Microfluidic Devices for Rapid DNA Analysis for Human Identification

The goal of this project is the development of new microfluidic devices with auxiliary optics, pneumatics, and software for rapid, automated analysis of DNA "fingerprints" for human identification. The NIST microfluidic devices are fabricated from common low-cost commercial plastics thereby facilitating their application as single-use devices and eliminating concerns of sample-to-sample cross contamination. Current device design and configuration are approaching the performance in salient figures-of-merit to current state-of-the-art equipment with the time required for analysis being reduced by ≈90%.

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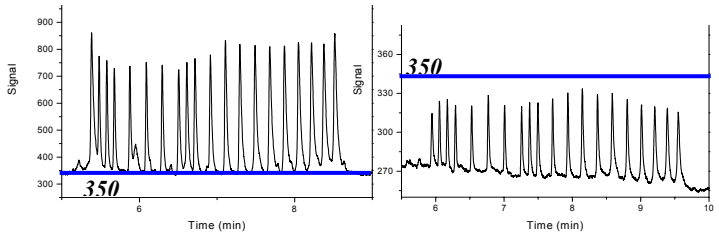
The National Institute of Justice (NIJ) estimated a backlog of a 542,700 cases for DNA analysis as of April 2004, and current forensic crime labs do not have the capacity to address this backlog in a timely manner. Forensic DNA analysis or "fingerprinting" involves the measurement of the molecular size of several fragments of DNA produced in a specially designed molecular-biological reaction. This NIST project is addressing this backlog by developing miniaturized analytical techniques that are faster and more economical, while still ensuring the data produced are of the highest quality. NIST will partner with the commercial sector to facilitate the transfer of this technology to the crime labs as required by NIJ.

This research team has developed a microfluidic device platform capable of analyzing eight forensic DNA samples simultaneously with integrated optics and electronics for detection and data analysis. The small, self-contained, portable device will allow for forensic analysis to be done in the field (in contrast to traditional laboratory DNA analysis techniques), thus enabling analysis at the crime scene, shortening analysis time, and enhancing police response time. The complete system, developed with our National Institutes of Health (NIH) collaborators, fits into a 60 cm x 60 cm x 30 cm enclosure mounted on a small transportable cart. The photograph is the NIST/NIH microfluidic DNA electrophoresis instrument. All components are mounted on a 30 cm x 30 cm optical table that rests atop a small cart, allowing for easy transport

A unique aspect of the NIST multiplexed forensic microfluidic device is that it is fabricated from inexpensive plastic materials making it well suited for forensic applications where analysis cost and sample cross contamination are critical issues. To perform high-quality DNA separations with the necessary resolution in plastic microfluidic devices, optimized surface coating technologies were developed using hydrophilic polymer formulations. The optimized surface coating methodologies had a tremendous positive impact on the separation performance. The graph below is demonstration of the NIST microfluidic DNA analyzer, showing the separation of a DNA "ladder" consisting of a variety of fragments of increasing size. The first panel shows a relatively poor performing coating of methylcellulose with a final separation resolution of 2.07, the second panel shows an optimize surface treatment and coating of poly(vinylalcohol) with a separation resolution of 5.38, more than doubling the resolution. While the scale of the two graphs is different, the blue lines represent the same signal intensity.



Impact: This project is focused on developing improved multiplexed DNA separation and analysis systems that can address the significant backlog of DNA samples to be analyzed in pending criminal investigations.

Future Plans: The completion of this phase of the project resulted in faster multiplexed DNA separation systems; however, DNA sample preparation steps (cell extraction, DNA purification, DNA amplification, etc.) are still performed manually in most crime labs. Further work focuses on integrating sample preparation approaches into the microfluidic format.

Patents: N. Y. Morgan, P. D. Smith, E. Wellner, ***A spatially selective, fixed-optics multicolor fluorescence detection system for a multichannel microfluidic device, and method for detection.*** U.S Patent Application no. 60/693,780 Filed 6/27/05