Research Article

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Electrodeposition of Transition Metal-influenced Magnetic Alloys and its Microstructural Properties

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ABSTRACT

Magnetic alloy coatings exhibit admirable magnetic properties and corrosion resistance; however, their applications are restricted due to complexities in the preparation process and high costs involved. In the present work, an attempt has been made to prepare cobalt alloys with other transition metals through a simple Electrodeposition method. In order to attain cobalt-rich alloys, appropriate chloride salts were chosen as precursors. After the deposition process, the deposited alloys were carried out for microstructural characterization. EDAX pattern of the prepared alloys confirmed the presence of relevant elements at a higher percentage; morphology properties of the films confirmed the even and crack-free coatings. The corrosion resistance of the prepared alloys was investigated in an acidic medium and it was found to be better when compared with the empty substrate. It was concluded that the Electrodeposition process has greater potential in producing alloys with better purity than other methods.

Keywords: Cobalt alloys; Corrosion resistance; Electrodeposition; Magnetic alloys.

1. INTRODUCTION

Electrodeposited Co, Ni metals and their alloys were frequently reported in past decades because of their wide range of applications (Sundaram *et al.* 2011; Landolt, 2002; Manimaran and Navaneetha, 2015). Even though cobalt has better magnetic properties than nickel, electrodeposited Cobaltare was more expensive than Nickel deposit because of cobalt and its precursor cost. Hence cobalt has been alloyed with many combinations of elements, especially with nickel and other transition metals (Prabhu Ganesan *et al.* 2006; Baldwin and Smith, 1996). When cobalt has been alloyed with any transition metal group element, it offered better physical properties such as magnetic properties, mechanical stability, thermal stability and electrochemical performance. In the past few years, Co-Ni alloys have been reported with tungsten, vanadium, manganese, tin and other expensive transition metals (Kannan and Kokila, 2015; Dimitra Vemardou *et al.* 2014; Rajkumar *et al.* 2019; Xu-Ming Sun *et al.* 2011; Kwang Pyo Chae, 2006). Over these, zinc and cadmium was a cost-effective alloy combination that offers good soft magnetic and corrosion resistance. In the present work, a comparative approach on Zinc and cadmium incorporated Co-Ni alloy was investigated through electrodeposition technique. To achieve Co, Ni-rich alloy, appropriate chloride salt has been chosen as precursors (Ezhil Inban Manimaran *et al.* 2017). To optimize the ideal deposition time, the thickness of the alloy was studied using weight balance method. Elemental constituents and morphological properties of the prepared alloy were studied and confirmed using EDAX pattern and FE-SEM micrographs, respectively. The corrosion behavior of the alloys was investigated using the weight loss method.

2. EXPERIMENTAL METHOD

An electrolyte composed of chosen chlorides was dissolved in deionized (DI) water by adding boric acid as a complexing agent. The details of bath composition used for the electrolyte has been given in Table 1; its pH has been controlled and maintained as 5. Both cadmium and zinc incorporated alloys have been electrodeposited on copper plates with the dimension of 1.5 cm x 5 cm (cathode) and it was pre-cleaned through the acid dipping process. Nickel rod with the same dimension has been used as anode in the deposition process. Both alloys were electrodeposited at the optimized current density of 10 mA/cm^2. After the deposition process, electroplated copper substrates were carefully removed from the bath and washed with DI water.

3. RESULT AND DISCUSSION

The thickness of the electroplated alloys was monitored with the help of the weighing balance method. Fig. 1 shows the thickness variation of both alloys; it confirms that when the deposition time was increased thickness of both alloys increased linearly. As the deposition time was increased to 40 minutes, films found to be having powder deposition, tending to peel off. This is due to the internal stress in the film, and it immensely increased for the film deposited at 40 minutes. The alloys electrodeposited at 10 mA/cm^2 for 30 minutes were taken for further characterization.

Table 1. Bath composition used for electrodeposition.

Alloys	Concentration	Ingredients in the bath
Co-Ni-Zn	0.2 M	Cobalt Chloride Nickel chloride Boric acid
	0.1 M	Zinc chloride Potassium chloride
Co-Ni-Cd	0.2 M	Cobalt Chloride Nickel chloride Boric acid
	0.02M	Cadmium chloride Ammonium chloride

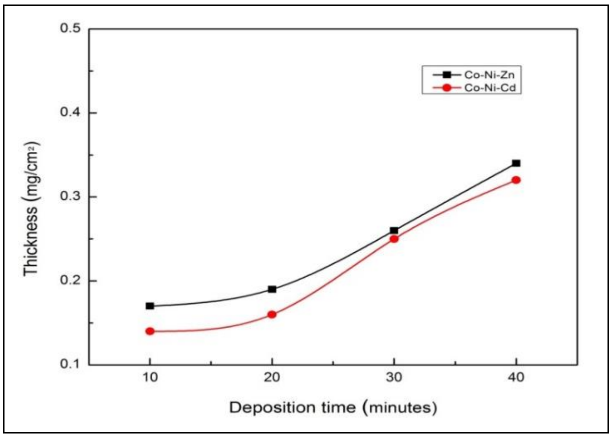

Fig .1: Thickness deviation of electrodeposited alloys.

Structural properties of the electrodeposited alloys were studied using X-ray diffractogram, and it is shown in Fig 2. Structural properties confirm good crystalline nature in the samples; this confirms that all the films deposited on copper plates have good crystallinity by nature. Cobalt and nickel diffraction planes were retained in both alloys with slightly varied intensity. However, the presence (102) (011) and (101) planes in the samples represent the cadmium and zinc elements in the alloy. The crystalline size of the samples calculated using Scherrer's formula was found to be in the range of 16 to 18 nm.

EDAX patterns of the electrodeposited Co-Ni-Cd and Co-Ni-Zn alloys were shown in Fig. 3(a, b). They confirmed the presence of cobalt and nickel elements, along with zinc and cadmium. In both alloys, cobalt and nickel deposition (30-50%) were reasonably good compared with other alloys. Morphological properties of the alloys were investigated using FE-SEM micrographs (Fig 4(a-b)), which revealed uniform deposition in both alloys. But in cadmium-incorporated alloys the surface were found to be having under-developing dendritic structures. It is due to the deposition of cadmium content at a higher percentage.

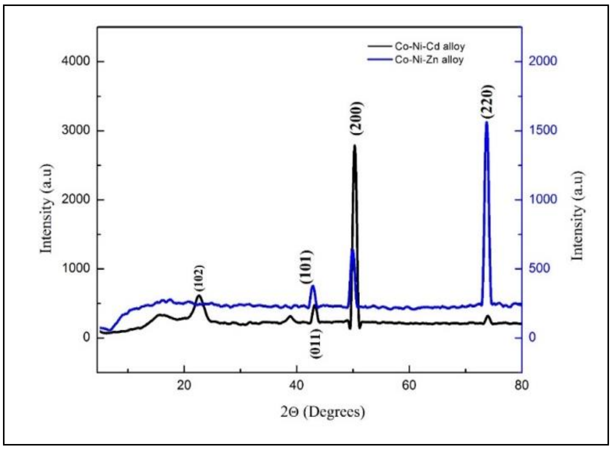

Fig. 2: X-ray diffractogram of electrodeposited alloys.

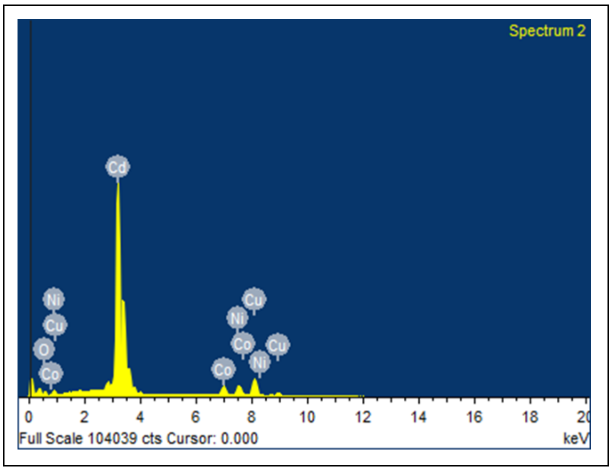

Fig. 3 (a): EDAX pattern of Co-Ni-Cd alloy electrodeposited at optimized deposition parameters.

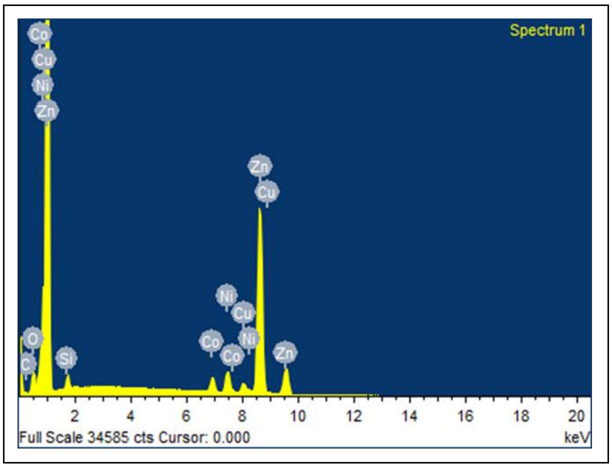

Fig. 3 (b): EDAX pattern of Co-Ni-Zn alloy electrodeposited at optimized deposition parameters.

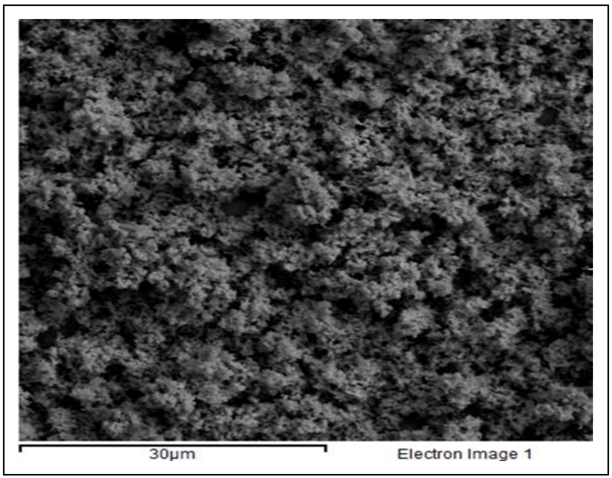

Fig. 4 (a): FE-SEM micrograph of Co-Ni-Cd alloy electrodeposited at optimized deposition parameters.

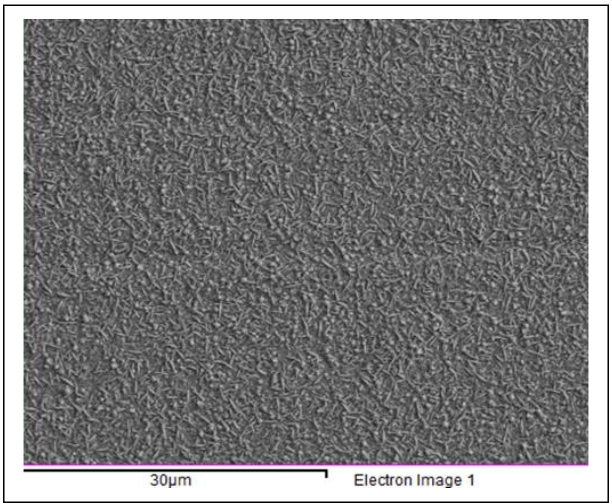

Fig. 4 (b): FE-SEM micrograph of Co-Ni-Zn alloy electrodeposited at optimized deposition parameters.

The corrosion behavior of the prepared alloys was investigated in an acidic medium (or bath); they were composed of diluted hydrochloric acid. The corrosion properties of the alloys were presented in Table 2. It was confirmed that both alloys exhibit far better corrosion properties than expected compared to the empty substrate. The presence of zinc and cadmium strongly enhanced the corrosion properties and equally supported by nickel deposits in the alloys.

Table 2. Corrosion behavior of the electrodeposited samples.

Samples	Corrosion Rate (mpy)
Copper substrate	730
Co-Ni-Cd	67
Co-Ni-Zn	62

4. CONCLUSION

Transition metals like cadmium and zinc have been incorporated with magnetic elements like cobalt and nickel and prepared as alloy using electrodeposition method. Microstructural and corrosion properties of the prepared alloys were investigated. Microstructural properties revealed the presence of cobalt, nickel, zinc and cadmium elements along with substrate peak. FE-SEM micrographs confirmed even and crack-free coatings, and the zinc-incorporated alloys exhibited under-developing dendritic structures. Magnetic properties of the alloys confirmed the soft ferromagnetic nature of both alloys. Corrosion properties were reasonably good, and they were immensely dependent on the incorporated (Zn, Cd) elements in the alloys. Precisely, the electrodeposited alloys which exhibit better corrosion resistance and soft magnetic nature can be used for making soft magnetic sensors and anti-corrosive coatings.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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