

Fabrication of Microelectrode Arrays for Oxygen Generation to Support Cellular Growth in Implantable Devices

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Primary CNF Tools Used: AJA Sputterer-1, Oxford 81/82, ABM Contact Aligner, YES Polyimide Bake Oven, P7 Profilometer

Abstract:

This project aims to develop a microelectrode array for wireless generation of oxygen to support cell culture in implantable, therapeutic devices. To achieve this goal, we have fabricated Platinum (Pt) microelectrodes using tools available at Cornell Nanofabrication Facility (CNF). The microfabricated electrodes are electrochemically coated with Iridium oxide (IrOx) films following transfer to flexible substrates (e.g., PDMS thin films). IrOx catalyzes water splitting, leading to oxygen evolution at a lower potential (~ 1.2 V) compared to bare Pt (~ 1.7 V). Based on the oxygen generation performance of the Pt/IrOx electrodes, the microelectrode design will be revised to optimize oxygen generation for cell growth. In future, the Pt/IrOx electrodes will be integrated with NFC chips to allow for wireless operation of the devices.

Summary of Research:

The Ti/Pt microelectrode array is fabricated following the steps in the schematic in Figure 1.1,² The Si wafers are cleaned and primed with HDMS using the YES vapor

process was employed to create the Pt electrodes with LOR 10B as the lift-off resist and Microposit S1813 to define the microelectrode arrays. The AJA sputtering tool was used to deposit 20 nm Ti as the adhesion layer followed by a 100 nm thick Pt layer on the resist bilayer stack. Lift-off was achieved using Remover PG and mild oxygen descum (Oxford 81) post lift-off was used to remove residual resists. Next, a polyimide insulation layer was patterned using photolithography, followed by oxygen etching (Oxford 81) to open active sites on the metal electrodes. A Chromium (Cr) protection layer was used to prevent PI etching from undesired areas, which was removed after the PI etching step, rendering the Ti/Pt microelectrodes ready for the transfer printing step (Figure 2).

Contact profilometry was employed to confirm the final thicknesses of the deposited metal and PI encapsulation layers (Figure 3).

The PMMA layer was dissolved in acetone and water-soluble tapes were used to pick up the electrodes from the wafer (Figure 4A). A 200 nm SiO₂ layer was deposited on the electrodes to promote adhesion to final substrates (e.g. PDMS thin films, Figure 4B).

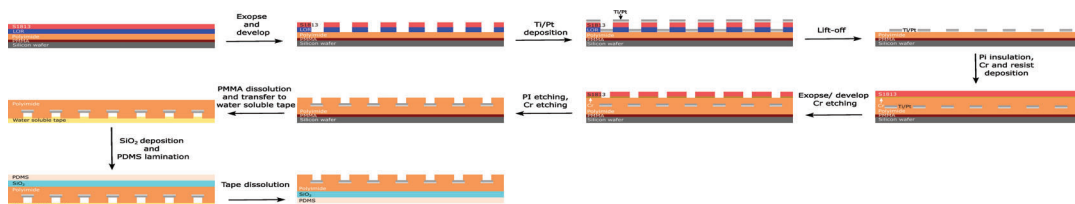


Figure 1: Schematic diagram for fabricating Pt microelectrodes of flexible support.

prime oven at CNF prior to coating with 50 nm PMMA (495 PMMA A5, Kayaku Advanced Materials) and 1.75 μm polyimide (PI 2545, HD microsystems). The lift-off

Flexible gold wires are used to connect these microelectrodes to electrochemical stations for targeted compound deposition, such as IrOx, and characterization of oxygen evolution.

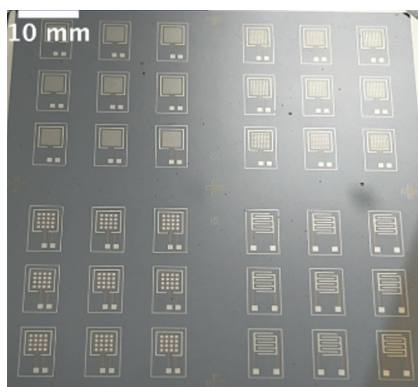


Figure 2: Pt microelectrodes fabricated on polyimide (PI) film supported on Si wafer using sputtering and lift-off. Images were taken at the end of the fabrication process after PI etching to expose the active electrode areas prior to transfer printing.

Conclusions and Future Steps:

Based on our preliminary experiments using the microfabricated devices, the designs are being updated to enhance performance. Our group is currently working on evaluating and establishing protocols for the IrOx deposition on microelectrode systems. We are exploring and investigating micro-coil antenna designs to integrate the microelectrodes into a wireless oxygen generation system.

References:

- [1] Brown, M. S., Browne, K., Kirchner, N. & Koh, A. Adhesive-Free, Stretchable, and Permeable Multiplex Wound Care Platform. ACS Sens 7, 1996–2005 (2022).
- [2] Lee, I. et al. Electrocatalytic on-site oxygenation for transplanted cell-based- therapies. Nat Commun 14, 7019 (2023).

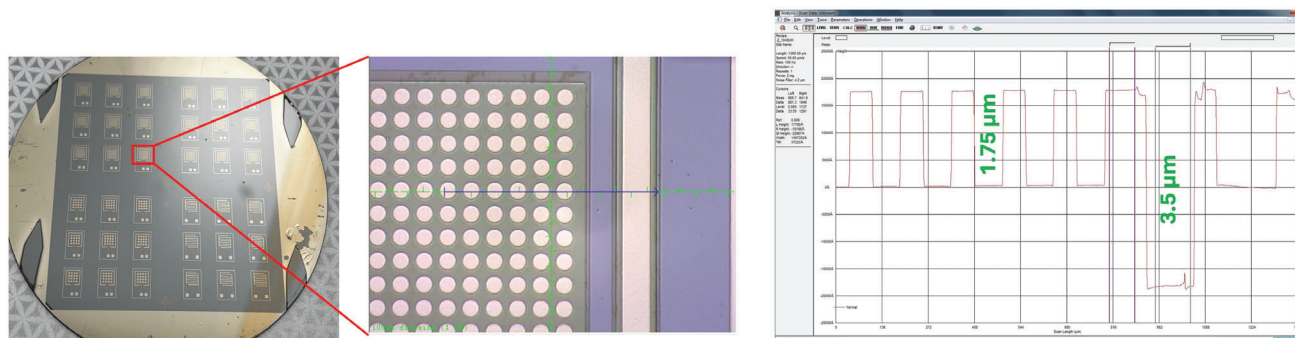


Figure 3: Profilometry performed using the P7 profilometer following the PI etching and Cr removal shows a 1.75 μm PI insulation layer patterning the 100 μm circular features and a 3.5 μm stack of the transferable electrode arrays patterned on the flexible PI supported on Si wafer.

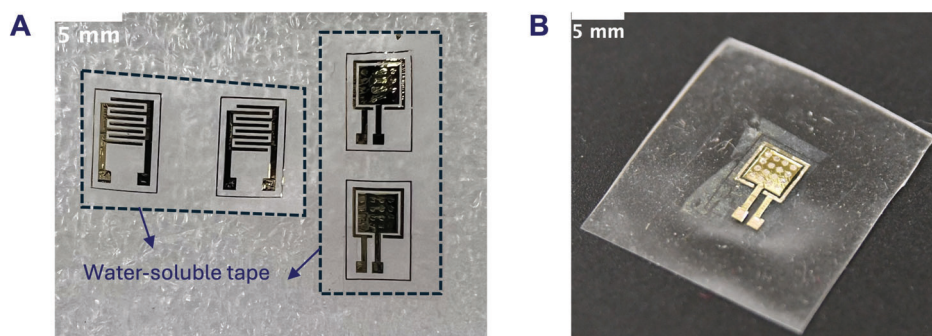


Figure 4: Pt microelectrode arrays (A) after 'pick-up' from the wafer to water-soluble tape and (B) after transferring to PDMS following the SiO₂ deposition.