

Controlling Fluid Flow to Conducting Polymer Biosensors Using Surface Modification



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Abstract

Fluorooctatrchlorosilane or FOTS, which is a hydrophobic monolayer (contact angle = 110°) that is used to modify substrate surfaces, is described for use in biosensor arrays. By lithographically patterning FOTS into arrays of hydrophilic channels with a hydrophobic background, confined passageways for fluid flow are created which allows a liquid sample to reach the sensing section of the substrate with low flow resistance. The sensor incorporates organic electrochemical transistors that are designed using poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) or PEDOT:PSS as the active layers for the gate and source-drain connections. This active layer represents the conducting polymer which interacts with the enzymatic ionic process and lowers the drain current depending on the concentration. The placement of deferent enzymes on each sensor in the array is used to measure the concentration of each unique parameter in the solution.

Introduction

Biosensors are used to detect and sense various materials, gases, and chemical compounds in an environment. The organic electrochemical biosensor that is used in this experiment senses for analytes in a chemical solution. Examples of such analytes are lactose, glucose, etc. A distribution array in order for different biosensors to sense unique analytes on the same platform has been designed using surface treatment techniques. This will enable users to detect multiple concentration levels at once and have micro-molar precision.

In previous designs, polydimethylsiloxane (PDMS) was used to control the fluid flow because of its barrier characteristics and simple fabrication methods. A technique that has been developed was to use a nanoscale monolayer as a surface treatment. This monolayer created a hydrophobic surface that could be placed anywhere on the surface.

Fabrication

The fabrication process consisted of developing two separate masks. The first mask had the fluidic pattern and the second mask had the source, drain, and gate placements for the multiple sensing sections. In order to fabricate the PEDOT:PSS connections, parylene has been coated on the silicon oxide wafer. The photolithographic process consisted of spinning SPR220-3.0 photoresist on the substrate and exposing it under the HTG System III-HR contact aligner for approximately 6 seconds. Before developing the substrate, it was placed in a 115°C heating plate for approx. 90 seconds. The substrate was developed using 30 MIF and then placed in the PlasmaTherm 72.

This process caused the exposed areas of the wafer to be etched away so that placement of the conducting polymer (PEDOT:PSS) could be placed. Acetone and IPA were used to rinse off the remaining photoresist so that the parylene could be the only layer left on the wafer. Spin-coating the PEDOT:PSS on the wafer allowed the polymer to fill in the patterns on the wafer. The parylene was then lifted off of the substrate by a peeling technique which only left the conducting layer. The substrate was then placed in a 120°C oven for 90 minutes. This process fabricated the source, drain, and gate onto the wafer.

The next process consisted of fabricating the distribution array of fluidic channels on the previously fabricated wafer. Again using the photo-lithographic techniques, the second mask was used to expose the fluidic channel regions onto the wafer. The wafer was developed using 300MIF and then was placed in the molecular vapor deposition tool, where it deposited a 5 nm hydrophobic layer of FOTS. Acetone and IPA was then used to remove the excess photoresist leaving only the outlined pattern and the connections hydrophilic.

Experimental Procedure

The substrates were tested by injected fluid via a syringe that held 40 ml. The fluidic channels were 3 mm in width and 5 mm in length. The fluid that was used to test the flow was de-ionized water. The water reached the testing sections effectively and enough fluid remained in the sensing area to test from. The PEDOT:PSS strips were tested for conductivity by using a voltmeter for ohmic resistance. By depositing an analyte as

the dielectric between the gate and source-drain electrodes, the biosensor was tested. Varying the gate voltage proved that the biosensor was functional because of the output drain current.

Results and Conclusions

The design enabled the surface-controlled fluid to flow with low resistance. Crosstalk between the channels was eliminated because of the hydrophobic gaps between the channels and the sensing sections. The multiple organic electro-chemical transistors were operable from the numerous fabrication processes and displayed functional voltage biasing.

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References

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Figure 1, top: Shows early design of fabricated substrate with 100 μm channels. The wafer has FOTS monolayer present which prohibits water-based solutions from adapting to the surface. The lightest area is covered with FOTS and the remaining is hydrophilic.

Figure 2, bottom: The design that worked best with the FOTS monolayer incorporated hydrophobic gaps that eliminated crosstalk between devices and the channel width allows fluid to flow with low resistance.

