a) (b)



(c) (d)

Fig.2. SEM images of NiFeCr films electrodeposited at (a)0.5A/dm^2 (b)1A/ dm^2 (c) 1.5 A/ dm^2 (d) 2A/ dm^2

3.3 Structural analysis

Fig.3 shows that XRD patterns of NiFeCr films deposited for varying current densities from 0.5 A/dm^2 to 2 A/dm^2 . The data obtained from the XRD pattern compared with the standard JCPDS data and were found to have BCC structure. The NiFeCr peaks are found at (110), (200) and (211). When the current density is increasing we observe the change in particle size. The average particle crystallite size is found as 27 nm. The crystal size of NiFeCr thin films obtained are tabulated as shown in Table 3.

Table 3.Crystal size of NiFeCr thin films

S.No	Bath Temperature (^{0}C)	2Θ (deg)	d (A^0)	Crystalline size D nm	Strain (ε) 10^{-4}	Dislocation density (10^{14}/m^2)
1	30^0	45.600	1.9871	27.105	13.43	13.61
2		45.413	1.9951	39.863	9.09	6.29
3		45.453	1.9933	41.505	8.74	5.80
4		45.561	1.9899	34.029	10.65	8.63

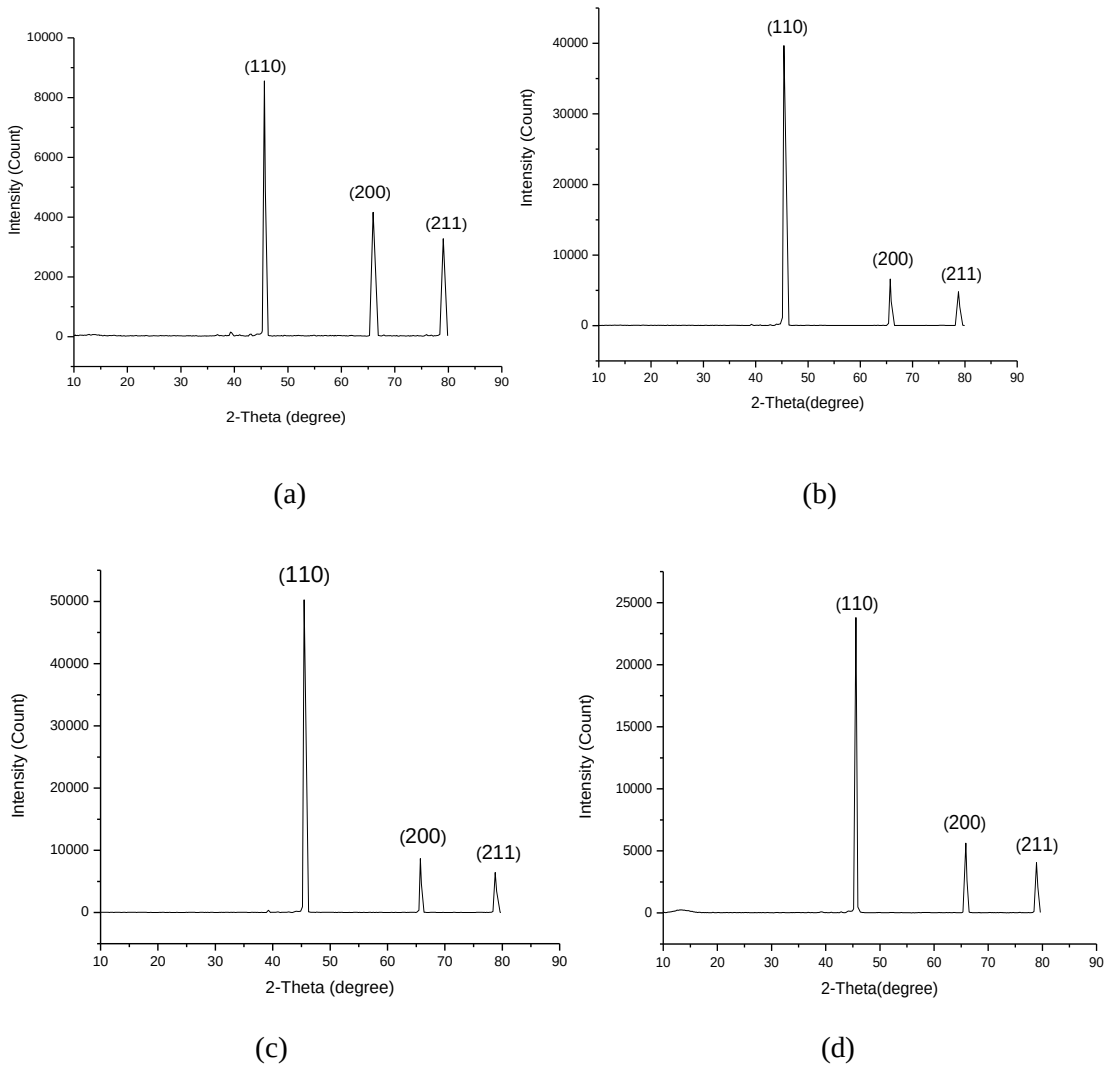


Fig.3. XRD patterns of NiFeCr thin films

3.4 Mechanical properties

The hardness of the deposited films was examined by using Vickers hardness test. The results are tabulated as shown in table.4

From the table 4 it is observed that the current density affects the hardness of the film. The highest hardness value is obtained at current density of 0.5 A/dm^2.

Table 4. Results of Vickers hardness test with varying current densities

S.No	Current density	Vickers hardness
1	0.5	260
2	1	175
3	1.5	184
4	2	145

3.5 Magnetic properties

The magnetic properties are determined by the crystalline nature of the film. The soft magnetic properties are determined by the parameters such as magnetization and coercivity [15].

The magnetic properties of electrodeposited NiFeCr films are obtained from VSM are tabulated as shown in Table.5

Table.5 magnetic properties of the films with varying current densities

S.No	Current density	Sample	Coercivity G	Retentivity emu	Magnetisation emu
1	0.5	1	63.277	759.34 x10^{-6}	12.047 x 10^{-3}
2	1	2	58.217	385.72 x10^{-6}	7.4249 x 10^{-3}
3	1.5	3	56.722	471.40 x10^{-6}	6.9990 x 10^{-3}
4	2	4	12.194	2.4454 x10^{-3}	0.11660

From table 5 we concluded that the NiFeCr thin films exhibits a higher value of saturation magnetization with lower value of coercivity. The high Cr content in the electrodeposited NiFeCr film affects the crystalline size. In the electroplated NiFeCrfilm the average crystalline size is in the order of 27 nm. So that the high Cr content and smallest particle size affects the magnetic properties. Among the magnetic properties, coercivity and the saturation magnetization are the impartant parameters. From fig. 4 we can say that the electrodeposited NiFeCr film possess the soft magnetic property. The current density was increases from 0.5 A / dm^2 to 2 A / dm^2 which also affects the magnetic nature of the films. The highest saturation magnetization of 0.11 with lower coercivity of 12 was obtained in the film at high current density. This is due to lower crystalline size and high Cr content.

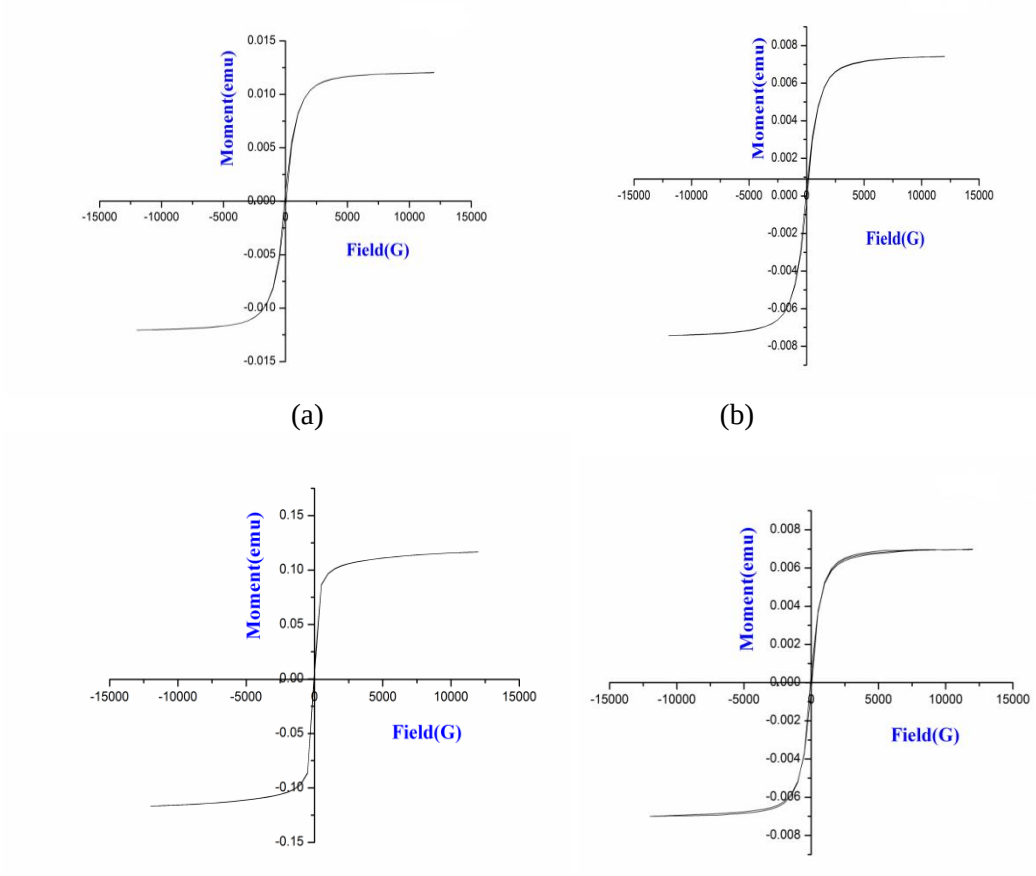


Fig.4 Hysteresis loops of NiFeCr films electrodeposited at (a) 0.5 A/dm^2 (b) 1 A/dm^2 (c) 1.5 A/dm^2 (d) 2 A/dm^2

4. Conclusion

Electrodeposition of Ni-Fe-Cr thin films has been studied in order to find the optimum conditions to obtain Cr content and better magnetic properties of the alloy. In this research work we have found that the NiFeCr film at 0.5 A/dm^2 has the high Cr content, fine grain size and magnetic properties. Hence for future works 0.5 A/dm^2 is chosen as the optimized current density.

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