# Improved organic semiconductor explosive sensors for application on minefields

J.M.E. Glackin, R.N. Gillanders, N. Kezić, J. Filipi, G.A. Turnbull

J.M.E. Glackin, R.N. Gillanders, G.A. Turnbull - Organic Semiconductor Centre, School of Physics & Astronomy, University of St Andrews, St Andrews, Fife KY16 9SS, Scotland
N. Kezić - HCR-CTRO Scientific Council, Croatia, nkezic@agr.hr
J. Filipi - Dept. of Ecology, Agronomy and Aquaculture, University of Zadar, Trg kneza Višeslava 9 Zadar, Croatia

## Abstract

Here we present progress made in the development of an organic semiconductor based sensor system for explosive vapours. The sensors, originally developed in the TIRAMISU project[1], monitor a change in fluorescence from a polymer film when it is exposed to trace vapours of TNT and similar explosives. The approach could be promising for applications in remote explosive scent trace (REST detection) for the technical survey of mine fields. Successful deployment of the detection system in the field, however, requires an improved method for sample collection and delivery to the sensor, and an approach to address the potential problem of false detection of distractants. We report here recent progress addressing these challenges.

## Introduction

Organic semiconductors are commonly used in OLED television and smartphone displays. Due to their chemical and physical properties they can also be used as a sensor to "sniff" for nitroaromatic explosive vapours[2-4], such as trinitrotoluene (TNT) with sensitivities comparable to canine methods. This is done by monitoring the light emission from thin films of the organic semiconductor when excited by an external light source such as a laser or LED. The presence of nitroaromatic molecules in the film causes a drop in the light emission, which is taken as an indication as the presence of explosives. In this paper we will discuss the work done to improve vapour delivery to these sensors, and to reduce the possibility of false positives.

## Application to remote explosive scent tracing (REST)

REST detection uses air sampling through a filter which is then tested for the presence of explosives. This technique has been developed by Mechem in their MEDDS system, using trained dogs as the detection mechanism for both explosives and drugs[5]. The REST collection approach could also be combined with the organic semiconductor explosives sensor, to allow on-field testing of samples for minefield area reduction. After initial field trials with the organic semiconductor based system developed in the TIRAMISU project, it was found that adaptations to the sampling filters were needed to enhance the delivery of collected explosives residues to the sensor.

In order to maximize the amount of explosive vapour and particles collected in the filter, materials to which explosives, such as TNT, selectively bind have been investigated.[6] In our studies the fluorinated polymer Aflas® (AGC Chemical Europe Ltd) was chosen as a suitable coating. This polymer acts as a preconcentrator which specifically accumulates explosives molecules, maximising the amount of explosive vapours collected. After sampling, the exposed filter is then placed in a sealed chamber with the sensor film, as shown in Figure 1 to test for the presence of explosives. An apparatus for performing these measurements in the field has also been developed. When heated above a certain temperature, the explosive molecules bound to the preconcentrator gain enough energy to desorb from the film. This generates a cloud of explosive vapour which can then be interrogated by an organic semiconductor explosive sensor, as shown in Figure 2.

These materials are also being used in the Bee4exp project to collect explosive residues picked up by bees while foraging, to develop a passive method of area reduction and quality assurance when clearing landmines. Entry and exit of honeybees from the hive are segregated using tubes which contain paper “doormats” coated with the Aflas® preconcentrator polymer. As the bees forage around a mine suspected area, tiny amounts of explosives residues are picked up on their bodies, which are then deposited and concentrated on the “doormats” in the hive entrance. A preliminary field trial conducted in September 2017 on the Benkovac test site has shown promising results, with work continuing to improve the sampling and collection methods.

## Introducing selectivity using molecular imprinted sol gels (MISG)

We also report an approach to improve the selectivity of the sensor against possible distractants. Much in the same way that not every metal object detected by a metal detector is a landmine, not every nitroaromatic vapour indicates the presence of explosives. Common non-explosive nitroaromatics include pesticides, such as dinoseb and perfume ingredients such as musk ketone. We are addressing this problem through the use of a molecular imprinted sol gel (MISG) to discriminate between similar analytes.

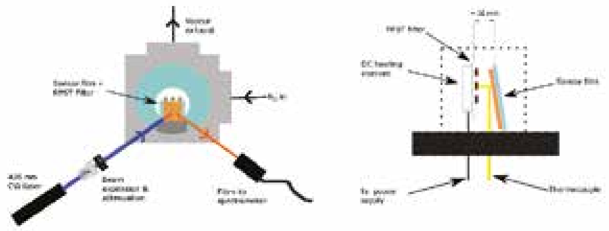

*Figure 1: Lab based setup for measuring REST samples. The sensor and filter are placed together in a sealed chamber and the sensor response is monitored as the filter is heated up to release the collected explosive vapours.*

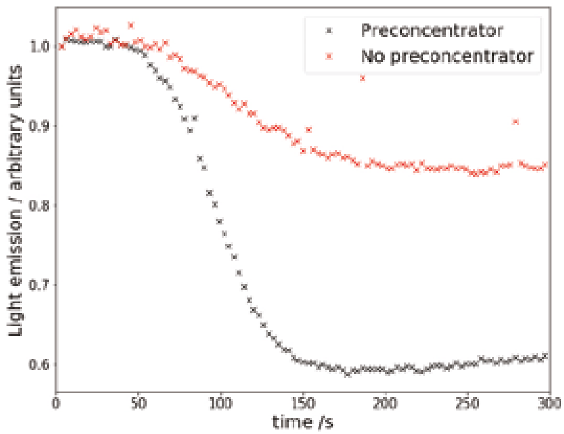


*Figure 2: Response of a super yellow thin film sensors exposed to silicon wafers that have previously been exposed to DNT contaminated nitrogen. The wafers are heated to 100oC in a sealed chamber with the sensor, and the light emission of the sensor is monitored. The red trace is the response from a bare silicon wafer and the black trace the response from a Aflas® coated wafer.*

Sol gels are a solution processed glass-like material whose properties can be controlled and adapted by the choice and ratio of precursors used. It has been shown that particular sol gels can selectively bind to nitroaromatic templating molecules[7-8]. The addition of a small amount of nitroaromatic molecules, such as TNT, can imprint the shape of the target molecule into the film when the film is formed. After washing out the template, the film can subsequently selectively sorb the target molecule. We have integrated the recognition sites with our sensor films to increase selectivity against some possible distractants such as agricultural pesticides.

## Conclusion

The REST sampling method has been combined with organic semiconductor explosive vapour sensors to improve vapour delivery to our sensors with the use of the preconcentrator polymer Aflas®. This preconcentrator material has been used in the Bee4exp project to test for trace amounts of explosive picked up by bees foraging in mine contaminated areas. Further field trials are ongoing to develop the method for area reduction in mine suspected areas.

Molecular imprinted sol gels have been demonstrated as a simple solution to the problem posed to organic semiconductor sensors by nitroaromatic distractants such as pesticides without the need of complex chemistry or the development of new sensor materials.

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