Sensors for Trace Detection of Explosives: A Review

Lama Moukalled[1], Karim Y. Kabalan[1], Ali El-Hajj[1], Mohammed Al-Husseini[2], Youssef Mouneimne[3], and Imad Mougharbel[4]

[1]Electrical and Computer Engineering Department, American University of Beirut, Lebanon
[2]Beirut Research & Innovation Center, Lebanese Center for Studies & Research, Beirut, Lebanon
[3]Kamal Chair Central Research Science Laboratory, American University of Beirut, Lebanon
[4]Electrical and Computer Engineering Department, Lebanese University, Lebanon
lama.mokalled@gmail.com, kabalan@aub.edu.lb, elhajj@aub.edu.lb, husseini@ieee.org, ym01@aub.edu.lb, imadmoug@ul.edu.lb

Abstract: **The detection of explosive devices including landmines is crucial in the battle against this seriously hazardous problem that affects hundreds of millions worldwide. The problem is intensifying, due to the spread of disperse wars, the increase in terrorist activities, and the boom in the production of these explosives. The detection approach must take into consideration several factors such as safety, detection sensitivity, accuracy, speed, and ease of implementation. This work discusses and compares electronic/chemical sensors, optical sensors, and biosensors and their usage in tracing explosive materials and detecting landmines.**

Index Terms **– Explosives; Landmines; Electronic/Chemical Sensors; Optical Sensors; Biosensors.**

I. INTRODUCTION

Landmines and explosives have posed a serious problem worldwide. Numerous solutions have been explored, implemented and used. Ongoing and active research work on these solutions has aimed at devising safer, faster more efficient, more reliable and less expensive methods for mines and explosives detection [1, 2].

Sniffing dogs have been considered one of the most effective and efficient detection methods currently in use [3, 4]. They smell explosives just like everything else, but they are trained to remember the signature smell of several explosive types, and that is why they react when they detect the smell of an explosive. Other than sniffing dogs, detection equipment could be used. Trace detectors are one type of equipment used to detect explosives of small magnitude. They do so either by sniffing explosive vapors, by sampling traces of the explosive particulates, or both. Vapor sampling requires no contact while particulate sampling requires direct contact to remove explosive material particles from a contaminated surface [5, 6]. For most applications, the location of the explosives or landmines is initially unknown or not easily reachable, hence our interest in vapor detection.

Solids and liquids, including explosive materials, emit vapor under certain temperature and pressure conditions. Landmines in specific could emit their explosive vapor for decades. Sampling and analysis of the vapor are done around the surface of explosive material without the need for direct contact with it. Vapor traces are currently detected by means of electronic/chemical sensors [7], optical sensors [8], and biosensors [9]. The following sections will shed light on the electronic/chemical detection methods, optical detection methods, and biosensors.

II. ELECTRONIC/CHEMICAL SENSORS

The well-known methods are the Ion Mobility Spectrometry (IMS), the ChemiLuminescence (CL), the Thermo-redox, the Surface Acoustic Wave/Gas Chromatography (SAW/GC), the Mass Spectrometry (MS), the Micro Electro-Mechanical Systems (MEMS), and the Electronic Nose (E-Nose).

III. OPTICAL TRACE DETECTION METHODS

Many alternatives are used for optically detecting traces emitted by explosive materials such as UltraViolet-VISible-Near-InfraRed (UV-VIS-NIR) Spectroscopy, Photoacoustic Spectroscopy (PAS), Cavity Ring Down Spectroscopy (CRDS), Light Detection and Ranging (LIDAR), and Differential Absorption LIDAR (DIAL).

IV. BIOSENSORS

Biosensors are analytical tools that incorporate biologically active materials in close conjunction with devices that will convert a biochemical signal into a quantifiable electrical signal. An example of a biosensor is one incorporating an antibody on top of a piezoelectric crystal detector. The crystal detector generates an electric signal that quantifies the mass change resulting when the antibody binds to a specific material, like explosive vapor.

V. COMPARISON

Optical trace detection methods generally have high sensitivity and fast response but they could falsely detect the composition of the material in question. The electronic/chemical ones are also sensitive and rapid in addition to being inexpensive, but they suffer from low selectivity meaning that different electronic/chemical sensors might be required for different materials. Biosensors, on the other hand, have a complicated design in terms of their integration of a biological material on top of an appropriate transduction element. However, the design of the biological material (e.g. antibody) itself is easier with the possibility of replacing it on the same transduction element to detect a different material composition.

VI. CONCLUSION

This work discussed and compared the electronic/chemical, optical and biosensor-based detection methods used in explosive vapor trace detection. Researching, implementing, and the usage of these methods is essential in the efforts to rid Lebanon of the problem of explosives, mainly landmines and the improvised explosive devices (IEDs).

ACKNOWLEDGMENT

The authors would like to acknowledge the support of the Lebanese National Council for Scientific Research (**LNCSR)** and Beirut Research & Innovation Center (**BRIC**).

REFERENCES

[1] M. Nambayah, T. Quickenden, “A quantitative assessment of chemical techniques for detecting traces of explosives at counter-terrorist portals”, *Talanta*, Vol. 63, pp. 461–467, 2004.

[2] S. Singh, M. Singh, Explosives Detection Systems (EDS) for Aviation Security: A Review, 2003.

[3] D. S. Moore, “Recent advances in trace explosives detection instrumentation,” Sens. Imag.: Int. J., Vol. 8, pp. 9–38, 2007.

[4] U. Tomsic, Detection of Explosives: Dogs vs. CMOS Capacitive Sensors, Department of Physics, University of Ljubljana, March 2013.

[5] M. Krausa, A.A. Reznev, Vapour and Trace Detection of Explosives for Anti-Terrorism Purposes, Nato Science Series, *Kluwer Academic Publisher*, 2004.

[6] J J. Yinon and S. Zitrin, “Modern Methods and Applications in Analysis of Explosives”, John Wiley & Sons LTd, England, 1996.

[7] J. S. Caygill, F. Davis, and P.J. Higson, Current Trends in Explosive Detection Techniques, *Talanta*, Vol. 88, 2012, pp. 14-29.

[8] C.A. Munson, J.L. Gottfried, F.C. De Lucia, K.L. McNesby, and A.W. Miziolek, “Laser-Based Detection Methods for Explosives”, *Army Research Laboratory*, Report ARL-TR-4279, 2007.

[9] R.G. Smith, N. D’Souza, and S. Nicklin, “A Review of Biosensors and Biologically-Inspired Systems for Explosives Detection, *Analyst*, Vol. 133, No. 5, 2008, pp. 571-584.

Explosives trace detectors (ETD) are explosive detection equipment able to detect explosives of small magnitude. The detection is accomplished by sampling non-visible "trace" amounts of particulates. Devices similar to ETDs are also used to detect narcotics. The equipment is used mainly in airports and other vulnerable areas considered susceptible to acts of unlawful interference. Dr. Stephen Lee is credited with inventing the Fido explosives detector while working at the Army Research Laboratory. Abstractâ€" The detection of explosives covers a very important hazardous problem for people, due to the advancement of dangerous terroristic activities as well as of breakdowns in the production of these explosives. Border conflicts and terrorist attacks increased and hence detection of hidden bombs and explosives in lands, luggage, vehicles, aircrafts, and suspects became a must.Â This paper deals with a review of electronic/chemical sensors, optical sensors, and biosensors and their usage in tracing explosive devices and detecting landmines. Available techniques are covered which are characterized by a high degree of technological development. In addition, means of detection for vapor trace explosives is also presented in this review paper. Trace detection of explosives generally involves the collection of vapour or particulate samples and analyzing them using a sensitive sensor system. Various factors, such as wide variety of compounds that can be used as explosives, the vast number of deployment means and the lack of inexpensive sensors providing both high sensitivity and selectivity have made trace detection a very complex and costly task. High sensitivity and selectivity, along with the availability of low-cost sensors, is essential to combat explosives-based terrorism. Nanosensors have the potential to satisfy all the requirements for an effective platform for the trace detection of explosives. Moore DS (2004) Instrumentation for trace detection of high explosives. Rev Sci Instrum 75(8):2499â€"2512. CAS Article Google Scholar. 5. Moore DS (2007) Recent advances in trace explosives detection instrumentation. Sens Imaging 8(1):9â€"38. Article Google Scholar.Â Ewing RG, Atkinson DA, Eiceman GA, Ewing GJ (2001) A critical review of ion mobility spectrometry for the detection of explosives and explosive related compounds. Talanta 54(3):515â€"529. CAS Article Google Scholar. 9. JimÃ¨nez AM, Navas JM (2004) Chemiluminescence detection systems for the analysis of explosives. J Hazard Mater 106(1):1â€"8. Article Google Scholar.