Kinetic Investigation of a Mechanism for Generating Microstructures on Polycrystalline Substrates Using an Electroplating Process

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Abstract

Introduction: The purpose of this study is to understand the growth mechanism of Cu films on a Cu-Zn system substrate with a pre-defined pattern. The pattern was defined by conducting a selective etching process on a two phase's polycrystalline substrate. Because of the differences in the chemical potentials of the crystal phases, the etching rate between the alpha and beta crystals were also different. As a result of this process, there were etched regions correspondent to beta-phase crystals and quasi non-etched regions that belong to alpha-phase crystals. Afterwards, the entire surface was covered with a polymer coat, and after drying, a polishing process was conducted in order to develop the pre-defined pattern, consisting of conductive and insulating regions, which are compatible with the crystal dimensions (Figure 1). Finally, microstructure patterns were generated through an electroplating process. Use of COMSOL Multiphysics: Due to the non-uniform electric field and corner effects, the observed growth tends to be faster in certain regions than others [1,2]. This effect brings limitations on the height of the created pattern. In other words, after several seconds of deposition, the generated patterns start to narrow their cavities, until closing the entire plated surface, and forming a homogenous region [3] (Figure 2). Considering the above mentioned phenomenon, a numerical model based on Faraday´s law in differential form was elaborated [4]. Butler-Volmer relations were also considered as boundary conditions for the anode and cathode reactions. 2D and 3D numerical models were solved by using a finite elements method with the software COMSOL (Figure 3). Results: Experiments were conducted, and microscopic pictures of the cross-section area were used for calibrating mass transfer coefficients, migration, diffusion and convection, and for matching the experiments with the simulations. As a result, it was possible to establish a relationship between the grains' sizes and the maximum possible height of the generated microstructure. Conclusions:
In this work, finite elements methods were conducted in order to evaluate the kinetic of the growth of microstructures using an electroplating technique. According to the adopted process, the height of the microstructures could be modeled by adjusting the size of the cathode crystal grains, e.g. conducting a pre heat treatment, prior to the process, and by the plating time. The developed microstructures can change the physical-chemical properties of the surface in many different alloys. Biocompatibility of implants' parts, anti-bacterial and catalytic functions could be enhanced by conducting this process.

Reference

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[3] N. G. Sarius et. al, Electroplating of Nickel in Grooves Under the Influence of Low and Medium Frequency Ultrasound, JOURNAL OF ELECTROCHEMISTRY AND PLATING TECHNOLOGY 1 (2011) 19 28.
[4] J. Deconinck, Mathematical modeling of electrode growth, JOURNAL OF APPLIED ELECTROCHEMISTRY 24 (1994) 212 218.

Figures used in the abstract

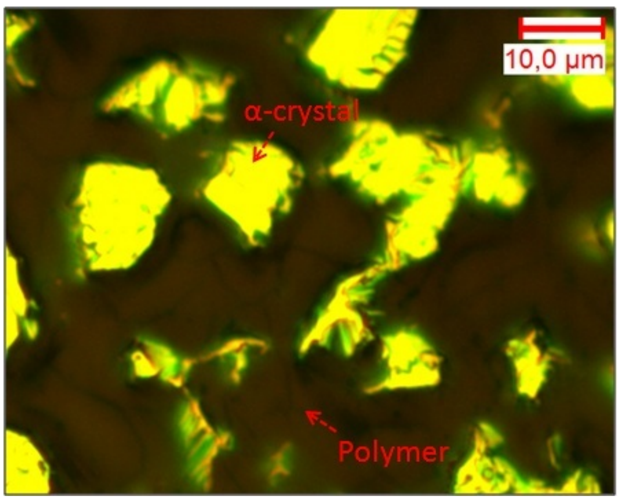

Figure 1: Developed process, top view – protected regions with polymer and exposed metal regions for electroplating.

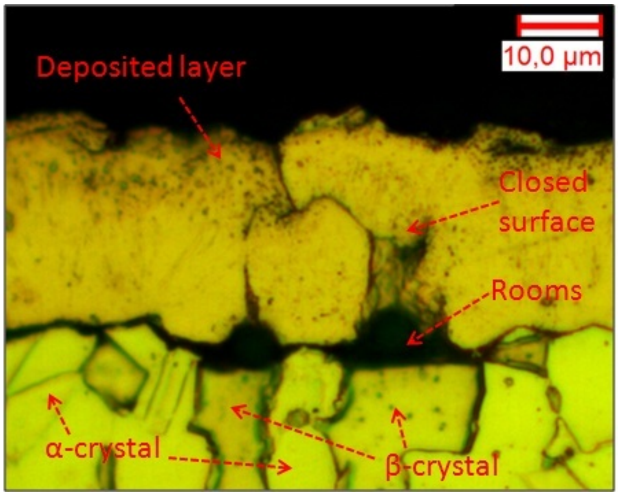

Figure 2: Cross-section view - closed surface after app. 10min plating.

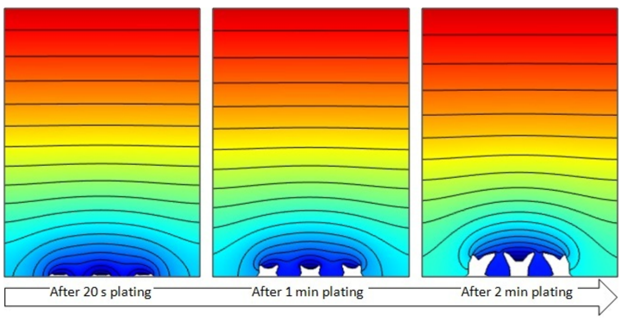

Figure 3: Results of the simulations after 2 min plating.