INKJET PRINTED MULTIMETAL MICROELECTRODES ON PDMS FOR FUNCTIONALIZED MICROFLUIDIC SYSTEMS

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ABSTRACT

A novel direct method of metal microelectrode patterning on polydimethylsiloxane (PDMS) using inkjet printed gold and silver nanoparticles to form electrochemical sensors is presented. Inkjet printing is an additive microfabrication technique enabling microelectrode patterning directly over large areas at low-temperatures. (3-mercaptopropyl) trimethoxysilane (MPTMS) to promote PDMS surface wettability and improve metal adhesion and a pixel-printing subsampling method to overcome surface tension driven ink-droplet coalescence, are then employed to form a robust fabrication process. The resulting printed gold and silver microelectrodes exhibit good compactness, continuity and conductivity, and are used to manufacture functionalized microfluidic systems with in-situ three-electrode electrochemical sensors.

KEYWORDS: Functionalized Microfluidics, Electrochemical Sensing, Inkjet Printing, Microelectrode Fabrication, Adhesion Promotion

INTRODUCTION

Metal microelectrode patterning is a long-standing technical difficulty for manufacturing functionalized PDMS microfluidic systems due to the poor wettability and adhesion of metals to hydrophobic PDMS. Numerous solutions for metal patterning on PDMS have been investigated, including chemical reduction, lift-off [1], screen-printing, and pattern transfer [2], each with their own limitations and drawbacks. In this study, a novel metal microelectrode patterning process combining inkjet printing with MPTMS adhesion promoter and pixel-printing subsampling method, are used to directly pattern gold and silver electrodes on PDMS to form integrated three-electrode sensors.

THEORY

Inkjet printing is an additive technology; meaning material, in liquid form, is selectively deposited from digital computer patterns to yield the designed geometry. However, PDMS is inherently hydrophobic, making it difficult for ink droplets to disperse on its surface, causing increased solvent evaporation time and the coalescence of adjacent droplets. Additionally, poor metal-PDMS adhesion inhibits robust microelectrode formation. The complete fabrication process of this study is shown in Figure 1(a). To overcome droplet coalescence, a subsampling "pixel-printing" method was developed as shown in Figure 1(b). The desired pattern is subsampled (same color) into 9 non-adjacent parts and then printed sequentially. MPTMS, a Si-based material to noble metal coupler, was also employed in a two-step immersion process (Figure 1(c)) to improve PDMS wettability and adhesion prior to metal printing.

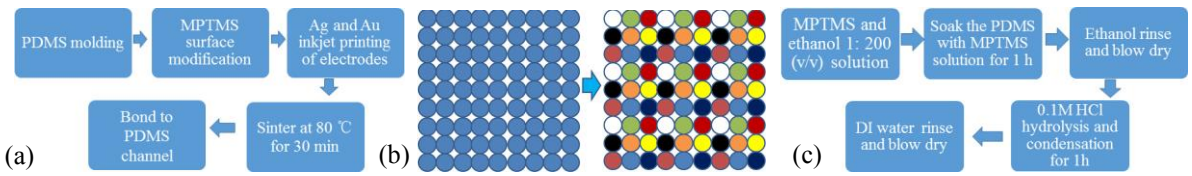

Figure 1: (a) Fabrication process, (b) The pixel-printing pattern subsampling technique to avoid ink coalescence, (c) MPTMS surface modification procedure to enhance surface wettability and adhesion of printed metal to PDMS.

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EXPERIMENTAL

A drop-on-demand inkjet deposition system (Fujifulm-Dimatix DMP-2831) was used to pattern silver (ANP DGP 40LT-15C) and gold nanoparticle [3] ink directly onto PDMS in an overlapping fashion to form a coherent pattern with high fidelity. To test metal adhesion, soaking (water, 2h), blowing (air, 0.5MPa, 5min) and ultrasonication (water, 10min) tests were applied to 2mm * 2mm pads on PDMS with varied surface treatments. A three-electrode electrochemical sensor was then printed on MPTMS modified PDMS using pixel-printing method from gold and silver. The silver electrode was chloridized to form an Ag/AgCl reference, yielding a function electrochemical sensor, before bonding to a microchannel.

RESULTS AND DISCUSSION

Figure 2(a) shows results of MPTMS alone (top), pixel-printing alone (center), and combined (bottom). MPTMS or pixel-printing alone results in drop coalescence, but the combination results in excellent pattern formation. Only MPTMS samples were found to survive the adhesion testing regime explored. Figure 2(b) shows the resulting gold and silver three-electrode sensor, with metal detail shown in Figure 2(c). After Ag/AgCl electrode formation, the sensor was aligned and bonded to a PDMS microchannel to yield an integrated electrochemical sensor for biosensing applications.

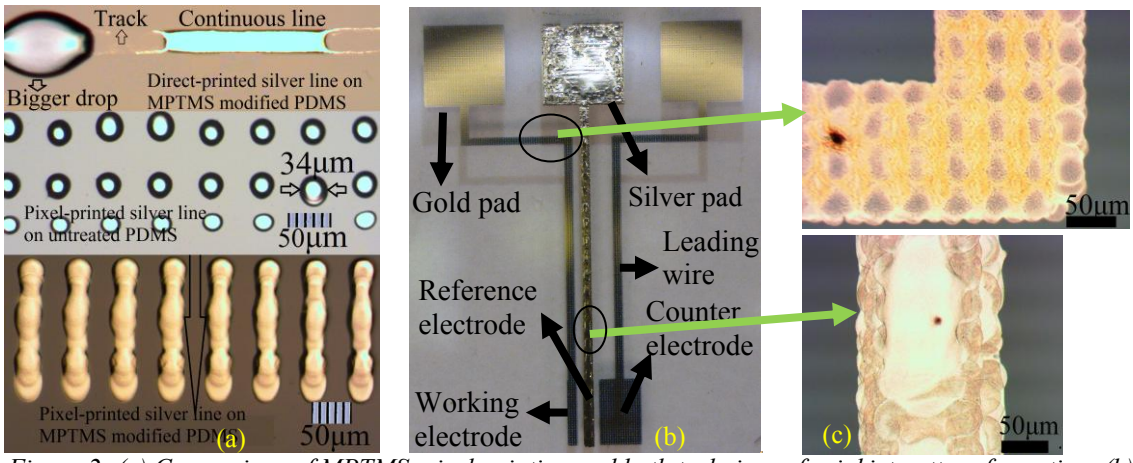

Figure 2: (a) Comparison of MPTMS, pixel-printing and both techniques for inkjet pattern formation, (b) The resulting three-electrode electrochemical sensor, (c) Metal details of the leading wire in the sensor

CONCLUSION

A novel multimetal microelectrode fabrication process for PDMS using inkjet printed silver and gold nanoparticle inks is presented. When combined with MPTMS to promote PDMS surface wettability and metal adhesion and a subsampling patterning technique, high-quality electrodes were obtained. The realized microelectrodes exhibited good continuity and excellent adhesion to the PDMS and were used to manufacture a functionalized lab-on-a-chip system successfully for integrated electrochemical sensing.

ACKNOWLEDGEMENTS

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