

# Effects of Deposition Variables on the Morphologies and Composition of Nickel-Cobalt Deposits Prepared by Cyclic Voltammetry

Allen Bai and Chi-Chang Hu\*

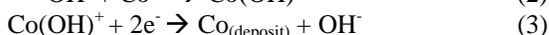
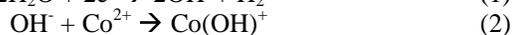
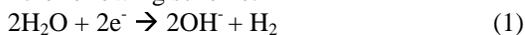
Department of Chemical Engineering, National Chung Cheng University, Chia-Yi 621, TAIWAN

## Abstract

Nickel-cobalt deposits were carried out using cyclic voltammetry from very simple chloride baths. The potential ranges of cyclic voltammetry are set between 0 to -1.2V or -0.35 to -1.2V (see Fig.1). The deposition of Ni-Co alloys was changed from the abnormal electroplating to the equilibrium electroplating when the upper potential limit of CV was changed from -0.35 to 0V. The composition of these Ni-Co deposits was not affected by varying the temperature of the plating bath while an increase in deposition rate was found with increasing the deposition temperature. The grain size became larger with increasing deposition temperature, cycle number and pH value, revealed by SEM. A modification in the morphology was found when the upper potential limit of CV was changed from -0.35 to 0 V.

## Introduction

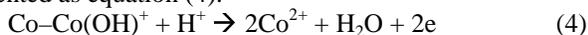
The electroplating of Ni-Co deposits is recognized as an abnormal electroplating which is defined as that during the alloy deposition, a more active metal (i.e., Co) is easier to be deposited than a less active metal (i.e., Ni) [1, 2]. This phenomenon was ascribed by the formation of a  $\text{Co(OH)}^+$  film at the liquid-electrode interface, preventing the adsorption of  $\text{Ni}^{2+}$  on the cathode [3, 4], which can be described in the following scheme:



Since the reproduced  $\text{OH}^-$  ions can combine with  $\text{Co}^{2+}$ , resulting in the continuous formation of the  $\text{Co(OH)}^+$  film, the Ni deposition is inhibited. Thus, decomposition of the  $\text{Co(OH)}^+$  film is expected to overcome this inhibition. The purpose of this work is to decompose the  $\text{Co(OH)}^+$  film during the Ni-Co electroplating by using cyclic voltammetry since the polarity of the Ni-Co deposits can be changed, resulting in the decomposition of the  $\text{Co(OH)}^+$  film.

## Results and Discussion

Typical CV curve of Ni-Co deposition is shown in Fig. 1. There are three regions on this curve; cathodic deposition, passive, and anodic dissolution regions. In the cathodic deposition region, Ni and Co were electroplated from  $\text{Co}^{2+}$  and  $\text{Ni}^{2+}$  meanwhile reactions 1-3 occurred simultaneously. Hence, the deposition of Ni is inhibited. When the potentials were located in the passive region, no sensible current due to cathodic deposition or anodic dissolution was found. Accordingly, the electroactive species dissolved in the bath (i.e.,  $\text{Co}^{2+}$  and  $\text{Ni}^{2+}$ ) should diffuse to the electrolyte-electrode interface and the relatively concentrated  $\text{OH}^-$  should diffuse out of this interface. When the potentials were positive than ca. -0.35V, the  $\text{Co(OH)}^+$  film was damaged by the anodic dissolution of the already-deposited Co, which can be presented as equation (4).



When the  $\text{Co(OH)}^+$  film dissolved in the plating bath, the inhibition of Ni deposition should be stopped and the abnormal electroplating became insignificant. When the

electrode potentials were shifted to more negative again, both Ni and Co were simultaneously deposited onto the substrate and the inhibition of more-noble metal deposition commenced again. Based on the above points of view, the inhibition of abnormal electroplating could be carried by the usage of CV deposition. In addition, the presence of the passive region provided the diffusion of the metal ions to the interface, causing the composition of Ni-Co alloys close to the metal ion composition in the plating baths. These results are showed in table1.

From SEM photographs, the grain size and the amount of the deposits were increased with the electroplating temperature. In addition, the morphologies of these deposits became smoother when the upper potential limit of CV was set in the anodic region, due to the significant dissolution of the already-deposited alloys.

## Reference:

- 1.A.Brenner, "Electrodeposition of Alloys," Academic press, New York and London (1963), Vol. II, 262-291
- 2.R. D. Armstrong, G. W. D. Briggs and E. A. Charles, *J. Appl. Electrochem.*, **18** (1988), 215.
- 3.K. M. Yin, J. H. Wei, J. R. Fu, B. N. Popov, S. N. Popova, R. E. Whrit, *J. Appl. Electrochem.*, **25** (1995), 543.
- 4.K. Y. Yin, *J. Electrochem. Soc.*, **144**(1997),1560

Table.1 Effects of the composition and temperature of the plating baths on the composition of Ni-Co deposits.

Co atomic % in the plating baths	Co atomic % in deposits			
	With anodic region		Without anodic region	
	25 <sup>o</sup> C	50 <sup>o</sup> C	25 <sup>o</sup> C	50 <sup>o</sup> C
100	100	100	100	100
80	84.5	83.4	92	93.8
60	64.1	63.2	71	72.9
40	54.8	51.9	67.5	62.5
20	23.9	23.6	41	42.1
0	0	0	0	0

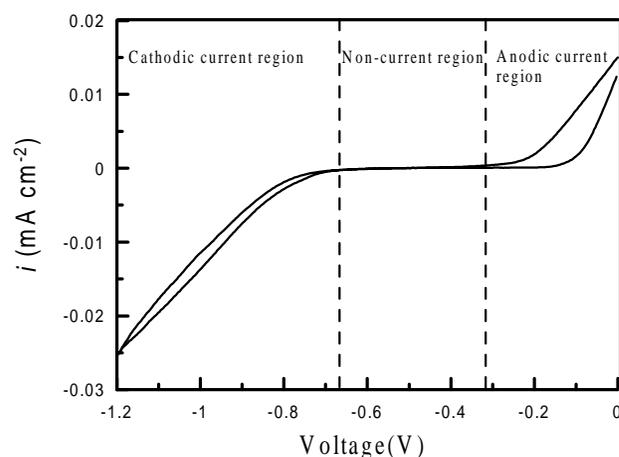


Fig. 1 The cyclic voltammogram of the Ni-Co deposition from a simple chloride bath.

\* To Whom all correspondence should be addressed