Electrodes Integrated Microfluidic Plastic Chips

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Disposable microchips offer unique advantages for microanalytical systems. For on-chip sample preparation and chip-based capillary electrophoresis, patterning and integration of electrodes on plastic chips can greatly enhance functionality and automation. Integrated electrodes also can help to minimize carryover and resultant cross-contamination for high-throughput screening (HTS) of pharmaceutical candidate compounds compared with external, reusable wire electrodes. We will report several methods to deposit electrodes on plastic microchips, together with their application for electrochemical detection, on-chip heating, and for driving electrophoretic separations (Figure 1). The electrodes were prepared by physical vapor deposition of metals, by electroless deposition, and by patterning of conductive inks. Patterned electrodes on plastic chips are robust and compatible with biomolecules including various enzymes and DNA.

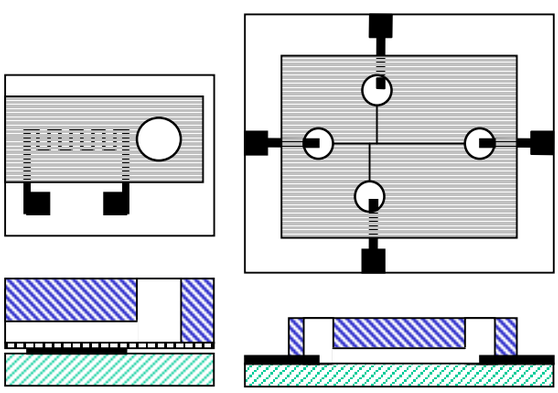

Figure 1. Top view and side view of electrodes patterened on plastic chips to serve as heate (left)r and driving electrodes for CE separation (right).

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We used patterned on-chip electrodes as both heater and temperature sensor. Heaters with very small dimensions (< 25 μm) were prepared, and show fast response to the application and removal of power. Local temperature depends on applied voltage as shown in Figure 2.

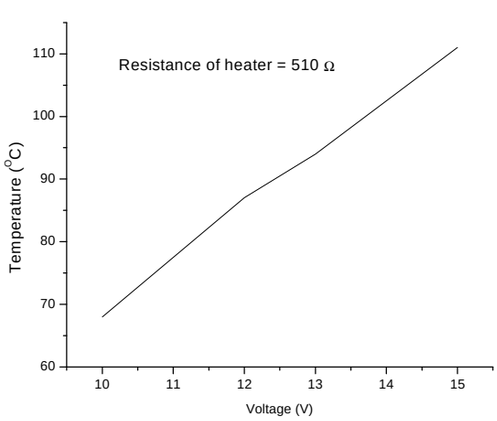

Figure 2. Thermal response of an integrated heater. The resistance of the ink-based heating trace is 510 Ω.

We also investigated the use of integrated electrodes to drive chip-based capillary electrophoresis (CE) for high throughput drug screening and genetic analysis applications. Figure 3 shows the separation of 4 probe molecules of differing electrophoretic mobility (so-called "eTag™ probes") using electrodes integrated on plastic CE microchips. The results from control experiments where Pt wires were used as driving electrodes are shown for comparison. Results for the FWHM of each peak and the peak area ratios for four different eTag probes suggest that the separations using patterned electrodes are essentially identical to those obtained using external Pt wire electrodes.

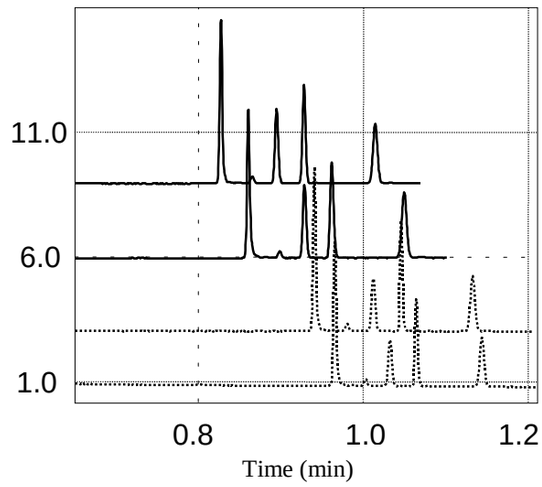

Figure 3. eTag probe separation using electrode-integrated plastic chip. 2 electropherograms in the same channel show good reproducibility of the separation. The 2 electropherograms in dashed line at the bottom are the results from a control experiment, where Pt wires were used as driving electrodes. A mixture of 4 probes, each at 2.5 nM concentration, was added to the sample well. The electric field strength for the separation is 400 V/cm.

Integrated electrodes sustained high electric fields with no observed degradation during CE separation. Figure 4 shows the separation of a mixture of single-stranded DNA fragments varying in length from 75 to 700 bases using electrode-integrated microchips at room temperature. All 18 expected peaks were observed over the course of the 1-hour separation. The patterned electrodes remained stable during this prolonged experiment.

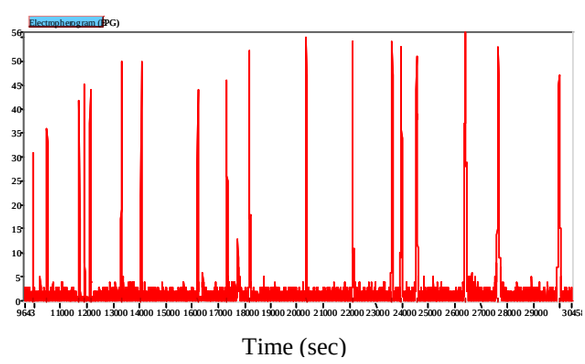

Figure4. ssDNA separation using electrode-integrated microchips. The separation channel is 18.5 cm long and the field strength is about 150 V/cm.