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Abstract

Influence of Ultrasonic Bath on Mold-Assisted Electrodeposition of Gold Microelectrode Arrays [†]

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Abstract: This study investigates the potential of ultrasonic baths to enhance mold-assisted electrodeposition for fabricating three-dimensional (3D) microelectrode arrays (MEAs) with improved quality and reliability. Focusing on gold microstructures, commonly employed in 3D MEAs due to their biocompatibility and electrical conductivity, we explore how ultrasonic vibrations impact the electrodeposition process. Through the formation of microscopic bubbles and reactive sites, ultrasonic baths accelerate deposition, offering potential benefits such as increased deposition rates, uniformity, and cost-effectiveness. Our experimental findings demonstrate significant improvements in deposition rate and uniformity, highlighting the potential of ultrasonic baths to advance the fabrication of 3D MEAs for various biomedical applications.

Keywords: electrodeposition; arrays; microelectrodes; bath; gold; ultrasonic; mold assisted

1. Introduction

Microelectrode arrays (MEAs) have become essential for electrophysiological investigations, particularly in neuroscience [1]. However, developing 3D MEAs with higher density and more complex architectures is still a challenge [2]. One promising approach is mold-assisted electrodeposition, which allows for the fabrication of 3D microstructures with precise geometries and controlled dimensions [3]. In this work, we investigate the utility of ultrasonic baths to improve the quality and reliability of the mold-assisted electrodeposition process. We focus specifically on the deposition of gold microstructures commonly used in 3D MEAs due to their biocompatibility and electrical conductivity. Our study builds on previous research on mold-assisted electrodeposition and ultrasonic vibrations' influence on various manufacturing processes [4,5]. In ultrasonic bath-assisted electrodeposition, the sound waves create microscopic bubbles in the liquid medium. These bubbles are then subjected to intense pressure and temperature changes, forming highly reactive sites on their surface. These sites can then act as catalysts, accelerating the electrodeposition process. There are numerous potential applications of ultrasonic baths in electrodeposition. They can be utilized to fabricate various micro- and nanoscale components, such as MEMS devices, nanotechnology components, and biomedical applications. Ultrasonic baths can also be used to produce gold microstructures with high accuracy and uniformity. Additionally, using ultrasonic baths can reduce the cost of the electrodeposition process, as the deposition rate can be increased without the need for additional chemicals or energy sources [6]. However, the influence of ultrasonic baths on the mold-assisted electrodeposition of gold microstructures for 3D MEA applications is yet to be investigated systematically. In this article, we present our experimental setup and methodology, as well as the results of our investigation. We demonstrate that an ultrasonic bath can significantly improve electrodeposited gold's deposition rate and uniformity, leading to the fabrication of an array of gold microelectrodes with improved thickness uniformity and improved adhesion to the substrate.

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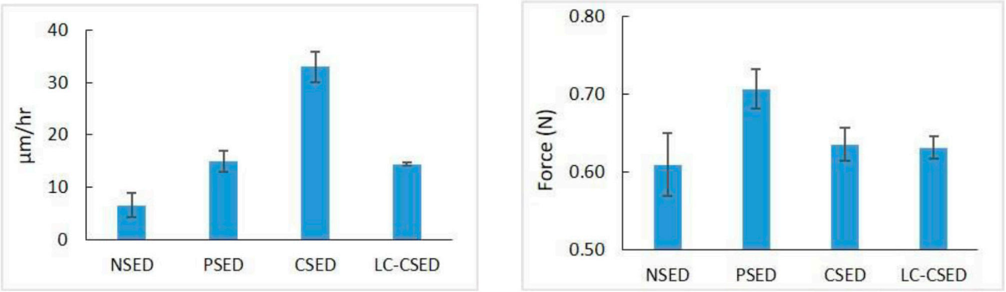
2. Materials and Methods

For the experimental setup, an additive-free AUROLYTE CN200 plating solution was chosen for the electrodeposition experiments, and a galvanostat was used to maintain the current density. Planar MEAs consisting of 60 electrodes arranged in a hexagonal pattern, with a diameter of 35 µm and a pitch of 195 µm, were utilized, with one-fourth of the electrodes connected to the working electrode of the galvanostat via custom routing. A resist mold consisting of cylindrical holes, having a diameter of 35 µm and a height of 110 µm, was fabricated over the planar MEA to support the electrodeposition of gold micro-pillars. The experiment was divided into four parts, including electrodeposition without an ultrasonic bath (NSED), ultrasonic-bath-assisted electrodeposition operating in pulsed mode with a duty cycle of 50% (PSED), continuously operating ultrasonic-bath-assisted electrodeposition (CSED), and continuously operating ultrasonic-bath-assisted electrodeposition with reduced current density (LC-CSED).

3. Results and Discussion

The electrodeposited MEAs were characterized using an optical profilometer to determine the rate of gold deposition and thickness uniformity. Figure 1a shows the gold deposition rate for all the experiments and the percentage standard deviation for the thickness of the electrodeposited microstructure across the array. It is clear that the presence of an ultrasonic bath can increase the gold deposition rate up to 5 times and reduce the standard deviation to half, improving the thickness uniformity. For the LC-CSED experiment, the current density was reduced to half compared to other experiments, leading to a reduced deposition rate but highly improved thickness uniformity, thus improving the quality of electrodeposition. Figure 1b shows a significant improvement in the adhesion strength and reduction in standard deviation for microstructures deposited with an ultrasonic bath, characterized using the xyztec Condor Sigma Multifunction Bond Tester. The investigations concerning the influence of ultrasonic baths on the mechanical, electrical, crystal orientation, and surface properties of electrodeposited gold microstructures are ongoing.



(**a**) (**b**)

Figure 1. (**a**) Bar graph representing gold electrodeposition rate for various tests with percentage standard deviation for the thickness of microstructures as error bars. (**b**) Bar graph representing mean adhesion strength of the electrodeposited microstructures with standard deviation as error bars.

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