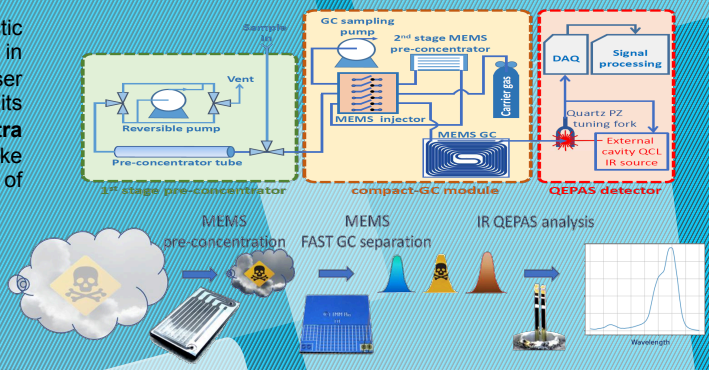
On-site GC-QEPAS analysis on the scene of crime: the RISEN project

Francesco Saverio ROMOLO* (1), Sandro MENGALI (2), Nicola LIBERATORE (2), Roberto VIOLA (2), Stefano ZAMPOLLI (3), Ivan ELMI (3), Roberto CHIRICO (4)

1 Department of Law, Università degli Studi di Bergamo, ITALY
2 Consorzio C.R.E.O. - Centro Ricerche Elettro Ottiche, SS 17 Località Boschetto, ITALY
3 Institute for Microelectronics and Microsystems CNR-IMM, Via P. Gobetti 101, 40129 Bologna, ITALY
4 ENEA, FSN-TECFIS-DIM C.R. Frascati Via Enrico Fermi, 45 00044 Frascati ITALY.

The capability to provide timely forensic analytical information is of paramount importance in criminal investigations involving chemical substances of toxicological interest. The project Real-tIme on-site forenSic tracE qualificatioN (RISEN) is developing a network of sensors to be deployed on crime scenes to provide timely information to protect security and safety of specialists on-site and saving the time needed to collect, transport and analyse them in a forensic laboratory. One of the sensor is an innovative hand-portable point sensor has been recently developed using a fully Micro-Electro-Mechanical-System (MEMS)-based compact-Gas Chromatography (GC) platform of the size of a few cm^3 coupled to a miniaturized detector based on InfraRed Quartz Enhanced Photo Acoustic Spectroscopy (QEPAS).

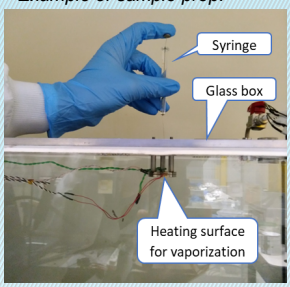
Sensing is based on the piezoelectric transduction of the photo-acoustic signal that is generated when laser radiation is absorbed by molecules in vapour phase in the QEPAS cell. Signal intensity is proportional to laser intensity, to the absorption cross section of the substance, and to its concentration. **QEPAS spectra are very similar to the spectra obtained by classical IR absorption spectroscopy** (IRAS), but, unlike IRAS cells, QEPAS cells can be designed as very cheap components of miniature size.



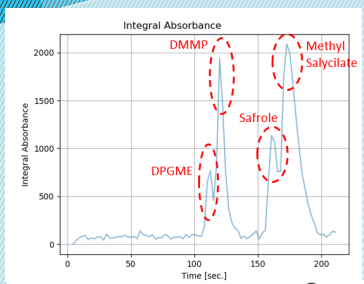
The GC-QEPAS consists of three modules:
- Compact air sampler and pre-concentrator
- FAST-GC module for chemical separation
- QEPAS module for chemical analysis

Sample prep: One syringe was used to vaporize between 1 and 100 microlitres of solutions of target substances in a 60 litres glass box. **Sampling time was less than 60 seconds**.

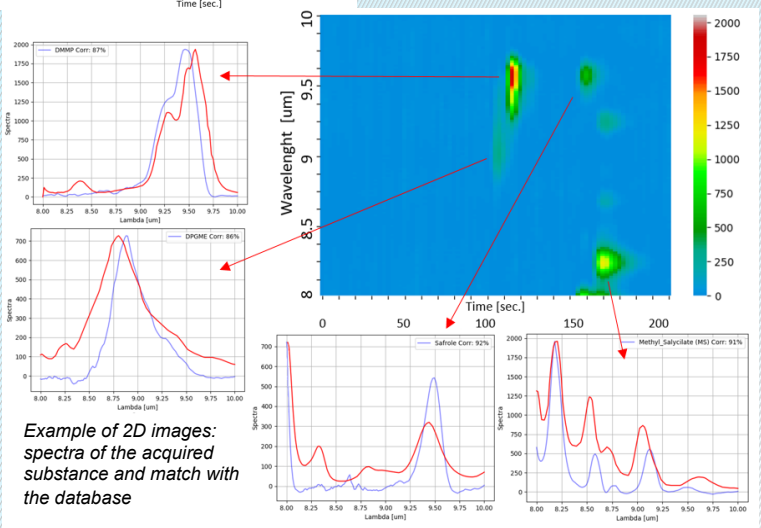
Example of sample prep.



Example of 4 different elution peaks



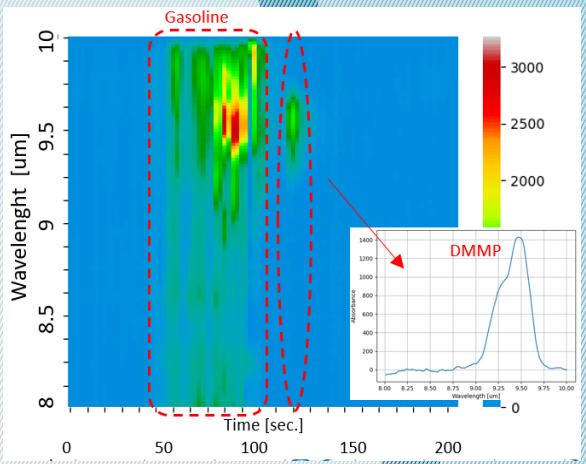
Example of 3D image (4 peaks): spectra vs times



Example of 2D images: spectra of the acquired substance and match with the database

Results: The GC-QEPAS sensor was used to successfully analyse ppm and sub-ppm amounts of two nerve agent simulants: dimethyl methyl phosphonate (DMMP) and dipropylene glycol methyl ether (DPGME). Methyl salicylate (a blister agent simulant) and sulfur mustard (a real blister agent sample) were also tested. Other substances of interest in forensic toxicology where tested, including precursors of drugs of abuse. The sensor showed also its capability of analyzing amphetamine types stimulants (ATS) and drug precursors both as pure compounds and as mixtures. LoDs measured were in the order of about 10 ng for many precursors, and ten times larger for target compounds containing an amino group.
Ethanol, propanol, gasoline and paint vapours at much higher concentrations, up to saturation vapor pressure, compared to the target chemical substances of forensic interest were also analysed to study the selectivity of the system in a real scenario.
The miniature size of the column has allowed the separation of substances in cycle times of 2-3 minutes.

Example of 3D image (DMMP and gasoline): spectra vs times



The total absorption chromatograms and the photoacoustic absorption spectra related to chromatographic peaks of both pure compounds and mixture demonstrate how the approach developed in the RISEN project will be able to support an improved approach to crime scene activities in the near future.

The RISEN project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883116.