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Fluorescence Multi-Sensor System for the Simultaneous Detection of Various Types of Explosives in Gas-Phase

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Abstract

The world is facing an increasing threat from improvised explosive devices (IEDs) used in terrorist attacks all around the world. Accordingly, the possibility for a fast and straightforward detection is of high importance. Therefore, a highly sensitive and selective handheld sensor system has been developed for the simultaneous detection of various types of explosives in gas-phase, using a combination of fluorescent sensor layers in a Lab-on-a-Chip system.

Keywords: Multi-sensor, fluorescence, detection, explosives, gas-phase

Introduction

IEDs have been used in various terroristic attacks within the last decades throughout the world. The type of explosive(s) used in such bombs can vary strongly, including nitro-based-explosives like TNT (Rijeka bombing), nitrate-esters like PETN and nitramines like RDX (Semtex; Pan Am 103 Bombing), peroxide-based explosives like TATP (Manchester Arena bombing) or ammonium nitrate (Breivik bombing). Thus, it is of utmost importance to develop a handheld sensor for the simultaneous detection of these kinds of explosives in gas-phase.

To achieve a simultaneous analysis of an unknown sample, a Lab-on-a-Chip (LoaC) system has been developed. To enable detection of low volatile explosives, the sample is heated in order to be transferred into gas-phase. The LoaC represents a microfluidic system in which this gas-phase is passed over various sensor layers. The combination and positioning of these films enable the simultaneous detection of various explosives. Using an optical system involving UV-irradiation and PMT, the signals can directly be analyzed. Inclusion of a customized software ensures high sensitivity and selectivity as well as a very good identification of false positive/negative measurements.

Merging all of the separately developed systems we were able to assemble a handheld prototype which is shown in Fig. 1.

Fig. 1. Handheld prototype (20 x 10 cm) for simultaneous detection of explosives in gas-phase.

Results and Discussion

A swipe sample, e.g. a Teflon strip, is wetted with a predetermined amount of analyte and dried. The sample is then heated to transfer the analyte into gas-phase. Using a pump, the gas stream is carried over the separate sensor layers of the LoaC. The speed is set to an average of 50 mL/min. It is a critical setting since it will determine the time of interaction between the sensor layer and the analyte. The principle of detection is hereby either a decrease or increase in fluorescence intensity upon reaction with the analyte. Nitro- and nitrate-based explosives as well as *2*,*3*-dimethyl-*2*,*3*-dinitrobutane (DMDNB), which is a common additive to industrially synthesized TNT, lead to a strong decrease in fluorescence intensity. The mechanism for this quenching is caused by the electron deficient property of e.g. TNT. Thus, an electron can be transferred from the implemented dye in the sensor layer, resulting in a decrease in fluorescence. Peroxide-based explosives on the other hand induce a fluorescence decrease. This mechanism is based on

two consecutive steps. Due to an acidic catalyst, TATP is decomposed to hydrogen peroxide. The dye induced into the sensor layer was prior selected to show an enhancement in fluorescence upon oxidation. The positioning of the acidic catalyst in the LoaC also allows a very good distinction between a peroxide-based explosive like TATP or HMTD and hydrogen peroxide.

The exemplary results of the gas-phase experiments are shown in Fig. 2 and Fig. 3.

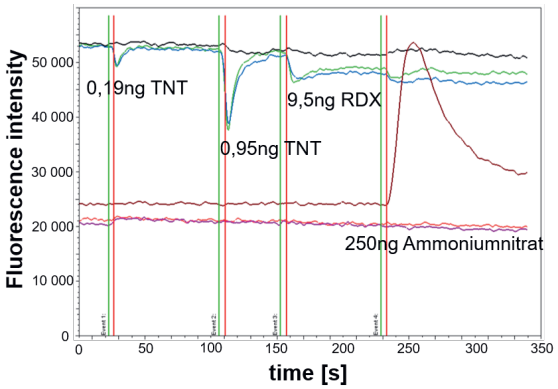

Fig. 2. Measurement various explosives with the handheld prototype.

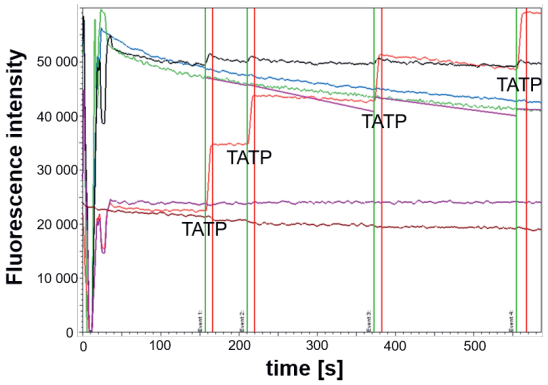

Fig. 3. Measurement of 155 ng TATP (4x) with the handheld prototype.

The combination of a handheld device with a LoaC, containing a series of separate sensor layers enables a straightforward and fast detection of various types of explosives in gas-phase with high sensitivity and selectivity. This prototype, due to its low weight and portability, shows promising performance for use in field experiments. The Limits of Detection (LoD) are shown in Tab. 1.

Tab. 1: Explosives with LoD

Explosive	LoD
TNT	0.2 ng
DMDNB	6.0 ng
TATP	10 ng
Ammonium nitrate	60 ng

This work presents the development of a handheld prototype for the simultaneous detection of various explosives. Due to the combination of fluorescent sensor layers and elaborated optical and microfluidic systems high sensitivity and selectivity could be achieved. Inclusion of a customized software allows a fast and user-friendly readout of the measurements. The high operator convenience shows a promising application in field experiments.

References

[1] A. K. Singh, N. G. Ditkofsky, J. D. York, H. H. Abujudeh, L. A. Avery, J. F. Brunner, A. D. Sodickson, M. H. Lev, Blast Injuries: From Improvised Explosive Device Blasts to the Boston Marathon Bombing, *Radiographics*, 36, 1, 295-307 (2016); doi: 10.1148/rg.2016150114

[2] J. V. Prata, A. I. Costa, C. M. Teixeira, A Solid-state Fluorescence Sensor for Nitroaromatics and Nitroanilines Based on a Conjugated Calix[4]arene Polymer, *Journal of Fluorescence* (2019); doi: https://doi.org/10.1007/s10895-019-02466-1

[3] S. Fan, J. Lai, P. L. Burn, P. E. Shaw, Solid-State Fluorescence-based Sensing of TATP via Hydrogen Peroxide Detection, *American Chemical Society Sensors*, 4, 134-142 (2019); doi: 10.1021/acssensors.8b01029