Cairo University

PREPARATION AND CHARECTERIZATION OF Ni-Co ELECTRODES FOR ALCOHOLIC FUEL CELLS

By

Mohamed Ramadan Nasr Ahmed Nasr

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Metallurgical Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

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Title of Thesis:

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Key Words:
Catalysts; fuel cells; nanomaterials; electrodeposition; Ni-Co alloys.

Summary:

Electrocatalytic electrode surface were developed for alcoholic fuel cell by electrodeposition of Ni-Co alloy on a 301 stainless steel foil. Material characterization by EDX and XRD confirmed deposition of Ni-Co alloy on the steel substrate. SEM showed nodular and/or angular particles and subparticles of the alloy coating. Polarization study showed very much increase in corrosion current density for the coated electrode compare to bare stainless steel. Lower polarization resistance and existence of oxidation peaks were obtained by EIS and CV tests respectively.

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Abstract

Electrocatalytic electrode surface were developed for alcoholic fuel cell by electrodeposition of Ni-Co alloy on a 301 stainless steel foil. Material characterization by EDX and XRD confirmed deposition of Ni-Co alloy on the steel substrate. SEM showed nodular and/or angular particles and subparticles of the alloy coating. The erosion resistance of the deposited electrodes was characterized by hardness test which showed excellent hardness to resist the erosion. The electrocatalytic activity of the coated electrodes were characterized by potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), and cyclic voltammetry tests in anodic solution for electrochemical oxidation of methanol and ethanol. Polarization study showed very much increase in corrosion current density for the coated electrode compare to bare stainless steel. The EIS test showed that polarization resistance of coated sample was drastically reduced compare to the bare substrate. The electrical equivalent circuit at the metal solution interface was found to be closed to Randle circuit. The cyclic voltammetry results show that higher peaks for the alcohol oxidation compared to the bare substrate. The deposits performed at current densities of 50 and 80 mA/cm^2 for 30 minutes give the best condition for higher catalytic activity of the Ni-Co nanocrystalline deposits for methanol and ethanol oxidation for direct alcoholic fuel cells.

Chapter 1: Introduction

In today’s world, higher demand on the energy is observed, and the prospect of an energy shortage, or even crisis, is likely in the near future. Many and various efforts being made to meet global energy needs. The energy carried by hydrogen and liquid biofuels such as methanol and ethanol has become an attractive option in terms of sustainability and low environmental impact. Within this category of energy conversion technologies, the fuel cell is one of the most environmentally friendly and sustainable possibilities. In the past several decades, governments, along with academic communities and industries have made large investments to develop fuel cells, especially proton exchange membrane fuel cells (PEMFCs), for stationary, portable, and transportation applications. So, great advances have been achieved in fuel cell technology in recent years. To date, several kinds of fuel cells, including direct methanol fuel cells (DMFCs), have shown great promise for near-term commercialization [1].

The basic problem in developing fuel cell is the polarizations of the cathode and anode which hinder high output current potential. Electrochemical oxidation of the fuel needs a high catalytic electrode surface where anodic reaction can take place at higher rates, producing high current output [2].

Nanomaterials have been of a particular interest for scientists and researchers due to the significant change in the properties of materials when their size decreases to the nanoscale. Especially nanocrystalline materials have been investigated for their excellent properties when the grain size is below 100 nm [3].

Platinum is a good electrode with high exchange current density for anodic and cathodic reactions of the many types of fuel cells but high cost of these materials restricts its application for commercial and domestic purposes. Besides the performance of a pure Pt, catalysts suffer considerable deterioration due to the formation of strongly adsorbed CO and halide. These remain strongly adsorbed on the Pt. Surface and block the active sites from further catalysis, resulting a dramatic decrease in efficiency and overall performance. Many efforts to reduce this poisoning have been centered on the addition of co-catalyst such as Ru, Sn, Au, W, Mo, Os, Re, Rh, Pd, Pb, Bi, and Ir to Pt to promote fuel oxidation. Platinum-based nanomaterials with high surface areas have been receiving increased attention due to their unique properties and a number of impressive applications in catalysis and fuel cells [4].

Because of higher cost for the Pt electrodes, new trends are directed towards lower cost and comparable electrocatalysis efficiency electrodes. Basically, the transition metals are the main metals which have enough catalytic