Electrochemistry of gold-based alloys

By

Heinrich Möller

A dissertation submitted in partial fulfillment of the requirements for the degree of

Master of Engineering

in the Department of Materials Science and Metallurgical Engineering,
Faculty of Engineering, Built Environment and Information Technology,
University of Pretoria

2002

Electrochemistry of gold-based alloys

by

Heinrich Möller

Supervisor: Prof. P.C. Pistorius

Department of Materials Science and Metallurgical Engineering

Degree: Master of Engineering

ABSTRACT

The electro-oxidation of organic compounds at noble metal electrodes has been widely studied in the past. A bimetallic electrode is often more active than the respective pure metals. However, the effect of the microstructure of the alloys on their electrochemical properties has largely been ignored in the past.

The electro-oxidation of ethylene glycol at gold-platinum and gold-titanium electrodes in different heat treatment conditions was studied to determine how the different microstructures would influence the electrochemistry of these alloys.

Kirkendall porosity was produced by the solid solution heat treatment of the two-phased 60Au-40Pt electrodes. The extra surface area due to the porosity resulted in high apparent current densities at the porous electrodes in both acid and alkaline solutions without ethylene glycol. Only slightly higher apparent current densities were obtained at the porous gold-platinum electrodes compared to the non-porous electrodes when ethylene glycol was present in the solution. Kirkendall porosity was not produced by the solid solution heat treatment of the two-phased 50Au-50Pt electrodes.

The gold-platinum electrodes were more active for the electro-oxidation of ethylene glycol than both pure gold and platinum. The electrodes in the solid solution heat treatment condition were more active than the two-phased electrodes. This can be explained by the Third-body effect, which means that platinum atoms that are surrounded by gold atoms are less likely to become poisoned by intermediates than platinum atoms

that are surrounded by other platinum atoms. Poisoning of all the electrodes occurred during electrolysis of ethylene glycol at a fixed potential. The poisoning species at pure gold and pure platinum could be removed by potential pulsing and sustainable electrolysis of ethylene glycol was possible at these electrodes. Unfortunately, the same technique was not as successful with the gold-platinum alloys and their activities declined during the long-term electrolysis of ethylene glycol.

The electrochemical behaviour of the Gold 990 (Au-1wt% Ti) electrodes is similar to pure gold in acid and alkaline solutions. It is possible that the titanium content is too low to have a significant influence on the electrochemical behaviour of gold. The titanium may also be in the passive condition or it may have dissolved selectively from the Gold 990 alloy resulting in a pure gold surface.

Keywords: Gold, platinum, gold-platinum alloys, gold-titanium alloys, Gold 990, Kirkendall porosity, electrochemistry, electro-oxidation, ethylene glycol, cyclic voltammetry.

ACKNOWLEDGEMENTS

I would like to thank and herewith express my sincere appreciation to the following:

- Professor Chris Pistorius, my supervisor, for guidance and continuous support.
- Mintek for financial assistance.
- Doctor Elma van der Lingen and Stephen Roberts from Mintek for guidance and sample preparation.
- The Department of Materials Science and Metallurgical Engineering and IMMRI for facilities.
- Lida Roos, my fiancée, for her love, continuos support and patience.
- My father, mother, Robert, Danie and Johan for their prayers and support.
- The Roose: Lida's parents, Hannes and Marileen for their continuous support.
- Carel Coetzee for assistance with the SEM.
- Doctor Sabine Verryn of the Geology department for assistance with XRD.
- Sarah Havenga and Johann Borman for their assistance.
- My friend Heinrich Hutchison for his valuable contribution.
- The personnel and specially my fellow graduate students for their support and advice.
- The Lord, for the abilities He gave me and the opportunity to develop them.

CONTENTS