A HYDRODYNAMICALLY FOCUSED STREAM AS A DYNAMIC TEMPLATE FOR SITE-SPECIFIC ELECTROCHEMICAL MICROPATTERNING OF CONDUCTING POLYMERS

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ABSTRACT

We demonstrated a site-specific fabrication of conducting polymer micropatterns by a novel electrochemical micropatterning technology, which utilizes a hydrodynamically focused laminar stream as a dynamic template. The resulting micropatterns in a microfluidic device is a ready-to-use sensor capable of detecting microliter amounts of organic solvent vapors. By employing two different sensing elements (polypyrrole (Ppy) and COOH-Ppy), the collective sensing responses are informative enough to identify a wide range of organic vapors.

KEYWORDS: Microfluidics, Hydrodynamic Focusing, Conducting Polymer, Micropatterning

INTRODUCTION

Micropatterning technology [1] has been a major driving force behind the development of organic microelectronic devices. There have been significant efforts devoted to exploring this technology for the fabrication of conducting polymer (CP)-based devices in particular, because CPs exhibit the unique advantages of tunable conductance, chemical specificity, flexible modification, and low fabrication cost. In general, most of the existing micropatterning approaches, for example, the embossing method, imprint lithography, capillary molding, and microcontact printing, require the use of prefabricated solid molds or templates to determine the features and dimensions of the micropatterns. However, the embedded features of these molds or templates are very much fixed and it is unlikely that they would be reprogrammed for different micropattern features. Herein, we introduce a new type of micropatterning approach in a microfluidic setting (Figure 1), in which a hydrodynamically focused laminar stream [2] was generated in situ for performing size-controllable, site-specific electrochemical deposition (ECD) of CP micropatterns across individually addressable electrode junction pairs [3].

EXPERIMENTAL

The electrode pattern array (20 pairs of electrode junctions) employed for the electrochemical deposition of conducting polymer micropatterns was fabricated by standard photolithographic techniques. The microfluidic component was fabricated using a soft lithography method. Using a electrochemical setup (Princeton 263A, EG & G Instruments Inc., TN), one-step galvanostatic electropolymerization proto-
col was employed for the production of Ppy and COOH-Ppy micropatterns on the electrode junctions with similar constant current density for 100 to 250 seconds according to the beam width (Figure 2c). The morphologies of the electrochemically fabricated CP micropatterns were observed by a field emission scanning electron microscope (SEM, S4700, Hitachi, Tokyo).

Figure 1. A hydrodynamically focused laminar stream produced in our microfluidic setup for site-specific ECD of size-controllable CP micropatterns.

Figure 2. a) Optical image of the actual microfluidic device. b) and c) A micrograph of the device in action. d) SEM image of the 1-µm-wide Ppy micropattern across a Pt electrode pair.

RESULTS AND DISCUSSION

The microfluidic device (Figure 2) is composed of 1) an array of 20 electrode junctions on a glass substrate (with three different types of junction gaps of 2, 4, and 10 µm) for electrochemical deposition of CP micropatterns and 2) an overlaying polydimethylsiloxane component (with embedded 200-µm-wide and 40-µm-high microchannels) for hydrodynamic focusing of the monomeric precursor (that is, pyrrole and its derivative) solution. The pyrrole solution (0.1 M pyrrole, 0.1 M LiClO4, and 1.0 mM HCl) was first introduced into the device through the central inlet at a constant flow rate (1.0 mL/min), and two pairs of sheath streams (18 MΩ water) were then employed to compress the pyrrole solution, which resulted in a hydrodynamically focused laminar stream. Again, the width and position of the resulting focused stream were controllable by the flow rates of the surrounding sheath streams (from 2.5 to 60 mL/min). Via this approach we fabricated site-specifically a sensor array composed of a number of intact Ppy- and functionalized Ppy-based micropat-
terns, which showed the capability to respond specifically to a collection of 12 organic vapors (20 µL each) (Figure 3) [4]. Compared to recently developed resistive sensors capable of detecting and identifying organic solvents, this binary sensor exhibits superior sensitivity (ng to µg by weight) and negligible memory effects.

**CONCLUSIONS**

In conclusion, a novel electrochemical micropatterning technology, which utilizes a hydrodynamically focused laminar stream as a dynamic template, has been successfully demonstrated for site-specific fabrication of a sensor array composed of a number of intact Ppy- and functionalized Ppy-based micropatterns. It is conceivable that this technology could be widely applied to micropatterning of other redox-active materials for broader application in microelectronic devices.

**ACKNOWLEDGEMENTS**

This research was supported by DOD-Defense Threat Reduced Agency (W911NF0610243), NIH-NCI NanoSystems Biology Cancer Center (U54CA119347) and National Nature Science Foundation of China (No 90406006).

**REFERENCES**


