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NATURE NANOTECHNOLOGY | LETTER

Zero-power infrared digitizers based on plasmonically enhanced micromechanical photoswitches

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Print

State-of-the-art sensors use active electronics to detect and discriminate light[1, 2, 3], sound[4, 5], vibration[6, 7] and other signals[8, 9]. They consume power constantly, even when there is no relevant data to be detected, which limits their lifetime and results in high costs of deployment and maintenance for unattended sensor networks. Here we propose a device concept that fundamentally breaks this paradigm—the sensors remain dormant with near-zero power consumption until awakened by a specific physical signature associated with an event of interest. In particular, we demonstrate infrared digitizing sensors that consist of plasmonically enhanced micromechanical photoswitches (PMPs) that selectively harvest the impinging electromagnetic energy in design-defined spectral bands of interest, and use it to create mechanically a conducting channel between two electrical contacts, without the need for any additional power source. Our zero-power digitizing sensor prototypes produce a digitized output bit (that is, a large and sharp off-to-on state transition with an on/off conductance ratio $>10^{12}$ and subthreshold slope >9 dec nW^{-1}) when exposed to infrared radiation in a specific narrow spectral band (~900 nm bandwidth in the mid-infrared) with the intensity above a power threshold of only ~500 nW, which is not achievable with any existing photoswitch technologies.

Subject terms: Nanophotonics and plasmonics NEMS Photonic devices Sensors

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Contributions

M.R. conceived the idea and initiated the research; M.R. and Z.Q. designed the device and the experiments; S.K. designed and characterized the infrared absorber; V.R. designed and implemented the experimental set-up; Z.Q. and S.K. fabricated the devices; Z.Q. and V.R. performed the experiments and analysed the data; N.E.M., V.R. and C.C. contributed to the device design; M.R. coordinated and supervised the research. M.R., Z.Q., N.E.M., S.K. and V.R. contributed to the preparation of the manuscript.

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Competing financial interests

A patent application has been filed under the Patent Cooperation Treaty (PCT), application no. PCT/US/16/48083.

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Supplementary information

PDF files

1. Supplementary information (2,572 KB)
   Supplementary information

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Analytical and Bioanalytical Chemistry

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Advances in explosives analysis—part I: animal, chemical, ion, and mechanical methods

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Picric acid

2,4,6-Trinitrophenol

NG

Nitroglycerine; nitro; glyceryl trinitrate; RNG; trinitroglycerine

NTO

Nitrotriazalone

PETN

Pentaerythritol tetranitrate; 2,2-bis[(nitroxy)methyl]-1,3-propanediol, dinitrate

RDX

Cyclonite; hexogen; hexahydro-1,3,5-trinitro-1,3,5-triazine

Semtex

Composition of PETN (or RDX and PETN) with heavy oils and rubbers

TATP

Triacetone triperoxide

Tetryl

Methyl-2,4,6-trinitrophenylnitramine

TNT

2,4,6-Trinitrotoluene; 2-methyl-1,3,5-trinitrobenzene

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Abstract

The number and capability of explosives detection and analysis methods have increased substantially since the publication of the Analytical and Bioanalytical Chemistry special issue devoted to Explosives Analysis (Moore and Goodpaster, Anal Bioanal Chem 395(2):245–246, 2009). Here we review and critically evaluate the latest (the past five years) important advances in explosives detection, with details of the improvements over previous methods, and suggest possible avenues towards further advances in, e.g., stand-off distance, detection limit, selectivity, and penetration through camouflage or packaging. The review consists of two parts. This part, Part I, reviews methods based on animals, chemicals (including colorimetry, molecularly imprinted polymers, electrochemistry, and immunochemistry), ions (both ion-mobility spectrometry and mass spectrometry), and mechanical devices. Part II will review methods based on photons, from very energetic photons including X-rays and gamma rays down to the terahertz range, and neutrons.

Keywords

Explosives detection Trace analysis Explosives Improvised explosives Instrumentation Reviews

Explosives glossary

AN

Ammonium nitrate

ANTA

3-Amino-5-nitro-1,2,4-triazole

DNB

Dinitrobenzene (isomers 1,3-DNB and 1,4-DNB)

DNT

Dinitrotoluene (isomers 2,4-DNT and 2,6-DNT)

FOX-7

1,1-Diamino-2,2-dinitroethene (DADNE)

HME

Homemade explosive

HMTD

Hexamethylene triperoxide diamine

HMX

Octagen; octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine

IED

Improvised explosive device

Moore DS, Goodpaster JV (2009) Explosives analysis. Anal Bioanal Chem 395(2):245–246. doi:10.1007/s00216-009-3003-6 CrossRefGoogle Scholar

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