FORENSIC MICROFLUIDICS OUTSIDE THE DNA BOX

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There have been remarkable advances in forensic microfluidics in the past decade, primarily in the area of DNA analysis and forensic biology. Other forensic disciplines could benefit from the development of simple microfluidic devices for field and crime scene use. Two classes of compounds amenable to microfluidic protocols are controlled substances (drugs)\(^1\) and explosives\(^2-4\). In such deployments, the role of the MFD is typically that of a screening tool that must provide a semi-quantitative presumptive result in which a positive result is interpreted as “more likely than not.” Although these requirements are less stringent than might be expected, there are other uniquely forensic requirements that create design and implementation challenges. These will be discussed in the presentation.

Specifically, to be of practical value in a forensic screening context, microfluidic devices should:

- be simple to operate
- provide output that can be interpreted by first responders (i.e., “red light /green light”)  
- be inexpensive
- be capable of preserving the integrity of evidence
- be disposable
- be multifunctional and amenable to multiple analytes
- be rugged
- be stable over long storage periods in a variety of environments
- have a passive design with minimal or no power requirements

An example of such a device is a microfluidic chip developed as a replacement for traditional color testing kits used by law enforcement officers. These kits are used to identify potential controlled substances and to determine if there is probable cause for further action. As the name implies, these tests rely on formation of colored dyes or transition metal complexes in which the color (subjectively evaluated) correlates to a drug or class of drug. The officer obtains a sample of the material (typically a powder) and using a disposable well plate, conducts a series of simple tests designed to detect opiate alkaloids (heroin and related compounds), phenylethylamines (methamphetamine and related compounds), and alkaloids (cocaine and related compounds). As an example, amphetamine and methamphetamine react with the Marquis reagent through a presumed condensation polymerization to form a dark orange dye (Figure 1). Similar reactions with other alkaloid drugs form other distinctive dyes. From the MFD design perspective, detection is simple; either direct visual interpretation or digital imaging can be exploited. In the latter, colors can be characterized by extraction of the red, green, and blue channels from digital images. Applications of the latter will be introduced and discussed during the presentation.

In field applications such as drug testing, the analytical advantage offered by a MFD is the ability to perform multiple tests on a single chip using negligible amounts of evidence. Tests are also not limited to those based on a color change. Another type of screening test once widely used in seized drug analysis was based on the formation of characteristic microcrystals between protonated alkaloids and various anions. One example is crystals formed...
between cocaine (RNH$_3^+$) and anions derived from precious metal acid salts such as gold and platinic acids (Figure 2). The salts of many drug cations are sufficiently distinctive to meet the presumptive test criterion of “more likely than not.” The ability to combine tests and to integrate field and laboratory testing on a single chip has distinct advantages in forensic settings.

This presentation will review recent developments and the current status of forensic MFDs outside of the DNA realm. Attention will be focused on recent work with a MFD designed to conduct color and crystal tests in the field. The design of the chip is shown in Figure 3 and the prototype is shown in Figure 4. This MFD conducts three simultaneous tests – two color change and one microcrystal. The latter would not be evaluated in the field, but rather in the lab and the purpose of this additional test is rapid elimination of any false positives that could arise even with two color tests.

The performance of this chip will be discussed and figures of merit presented. This will include evaluations of flow patterns and mixing criteria identified as critical in non-electrophoretic devices. For example, as seen in the figure at left (Figure 5), some color change reagents that incorporate transition metals form insoluble ion pair complexes as opposed to soluble dyes. Different approaches to mixing are required to accommodate both contingences. The presentation will conclude with a discussion of current and future applications of forensic microfluidics including detection of the predator drug GHB and potential applications to gunshot residue (GSR).

REFERENCES