Applied Surface Science 257 (2010) 1027–1033

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

# Effective electrodeposition of Co–Ni–Cu alloys nanoparticles in the presence of alkyl polyglucoside surfactant

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ARTICLE INFO

*Article history:*
Received 12 April 2010
Received in revised form 30 July 2010
Accepted 30 July 2010
Available online 7 August 2010

*Keywords:*
Co–Ni–Cu nanoparticle
Electrodeposition
Cyclic voltammetry
Alkyl polyglucoside
Critical micelle concentration

ABSTRACT

The effect of alkyl polyglucoside (APG) surfactant on the electrodeposition Co–Ni–Cu alloys nanoparticles has been investigated. In a typical electrodeposition experiment, it was found that as prepared Co–Ni–Cu alloys nanoparticles characteristics, such as size homogeneity, density, dispersion on the electrode substrate and the chemicals composition, depended strongly on the concentration of APG used in the reaction as well as the applied deposition potential. For the case of chemicals composition, low APG concentration (below CMC) was found to be effective for the preparation of excellent composition of the nanoalloys. Meanwhile, for the case of size homogeneity, density, and dispersion on the surface, high APG concentration (above CMC) and high deposition potential were preferred. It was also found that, at concentration above the CMC, the APG surfactant showed a metals ions deposition inhibition characteristic that caused increasing in the electrodeposition overpotential of the entire metals ions, namely cobalt, nickel and copper. As the result the copper was found to place a high percentage in the nanoalloys deposits. Owing to its simple procedure in controlling the composition and the nanoalloys growth characteristic, present approach should find a potential application in preparing Co–Ni–Cu magnetic nanoparticles for used in currently existing applications.



## 1. Introduction

Recently, there is an increasing interest in the synthesis of the Co–Ni–Cu alloys nanoparticles due to its unique magnetic and magnetoresistive properties, which depend on the composition, for used in magnetic device applications such as MEMS [1], magnetic recording and magnetic data storage [2]. For example, by modifying the composition of the Co–Ni–Cu alloys nanoparticles, the magnetic coercivity ($H_c$) of 42.7 to 840 Oe can be obtained [3–5]. Therefore, to find technique to grow the Co–Ni–Cu alloys nanoparticles with unique growth characteristic is highly required. There are variety of techniques for preparation of Co–Ni–Cu alloys such as mechanical alloying [3], positive microemulsion [4], melt spinning [6] and electrodeposition [1,7]. Among the available techniques, electrodeposition, also known as electrochemical deposition, is considered as a practical and widely used method for nanoparticles preparation due to its ability to directly attach the nanoparticles on the substrate [8,9]. Owing to its simple and easy process in term of controlling the experimental parameters [10], economically cheap [11,12] and broad range industrial applicability [12] put this technique as a prospective tool for future nanoparticles fabrication.

Currently, the controlled-size and shape of the electrodeposited growth Co–Ni–Cu nanoparticles have become a central issue in the nanomaterials chemistry synthesis field due to the presence of strong relationship between properties on shape and size. The addition of surfactant into the electrolyte is amongst a straightforward technique to control over the nanoparticles growth as the result of their unique roles in modifying the deposition preference and properties that in turn enable for obtaining a controlled-size [13,14], -morphology and -nanostructure [15]. Alkyl polyglucoside (APG) can be proposed as a potential surfactant for a control over the growth of the electrodeposited Co–Ni–Cu nanoparticles due to its nonionic characteristic with excellent psychochemical properties [16,17] and good electrolyte tolerance [18]. Furthermore, it also features non-toxicity, biodegradable in aqueous medium [19,20] and environmental friendly characteristic [21–23] that made it as a promising candidate for use in electrochemical deposition of nanoparticles.

In this paper, we report our attempts in controlling the homogeneity, density as well as the dispersion of the Co–Ni–Cu nanoparticles growth on the substrate by optimizing the concentra-

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doi:10.1016/j.apsusc.2010.07.103

tion of the APG surfactant and applied electrodeposition potential. By using an optimum concentration of APG that reflected by its CMC value, homogenous and controlled-size and -density of Co–Ni–Cu nanoalloys can be successfully grown on the surface of electrode. The electrodeposited Co–Ni–Cu alloys nanoparticles should find extensive used in magnetic device applications.

## 2. Experimental

Technical grade Glucopone 215 CSUP, commercial name of the alkyl polyglucoside (APG), was obtained from Fluka. Analytical grade boric acid ($H_3BO_3$) and all metal salts (technical grade $CoSO_4{\cdot}7H_2O$, ACS reagent $NiSO_4{\cdot}6H_2O$ and ACS reagent $CuSO_4{\cdot}5H_2O$) were purchased from Sigma–Aldrich. Indium-tin oxide (ITO) coated on glass plate with sheet resistance 10 Ω/□ was obtained from Praezisions Glas & Optik GmbH.

The electrolytes containing 0.018 M $CoSO_4$, 0.18 M $NiSO_4$, 0.002 M $CuSO_4$ and 0.4 M $H_3BO_3$ were prepared using pure water with resistivity of 18.2 MΩ cm. Prior to electrochemical studies, the critical micelle concentration (CMC) of APG in the electrolyte was studied and determined by the surface tension experiments that carried out using a KSV Tensiometer model Sigma 703D.

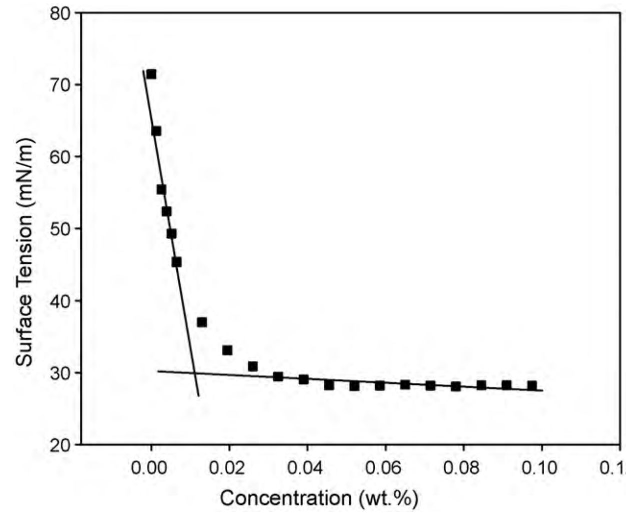


**Fig. 1.** Scatter plot of surface tension at 25 °C from different concentration of APG in electrolyte containing $1.8 \times 10^{-2}$ M $CoSO_4$, 0.18 M $NiSO_4$, $2 \times 10^{-3}$ M $CuSO_4$ and 0.4 M $H_3BO_3$.

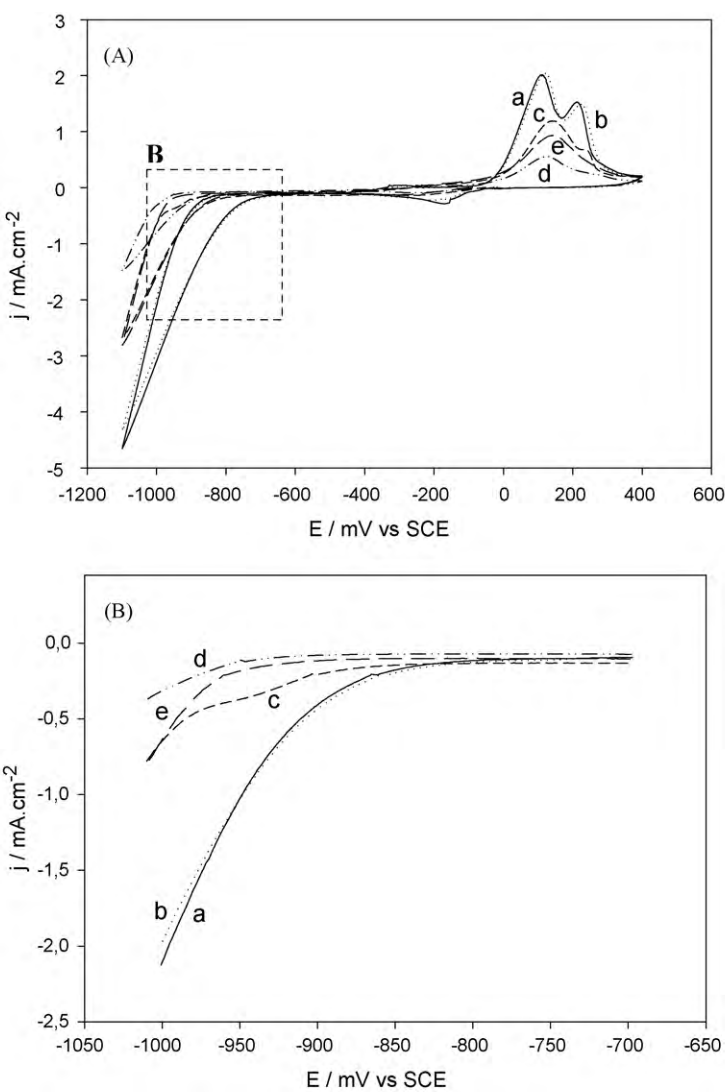


**Fig. 2.** (a) Typical cyclic voltammograms of electrolyte containing $1.8 \times 10^{-2}$ M $CoSO_4$, 0.18 M $NiSO_4$, $2 \times 10^{-3}$ M $CuSO_4$ and 0.4 M $H_3BO_3$ in the presence of various concentration of APG surfactant (a) 0 wt.%, (b) $2.6 \times 10^{-3}$ wt.%, (c) 0.65 wt.%, (d) 1.95 wt.% and (e) 3.25 wt.% on ITO surface. (b) Cathodic scan of the cyclic voltammogram at the potential range of −700 to −1050 mV vs. SCE. The scan rate is 10 mV $s^{-1}$.