Detection of trace amounts of explosives and/or explosive related compounds on various surfaces by a new sensing technique/material.

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Detection of trace amounts of explosives and/or explosive related compounds on various surfaces by a new sensing technique/material

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A novel sensing technique/material for detection of trace amounts of explosives, or explosive related compounds (ERC) on different objects/surfaces is presented. It is based on a specific color reaction between cyclopentadienylmanganesetricarbonyl (cymantrene) and explosives/ERC. The reaction is performed within a specifically designed thin film polymer with embedded cymantrene. It is easily seen after short time, low-power UV irradiation. New technique provides fast and simple detection of explosive fingerprint residues on various surfaces. The distinct papillary image fingerprints of explosive/ERS contaminated finger tips can be obtained.

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1. Introduction

In recent years, the issue of use of explosives by suicidal terrorists was added to the problems of environmental detection and monitoring of traces of explosives from unexploded land mines, industrial leakage at manufacturing facilities, improper disposal, etc. In spite of the spectacular progress in real-time detection of explosives made lately, the issue still remains one of the challenging tasks. Modern detection techniques and commercially available sensors can be used both for gas and surface analysis. They are primarily based on ionization and separation analysis of explosive vapors, pyrolysis, and gas phase reactions, interaction of explosive compounds (EC) with radiation, use of immunochromatographic reactions between EC and their specific antibodies, etc. (for the latest review, see [1]). Their sensitivity is high, but most of them are rather expensive and require skilled technicians to perform the analysis.

In this paper we present a novel, simple and inexpensive sensor technique/sensing material for the detection of trace amounts of explosives, or explosive related compounds (ERC) on different objects/surfaces. The method is based on a specific color reaction between common EC/ERC and a specific organic reagent/dye, cyclopentadienylmanganesetricarbonyl (cymantrene) [2]. The reaction is performed within a specifically designed thin film polymer with embedded cymantrene. The reaction in liquid phase was reported in general features earlier [3]. It yields a characteristic blue color after short time, low-power UV irradiation.

2. Experimental

2.1. Sensitive technique and material

A special “sensitive technique” was designed to detect EC/ERS on different surfaces. Detection reaction was performed within a thin film/gel of a designer polymer with embedded “sensing” chemical—cymantrene. Among different polymers tested, divinyl-styrene copolymer (DSC), gave the best results and was primarily used in this paper. The method is based on a specific color reaction between common EC/ERC and a specific organic reagent/dye, cyclopentadienylmanganesetricarbonyl, also known by a trivial name cymantrene [2]. The reaction is performed within a specifically designed thin film polymer with embedded cymantrene. The reaction in liquid phase was reported in general features earlier [3]. It yields a characteristic blue color after short time, low-power UV irradiation.

2.2. TNT simulators used

To reduce the danger of explosion the experiments were performed with practically non-explosive TNT homo-
logues: 2,4-dinitrotoluene; 1,3-dinitrobenzene, and ortho-
mononitrotoluene (DNT, DNB, and OMNT, respectively).
The first two are byproduct impurities of TNT, and OMNT
is specified by ICAO as a volatile taggant of TNT [3].
All chemicals were of the highest purity grade commer-
cially available, and were further checked for purity by IR
spectroscopy.

2.3. ERS detection

The qualitative and quantitative detection of ERS used
were performed in two different sets of experiments. In the
first, homogeneous, smooth, and transparent designer poly-
mer/cymantrene films of uniform thickness ($3 \pm 0.3\,\mu m$)
were deposited (spin rotation, 3500 rpm) onto $30\,mm \times
15\,mm \times 1.5\,mm$ glass plates, and toluene was allowed
to evaporate. The films were used as tactile sensors: upon gen-
tle contact with an ERS contaminated finger tip they re-
tained trace amounts of ERS as clear imprints (fingerprint
samples). Two parallel series of fingerprints were made in
every experimental cycle.

In the other set of qualitative experiments the sensitive
films were deposited by spraying (spray kit) or spin rota-
tion onto the surface of different pieces of material already
contaminated with ERS (sprayed film samples). The materi-
als used were: wood (furniture), leather, plastics, (baggage),
glass, common metals, paper (books, newspapers), wrapping
paper, etc.

2.4. Fingerprints deposition procedure

For better reproducibility a special fingerprint “inking”
procedure was developed. A porous filter was soaked in
30–50% solution of DNT or DNB in toluene and, after
toluene evaporation, placed into a sealed box. Subsequent
gentle touching of the filter with a finger tip resulted in its
“inking”. For the production of uniformly sized fingerprints
(usually thumbsprints) a metal screen with a circular/square
hole of $1\,cm^2$ area was placed on top of the sensitive poly-
mer film, so that only this area of the film was accessible to
the “inked” finger. To prevent accidental contamination (see
[4]) the imprinting procedure was performed with special
precautions.

To evaluate the probability of false signals a separate (con-
trol) series of experiments were made. First, the thumbsprints
made by “clean”, that is, non “inked”-fingers were exam-
ined. Second, the commonly used “domestic” chemicals that
did not contain NO$_2$ were used as “inking” controls (oil,
tobacco water extract, some beverages, perfumes, some dis-
solved medicine, etc.).

2.5. UV irradiation

Commercially available common UV-hydrogen lamp
(maximum irradiation near 330–350 nm) with laboratory
made reflector was employed for irradiation of samples.

The effective UV radiation intensity on the sensitive surface
was estimated to be about $10\,mW/cm^2$. The irradiation time
required to produce steady colored images (fingerprints) was
about 1–3 min.

2.6. The quantification of the ERS residues

Because of the color character of the reaction and transpar-
ency of samples the amount of explosive/ERS in fin-
gerprint samples can be easily quantified by the optical
absorption ($A$) measurements of samples in the near 680 nm
spectral region. The commonly used spectrophotometers
(Hitachi, model U-3410 and Varian, model Carry-100) were
exploited in the experiment. The non UV-irradiated samples
of parallel series were used as the reference controls.

3. Results and discussions

Since the results obtained for all three ERS substances
(see Section 2) were similar, only the results with DNT are
presented and discussed below.

After UV irradiation, a blue–green color was developed
in all tested fingerprints and “sprayed film” samples; neither
of the controls exhibited it.

A typical thumbprint is shown in Fig. 1. It is easy to
see that the technique/material proposed can provide high
quality fingerprints with distinctive papillary structure. It is
interesting to note that the reaction can be easily seen even on
non-transparent, “colored” materials, such as dark-painted
metals, etc. (not shown).

To determine the “fingerprint” sensitivity of the technique
the set of samples/imprints containing progressively dimin-
ishing amounts of explosives were produced by successive
fingerprinting (each time on a new film) of a finger “inked”
only once at the start. Several hundreds imprints obtained in
this way were numbered consecutively, starting with $N = 1$.
For the simplification of the subsequent analysis of the sam-
ples only fraction of them was UV-irradiated and measured
for absorbency.

Dependence of the absorbance of a sample, at 680 nm
($A_{680}$) on its consecutive number is shown Fig. 2. It is seen
that even the 500th fingerprint can still be detected by
the technique. Quantitative estimation showed that under
the specified conditions the detection limit of the proposed
technique is about 0.2 ng of DNT. It is worth to note that in
similar experiments with Semtex-H (plasticized explosive with high RDX content) but employing GC, Neudorf et al. [4,5] could quantify only up to the 250th fingerprint.

There was a fair consistency in the absorbance of “fresh” fingerprints (several first imprints after the inking procedure), their A values being as high as 0.2. This suggests that simple, photometer-types devices like a commercial glucometer could be routinely used for the measurements.

One of the main features of the sensitive technique designed and reported here is high quality fingerprints images. That opens the possibility, that with further refinement of the technique, the detection of EC/ERS on finger tips of an individual could be simultaneously matched with fingerprint data-bases and be of help in determining his/her identity.

The other possible applications of the technique introduced may be in explosion-scene investigations for the screening of debris possibly contaminated with explosive for subsequent, more thorough (and expensive) analyses, during security checks at small airports, etc. It may also be of use in forensic labs and industries dealing with production of explosives, or manufacturing nitrogroup-containing chemicals to check for possible leaks.

4. Conclusions

A new technique/new material for the detection of trace amounts of explosives and/or explosive related substances on various surfaces is presented. It is fairly sensitive, reproducible and not expensive. Real-time detection of a fingerprint papillary image can be obtained. The material/technique may have many possible applications.

References